

Throughput Prediction in the Multistage Continuous Flow Manufacturing Process via Machine learning

July 11, 2024

```
[2]: import pandas as pd
import statsmodels.api as sm
import numpy as np
from sklearn.model_selection import train_test_split
from sklearn import tree
from sklearn.preprocessing import StandardScaler
from sklearn.svm import SVR
from sklearn.neighbors import KNeighborsRegressor
from sklearn.pipeline import make_pipeline
import time
import warnings
warnings.filterwarnings('ignore')
```

```
[3]: #Start time record for process
start_time = time.time()
```

```
[4]: file= "Dissertation.csv"
```

```
[5]: print("*****Import raw data*****")
#raw_data = pd.read_csv("Dissertation.csv", index_col="time_stamp")
raw_data= pd.read_csv(file, index_col="time_stamp")
print(raw_data.info())
print(raw_data.head())
```

```
*****Import raw data*****
<class 'pandas.core.frame.DataFrame'>
Index: 14088 entries, 3/6/2019 10:52 to 3/6/2019 14:47
Columns: 115 entries, AmbientConditions.AmbientHumidity.U.Actual to
Stage2.Output.Measurement14.U.Setpoint
dtypes: float64(108), int64(7)
memory usage: 12.5+ MB
None
          AmbientConditions.AmbientHumidity.U.Actual \
time_stamp
3/6/2019 10:52                               17.24
3/6/2019 10:52                               17.24
```

3/6/2019 10:52	17.24
3/6/2019 10:52	17.24
3/6/2019 10:52	17.24

AmbientConditions.AmbientTemperature.U.Actual \

time_stamp	
3/6/2019 10:52	23.53
3/6/2019 10:52	23.53
3/6/2019 10:52	23.53
3/6/2019 10:52	23.53
3/6/2019 10:52	23.53

Machine1.RawMaterial.Property1 \

time_stamp	
3/6/2019 10:52	11.54
3/6/2019 10:52	11.54
3/6/2019 10:52	11.54
3/6/2019 10:52	11.54
3/6/2019 10:52	11.54

Machine1.RawMaterial.Property2 \

time_stamp	
3/6/2019 10:52	200
3/6/2019 10:52	200
3/6/2019 10:52	200
3/6/2019 10:52	200
3/6/2019 10:52	200

Machine1.RawMaterial.Property3 \

time_stamp	
3/6/2019 10:52	963.0
3/6/2019 10:52	963.0
3/6/2019 10:52	963.0
3/6/2019 10:52	963.0
3/6/2019 10:52	963.0

Machine1.RawMaterial.Property4 \

time_stamp	
3/6/2019 10:52	247
3/6/2019 10:52	247
3/6/2019 10:52	247
3/6/2019 10:52	247
3/6/2019 10:52	247

Machine1.RawMaterialFeederParameter.U.Actual \

time_stamp	
3/6/2019 10:52	1241.26
3/6/2019 10:52	1246.09

3/6/2019 10:52	1246.29
3/6/2019 10:52	1247.59
3/6/2019 10:52	1252.83
Machine1.Zone1Temperature.C.Actual \	
time_stamp	
3/6/2019 10:52	72.0
3/6/2019 10:52	72.0
3/6/2019 10:52	72.0
3/6/2019 10:52	72.0
3/6/2019 10:52	72.1
Machine1.Zone2Temperature.C.Actual \	
time_stamp	
3/6/2019 10:52	72.3
3/6/2019 10:52	72.3
3/6/2019 10:52	72.3
3/6/2019 10:52	72.3
3/6/2019 10:52	72.4
Machine1.MotorAmperage.U.Actual ... \	
time_stamp	...
3/6/2019 10:52	48.03 ...
3/6/2019 10:52	48.03 ...
3/6/2019 10:52	48.16 ...
3/6/2019 10:52	48.57 ...
3/6/2019 10:52	48.57 ...
Stage2.Output.Measurement10.U.Actual \	
time_stamp	
3/6/2019 10:52	0.0
3/6/2019 10:52	0.0
3/6/2019 10:52	0.0
3/6/2019 10:52	0.0
3/6/2019 10:52	0.0
Stage2.Output.Measurement10.U.Setpoint \	
time_stamp	
3/6/2019 10:52	7.93
3/6/2019 10:52	7.93
3/6/2019 10:52	7.93
3/6/2019 10:52	7.93
3/6/2019 10:52	7.93
Stage2.Output.Measurement11.U.Actual \	
time_stamp	
3/6/2019 10:52	0.0
3/6/2019 10:52	0.0

3/6/2019 10:52	0.0
3/6/2019 10:52	0.0
3/6/2019 10:52	0.0
	Stage2.Output.Measurement11.U.Setpoint \
time_stamp	
3/6/2019 10:52	5.65
3/6/2019 10:52	5.65
3/6/2019 10:52	5.65
3/6/2019 10:52	5.65
3/6/2019 10:52	5.65
	Stage2.Output.Measurement12.U.Actual \
time_stamp	
3/6/2019 10:52	0.0
3/6/2019 10:52	0.0
3/6/2019 10:52	0.0
3/6/2019 10:52	0.0
3/6/2019 10:52	0.0
	Stage2.Output.Measurement12.U.Setpoint \
time_stamp	
3/6/2019 10:52	1.85
3/6/2019 10:52	1.85
3/6/2019 10:52	1.85
3/6/2019 10:52	1.85
3/6/2019 10:52	1.85
	Stage2.Output.Measurement13.U.Actual \
time_stamp	
3/6/2019 10:52	0.0
3/6/2019 10:52	0.0
3/6/2019 10:52	0.0
3/6/2019 10:52	0.0
3/6/2019 10:52	0.0
	Stage2.Output.Measurement13.U.Setpoint \
time_stamp	
3/6/2019 10:52	2.89
3/6/2019 10:52	2.89
3/6/2019 10:52	2.89
3/6/2019 10:52	2.89
3/6/2019 10:52	2.89
	Stage2.Output.Measurement14.U.Actual \
time_stamp	
3/6/2019 10:52	0.0
3/6/2019 10:52	0.0

```

3/6/2019 10:52          0.0
3/6/2019 10:52          0.0
3/6/2019 10:52          0.0

```

Stage2.Output.Measurement14.U.Setpoint

time_stamp	
3/6/2019 10:52	11.71
3/6/2019 10:52	11.71
3/6/2019 10:52	11.71
3/6/2019 10:52	11.71
3/6/2019 10:52	11.71

[5 rows x 115 columns]

```

[6]: #Drop setpoint data
print("*****Remove set point Coulmns from raw"
      "data*****")
set_point = [42,44,46,48,50,52,54,56,58,60,62,64,66,68,70,86,88,90,92,94,96,98,100,102,104,106,108,110,
set_point_name = list(raw_data.columns[set_point])
set_data = raw_data.drop(columns = set_point_name, axis=1)
print(set_data.info())

```

*****Remove set point Coulmns from raw

data*****

<class 'pandas.core.frame.DataFrame'>

Index: 14088 entries, 3/6/2019 10:52 to 3/6/2019 14:47

Data columns (total 85 columns):

#	Column	Non-Null Count	Dtype
0	AmbientConditions.AmbientHumidity.U.Actual	14088	float64
1	AmbientConditions.AmbientTemperature.U.Actual	14088	float64
2	Machine1.RawMaterial.Property1	14088	float64
3	Machine1.RawMaterial.Property2	14088	int64
4	Machine1.RawMaterial.Property3	14088	float64
5	Machine1.RawMaterial.Property4	14088	int64
6	Machine1.RawMaterialFeederParameter.U.Actual	14088	float64
7	Machine1.Zone1Temperature.C.Actual	14088	float64
8	Machine1.Zone2Temperature.C.Actual	14088	float64
9	Machine1.MotorAmperage.U.Actual	14088	float64
10	Machine1.MotorRPM.C.Actual	14088	float64
11	Machine1.MaterialPressure.U.Actual	14088	float64
12	Machine1.MaterialTemperature.U.Actual	14088	float64
13	Machine1.ExitZoneTemperature.C.Actual	14088	float64
14	Machine2.RawMaterial.Property1	14088	float64
15	Machine2.RawMaterial.Property2	14088	int64
16	Machine2.RawMaterial.Property3	14088	float64
17	Machine2.RawMaterial.Property4	14088	int64

18	Machine2.RawMaterialFeederParameter.U.Actual	14088	non-null	float64
19	Machine2.Zone1Temperature.C.Actual	14088	non-null	float64
20	Machine2.Zone2Temperature.C.Actual	14088	non-null	float64
21	Machine2.MotorAmperage.U.Actual	14088	non-null	float64
22	Machine2.MotorRPM.C.Actual	14088	non-null	float64
23	Machine2.MaterialPressure.U.Actual	14088	non-null	float64
24	Machine2.MaterialTemperature.U.Actual	14088	non-null	float64
25	Machine2.ExitZoneTemperature.C.Actual	14088	non-null	float64
26	Machine3.RawMaterial.Property1	14088	non-null	float64
27	Machine3.RawMaterial.Property2	14088	non-null	int64
28	Machine3.RawMaterial.Property3	14088	non-null	float64
29	Machine3.RawMaterial.Property4	14088	non-null	int64
30	Machine3.RawMaterialFeederParameter.U.Actual	14088	non-null	float64
31	Machine3.Zone1Temperature.C.Actual	14088	non-null	float64
32	Machine3.Zone2Temperature.C.Actual	14088	non-null	float64
33	Machine3.MotorAmperage.U.Actual	14088	non-null	float64
34	Machine3.MotorRPM.C.Actual	14088	non-null	float64
35	Machine3.MaterialPressure.U.Actual	14088	non-null	float64
36	Machine3.MaterialTemperature.U.Actual	14088	non-null	float64
37	Machine3.ExitZoneTemperature.C.Actual	14088	non-null	float64
38	FirstStage.CombinerOperation.Temperature1.U.Actual	14088	non-null	float64
39	FirstStage.CombinerOperation.Temperature2.U.Actual	14088	non-null	float64
40	FirstStage.CombinerOperation.Temperature3.C.Actual	14088	non-null	float64
41	Stage1.Output.Measurement0.U.Actual	14088	non-null	float64
42	Stage1.Output.Measurement1.U.Actual	14088	non-null	float64
43	Stage1.Output.Measurement2.U.Actual	14088	non-null	float64
44	Stage1.Output.Measurement3.U.Actual	14088	non-null	float64
45	Stage1.Output.Measurement4.U.Actual	14088	non-null	float64
46	Stage1.Output.Measurement5.U.Actual	14088	non-null	float64
47	Stage1.Output.Measurement6.U.Actual	14088	non-null	float64
48	Stage1.Output.Measurement7.U.Actual	14088	non-null	float64
49	Stage1.Output.Measurement8.U.Actual	14088	non-null	float64
50	Stage1.Output.Measurement9.U.Actual	14088	non-null	float64
51	Stage1.Output.Measurement10.U.Actual	14088	non-null	float64
52	Stage1.Output.Measurement11.U.Actual	14088	non-null	float64
53	Stage1.Output.Measurement12.U.Actual	14088	non-null	float64
54	Stage1.Output.Measurement13.U.Actual	14088	non-null	float64
55	Stage1.Output.Measurement14.U.Actual	14088	non-null	float64
56	Machine4.Temperature1.C.Actual	14088	non-null	float64
57	Machine4.Temperature2.C.Actual	14088	non-null	float64
58	Machine4.Pressure.C.Actual	14088	non-null	float64
59	Machine4.Temperature3.C.Actual	14088	non-null	float64
60	Machine4.Temperature4.C.Actual	14088	non-null	float64
61	Machine4.Temperature5.C.Actual	14088	non-null	float64
62	Machine4.ExitTemperature.U.Actual	14088	non-null	float64
63	Machine5.Temperature1.C.Actual	14088	non-null	float64
64	Machine5.Temperature2.C.Actual	14088	non-null	float64
65	Machine5.Temperature3.C.Actual	14088	non-null	float64

```

66 Machine5.Temperature4.C.Actual           14088 non-null float64
67 Machine5.Temperature5.C.Actual           14088 non-null float64
68 Machine5.Temperature6.C.Actual           14088 non-null float64
69 Machine5.ExitTemperature.U.Actual        14088 non-null float64
70 Stage2.Output.Measurement0.U.Actual      14088 non-null float64
71 Stage2.Output.Measurement1.U.Actual      14088 non-null float64
72 Stage2.Output.Measurement2.U.Actual      14088 non-null float64
73 Stage2.Output.Measurement3.U.Actual      14088 non-null float64
74 Stage2.Output.Measurement4.U.Actual      14088 non-null float64
75 Stage2.Output.Measurement5.U.Actual      14088 non-null float64
76 Stage2.Output.Measurement6.U.Actual      14088 non-null float64
77 Stage2.Output.Measurement7.U.Actual      14088 non-null float64
78 Stage2.Output.Measurement8.U.Actual      14088 non-null float64
79 Stage2.Output.Measurement9.U.Actual      14088 non-null float64
80 Stage2.Output.Measurement10.U.Actual     14088 non-null float64
81 Stage2.Output.Measurement11.U.Actual     14088 non-null float64
82 Stage2.Output.Measurement12.U.Actual     14088 non-null float64
83 Stage2.Output.Measurement13.U.Actual     14088 non-null float64
84 Stage2.Output.Measurement14.U.Actual     14088 non-null float64
dtypes: float64(79), int64(6)
memory usage: 9.2+ MB
None

```

```
[7]: #Count 0 value in data
print("*****Check 0 more than 30% in columns to eliminate them to reduce the data*****")
for i in range(len(set_data.columns[:])):
    CC = set_data.values[:,i]
    CCN = (((np.count_nonzero(CC == 0))/14088)*100)
    if (CCN>30):
        DROP = (set_data.columns[i])
        print ("    Column Number ",i," Name ",DROP, " Value =", "{:.2f}".
format(CCN ))
```

```
*****Check 0 more than 30% in columns to eliminate them to reduce the data*****
    Column Number 42 Name Stage1.Output.Measurement1.U.Actual Value = 41.88
    Column Number 46 Name Stage1.Output.Measurement5.U.Actual Value = 95.12
    Column Number 47 Name Stage1.Output.Measurement6.U.Actual Value = 33.38
    Column Number 48 Name Stage1.Output.Measurement7.U.Actual Value = 62.19
    Column Number 52 Name Stage1.Output.Measurement11.U.Actual Value = 74.26
    Column Number 55 Name Stage1.Output.Measurement14.U.Actual Value = 35.53
    Column Number 74 Name Stage2.Output.Measurement4.U.Actual Value = 90.53
```

```
[8]: #Drop columns 0 more than 30% of output
Drop_list = [42,46,47,48,52,55,74]
Drop_list_name = list(set_data.columns[Drop_list])
Araw_data = set_data.drop(columns= Drop_list_name, axis=1 )
```

```
#Araw_list = list(Araw_data.columns)
print("*****Columns after drop*****")
print(" ",Araw_data.info())
```

```
*****Columns after
drop*****
<class 'pandas.core.frame.DataFrame'>
Index: 14088 entries, 3/6/2019 10:52 to 3/6/2019 14:47
Data columns (total 78 columns):
```

#	Column	Non-Null Count	Dtype
0	AmbientConditions.AmbientHumidity.U.Actual	14088	float64
1	AmbientConditions.AmbientTemperature.U.Actual	14088	float64
2	Machine1.RawMaterial.Property1	14088	float64
3	Machine1.RawMaterial.Property2	14088	int64
4	Machine1.RawMaterial.Property3	14088	float64
5	Machine1.RawMaterial.Property4	14088	int64
6	Machine1.RawMaterialFeederParameter.U.Actual	14088	float64
7	Machine1.Zone1Temperature.C.Actual	14088	float64
8	Machine1.Zone2Temperature.C.Actual	14088	float64
9	Machine1.MotorAmperage.U.Actual	14088	float64
10	Machine1.MotorRPM.C.Actual	14088	float64
11	Machine1.MaterialPressure.U.Actual	14088	float64
12	Machine1.MaterialTemperature.U.Actual	14088	float64
13	Machine1.ExitZoneTemperature.C.Actual	14088	float64
14	Machine2.RawMaterial.Property1	14088	float64
15	Machine2.RawMaterial.Property2	14088	int64
16	Machine2.RawMaterial.Property3	14088	float64
17	Machine2.RawMaterial.Property4	14088	int64
18	Machine2.RawMaterialFeederParameter.U.Actual	14088	float64
19	Machine2.Zone1Temperature.C.Actual	14088	float64
20	Machine2.Zone2Temperature.C.Actual	14088	float64
21	Machine2.MotorAmperage.U.Actual	14088	float64
22	Machine2.MotorRPM.C.Actual	14088	float64
23	Machine2.MaterialPressure.U.Actual	14088	float64
24	Machine2.MaterialTemperature.U.Actual	14088	float64
25	Machine2.ExitZoneTemperature.C.Actual	14088	float64
26	Machine3.RawMaterial.Property1	14088	float64
27	Machine3.RawMaterial.Property2	14088	int64
28	Machine3.RawMaterial.Property3	14088	float64
29	Machine3.RawMaterial.Property4	14088	int64
30	Machine3.RawMaterialFeederParameter.U.Actual	14088	float64
31	Machine3.Zone1Temperature.C.Actual	14088	float64
32	Machine3.Zone2Temperature.C.Actual	14088	float64
33	Machine3.MotorAmperage.U.Actual	14088	float64
34	Machine3.MotorRPM.C.Actual	14088	float64
35	Machine3.MaterialPressure.U.Actual	14088	float64

```

36 Machine3.MaterialTemperature.U.Actual           14088 non-null float64
37 Machine3.ExitZoneTemperature.C.Actual          14088 non-null float64
38 FirstStage.CombinerOperation.Temperature1.U.Actual 14088 non-null float64
39 FirstStage.CombinerOperation.Temperature2.U.Actual 14088 non-null float64
40 FirstStage.CombinerOperation.Temperature3.C.Actual 14088 non-null float64
41 Stage1.Output.Measurement0.U.Actual           14088 non-null float64
42 Stage1.Output.Measurement2.U.Actual           14088 non-null float64
43 Stage1.Output.Measurement3.U.Actual           14088 non-null float64
44 Stage1.Output.Measurement4.U.Actual           14088 non-null float64
45 Stage1.Output.Measurement8.U.Actual           14088 non-null float64
46 Stage1.Output.Measurement9.U.Actual           14088 non-null float64
47 Stage1.Output.Measurement10.U.Actual          14088 non-null float64
48 Stage1.Output.Measurement12.U.Actual          14088 non-null float64
49 Stage1.Output.Measurement13.U.Actual          14088 non-null float64
50 Machine4.Temperature1.C.Actual               14088 non-null float64
51 Machine4.Temperature2.C.Actual               14088 non-null float64
52 Machine4.Pressure.C.Actual                  14088 non-null float64
53 Machine4.Temperature3.C.Actual               14088 non-null float64
54 Machine4.Temperature4.C.Actual               14088 non-null float64
55 Machine4.Temperature5.C.Actual               14088 non-null float64
56 Machine4.ExitTemperature.U.Actual            14088 non-null float64
57 Machine5.Temperature1.C.Actual               14088 non-null float64
58 Machine5.Temperature2.C.Actual               14088 non-null float64
59 Machine5.Temperature3.C.Actual               14088 non-null float64
60 Machine5.Temperature4.C.Actual               14088 non-null float64
61 Machine5.Temperature5.C.Actual               14088 non-null float64
62 Machine5.Temperature6.C.Actual               14088 non-null float64
63 Machine5.ExitTemperature.U.Actual            14088 non-null float64
64 Stage2.Output.Measurement0.U.Actual          14088 non-null float64
65 Stage2.Output.Measurement1.U.Actual          14088 non-null float64
66 Stage2.Output.Measurement2.U.Actual          14088 non-null float64
67 Stage2.Output.Measurement3.U.Actual          14088 non-null float64
68 Stage2.Output.Measurement5.U.Actual          14088 non-null float64
69 Stage2.Output.Measurement6.U.Actual          14088 non-null float64
70 Stage2.Output.Measurement7.U.Actual          14088 non-null float64
71 Stage2.Output.Measurement8.U.Actual          14088 non-null float64
72 Stage2.Output.Measurement9.U.Actual          14088 non-null float64
73 Stage2.Output.Measurement10.U.Actual         14088 non-null float64
74 Stage2.Output.Measurement11.U.Actual         14088 non-null float64
75 Stage2.Output.Measurement12.U.Actual         14088 non-null float64
76 Stage2.Output.Measurement13.U.Actual         14088 non-null float64
77 Stage2.Output.Measurement14.U.Actual         14088 non-null float64

dtypes: float64(72), int64(6)
memory usage: 8.5+ MB
None

```

```
[9]: # Checking for missing values
missing_values = Araw_data.isnull().sum()
missing_values = missing_values[missing_values > 0].sort_values(ascending=False)
missing_values
```

[9]: Series([], dtype: int64)

```
[10]: import pandas as pd
import numpy as np
import matplotlib.pyplot as plt

# Assuming Araw_data is the DataFrame after previous steps

# Function to plot box plot
def plot_box(data, title):
    plt.figure(figsize=(20, 10))
    data.boxplot(rot=90)
    plt.title(title)
    plt.show()

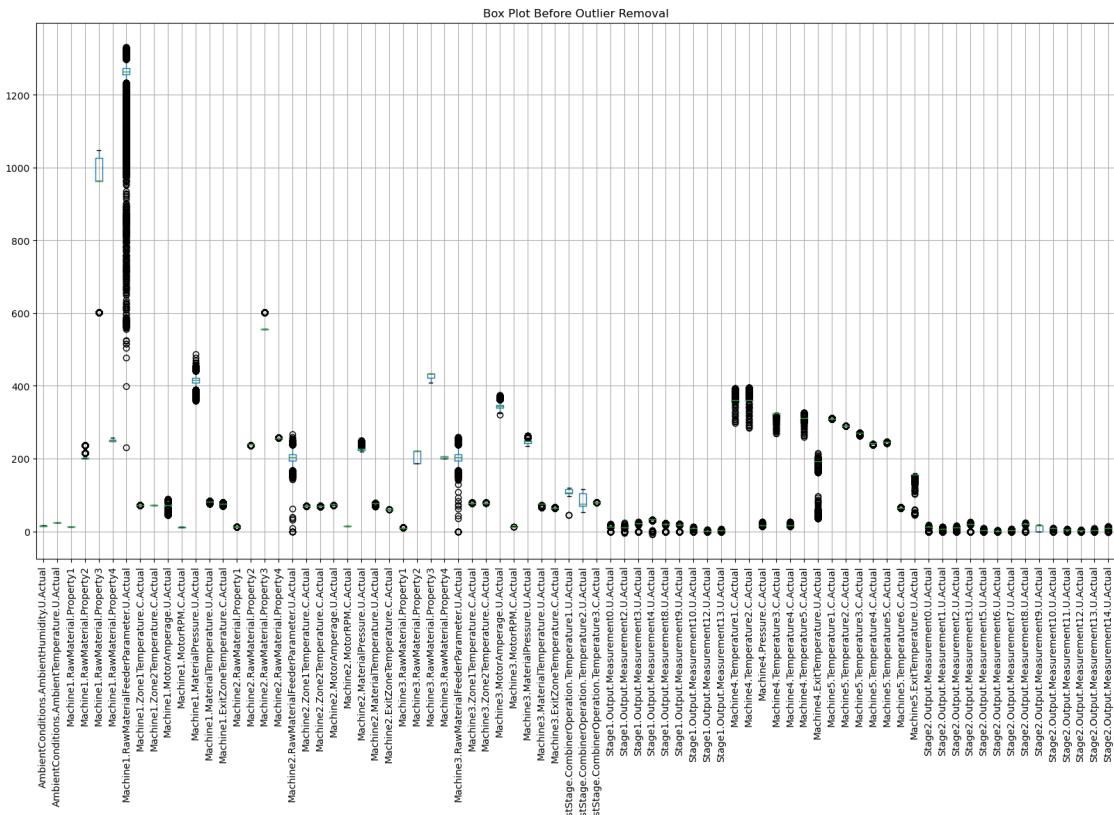
# Plot box plot before outlier removal
plot_box(Araw_data, "Box Plot Before Outlier Removal")

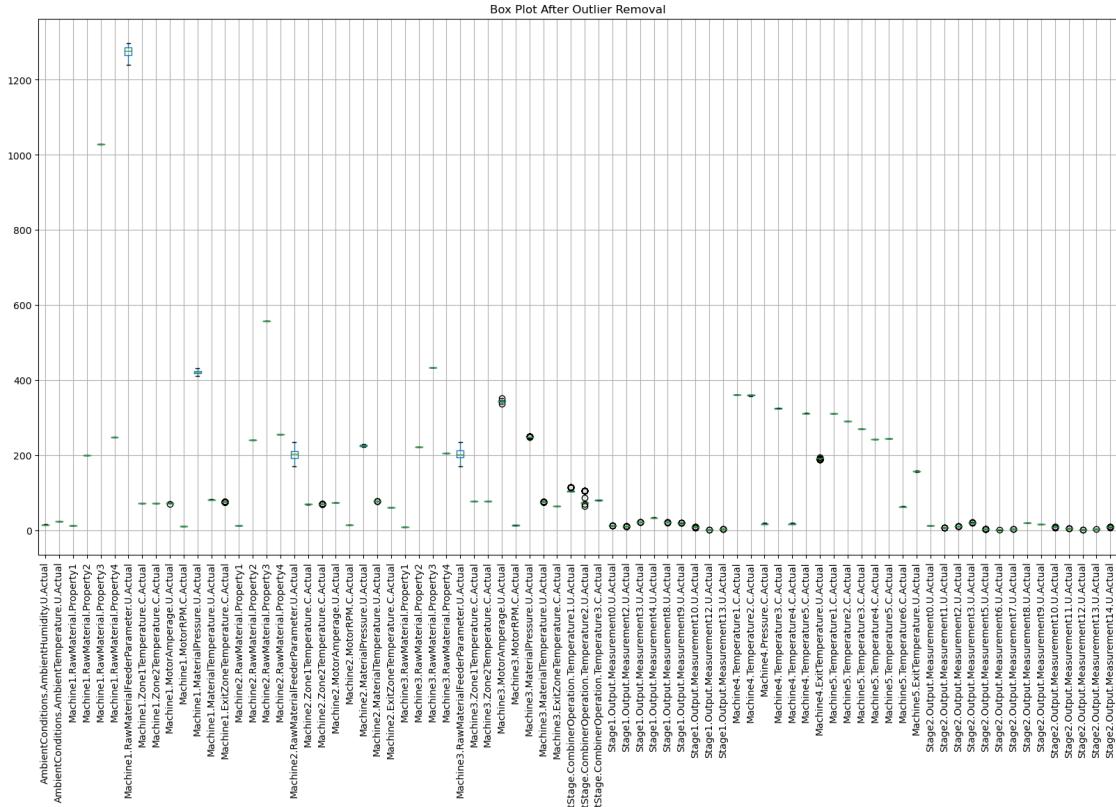
# Function to remove outliers using IQR method
def remove_outliers(df):
    Q1 = df.quantile(0.25)
    Q3 = df.quantile(0.75)
    IQR = Q3 - Q1
    df_clean = df[~((df < (Q1 - 1.5 * IQR)) | (df > (Q3 + 1.5 * IQR))).any(axis=1)]
    return df_clean

# Remove outliers
Araw_data_clean = remove_outliers(Araw_data)

# Plot box plot after outlier removal
plot_box(Araw_data_clean, "Box Plot After Outlier Removal")

print("*****Data Info Before Outlier Removal*****")
print(Araw_data.info())
print("*****Data Info After Outlier Removal*****")
print(Araw_data_clean.info())
```





```
*****Data Info Before Outlier
Removal*****
<class 'pandas.core.frame.DataFrame'>
Index: 14088 entries, 3/6/2019 10:52 to 3/6/2019 14:47
Data columns (total 78 columns):
```

#	Column	Non-Null Count	Dtype
0	AmbientConditions.AmbientHumidity.U.Actual	14088	float64
1	AmbientConditions.AmbientTemperature.U.Actual	14088	float64
2	Machine1.RawMaterial.Property1	14088	non-null
3	Machine1.RawMaterial.Property2	14088	non-null
4	Machine1.RawMaterial.Property3	14088	non-null
5	Machine1.RawMaterial.Property4	14088	non-null
6	Machine1.RawMaterialFeederParameter.U.Actual	14088	non-null
7	Machine1.Zone1Temperature.C.Actual	14088	non-null
8	Machine1.Zone2Temperature.C.Actual	14088	non-null
9	Machine1.MotorAmperage.U.Actual	14088	non-null
10	Machine1.MotorRPM.C.Actual	14088	non-null
11	Machine1.MaterialPressure.U.Actual	14088	non-null
12	Machine1.MaterialTemperature.U.Actual	14088	non-null
13	Machine1.ExitZoneTemperature.C.Actual	14088	non-null
14	Machine2.Zone1Temperature.C.Actual	14088	non-null
15	Machine2.Zone2Temperature.C.Actual	14088	non-null
16	Machine2.MotorAmperage.U.Actual	14088	non-null
17	Machine2.MotorRPM.C.Actual	14088	non-null
18	Machine2.MaterialPressure.U.Actual	14088	non-null
19	Machine2.MaterialTemperature.U.Actual	14088	non-null
20	Machine2.ExitZoneTemperature.C.Actual	14088	non-null
21	Machine3.Zone1Temperature.C.Actual	14088	non-null
22	Machine3.Zone2Temperature.C.Actual	14088	non-null
23	Machine3.MotorAmperage.U.Actual	14088	non-null
24	Machine3.MotorRPM.C.Actual	14088	non-null
25	Machine3.MaterialPressure.U.Actual	14088	non-null
26	Machine3.MaterialTemperature.U.Actual	14088	non-null
27	Machine3.ExitZoneTemperature.C.Actual	14088	non-null
28	FirstStage.CombineOperation.Temperature1.U.Actual	14088	non-null
29	FirstStage.CombineOperation.Temperature2.C.Actual	14088	non-null
30	FirstStage.CombineOperation.Temperature3.C.Actual	14088	non-null
31	Stage1.Output.Measurement1.U.Actual	14088	non-null
32	Stage1.Output.Measurement2.U.Actual	14088	non-null
33	Stage1.Output.Measurement3.U.Actual	14088	non-null
34	Stage1.Output.Measurement4.U.Actual	14088	non-null
35	Stage1.Output.Measurement5.U.Actual	14088	non-null
36	Stage1.Output.Measurement6.U.Actual	14088	non-null
37	Stage1.Output.Measurement7.U.Actual	14088	non-null
38	Stage1.Output.Measurement8.U.Actual	14088	non-null
39	Stage1.Output.Measurement9.U.Actual	14088	non-null
40	Stage1.Output.Measurement10.U.Actual	14088	non-null
41	Stage1.Output.Measurement11.U.Actual	14088	non-null
42	Stage1.Output.Measurement12.U.Actual	14088	non-null
43	Stage1.Output.Measurement13.U.Actual	14088	non-null
44	Machine4.Temperature1.C.Actual	14088	non-null
45	Machine4.Temperature2.C.Actual	14088	non-null
46	Machine4.Temperature3.C.Actual	14088	non-null
47	Machine4.Temperature4.C.Actual	14088	non-null
48	Machine4.Temperature5.C.Actual	14088	non-null
49	Machine4.Temperature6.C.Actual	14088	non-null
50	Machine4.Temperature7.C.Actual	14088	non-null
51	Machine4.Temperature8.C.Actual	14088	non-null
52	Machine4.Temperature9.C.Actual	14088	non-null
53	Machine4.Temperature10.C.Actual	14088	non-null
54	Machine4.Temperature11.C.Actual	14088	non-null
55	Machine4.Temperature12.C.Actual	14088	non-null
56	Machine5.Temperature1.C.Actual	14088	non-null
57	Machine5.Temperature2.C.Actual	14088	non-null
58	Machine5.Temperature3.C.Actual	14088	non-null
59	Machine5.Temperature4.C.Actual	14088	non-null
60	Machine5.Temperature5.C.Actual	14088	non-null
61	Machine5.Temperature6.C.Actual	14088	non-null
62	Machine5.Temperature7.C.Actual	14088	non-null
63	Machine5.Temperature8.C.Actual	14088	non-null
64	Machine5.Temperature9.C.Actual	14088	non-null
65	Machine5.Temperature10.C.Actual	14088	non-null
66	Machine5.Temperature11.C.Actual	14088	non-null
67	Machine5.Temperature12.C.Actual	14088	non-null
68	Stage1.Output.Measurement1.U.Actual	14088	non-null
69	Stage1.Output.Measurement2.U.Actual	14088	non-null
70	Stage1.Output.Measurement3.U.Actual	14088	non-null
71	Stage1.Output.Measurement4.U.Actual	14088	non-null
72	Stage1.Output.Measurement5.U.Actual	14088	non-null
73	Stage1.Output.Measurement6.U.Actual	14088	non-null
74	Stage1.Output.Measurement7.U.Actual	14088	non-null
75	Stage1.Output.Measurement8.U.Actual	14088	non-null
76	Stage1.Output.Measurement9.U.Actual	14088	non-null
77	Stage1.Output.Measurement10.U.Actual	14088	non-null
78	Stage1.Output.Measurement11.U.Actual	14088	non-null
79	Stage1.Output.Measurement12.U.Actual	14088	non-null
80	Stage1.Output.Measurement13.U.Actual	14088	non-null
81	Stage1.Output.Measurement14.U.Actual	14088	non-null

14	Machine2.RawMaterial.Property1	14088	non-null	float64
15	Machine2.RawMaterial.Property2	14088	non-null	int64
16	Machine2.RawMaterial.Property3	14088	non-null	float64
17	Machine2.RawMaterial.Property4	14088	non-null	int64
18	Machine2.RawMaterialFeederParameter.U.Actual	14088	non-null	float64
19	Machine2.Zone1Temperature.C.Actual	14088	non-null	float64
20	Machine2.Zone2Temperature.C.Actual	14088	non-null	float64
21	Machine2.MotorAmperage.U.Actual	14088	non-null	float64
22	Machine2.MotorRPM.C.Actual	14088	non-null	float64
23	Machine2.MaterialPressure.U.Actual	14088	non-null	float64
24	Machine2.MaterialTemperature.U.Actual	14088	non-null	float64
25	Machine2.ExitZoneTemperature.C.Actual	14088	non-null	float64
26	Machine3.RawMaterial.Property1	14088	non-null	float64
27	Machine3.RawMaterial.Property2	14088	non-null	int64
28	Machine3.RawMaterial.Property3	14088	non-null	float64
29	Machine3.RawMaterial.Property4	14088	non-null	int64
30	Machine3.RawMaterialFeederParameter.U.Actual	14088	non-null	float64
31	Machine3.Zone1Temperature.C.Actual	14088	non-null	float64
32	Machine3.Zone2Temperature.C.Actual	14088	non-null	float64
33	Machine3.MotorAmperage.U.Actual	14088	non-null	float64
34	Machine3.MotorRPM.C.Actual	14088	non-null	float64
35	Machine3.MaterialPressure.U.Actual	14088	non-null	float64
36	Machine3.MaterialTemperature.U.Actual	14088	non-null	float64
37	Machine3.ExitZoneTemperature.C.Actual	14088	non-null	float64
38	FirstStage.CombinerOperation.Temperature1.U.Actual	14088	non-null	float64
39	FirstStage.CombinerOperation.Temperature2.U.Actual	14088	non-null	float64
40	FirstStage.CombinerOperation.Temperature3.C.Actual	14088	non-null	float64
41	Stage1.Output.Measurement0.U.Actual	14088	non-null	float64
42	Stage1.Output.Measurement2.U.Actual	14088	non-null	float64
43	Stage1.Output.Measurement3.U.Actual	14088	non-null	float64
44	Stage1.Output.Measurement4.U.Actual	14088	non-null	float64
45	Stage1.Output.Measurement8.U.Actual	14088	non-null	float64
46	Stage1.Output.Measurement9.U.Actual	14088	non-null	float64
47	Stage1.Output.Measurement10.U.Actual	14088	non-null	float64
48	Stage1.Output.Measurement12.U.Actual	14088	non-null	float64
49	Stage1.Output.Measurement13.U.Actual	14088	non-null	float64
50	Machine4.Temperature1.C.Actual	14088	non-null	float64
51	Machine4.Temperature2.C.Actual	14088	non-null	float64
52	Machine4.Pressure.C.Actual	14088	non-null	float64
53	Machine4.Temperature3.C.Actual	14088	non-null	float64
54	Machine4.Temperature4.C.Actual	14088	non-null	float64
55	Machine4.Temperature5.C.Actual	14088	non-null	float64
56	Machine4.ExitTemperature.U.Actual	14088	non-null	float64
57	Machine5.Temperature1.C.Actual	14088	non-null	float64
58	Machine5.Temperature2.C.Actual	14088	non-null	float64
59	Machine5.Temperature3.C.Actual	14088	non-null	float64
60	Machine5.Temperature4.C.Actual	14088	non-null	float64
61	Machine5.Temperature5.C.Actual	14088	non-null	float64

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62 Machine5.Temperature6.C.Actual           14088 non-null float64
63 Machine5.ExitTemperature.U.Actual       14088 non-null float64
64 Stage2.Output.Measurement0.U.Actual    14088 non-null float64
65 Stage2.Output.Measurement1.U.Actual    14088 non-null float64
66 Stage2.Output.Measurement2.U.Actual    14088 non-null float64
67 Stage2.Output.Measurement3.U.Actual    14088 non-null float64
68 Stage2.Output.Measurement5.U.Actual    14088 non-null float64
69 Stage2.Output.Measurement6.U.Actual    14088 non-null float64
70 Stage2.Output.Measurement7.U.Actual    14088 non-null float64
71 Stage2.Output.Measurement8.U.Actual    14088 non-null float64
72 Stage2.Output.Measurement9.U.Actual    14088 non-null float64
73 Stage2.Output.Measurement10.U.Actual   14088 non-null float64
74 Stage2.Output.Measurement11.U.Actual   14088 non-null float64
75 Stage2.Output.Measurement12.U.Actual   14088 non-null float64
76 Stage2.Output.Measurement13.U.Actual   14088 non-null float64
77 Stage2.Output.Measurement14.U.Actual   14088 non-null float64
dtypes: float64(72), int64(6)
memory usage: 8.5+ MB
None
*****Data Info After Outlier Removal*****
<class 'pandas.core.frame.DataFrame'>
Index: 191 entries, 3/6/2019 12:46 to 3/6/2019 13:15
Data columns (total 78 columns):
 #   Column                      Non-Null Count Dtype
 ---  ----
 0   AmbientConditions.AmbientHumidity.U.Actual 191 non-null float64
 1   AmbientConditions.AmbientTemperature.U.Actual 191 non-null float64
 2   Machine1.RawMaterial.Property1               191 non-null float64
 3   Machine1.RawMaterial.Property2               191 non-null int64
 4   Machine1.RawMaterial.Property3               191 non-null float64
 5   Machine1.RawMaterial.Property4               191 non-null int64
 6   Machine1.RawMaterialFeederParameter.U.Actual 191 non-null float64
 7   Machine1.Zone1Temperature.C.Actual          191 non-null float64
 8   Machine1.Zone2Temperature.C.Actual          191 non-null float64
 9   Machine1.MotorAmperage.U.Actual             191 non-null float64
 10  Machine1.MotorRPM.C.Actual                 191 non-null float64
 11  Machine1.MaterialPressure.U.Actual          191 non-null float64
 12  Machine1.MaterialTemperature.U.Actual        191 non-null float64
 13  Machine1.ExitZoneTemperature.C.Actual        191 non-null float64
 14  Machine2.RawMaterial.Property1              191 non-null float64
 15  Machine2.RawMaterial.Property2              191 non-null int64
 16  Machine2.RawMaterial.Property3              191 non-null float64
 17  Machine2.RawMaterial.Property4              191 non-null int64
 18  Machine2.RawMaterialFeederParameter.U.Actual 191 non-null float64
 19  Machine2.Zone1Temperature.C.Actual          191 non-null float64
 20  Machine2.Zone2Temperature.C.Actual          191 non-null float64
 21  Machine2.MotorAmperage.U.Actual             191 non-null float64

```

22	Machine2.MotorRPM.C.Actual	191	non-null	float64
23	Machine2.MaterialPressure.U.Actual	191	non-null	float64
24	Machine2.MaterialTemperature.U.Actual	191	non-null	float64
25	Machine2.ExitZoneTemperature.C.Actual	191	non-null	float64
26	Machine3.RawMaterial.Property1	191	non-null	float64
27	Machine3.RawMaterial.Property2	191	non-null	int64
28	Machine3.RawMaterial.Property3	191	non-null	float64
29	Machine3.RawMaterial.Property4	191	non-null	int64
30	Machine3.RawMaterialFeederParameter.U.Actual	191	non-null	float64
31	Machine3.Zone1Temperature.C.Actual	191	non-null	float64
32	Machine3.Zone2Temperature.C.Actual	191	non-null	float64
33	Machine3.MotorAmperage.U.Actual	191	non-null	float64
34	Machine3.MotorRPM.C.Actual	191	non-null	float64
35	Machine3.MaterialPressure.U.Actual	191	non-null	float64
36	Machine3.MaterialTemperature.U.Actual	191	non-null	float64
37	Machine3.ExitZoneTemperature.C.Actual	191	non-null	float64
38	FirstStage.CombinerOperation.Temperature1.U.Actual	191	non-null	float64
39	FirstStage.CombinerOperation.Temperature2.U.Actual	191	non-null	float64
40	FirstStage.CombinerOperation.Temperature3.C.Actual	191	non-null	float64
41	Stage1.Output.Measurement0.U.Actual	191	non-null	float64
42	Stage1.Output.Measurement2.U.Actual	191	non-null	float64
43	Stage1.Output.Measurement3.U.Actual	191	non-null	float64
44	Stage1.Output.Measurement4.U.Actual	191	non-null	float64
45	Stage1.Output.Measurement8.U.Actual	191	non-null	float64
46	Stage1.Output.Measurement9.U.Actual	191	non-null	float64
47	Stage1.Output.Measurement10.U.Actual	191	non-null	float64
48	Stage1.Output.Measurement12.U.Actual	191	non-null	float64
49	Stage1.Output.Measurement13.U.Actual	191	non-null	float64
50	Machine4.Temperature1.C.Actual	191	non-null	float64
51	Machine4.Temperature2.C.Actual	191	non-null	float64
52	Machine4.Pressure.C.Actual	191	non-null	float64
53	Machine4.Temperature3.C.Actual	191	non-null	float64
54	Machine4.Temperature4.C.Actual	191	non-null	float64
55	Machine4.Temperature5.C.Actual	191	non-null	float64
56	Machine4.ExitTemperature.U.Actual	191	non-null	float64
57	Machine5.Temperature1.C.Actual	191	non-null	float64
58	Machine5.Temperature2.C.Actual	191	non-null	float64
59	Machine5.Temperature3.C.Actual	191	non-null	float64
60	Machine5.Temperature4.C.Actual	191	non-null	float64
61	Machine5.Temperature5.C.Actual	191	non-null	float64
62	Machine5.Temperature6.C.Actual	191	non-null	float64
63	Machine5.ExitTemperature.U.Actual	191	non-null	float64
64	Stage2.Output.Measurement0.U.Actual	191	non-null	float64
65	Stage2.Output.Measurement1.U.Actual	191	non-null	float64
66	Stage2.Output.Measurement2.U.Actual	191	non-null	float64
67	Stage2.Output.Measurement3.U.Actual	191	non-null	float64
68	Stage2.Output.Measurement5.U.Actual	191	non-null	float64
69	Stage2.Output.Measurement6.U.Actual	191	non-null	float64

```

70 Stage2.Output.Measurement7.U.Actual      191 non-null   float64
71 Stage2.Output.Measurement8.U.Actual      191 non-null   float64
72 Stage2.Output.Measurement9.U.Actual      191 non-null   float64
73 Stage2.Output.Measurement10.U.Actual     191 non-null   float64
74 Stage2.Output.Measurement11.U.Actual     191 non-null   float64
75 Stage2.Output.Measurement12.U.Actual     191 non-null   float64
76 Stage2.Output.Measurement13.U.Actual     191 non-null   float64
77 Stage2.Output.Measurement14.U.Actual     191 non-null   float64
dtypes: float64(72), int64(6)
memory usage: 117.9+ KB
None

```

```
[11]: # Summary statistics
summary_stats = Araw_data_clean.describe()
print(summary_stats)
```

	AmbientConditions.AmbientHumidity.U.Actual	Machine1.RawMaterial.Property1	Machine1.RawMaterial.Property2
count	191.000000	1.910000e+02	191.0
mean	14.908010	1.154000e+01	200.0
std	0.187586	2.315333e-14	0.0
min	14.650000	1.154000e+01	200.0
25%	14.650000	1.154000e+01	200.0
50%	14.920000	1.154000e+01	200.0
75%	15.120000	1.154000e+01	200.0
max	15.220000	1.154000e+01	200.0

	AmbientConditions.AmbientTemperature.U.Actual	Machine1.RawMaterial.Property3	Machine1.RawMaterial.Property4
count	191.000000	1.910000e+02	191.0
mean	23.287749		
std	0.194310		
min	23.020000		
25%	23.160000		
50%	23.190000		
75%	23.530000		
max	23.590000		

mean	1.027430e+03	247.0
std	4.559425e-12	0.0
min	1.027430e+03	247.0
25%	1.027430e+03	247.0
50%	1.027430e+03	247.0
75%	1.027430e+03	247.0
max	1.027430e+03	247.0
Machine1.RawMaterialFeederParameter.U.Actual \		
count	191.000000	
mean	1275.357592	
std	11.999624	
min	1240.120000	
25%	1266.105000	
50%	1276.570000	
75%	1285.555000	
max	1297.890000	
Machine1.Zone1Temperature.C.Actual Machine1.Zone2Temperature.C.Actual \		
count	191.0	191.000000
mean	72.0	72.036649
std	0.0	0.365221
min	72.0	71.500000
25%	72.0	71.700000
50%	72.0	72.000000
75%	72.0	72.400000
max	72.0	72.600000
Machine1.MotorAmperage.U.Actual ... \		
count	191.000000 ...	
mean	72.030681 ...	
std	0.520861 ...	
min	70.360000 ...	
25%	71.710000 ...	
50%	71.980000 ...	
75%	72.520000 ...	
max	73.320000 ...	
Stage2.Output.Measurement5.U.Actual \		
count	191.000000	
mean	2.710890	
std	0.056733	
min	2.580000	
25%	2.680000	
50%	2.700000	
75%	2.730000	
max	2.960000	

```

        Stage2.Output.Measurement6.U.Actual \
count                191.000000
mean                 0.585026
std                  0.102036
min                 0.330000
25%                 0.515000
50%                 0.590000
75%                 0.650000
max                 0.870000

        Stage2.Output.Measurement7.U.Actual \
count                191.000000
mean                 2.984817
std                  0.023816
min                 2.920000
25%                 2.970000
50%                 2.990000
75%                 3.000000
max                 3.050000

        Stage2.Output.Measurement8.U.Actual \
count                191.000000
mean                 19.791571
std                  0.285411
min                 19.050000
25%                 19.590000
50%                 19.800000
75%                 20.030000
max                 20.280000

        Stage2.Output.Measurement9.U.Actual \
count                191.000000
mean                 16.606387
std                  0.059223
min                 16.480000
25%                 16.560000
50%                 16.610000
75%                 16.650000
max                 16.760000

        Stage2.Output.Measurement10.U.Actual \
count               191.000000
mean                 7.935183
std                  0.051625
min                 7.780000
25%                 7.900000
50%                 7.930000
75%                 7.960000

```

```

max                      8.060000
Stage2.Output.Measurement11.U.Actual \
count                  191.000000
mean                   5.613508
std                     0.044977
min                     5.490000
25%                     5.580000
50%                     5.610000
75%                     5.640000
max                     5.790000

Stage2.Output.Measurement12.U.Actual \
count                  191.000000
mean                   2.070785
std                     0.034227
min                     1.960000
25%                     2.050000
50%                     2.070000
75%                     2.090000
max                     2.150000

Stage2.Output.Measurement13.U.Actual \
count                  191.000000
mean                   3.495550
std                     0.049859
min                     3.380000
25%                     3.460000
50%                     3.490000
75%                     3.520000
max                     3.620000

Stage2.Output.Measurement14.U.Actual
count                  191.000000
mean                   7.969319
std                     0.176015
min                     7.540000
25%                     7.870000
50%                     7.940000
75%                     8.050000
max                     8.580000

[8 rows x 78 columns]

```

```
[12]: # Check for missing values
missing_values = Araw_data_clean.isnull().sum()
print("Missing Values:\n", missing_values)
```

```

Missing Values:
AmbientConditions.AmbientHumidity.U.Actual      0
AmbientConditions.AmbientTemperature.U.Actual    0
Machine1.RawMaterial.Property1                  0
Machine1.RawMaterial.Property2                  0
Machine1.RawMaterial.Property3                  0
..
Stage2.Output.Measurement10.U.Actual          0
Stage2.Output.Measurement11.U.Actual          0
Stage2.Output.Measurement12.U.Actual          0
Stage2.Output.Measurement13.U.Actual          0
Stage2.Output.Measurement14.U.Actual          0
Length: 78, dtype: int64

```

```

[13]: #Feature Selection of Data for model A
Input_A = Araw_data_clean.values[:,0:41]
Input_AN = Araw_data_clean.columns[0:41]
Input_AA = pd.DataFrame(data=Input_A, columns=Input_AN)
Input_AAN = pd.DataFrame(data=Input_A) #Non name
Output_A = Araw_data_clean.values[:,41:50]
Output_AN = Araw_data_clean.columns[41:50]
Output_AA = pd.DataFrame(data=Output_A, columns=Output_AN)
print("Input for model A")
print(Input_AA.info())
print("Output for model A")
print(Output_AA.info())

```

```

Input for model A
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 191 entries, 0 to 190
Data columns (total 41 columns):
 #   Column           Non-Null Count Dtype
 ---  -- 
 0   AmbientConditions.AmbientHumidity.U.Actual  191 non-null   float64
 1   AmbientConditions.AmbientTemperature.U.Actual 191 non-null   float64
 2   Machine1.RawMaterial.Property1               191 non-null   float64
 3   Machine1.RawMaterial.Property2               191 non-null   float64
 4   Machine1.RawMaterial.Property3               191 non-null   float64
 5   Machine1.RawMaterial.Property4               191 non-null   float64
 6   Machine1.RawMaterialFeederParameter.U.Actual 191 non-null   float64
 7   Machine1.Zone1Temperature.C.Actual          191 non-null   float64
 8   Machine1.Zone2Temperature.C.Actual          191 non-null   float64
 9   Machine1.MotorAmperage.U.Actual            191 non-null   float64
 10  Machine1.MotorRPM.C.Actual                191 non-null   float64
 11  Machine1.MaterialPressure.U.Actual         191 non-null   float64
 12  Machine1.MaterialTemperature.U.Actual       191 non-null   float64
 13  Machine1.ExitZoneTemperature.C.Actual      191 non-null   float64
 14  Machine2.RawMaterial.Property1             191 non-null   float64

```

```

15 Machine2.RawMaterial.Property2           191 non-null   float64
16 Machine2.RawMaterial.Property3           191 non-null   float64
17 Machine2.RawMaterial.Property4           191 non-null   float64
18 Machine2.RawMaterialFeederParameter.U.Actual 191 non-null   float64
19 Machine2.Zone1Temperature.C.Actual       191 non-null   float64
20 Machine2.Zone2Temperature.C.Actual       191 non-null   float64
21 Machine2.MotorAmperage.U.Actual         191 non-null   float64
22 Machine2.MotorRPM.C.Actual              191 non-null   float64
23 Machine2.MaterialPressure.U.Actual       191 non-null   float64
24 Machine2.MaterialTemperature.U.Actual    191 non-null   float64
25 Machine2.ExitZoneTemperature.C.Actual    191 non-null   float64
26 Machine3.RawMaterial.Property1           191 non-null   float64
27 Machine3.RawMaterial.Property2           191 non-null   float64
28 Machine3.RawMaterial.Property3           191 non-null   float64
29 Machine3.RawMaterial.Property4           191 non-null   float64
30 Machine3.RawMaterialFeederParameter.U.Actual 191 non-null   float64
31 Machine3.Zone1Temperature.C.Actual       191 non-null   float64
32 Machine3.Zone2Temperature.C.Actual       191 non-null   float64
33 Machine3.MotorAmperage.U.Actual         191 non-null   float64
34 Machine3.MotorRPM.C.Actual              191 non-null   float64
35 Machine3.MaterialPressure.U.Actual       191 non-null   float64
36 Machine3.MaterialTemperature.U.Actual    191 non-null   float64
37 Machine3.ExitZoneTemperature.C.Actual    191 non-null   float64
38 FirstStage.CombinerOperation.Temperature1.U.Actual 191 non-null   float64
39 FirstStage.CombinerOperation.Temperature2.U.Actual 191 non-null   float64
40 FirstStage.CombinerOperation.Temperature3.C.Actual 191 non-null   float64
dtypes: float64(41)
memory usage: 61.3 KB
None
Output for model A
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 191 entries, 0 to 190
Data columns (total 9 columns):
 #  Column                      Non-Null Count Dtype
 --- 
 0  Stage1.Output.Measurement0.U.Actual 191 non-null   float64
 1  Stage1.Output.Measurement2.U.Actual 191 non-null   float64
 2  Stage1.Output.Measurement3.U.Actual 191 non-null   float64
 3  Stage1.Output.Measurement4.U.Actual 191 non-null   float64
 4  Stage1.Output.Measurement8.U.Actual 191 non-null   float64
 5  Stage1.Output.Measurement9.U.Actual 191 non-null   float64
 6  Stage1.Output.Measurement10.U.Actual 191 non-null   float64
 7  Stage1.Output.Measurement12.U.Actual 191 non-null   float64
 8  Stage1.Output.Measurement13.U.Actual 191 non-null   float64
dtypes: float64(9)
memory usage: 13.6 KB
None

```

```
[14]: import pandas as pd

# Assuming Araw_data_clean is already defined and cleaned as shown in the
# provided code

# Feature Selection of Data for model A
Input_A = Araw_data_clean.values[:, 0:41]
Input_AN = Araw_data_clean.columns[0:41]
Input_AA = pd.DataFrame(data=Input_A, columns=Input_AN)

# Calculating the pairwise correlation matrix
correlation_matrix = Input_AA.corr()

# Displaying the correlation matrix
print("Pairwise Correlation Matrix for Model A:")
print(correlation_matrix)
```

```
Pairwise Correlation Matrix for Model A:
AmbientConditions.AmbientHumidity.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
1.000000
AmbientConditions.AmbientTemperature.U.Actual
-0.909604
Machine1.RawMaterial.Property1
NaN
Machine1.RawMaterial.Property2
NaN
Machine1.RawMaterial.Property3
NaN
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
-0.122174
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
0.040787
Machine1.MotorAmperage.U.Actual
0.035803
Machine1.MotorRPM.C.Actual
-0.929385
Machine1.MaterialPressure.U.Actual
-0.083879
Machine1.MaterialTemperature.U.Actual
-0.875396
Machine1.ExitZoneTemperature.C.Actual
0.031565
Machine2.RawMaterial.Property1
```

NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
-0.208417
Machine2.Zone1Temperature.C.Actual
-0.189531
Machine2.Zone2Temperature.C.Actual
0.080235
Machine2.MotorAmperage.U.Actual
-0.051648
Machine2.MotorRPM.C.Actual
0.042159
Machine2.MaterialPressure.U.Actual
-0.029537
Machine2.MaterialTemperature.U.Actual
0.376851
Machine2.ExitZoneTemperature.C.Actual
0.078937
Machine3.RawMaterial.Property1
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
-0.179830
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual
-0.171188
Machine3.MotorAmperage.U.Actual
0.087768
Machine3.MotorRPM.C.Actual
0.716706
Machine3.MaterialPressure.U.Actual
0.598059
Machine3.MaterialTemperature.U.Actual
0.302541
Machine3.ExitZoneTemperature.C.Actual
NaN
FirstStage.CombinerOperation.Temperature1.U.Actual

```
-0.338124
FirstStage.CombinerOperation.Temperature2.U.Actual
-0.451643
FirstStage.CombinerOperation.Temperature3.C.Actual
0.068735

AmbientConditions.AmbientTemperature.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
-0.909604
AmbientConditions.AmbientTemperature.U.Actual
1.000000
Machine1.RawMaterial.Property1
NaN
Machine1.RawMaterial.Property2
NaN
Machine1.RawMaterial.Property3
NaN
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
0.091104
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
0.068065
Machine1.MotorAmperage.U.Actual
-0.087896
Machine1.MotorRPM.C.Actual
0.856091
Machine1.MaterialPressure.U.Actual
0.018714
Machine1.MaterialTemperature.U.Actual
0.771784
Machine1.ExitZoneTemperature.C.Actual
-0.143144
Machine2.RawMaterial.Property1
NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
0.231668
Machine2.Zone1Temperature.C.Actual
0.190486
Machine2.Zone2Temperature.C.Actual
```

```
-0.096855
Machine2.MotorAmperage.U.Actual
0.030021
Machine2.MotorRPM.C.Actual
-0.006946
Machine2.MaterialPressure.U.Actual
0.014800
Machine2.MaterialTemperature.U.Actual
-0.250309
Machine2.ExitZoneTemperature.C.Actual
0.010642
Machine3.RawMaterial.Property1
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
0.170433
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual
0.266801
Machine3.MotorAmperage.U.Actual
-0.062943
Machine3.MotorRPM.C.Actual
-0.505707
Machine3.MaterialPressure.U.Actual
-0.361342
Machine3.MaterialTemperature.U.Actual
-0.525419
Machine3.ExitZoneTemperature.C.Actual
NaN
FirstStage.CombinerOperation.Temperature1.U.Actual
0.317172
FirstStage.CombinerOperation.Temperature2.U.Actual
0.407969
FirstStage.CombinerOperation.Temperature3.C.Actual
-0.104086

Machine1.RawMaterial.Property1 \
AmbientConditions.AmbientHumidity.U.Actual
NaN
AmbientConditions.AmbientTemperature.U.Actual
NaN
Machine1.RawMaterial.Property1
```

NaN
Machine1.RawMaterial.Property2
NaN
Machine1.RawMaterial.Property3
NaN
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
NaN
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
NaN
Machine1.MotorAmperage.U.Actual
NaN
Machine1.MotorRPM.C.Actual
NaN
Machine1.MaterialPressure.U.Actual
NaN
Machine1.MaterialTemperature.U.Actual
NaN
Machine1.ExitZoneTemperature.C.Actual
NaN
Machine2.RawMaterial.Property1
NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
NaN
Machine2.Zone1Temperature.C.Actual
NaN
Machine2.Zone2Temperature.C.Actual
NaN
Machine2.MotorAmperage.U.Actual
NaN
Machine2.MotorRPM.C.Actual
NaN
Machine2.MaterialPressure.U.Actual
NaN
Machine2.MaterialTemperature.U.Actual
NaN
Machine2.ExitZoneTemperature.C.Actual
NaN
Machine3.RawMaterial.Property1

```
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
NaN
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual
NaN
Machine3.MotorAmperage.U.Actual
NaN
Machine3.MotorRPM.C.Actual
NaN
Machine3.MaterialPressure.U.Actual
NaN
Machine3.MaterialTemperature.U.Actual
NaN
Machine3.ExitZoneTemperature.C.Actual
NaN
FirstStage.CombinerOperation.Temperature1.U.Actual
NaN
FirstStage.CombinerOperation.Temperature2.U.Actual
NaN
FirstStage.CombinerOperation.Temperature3.C.Actual
NaN

Machine1.RawMaterial.Property2 \
AmbientConditions.AmbientHumidity.U.Actual
NaN
AmbientConditions.AmbientTemperature.U.Actual
NaN
Machine1.RawMaterial.Property1
NaN
Machine1.RawMaterial.Property2
NaN
Machine1.RawMaterial.Property3
NaN
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
NaN
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
```

NaN
Machine1.MotorAmperage.U.Actual
NaN
Machine1.MotorRPM.C.Actual
NaN
Machine1.MaterialPressure.U.Actual
NaN
Machine1.MaterialTemperature.U.Actual
NaN
Machine1.ExitZoneTemperature.C.Actual
NaN
Machine2.RawMaterial.Property1
NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
NaN
Machine2.Zone1Temperature.C.Actual
NaN
Machine2.Zone2Temperature.C.Actual
NaN
Machine2.MotorAmperage.U.Actual
NaN
Machine2.MotorRPM.C.Actual
NaN
Machine2.MaterialPressure.U.Actual
NaN
Machine2.MaterialTemperature.U.Actual
NaN
Machine2.ExitZoneTemperature.C.Actual
NaN
Machine3.RawMaterial.Property1
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
NaN
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual

NaN
Machine3.MotorAmperage.U.Actual
NaN
Machine3.MotorRPM.C.Actual
NaN
Machine3.MaterialPressure.U.Actual
NaN
Machine3.MaterialTemperature.U.Actual
NaN
Machine3.ExitZoneTemperature.C.Actual
NaN
FirstStage.CombinerOperation.Temperature1.U.Actual
NaN
FirstStage.CombinerOperation.Temperature2.U.Actual
NaN
FirstStage.CombinerOperation.Temperature3.C.Actual
NaN

Machine1.RawMaterial.Property3 \
AmbientConditions.AmbientHumidity.U.Actual
NaN
AmbientConditions.AmbientTemperature.U.Actual
NaN
Machine1.RawMaterial.Property1
NaN
Machine1.RawMaterial.Property2
NaN
Machine1.RawMaterial.Property3
NaN
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
NaN
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
NaN
Machine1.MotorAmperage.U.Actual
NaN
Machine1.MotorRPM.C.Actual
NaN
Machine1.MaterialPressure.U.Actual
NaN
Machine1.MaterialTemperature.U.Actual
NaN
Machine1.ExitZoneTemperature.C.Actual
NaN
Machine2.RawMaterial.Property1

NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
NaN
Machine2.Zone1Temperature.C.Actual
NaN
Machine2.Zone2Temperature.C.Actual
NaN
Machine2.MotorAmperage.U.Actual
NaN
Machine2.MotorRPM.C.Actual
NaN
Machine2.MaterialPressure.U.Actual
NaN
Machine2.MaterialTemperature.U.Actual
NaN
Machine2.ExitZoneTemperature.C.Actual
NaN
Machine3.RawMaterial.Property1
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
NaN
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual
NaN
Machine3.MotorAmperage.U.Actual
NaN
Machine3.MotorRPM.C.Actual
NaN
Machine3.MaterialPressure.U.Actual
NaN
Machine3.MaterialTemperature.U.Actual
NaN
Machine3.ExitZoneTemperature.C.Actual
NaN
FirstStage.CombinerOperation.Temperature1.U.Actual

NaN
FirstStage.CombinerOperation.Temperature2.U.Actual
NaN
FirstStage.CombinerOperation.Temperature3.C.Actual
NaN

Machine1.RawMaterial.Property4 \
AmbientConditions.AmbientHumidity.U.Actual
NaN
AmbientConditions.AmbientTemperature.U.Actual
NaN
Machine1.RawMaterial.Property1
NaN
Machine1.RawMaterial.Property2
NaN
Machine1.RawMaterial.Property3
NaN
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
NaN
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
NaN
Machine1.MotorAmperage.U.Actual
NaN
Machine1.MotorRPM.C.Actual
NaN
Machine1.MaterialPressure.U.Actual
NaN
Machine1.MaterialTemperature.U.Actual
NaN
Machine1.ExitZoneTemperature.C.Actual
NaN
Machine2.RawMaterial.Property1
NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
NaN
Machine2.Zone1Temperature.C.Actual
NaN
Machine2.Zone2Temperature.C.Actual

NaN
Machine2.MotorAmperage.U.Actual
NaN
Machine2.MotorRPM.C.Actual
NaN
Machine2.MaterialPressure.U.Actual
NaN
Machine2.MaterialTemperature.U.Actual
NaN
Machine2.ExitZoneTemperature.C.Actual
NaN
Machine3.RawMaterial.Property1
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
NaN
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual
NaN
Machine3.MotorAmperage.U.Actual
NaN
Machine3.MotorRPM.C.Actual
NaN
Machine3.MaterialPressure.U.Actual
NaN
Machine3.MaterialTemperature.U.Actual
NaN
Machine3.ExitZoneTemperature.C.Actual
NaN
FirstStage.CombinerOperation.Temperature1.U.Actual
NaN
FirstStage.CombinerOperation.Temperature2.U.Actual
NaN
FirstStage.CombinerOperation.Temperature3.C.Actual
NaN

Machine1.RawMaterialFeederParameter.U.Actual \\\nAmbientConditions.AmbientHumidity.U.Actual
-0.122174
AmbientConditions.AmbientTemperature.U.Actual
0.091104
Machine1.RawMaterial.Property1

NaN
Machine1.RawMaterial.Property2
NaN
Machine1.RawMaterial.Property3
NaN
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
1.000000
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
-0.174374
Machine1.MotorAmperage.U.Actual
0.220124
Machine1.MotorRPM.C.Actual
0.085257
Machine1.MaterialPressure.U.Actual
0.121123
Machine1.MaterialTemperature.U.Actual
0.036910
Machine1.ExitZoneTemperature.C.Actual
0.075189
Machine2.RawMaterial.Property1
NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
0.105060
Machine2.Zone1Temperature.C.Actual
0.017952
Machine2.Zone2Temperature.C.Actual
-0.107252
Machine2.MotorAmperage.U.Actual
0.114428
Machine2.MotorRPM.C.Actual
0.081641
Machine2.MaterialPressure.U.Actual
0.132616
Machine2.MaterialTemperature.U.Actual
-0.106468
Machine2.ExitZoneTemperature.C.Actual
-0.003015
Machine3.RawMaterial.Property1

```
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
0.127261
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual
-0.057042
Machine3.MotorAmperage.U.Actual
-0.037744
Machine3.MotorRPM.C.Actual
-0.128803
Machine3.MaterialPressure.U.Actual
-0.207238
Machine3.MaterialTemperature.U.Actual
-0.028946
Machine3.ExitZoneTemperature.C.Actual
NaN
FirstStage.CombinerOperation.Temperature1.U.Actual
0.013763
FirstStage.CombinerOperation.Temperature2.U.Actual
0.049616
FirstStage.CombinerOperation.Temperature3.C.Actual
0.014793

Machine1.Zone1Temperature.C.Actual \
AmbientConditions.AmbientHumidity.U.Actual
NaN
AmbientConditions.AmbientTemperature.U.Actual
NaN
Machine1.RawMaterial.Property1
NaN
Machine1.RawMaterial.Property2
NaN
Machine1.RawMaterial.Property3
NaN
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
NaN
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
```

NaN
Machine1.MotorAmperage.U.Actual
NaN
Machine1.MotorRPM.C.Actual
NaN
Machine1.MaterialPressure.U.Actual
NaN
Machine1.MaterialTemperature.U.Actual
NaN
Machine1.ExitZoneTemperature.C.Actual
NaN
Machine2.RawMaterial.Property1
NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
NaN
Machine2.Zone1Temperature.C.Actual
NaN
Machine2.Zone2Temperature.C.Actual
NaN
Machine2.MotorAmperage.U.Actual
NaN
Machine2.MotorRPM.C.Actual
NaN
Machine2.MaterialPressure.U.Actual
NaN
Machine2.MaterialTemperature.U.Actual
NaN
Machine2.ExitZoneTemperature.C.Actual
NaN
Machine3.RawMaterial.Property1
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
NaN
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual

NaN
Machine3.MotorAmperage.U.Actual
NaN
Machine3.MotorRPM.C.Actual
NaN
Machine3.MaterialPressure.U.Actual
NaN
Machine3.MaterialTemperature.U.Actual
NaN
Machine3.ExitZoneTemperature.C.Actual
NaN
FirstStage.CombinerOperation.Temperature1.U.Actual
NaN
FirstStage.CombinerOperation.Temperature2.U.Actual
NaN
FirstStage.CombinerOperation.Temperature3.C.Actual
NaN

Machine1.Zone2Temperature.C.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.040787
AmbientConditions.AmbientTemperature.U.Actual
0.068065
Machine1.RawMaterial.Property1
NaN
Machine1.RawMaterial.Property2
NaN
Machine1.RawMaterial.Property3
NaN
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
-0.174374
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
1.000000
Machine1.MotorAmperage.U.Actual
-0.130224
Machine1.MotorRPM.C.Actual
-0.106457
Machine1.MaterialPressure.U.Actual
-0.308927
Machine1.MaterialTemperature.U.Actual
0.168334
Machine1.ExitZoneTemperature.C.Actual
-0.099859
Machine2.RawMaterial.Property1

NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
-0.049589
Machine2.Zone1Temperature.C.Actual
0.086143
Machine2.Zone2Temperature.C.Actual
0.050328
Machine2.MotorAmperage.U.Actual
-0.202224
Machine2.MotorRPM.C.Actual
-0.012108
Machine2.MaterialPressure.U.Actual
-0.016742
Machine2.MaterialTemperature.U.Actual
0.094832
Machine2.ExitZoneTemperature.C.Actual
-0.104653
Machine3.RawMaterial.Property1
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
-0.087144
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual
-0.028745
Machine3.MotorAmperage.U.Actual
0.029140
Machine3.MotorRPM.C.Actual
0.141516
Machine3.MaterialPressure.U.Actual
0.257630
Machine3.MaterialTemperature.U.Actual
-0.246943
Machine3.ExitZoneTemperature.C.Actual
NaN
FirstStage.CombinerOperation.Temperature1.U.Actual

```
0.125837
FirstStage.CombinerOperation.Temperature2.U.Actual
0.092470
FirstStage.CombinerOperation.Temperature3.C.Actual
-0.262165

Machine1.MotorAmperage.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.035803
AmbientConditions.AmbientTemperature.U.Actual
-0.087896
Machine1.RawMaterial.Property1
NaN
Machine1.RawMaterial.Property2
NaN
Machine1.RawMaterial.Property3
NaN
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
0.220124
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
-0.130224
Machine1.MotorAmperage.U.Actual
1.000000
Machine1.MotorRPM.C.Actual
-0.090645
Machine1.MaterialPressure.U.Actual
0.444401
Machine1.MaterialTemperature.U.Actual
-0.036479
Machine1.ExitZoneTemperature.C.Actual
0.078404
Machine2.RawMaterial.Property1
NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
-0.147305
Machine2.Zone1Temperature.C.Actual
0.041922
Machine2.Zone2Temperature.C.Actual
```

```

-0.099282
Machine2.MotorAmperage.U.Actual
0.012406
Machine2.MotorRPM.C.Actual
-0.008876
Machine2.MaterialPressure.U.Actual
0.085440
Machine2.MaterialTemperature.U.Actual
-0.200496
Machine2.ExitZoneTemperature.C.Actual
0.046940
Machine3.RawMaterial.Property1
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
-0.003345
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual
0.003941
Machine3.MotorAmperage.U.Actual
-0.123097
Machine3.MotorRPM.C.Actual
0.033644
Machine3.MaterialPressure.U.Actual
0.028006
Machine3.MaterialTemperature.U.Actual
0.142625
Machine3.ExitZoneTemperature.C.Actual
NaN
FirstStage.CombinerOperation.Temperature1.U.Actual
-0.252034
FirstStage.CombinerOperation.Temperature2.U.Actual
-0.224204
FirstStage.CombinerOperation.Temperature3.C.Actual
-0.006464

```

... \

```

AmbientConditions.AmbientHumidity.U.Actual ...
AmbientConditions.AmbientTemperature.U.Actual ...
Machine1.RawMaterial.Property1 ...
Machine1.RawMaterial.Property2 ...
Machine1.RawMaterial.Property3 ...

```

Machine1.RawMaterial.Property4	...
Machine1.RawMaterialFeederParameter.U.Actual	...
Machine1.Zone1Temperature.C.Actual	...
Machine1.Zone2Temperature.C.Actual	...
Machine1.MotorAmperage.U.Actual	...
Machine1.MotorRPM.C.Actual	...
Machine1.MaterialPressure.U.Actual	...
Machine1.MaterialTemperature.U.Actual	...
Machine1.ExitZoneTemperature.C.Actual	...
Machine2.RawMaterial.Property1	...
Machine2.RawMaterial.Property2	...
Machine2.RawMaterial.Property3	...
Machine2.RawMaterial.Property4	...
Machine2.RawMaterialFeederParameter.U.Actual	...
Machine2.Zone1Temperature.C.Actual	...
Machine2.Zone2Temperature.C.Actual	...
Machine2.MotorAmperage.U.Actual	...
Machine2.MotorRPM.C.Actual	...
Machine2.MaterialPressure.U.Actual	...
Machine2.MaterialTemperature.U.Actual	...
Machine2.ExitZoneTemperature.C.Actual	...
Machine3.RawMaterial.Property1	...
Machine3.RawMaterial.Property2	...
Machine3.RawMaterial.Property3	...
Machine3.RawMaterial.Property4	...
Machine3.RawMaterialFeederParameter.U.Actual	...
Machine3.Zone1Temperature.C.Actual	...
Machine3.Zone2Temperature.C.Actual	...
Machine3.MotorAmperage.U.Actual	...
Machine3.MotorRPM.C.Actual	...
Machine3.MaterialPressure.U.Actual	...
Machine3.MaterialTemperature.U.Actual	...
Machine3.ExitZoneTemperature.C.Actual	...
FirstStage.CombinerOperation.Temperature1.U.Actual	...
FirstStage.CombinerOperation.Temperature2.U.Actual	...
FirstStage.CombinerOperation.Temperature3.C.Actual	...
Machine3.Zone1Temperature.C.Actual \	
AmbientConditions.AmbientHumidity.U.Actual	
NaN	
AmbientConditions.AmbientTemperature.U.Actual	
NaN	
Machine1.RawMaterial.Property1	
NaN	
Machine1.RawMaterial.Property2	
NaN	
Machine1.RawMaterial.Property3	
NaN	

```
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
NaN
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
NaN
Machine1.MotorAmperage.U.Actual
NaN
Machine1.MotorRPM.C.Actual
NaN
Machine1.MaterialPressure.U.Actual
NaN
Machine1.MaterialTemperature.U.Actual
NaN
Machine1.ExitZoneTemperature.C.Actual
NaN
Machine2.RawMaterial.Property1
NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
NaN
Machine2.Zone1Temperature.C.Actual
NaN
Machine2.Zone2Temperature.C.Actual
NaN
Machine2.MotorAmperage.U.Actual
NaN
Machine2.MotorRPM.C.Actual
NaN
Machine2.MaterialPressure.U.Actual
NaN
Machine2.MaterialTemperature.U.Actual
NaN
Machine2.ExitZoneTemperature.C.Actual
NaN
Machine3.RawMaterial.Property1
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
```

```
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
NaN
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual
NaN
Machine3.MotorAmperage.U.Actual
NaN
Machine3.MotorRPM.C.Actual
NaN
Machine3.MaterialPressure.U.Actual
NaN
Machine3.MaterialTemperature.U.Actual
NaN
Machine3.ExitZoneTemperature.C.Actual
NaN
FirstStage.CombinerOperation.Temperature1.U.Actual
NaN
FirstStage.CombinerOperation.Temperature2.U.Actual
NaN
FirstStage.CombinerOperation.Temperature3.C.Actual
NaN

Machine3.Zone2Temperature.C.Actual \
AmbientConditions.AmbientHumidity.U.Actual
-0.171188
AmbientConditions.AmbientTemperature.U.Actual
0.266801
Machine1.RawMaterial.Property1
NaN
Machine1.RawMaterial.Property2
NaN
Machine1.RawMaterial.Property3
NaN
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
-0.057042
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
-0.028745
Machine1.MotorAmperage.U.Actual
0.003941
Machine1.MotorRPM.C.Actual
0.226569
```

```
Machine1.MaterialPressure.U.Actual  
0.028824  
Machine1.MaterialTemperature.U.Actual  
0.119540  
Machine1.ExitZoneTemperature.C.Actual  
-0.246317  
Machine2.RawMaterial.Property1  
NaN  
Machine2.RawMaterial.Property2  
NaN  
Machine2.RawMaterial.Property3  
NaN  
Machine2.RawMaterial.Property4  
NaN  
Machine2.RawMaterialFeederParameter.U.Actual  
0.165766  
Machine2.Zone1Temperature.C.Actual  
0.037706  
Machine2.Zone2Temperature.C.Actual  
-0.103708  
Machine2.MotorAmperage.U.Actual  
-0.058611  
Machine2.MotorRPM.C.Actual  
-0.129079  
Machine2.MaterialPressure.U.Actual  
-0.084423  
Machine2.MaterialTemperature.U.Actual  
-0.044293  
Machine2.ExitZoneTemperature.C.Actual  
0.344910  
Machine3.RawMaterial.Property1  
NaN  
Machine3.RawMaterial.Property2  
NaN  
Machine3.RawMaterial.Property3  
NaN  
Machine3.RawMaterial.Property4  
NaN  
Machine3.RawMaterialFeederParameter.U.Actual  
0.121329  
Machine3.Zone1Temperature.C.Actual  
NaN  
Machine3.Zone2Temperature.C.Actual  
1.000000  
Machine3.MotorAmperage.U.Actual  
0.008878  
Machine3.MotorRPM.C.Actual  
0.037219
```

```
Machine3.MaterialPressure.U.Actual  
0.184133  
Machine3.MaterialTemperature.U.Actual  
-0.004267  
Machine3.ExitZoneTemperature.C.Actual  
NaN  
FirstStage.CombinerOperation.Temperature1.U.Actual  
0.222053  
FirstStage.CombinerOperation.Temperature2.U.Actual  
0.222192  
FirstStage.CombinerOperation.Temperature3.C.Actual  
0.262298  
  
Machine3.MotorAmperage.U.Actual \  
AmbientConditions.AmbientHumidity.U.Actual  
0.087768  
AmbientConditions.AmbientTemperature.U.Actual  
-0.062943  
Machine1.RawMaterial.Property1  
NaN  
Machine1.RawMaterial.Property2  
NaN  
Machine1.RawMaterial.Property3  
NaN  
Machine1.RawMaterial.Property4  
NaN  
Machine1.RawMaterialFeederParameter.U.Actual  
-0.037744  
Machine1.Zone1Temperature.C.Actual  
NaN  
Machine1.Zone2Temperature.C.Actual  
0.029140  
Machine1.MotorAmperage.U.Actual  
-0.123097  
Machine1.MotorRPM.C.Actual  
-0.056496  
Machine1.MaterialPressure.U.Actual  
-0.124076  
Machine1.MaterialTemperature.U.Actual  
-0.127201  
Machine1.ExitZoneTemperature.C.Actual  
-0.065903  
Machine2.RawMaterial.Property1  
NaN  
Machine2.RawMaterial.Property2  
NaN  
Machine2.RawMaterial.Property3  
NaN
```

```
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
0.013459
Machine2.Zone1Temperature.C.Actual
-0.020328
Machine2.Zone2Temperature.C.Actual
-0.006802
Machine2.MotorAmperage.U.Actual
0.242165
Machine2.MotorRPM.C.Actual
0.043097
Machine2.MaterialPressure.U.Actual
0.091022
Machine2.MaterialTemperature.U.Actual
0.021315
Machine2.ExitZoneTemperature.C.Actual
0.128553
Machine3.RawMaterial.Property1
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
0.036521
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual
0.008878
Machine3.MotorAmperage.U.Actual
1.000000
Machine3.MotorRPM.C.Actual
0.044829
Machine3.MaterialPressure.U.Actual
0.130004
Machine3.MaterialTemperature.U.Actual
0.008828
Machine3.ExitZoneTemperature.C.Actual
NaN
FirstStage.CombinerOperation.Temperature1.U.Actual
-0.017302
FirstStage.CombinerOperation.Temperature2.U.Actual
-0.035655
FirstStage.CombinerOperation.Temperature3.C.Actual
-0.031174
```

	Machine3.MotorRPM.C.Actual
\	
AmbientConditions.AmbientHumidity.U.Actual	0.716706
AmbientConditions.AmbientTemperature.U.Actual	-0.505707
Machine1.RawMaterial.Property1	NaN
Machine1.RawMaterial.Property2	NaN
Machine1.RawMaterial.Property3	NaN
Machine1.RawMaterial.Property4	NaN
Machine1.RawMaterialFeederParameter.U.Actual	-0.128803
Machine1.Zone1Temperature.C.Actual	NaN
Machine1.Zone2Temperature.C.Actual	0.141516
Machine1.MotorAmperage.U.Actual	0.033644
Machine1.MotorRPM.C.Actual	-0.673211
Machine1.MaterialPressure.U.Actual	-0.160312
Machine1.MaterialTemperature.U.Actual	-0.643853
Machine1.ExitZoneTemperature.C.Actual	-0.090747
Machine2.RawMaterial.Property1	NaN
Machine2.RawMaterial.Property2	NaN
Machine2.RawMaterial.Property3	NaN
Machine2.RawMaterial.Property4	NaN
Machine2.RawMaterialFeederParameter.U.Actual	-0.187104
Machine2.Zone1Temperature.C.Actual	-0.108451
Machine2.Zone2Temperature.C.Actual	0.089439
Machine2.MotorAmperage.U.Actual	-0.033185
Machine2.MotorRPM.C.Actual	0.114787
Machine2.MaterialPressure.U.Actual	-0.077026
Machine2.MaterialTemperature.U.Actual	0.379648
Machine2.ExitZoneTemperature.C.Actual	0.125058
Machine3.RawMaterial.Property1	NaN
Machine3.RawMaterial.Property2	NaN
Machine3.RawMaterial.Property3	NaN
Machine3.RawMaterial.Property4	NaN
Machine3.RawMaterialFeederParameter.U.Actual	-0.206866
Machine3.Zone1Temperature.C.Actual	NaN
Machine3.Zone2Temperature.C.Actual	0.037219
Machine3.MotorAmperage.U.Actual	0.044829
Machine3.MotorRPM.C.Actual	1.000000
Machine3.MaterialPressure.U.Actual	0.633475
Machine3.MaterialTemperature.U.Actual	0.039391
Machine3.ExitZoneTemperature.C.Actual	NaN
FirstStage.CombinerOperation.Temperature1.U.Actual	-0.281894
FirstStage.CombinerOperation.Temperature2.U.Actual	-0.365111
FirstStage.CombinerOperation.Temperature3.C.Actual	0.066181
Machine3.MaterialPressure.U.Actual \	
AmbientConditions.AmbientHumidity.U.Actual	
0.598059	

```
AmbientConditions.AmbientTemperature.U.Actual  
-0.361342  
Machine1.RawMaterial.Property1  
NaN  
Machine1.RawMaterial.Property2  
NaN  
Machine1.RawMaterial.Property3  
NaN  
Machine1.RawMaterial.Property4  
NaN  
Machine1.RawMaterialFeederParameter.U.Actual  
-0.207238  
Machine1.Zone1Temperature.C.Actual  
NaN  
Machine1.Zone2Temperature.C.Actual  
0.257630  
Machine1.MotorAmperage.U.Actual  
0.028006  
Machine1.MotorRPM.C.Actual  
-0.536045  
Machine1.MaterialPressure.U.Actual  
-0.192370  
Machine1.MaterialTemperature.U.Actual  
-0.463769  
Machine1.ExitZoneTemperature.C.Actual  
-0.147638  
Machine2.RawMaterial.Property1  
NaN  
Machine2.RawMaterial.Property2  
NaN  
Machine2.RawMaterial.Property3  
NaN  
Machine2.RawMaterial.Property4  
NaN  
Machine2.RawMaterialFeederParameter.U.Actual  
-0.000612  
Machine2.Zone1Temperature.C.Actual  
-0.091682  
Machine2.Zone2Temperature.C.Actual  
0.063957  
Machine2.MotorAmperage.U.Actual  
-0.179869  
Machine2.MotorRPM.C.Actual  
0.021303  
Machine2.MaterialPressure.U.Actual  
-0.094597  
Machine2.MaterialTemperature.U.Actual  
0.225170
```

```
Machine2.ExitZoneTemperature.C.Actual  
0.089968  
Machine3.RawMaterial.Property1  
NaN  
Machine3.RawMaterial.Property2  
NaN  
Machine3.RawMaterial.Property3  
NaN  
Machine3.RawMaterial.Property4  
NaN  
Machine3.RawMaterialFeederParameter.U.Actual  
-0.051286  
Machine3.Zone1Temperature.C.Actual  
NaN  
Machine3.Zone2Temperature.C.Actual  
0.184133  
Machine3.MotorAmperage.U.Actual  
0.130004  
Machine3.MotorRPM.C.Actual  
0.633475  
Machine3.MaterialPressure.U.Actual  
1.000000  
Machine3.MaterialTemperature.U.Actual  
0.061258  
Machine3.ExitZoneTemperature.C.Actual  
NaN  
FirstStage.CombinerOperation.Temperature1.U.Actual  
-0.122050  
FirstStage.CombinerOperation.Temperature2.U.Actual  
-0.221402  
FirstStage.CombinerOperation.Temperature3.C.Actual  
0.020413  
  
Machine3.MaterialTemperature.U.Actual \\  
AmbientConditions.AmbientHumidity.U.Actual  
0.302541  
AmbientConditions.AmbientTemperature.U.Actual  
-0.525419  
Machine1.RawMaterial.Property1  
NaN  
Machine1.RawMaterial.Property2  
NaN  
Machine1.RawMaterial.Property3  
NaN  
Machine1.RawMaterial.Property4  
NaN  
Machine1.RawMaterialFeederParameter.U.Actual  
-0.028946
```

```
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
-0.246943
Machine1.MotorAmperage.U.Actual
0.142625
Machine1.MotorRPM.C.Actual
-0.344940
Machine1.MaterialPressure.U.Actual
0.136839
Machine1.MaterialTemperature.U.Actual
-0.402755
Machine1.ExitZoneTemperature.C.Actual
0.203898
Machine2.RawMaterial.Property1
NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
-0.136385
Machine2.Zone1Temperature.C.Actual
-0.089904
Machine2.Zone2Temperature.C.Actual
0.071093
Machine2.MotorAmperage.U.Actual
-0.018824
Machine2.MotorRPM.C.Actual
0.018949
Machine2.MaterialPressure.U.Actual
0.025868
Machine2.MaterialTemperature.U.Actual
-0.035319
Machine2.ExitZoneTemperature.C.Actual
-0.218919
Machine3.RawMaterial.Property1
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
-0.091106
```

```
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual
-0.004267
Machine3.MotorAmperage.U.Actual
0.008828
Machine3.MotorRPM.C.Actual
0.039391
Machine3.MaterialPressure.U.Actual
0.061258
Machine3.MaterialTemperature.U.Actual
1.000000
Machine3.ExitZoneTemperature.C.Actual
NaN
FirstStage.CombinerOperation.Temperature1.U.Actual
-0.145629
FirstStage.CombinerOperation.Temperature2.U.Actual
-0.174804
FirstStage.CombinerOperation.Temperature3.C.Actual
0.037602

Machine3.ExitZoneTemperature.C.Actual \
AmbientConditions.AmbientHumidity.U.Actual
NaN
AmbientConditions.AmbientTemperature.U.Actual
NaN
Machine1.RawMaterial.Property1
NaN
Machine1.RawMaterial.Property2
NaN
Machine1.RawMaterial.Property3
NaN
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
NaN
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
NaN
Machine1.MotorAmperage.U.Actual
NaN
Machine1.MotorRPM.C.Actual
NaN
Machine1.MaterialPressure.U.Actual
NaN
Machine1.MaterialTemperature.U.Actual
NaN
```

```
Machine1.ExitZoneTemperature.C.Actual  
NaN  
Machine2.RawMaterial.Property1  
NaN  
Machine2.RawMaterial.Property2  
NaN  
Machine2.RawMaterial.Property3  
NaN  
Machine2.RawMaterial.Property4  
NaN  
Machine2.RawMaterialFeederParameter.U.Actual  
NaN  
Machine2.Zone1Temperature.C.Actual  
NaN  
Machine2.Zone2Temperature.C.Actual  
NaN  
Machine2.MotorAmperage.U.Actual  
NaN  
Machine2.MotorRPM.C.Actual  
NaN  
Machine2.MaterialPressure.U.Actual  
NaN  
Machine2.MaterialTemperature.U.Actual  
NaN  
Machine2.ExitZoneTemperature.C.Actual  
NaN  
Machine3.RawMaterial.Property1  
NaN  
Machine3.RawMaterial.Property2  
NaN  
Machine3.RawMaterial.Property3  
NaN  
Machine3.RawMaterial.Property4  
NaN  
Machine3.RawMaterialFeederParameter.U.Actual  
NaN  
Machine3.Zone1Temperature.C.Actual  
NaN  
Machine3.Zone2Temperature.C.Actual  
NaN  
Machine3.MotorAmperage.U.Actual  
NaN  
Machine3.MotorRPM.C.Actual  
NaN  
Machine3.MaterialPressure.U.Actual  
NaN  
Machine3.MaterialTemperature.U.Actual  
NaN
```

```
Machine3.ExitZoneTemperature.C.Actual  
NaN  
FirstStage.CombinerOperation.Temperature1.U.Actual  
NaN  
FirstStage.CombinerOperation.Temperature2.U.Actual  
NaN  
FirstStage.CombinerOperation.Temperature3.C.Actual  
NaN  
  
FirstStage.CombinerOperation.Temperature1.U.Actual \  
AmbientConditions.AmbientHumidity.U.Actual  
-0.338124  
AmbientConditions.AmbientTemperature.U.Actual  
0.317172  
Machine1.RawMaterial.Property1  
NaN  
Machine1.RawMaterial.Property2  
NaN  
Machine1.RawMaterial.Property3  
NaN  
Machine1.RawMaterial.Property4  
NaN  
Machine1.RawMaterialFeederParameter.U.Actual  
0.013763  
Machine1.Zone1Temperature.C.Actual  
NaN  
Machine1.Zone2Temperature.C.Actual  
0.125837  
Machine1.MotorAmperage.U.Actual  
-0.252034  
Machine1.MotorRPM.C.Actual  
0.432578  
Machine1.MaterialPressure.U.Actual  
-0.116284  
Machine1.MaterialTemperature.U.Actual  
0.305760  
Machine1.ExitZoneTemperature.C.Actual  
-0.125393  
Machine2.RawMaterial.Property1  
NaN  
Machine2.RawMaterial.Property2  
NaN  
Machine2.RawMaterial.Property3  
NaN  
Machine2.RawMaterial.Property4  
NaN  
Machine2.RawMaterialFeederParameter.U.Actual  
0.307538
```

```
Machine2.Zone1Temperature.C.Actual  
0.120479  
Machine2.Zone2Temperature.C.Actual  
0.140678  
Machine2.MotorAmperage.U.Actual  
-0.091539  
Machine2.MotorRPM.C.Actual  
-0.111397  
Machine2.MaterialPressure.U.Actual  
-0.067068  
Machine2.MaterialTemperature.U.Actual  
0.156567  
Machine2.ExitZoneTemperature.C.Actual  
-0.012410  
Machine3.RawMaterial.Property1  
NaN  
Machine3.RawMaterial.Property2  
NaN  
Machine3.RawMaterial.Property3  
NaN  
Machine3.RawMaterial.Property4  
NaN  
Machine3.RawMaterialFeederParameter.U.Actual  
0.299304  
Machine3.Zone1Temperature.C.Actual  
NaN  
Machine3.Zone2Temperature.C.Actual  
0.222053  
Machine3.MotorAmperage.U.Actual  
-0.017302  
Machine3.MotorRPM.C.Actual  
-0.281894  
Machine3.MaterialPressure.U.Actual  
-0.122050  
Machine3.MaterialTemperature.U.Actual  
-0.145629  
Machine3.ExitZoneTemperature.C.Actual  
NaN  
FirstStage.CombinerOperation.Temperature1.U.Actual  
1.000000  
FirstStage.CombinerOperation.Temperature2.U.Actual  
0.978113  
FirstStage.CombinerOperation.Temperature3.C.Actual  
0.161517  
  
FirstStage.CombinerOperation.Temperature2.U.Actual \\\nAmbientConditions.AmbientHumidity.U.Actual  
-0.451643
```

```
AmbientConditions.AmbientTemperature.U.Actual  
0.407969  
Machine1.RawMaterial.Property1  
NaN  
Machine1.RawMaterial.Property2  
NaN  
Machine1.RawMaterial.Property3  
NaN  
Machine1.RawMaterial.Property4  
NaN  
Machine1.RawMaterialFeederParameter.U.Actual  
0.049616  
Machine1.Zone1Temperature.C.Actual  
NaN  
Machine1.Zone2Temperature.C.Actual  
0.092470  
Machine1.MotorAmperage.U.Actual  
-0.224204  
Machine1.MotorRPM.C.Actual  
0.537219  
Machine1.MaterialPressure.U.Actual  
-0.089767  
Machine1.MaterialTemperature.U.Actual  
0.404468  
Machine1.ExitZoneTemperature.C.Actual  
-0.096736  
Machine2.RawMaterial.Property1  
NaN  
Machine2.RawMaterial.Property2  
NaN  
Machine2.RawMaterial.Property3  
NaN  
Machine2.RawMaterial.Property4  
NaN  
Machine2.RawMaterialFeederParameter.U.Actual  
0.299499  
Machine2.Zone1Temperature.C.Actual  
0.148730  
Machine2.Zone2Temperature.C.Actual  
0.123221  
Machine2.MotorAmperage.U.Actual  
-0.076836  
Machine2.MotorRPM.C.Actual  
-0.128837  
Machine2.MaterialPressure.U.Actual  
-0.049871  
Machine2.MaterialTemperature.U.Actual  
0.083431
```

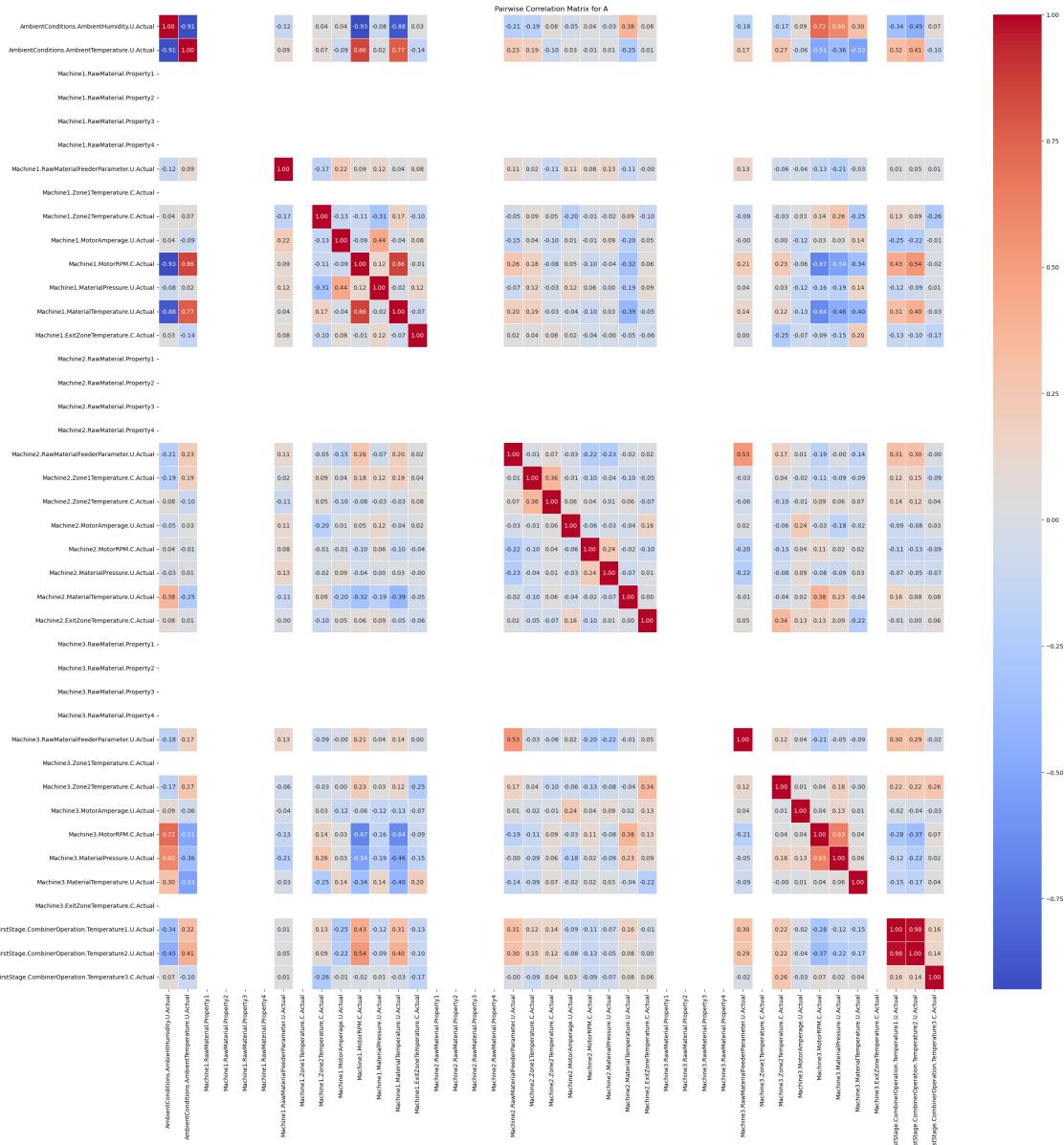
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Machine2.ExitZoneTemperature.C.Actual  
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Machine3.RawMaterial.Property1  
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Machine3.RawMaterial.Property2  
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Machine3.RawMaterial.Property3  
NaN  
Machine3.RawMaterial.Property4  
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Machine3.RawMaterialFeederParameter.U.Actual  
0.291271  
Machine3.Zone1Temperature.C.Actual  
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Machine3.Zone2Temperature.C.Actual  
0.222192  
Machine3.MotorAmperage.U.Actual  
-0.035655  
Machine3.MotorRPM.C.Actual  
-0.365111  
Machine3.MaterialPressure.U.Actual  
-0.221402  
Machine3.MaterialTemperature.U.Actual  
-0.174804  
Machine3.ExitZoneTemperature.C.Actual  
NaN  
FirstStage.CombinerOperation.Temperature1.U.Actual  
0.978113  
FirstStage.CombinerOperation.Temperature2.U.Actual  
1.000000  
FirstStage.CombinerOperation.Temperature3.C.Actual  
0.140491  
  
FirstStage.CombinerOperation.Temperature3.C.Actual  
AmbientConditions.AmbientHumidity.U.Actual  
0.068735  
AmbientConditions.AmbientTemperature.U.Actual  
-0.104086  
Machine1.RawMaterial.Property1  
NaN  
Machine1.RawMaterial.Property2  
NaN  
Machine1.RawMaterial.Property3  
NaN  
Machine1.RawMaterial.Property4  
NaN  
Machine1.RawMaterialFeederParameter.U.Actual  
0.014793
```

```
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
-0.262165
Machine1.MotorAmperage.U.Actual
-0.006464
Machine1.MotorRPM.C.Actual
-0.015200
Machine1.MaterialPressure.U.Actual
0.011167
Machine1.MaterialTemperature.U.Actual
-0.027361
Machine1.ExitZoneTemperature.C.Actual
-0.168143
Machine2.RawMaterial.Property1
NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
-0.000423
Machine2.Zone1Temperature.C.Actual
-0.091422
Machine2.Zone2Temperature.C.Actual
0.038847
Machine2.MotorAmperage.U.Actual
0.026084
Machine2.MotorRPM.C.Actual
-0.092999
Machine2.MaterialPressure.U.Actual
-0.071830
Machine2.MaterialTemperature.U.Actual
0.080340
Machine2.ExitZoneTemperature.C.Actual
0.063512
Machine3.RawMaterial.Property1
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
-0.022014
```

```
Machine3.Zone1Temperature.C.Actual  
NaN  
Machine3.Zone2Temperature.C.Actual  
0.262298  
Machine3.MotorAmperage.U.Actual  
-0.031174  
Machine3.MotorRPM.C.Actual  
0.066181  
Machine3.MaterialPressure.U.Actual  
0.020413  
Machine3.MaterialTemperature.U.Actual  
0.037602  
Machine3.ExitZoneTemperature.C.Actual  
NaN  
FirstStage.CombinerOperation.Temperature1.U.Actual  
0.161517  
FirstStage.CombinerOperation.Temperature2.U.Actual  
0.140491  
FirstStage.CombinerOperation.Temperature3.C.Actual  
1.000000
```

[41 rows x 41 columns]

```
[15]: import seaborn as sns  
import matplotlib.pyplot as plt  
  
# Plotting the correlation matrix as a heatmap  
plt.figure(figsize=(30, 30))  
sns.heatmap(correlation_matrix, annot=True, fmt=".2f", cmap='coolwarm',  
            linewidths=0.5)  
plt.title("Pairwise Correlation Matrix for A")  
plt.show()
```



```
[16]: # Feature Scaling for Model A
import pandas as pd
import numpy as np
from sklearn.preprocessing import StandardScaler
from sklearn.feature_selection import mutual_info_regression
import matplotlib.pyplot as plt

scaler = StandardScaler()
X_scaled = scaler.fit_transform(Input_AA)
y_scaled = scaler.fit_transform(Output_AA)
```

```
[17]: # Calculate mutual information for each output feature
mi_scores = []
for i in range(y_scaled.shape[1]):
    mi_scores.append(mutual_info_regression(X_scaled, y_scaled[:, i]))
```

```
[18]: # Average mutual information scores across all output features
mi_scores_avg = np.mean(mi_scores, axis=0)
mi_scores_series = pd.Series(mi_scores_avg, index=Input_AN).
    ↪sort_values(ascending=False)

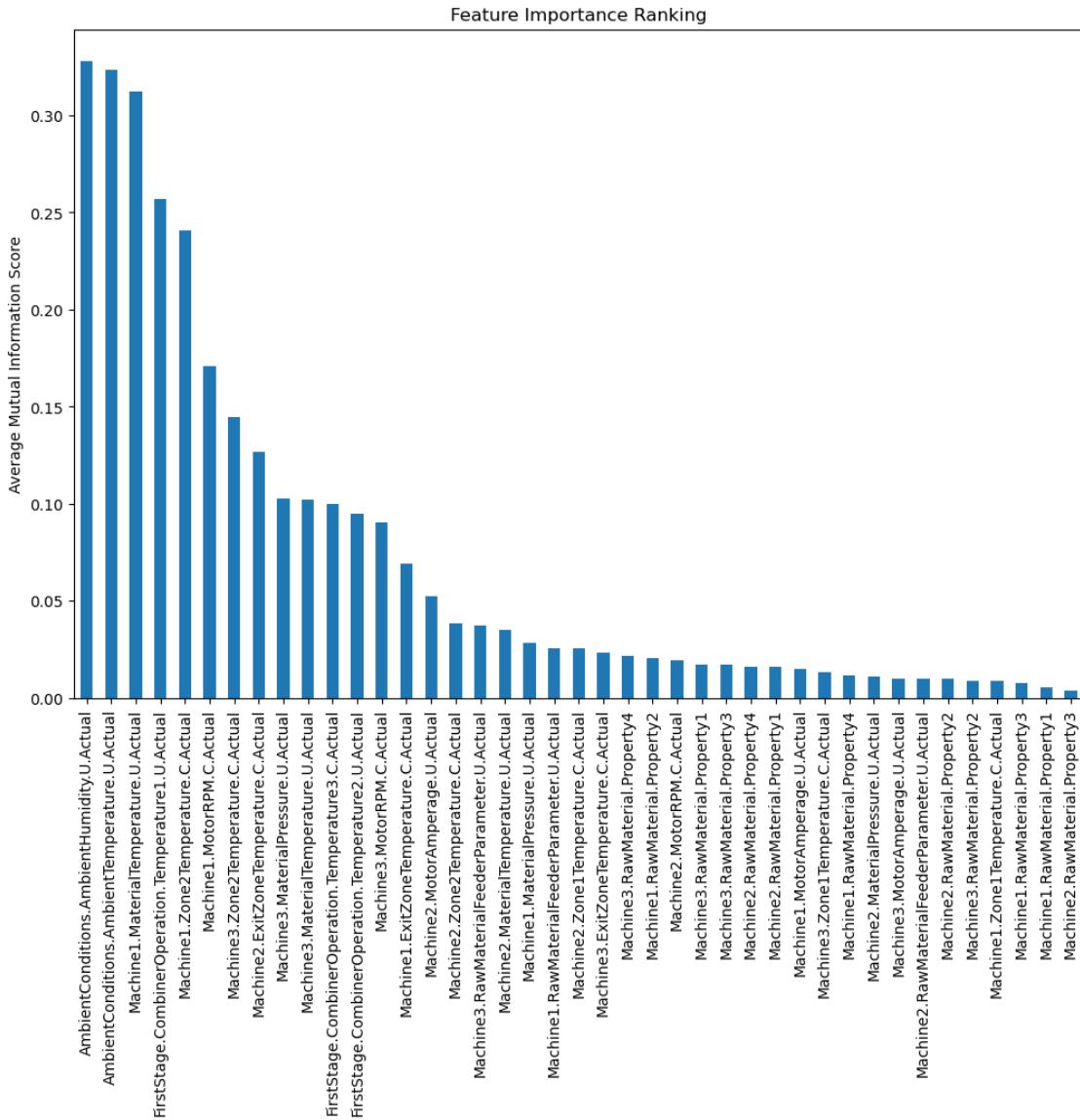
# Display feature ranking
print("Feature Ranking based on Mutual Information Scores:")
print(mi_scores_series)
```

Feature Ranking based on Mutual Information Scores:

AmbientConditions.AmbientHumidity.U.Actual	0.327989
AmbientConditions.AmbientTemperature.U.Actual	0.323584
Machine1.MaterialTemperature.U.Actual	0.312117
FirstStage.CombinerOperation.Temperature1.U.Actual	0.256929
Machine1.Zone2Temperature.C.Actual	0.240545
Machine1.MotorRPM.C.Actual	0.170870
Machine3.Zone2Temperature.C.Actual	0.144790
Machine2.ExitZoneTemperature.C.Actual	0.126389
Machine3.MaterialPressure.U.Actual	0.102345
Machine3.MaterialTemperature.U.Actual	0.101780
FirstStage.CombinerOperation.Temperature3.C.Actual	0.099677
FirstStage.CombinerOperation.Temperature2.U.Actual	0.094974
Machine3.MotorRPM.C.Actual	0.090138
Machine1.ExitZoneTemperature.C.Actual	0.068936
Machine2.MotorAmperage.U.Actual	0.052366
Machine2.Zone2Temperature.C.Actual	0.038056
Machine3.RawMaterialFeederParameter.U.Actual	0.037076
Machine2.MaterialTemperature.U.Actual	0.034690
Machine1.MaterialPressure.U.Actual	0.028141
Machine1.RawMaterialFeederParameter.U.Actual	0.025728
Machine2.Zone1Temperature.C.Actual	0.025280
Machine3.ExitZoneTemperature.C.Actual	0.023246
Machine3.RawMaterial.Property4	0.021792
Machine1.RawMaterial.Property2	0.020584
Machine2.MotorRPM.C.Actual	0.019485
Machine3.RawMaterial.Property1	0.016864
Machine3.RawMaterial.Property3	0.016794
Machine2.RawMaterial.Property4	0.015960
Machine2.RawMaterial.Property1	0.015880
Machine1.MotorAmperage.U.Actual	0.014640
Machine3.Zone1Temperature.C.Actual	0.013272
Machine1.RawMaterial.Property4	0.011333
Machine2.MaterialPressure.U.Actual	0.010808

```
Machine3.MotorAmperage.U.Actual           0.010029
Machine2.RawMaterialFeederParameter.U.Actual 0.009947
Machine2.RawMaterial.Property2             0.009643
Machine3.RawMaterial.Property2             0.008705
Machine1.Zone1Temperature.C.Actual         0.008497
Machine1.RawMaterial.Property3             0.007405
Machine1.RawMaterial.Property1             0.005540
Machine2.RawMaterial.Property3             0.003588
dtype: float64
```

```
[19]: # Plot the feature importance
plt.figure(figsize=(12, 8))
mi_scores_series.plot(kind='bar')
plt.title('Feature Importance Ranking')
plt.ylabel('Average Mutual Information Score')
plt.show()
```



[20] : #Feature Selection of Data for model B

```

IN  = [0,1,50,51,52,53,54,55,56,57,58,59,60,61,62,63]
Input_B = Araw_data_clean.values[:,IN]
Input_BN = Araw_data_clean.columns[IN]
Input_BAN = pd.DataFrame(data=Input_B) #Non name
Input_BA = pd.DataFrame(data=Input_B, columns=Input_BN)
Output_B = Araw_data_clean.values[:,64:78]
Output_BN = Araw_data_clean.columns[64:78]
Output_BA = pd.DataFrame(data=Output_B, columns=Output_BN)
print("Input for model B")
print(Input_BA.info())
print("Output for model B")

```

```
print(Output_BA.info())
```

```
Input for model B
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 191 entries, 0 to 190
Data columns (total 16 columns):
 #   Column           Non-Null Count Dtype  
 ---  --  
 0   AmbientConditions.AmbientHumidity.U.Actual    191 non-null   float64 
 1   AmbientConditions.AmbientTemperature.U.Actual  191 non-null   float64 
 2   Machine4.Temperature1.C.Actual                191 non-null   float64 
 3   Machine4.Temperature2.C.Actual                191 non-null   float64 
 4   Machine4.Pressure.C.Actual                   191 non-null   float64 
 5   Machine4.Temperature3.C.Actual                191 non-null   float64 
 6   Machine4.Temperature4.C.Actual                191 non-null   float64 
 7   Machine4.Temperature5.C.Actual                191 non-null   float64 
 8   Machine4.ExitTemperature.U.Actual              191 non-null   float64 
 9   Machine5.Temperature1.C.Actual                191 non-null   float64 
 10  Machine5.Temperature2.C.Actual                191 non-null   float64 
 11  Machine5.Temperature3.C.Actual                191 non-null   float64 
 12  Machine5.Temperature4.C.Actual                191 non-null   float64 
 13  Machine5.Temperature5.C.Actual                191 non-null   float64 
 14  Machine5.Temperature6.C.Actual                191 non-null   float64 
 15  Machine5.ExitTemperature.U.Actual              191 non-null   float64 
dtypes: float64(16)
memory usage: 24.0 KB
None
Output for model B
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 191 entries, 0 to 190
Data columns (total 14 columns):
 #   Column           Non-Null Count Dtype  
 ---  --  
 0   Stage2.Output.Measurement0.U.Actual        191 non-null   float64 
 1   Stage2.Output.Measurement1.U.Actual        191 non-null   float64 
 2   Stage2.Output.Measurement2.U.Actual        191 non-null   float64 
 3   Stage2.Output.Measurement3.U.Actual        191 non-null   float64 
 4   Stage2.Output.Measurement5.U.Actual        191 non-null   float64 
 5   Stage2.Output.Measurement6.U.Actual        191 non-null   float64 
 6   Stage2.Output.Measurement7.U.Actual        191 non-null   float64 
 7   Stage2.Output.Measurement8.U.Actual        191 non-null   float64 
 8   Stage2.Output.Measurement9.U.Actual        191 non-null   float64 
 9   Stage2.Output.Measurement10.U.Actual       191 non-null   float64 
 10  Stage2.Output.Measurement11.U.Actual       191 non-null   float64 
 11  Stage2.Output.Measurement12.U.Actual       191 non-null   float64 
 12  Stage2.Output.Measurement13.U.Actual       191 non-null   float64 
 13  Stage2.Output.Measurement14.U.Actual       191 non-null   float64 
dtypes: float64(14)
```

```
memory usage: 21.0 KB
```

```
None
```

```
[21]: #Pair wise Coraltion of Matrix of Model B
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt

# Assuming Araw_data_clean is already defined and cleaned as shown in the
# provided code

# Feature Selection of Data for model B
IN = [0, 1, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63]
Input_B = Araw_data_clean.values[:, IN]
Input_BN = Araw_data_clean.columns[IN]
Input_BAN = pd.DataFrame(data=Input_B) # Non-name DataFrame
Input_BA = pd.DataFrame(data=Input_B, columns=Input_BN)

# Calculating the pairwise correlation matrix
correlation_matrix_B = Input_BA.corr()

# Displaying the correlation matrix
print("Pairwise Correlation Matrix for Model B:")
print(correlation_matrix_B)

# Plotting the correlation matrix as a heatmap
plt.figure(figsize=(14, 10))
sns.heatmap(correlation_matrix_B, annot=True, fmt=".2f", cmap='coolwarm',
            linewidths=0.5)
plt.title("Pairwise Correlation Matrix for Model B")
plt.show()
```

```
Pairwise Correlation Matrix for Model B:
AmbientConditions.AmbientHumidity.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
1.000000
AmbientConditions.AmbientTemperature.U.Actual
-0.909604
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
0.390033
Machine4.Pressure.C.Actual
0.037522
Machine4.Temperature3.C.Actual
-0.427556
Machine4.Temperature4.C.Actual
0.037522
```

```
Machine4.Temperature5.C.Actual
0.147497
Machine4.ExitTemperature.U.Actual
-0.003352
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
-0.871569
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
-0.874571
Machine5.ExitTemperature.U.Actual
0.646153

AmbientConditions.AmbientTemperature.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
-0.909604
AmbientConditions.AmbientTemperature.U.Actual
1.000000
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
-0.289789
Machine4.Pressure.C.Actual
-0.077463
Machine4.Temperature3.C.Actual
0.330402
Machine4.Temperature4.C.Actual
-0.077463
Machine4.Temperature5.C.Actual
-0.310889
Machine4.ExitTemperature.U.Actual
0.005040
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
0.763961
Machine5.Temperature5.C.Actual
NaN
```

Machine5.Temperature6.C.Actual
 0.917584
 Machine5.ExitTemperature.U.Actual
 -0.506046

AmbientConditions.AmbientHumidity.U.Actual	Machine4.Temperature1.C.Actual \	NaN
AmbientConditions.AmbientTemperature.U.Actual		NaN
Machine4.Temperature1.C.Actual		NaN
Machine4.Temperature2.C.Actual		NaN
Machine4.Pressure.C.Actual		NaN
Machine4.Temperature3.C.Actual		NaN
Machine4.Temperature4.C.Actual		NaN
Machine4.Temperature5.C.Actual		NaN
Machine4.ExitTemperature.U.Actual		NaN
Machine5.Temperature1.C.Actual		NaN
Machine5.Temperature2.C.Actual		NaN
Machine5.Temperature3.C.Actual		NaN
Machine5.Temperature4.C.Actual		NaN
Machine5.Temperature5.C.Actual		NaN
Machine5.Temperature6.C.Actual		NaN
Machine5.ExitTemperature.U.Actual		NaN

AmbientConditions.AmbientHumidity.U.Actual	Machine4.Temperature2.C.Actual \	0.390033
AmbientConditions.AmbientTemperature.U.Actual		-0.289789
Machine4.Temperature1.C.Actual		NaN
Machine4.Temperature2.C.Actual		1.000000
Machine4.Pressure.C.Actual		-0.060130
Machine4.Temperature3.C.Actual		-0.264777
Machine4.Temperature4.C.Actual		-0.060130
Machine4.Temperature5.C.Actual		0.378734
Machine4.ExitTemperature.U.Actual		0.215612
Machine5.Temperature1.C.Actual		NaN
Machine5.Temperature2.C.Actual		NaN
Machine5.Temperature3.C.Actual		NaN
Machine5.Temperature4.C.Actual		-0.230885
Machine5.Temperature5.C.Actual		NaN
Machine5.Temperature6.C.Actual		-0.271343
Machine5.ExitTemperature.U.Actual		0.128764

AmbientConditions.AmbientHumidity.U.Actual	Machine4.Pressure.C.Actual \	0.037522
AmbientConditions.AmbientTemperature.U.Actual		-0.077463
Machine4.Temperature1.C.Actual		NaN
Machine4.Temperature2.C.Actual		-0.060130
Machine4.Pressure.C.Actual		1.000000
Machine4.Temperature3.C.Actual		-0.075898

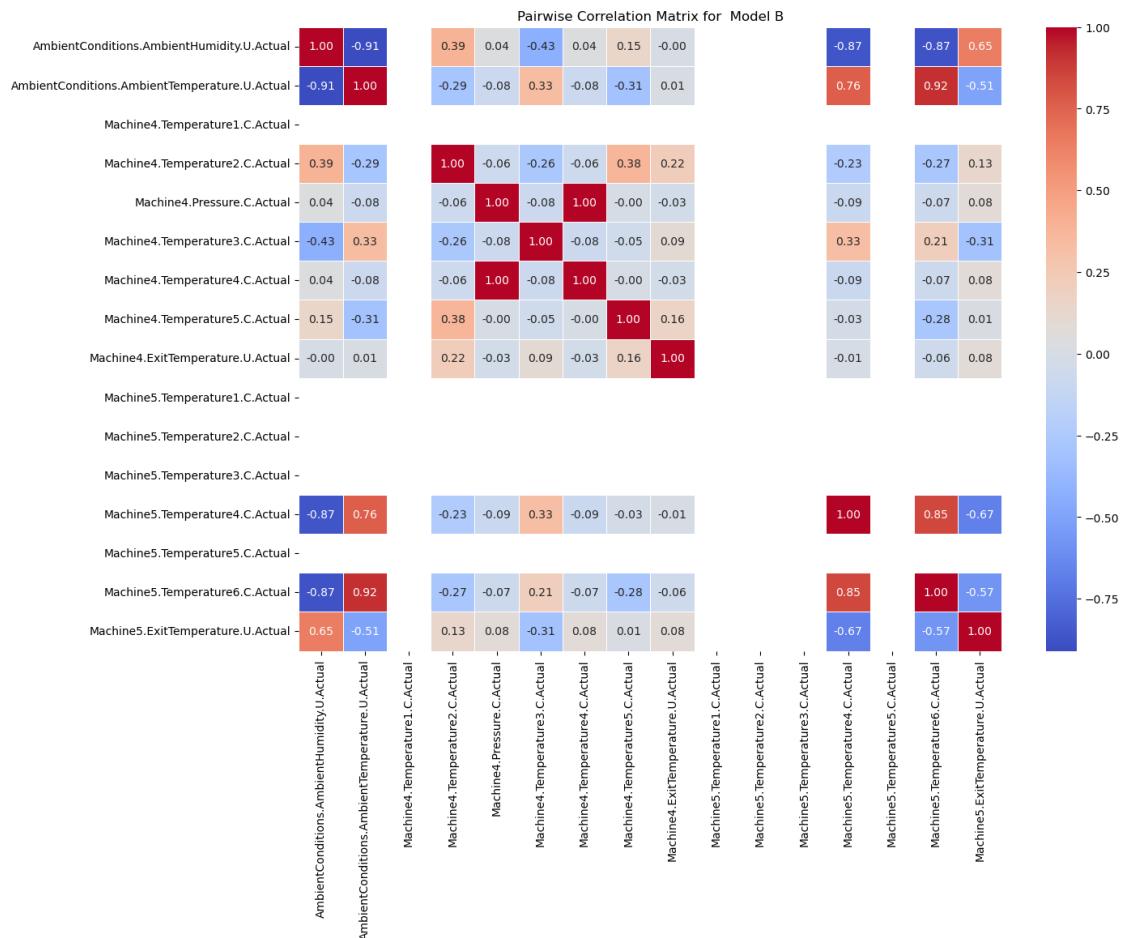
Machine4.Temperature4.C.Actual	1.000000
Machine4.Temperature5.C.Actual	-0.000313
Machine4.ExitTemperature.U.Actual	-0.031819
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN
Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	-0.085581
Machine5.Temperature5.C.Actual	NaN
Machine5.Temperature6.C.Actual	-0.073525
Machine5.ExitTemperature.U.Actual	0.080503
Machine4.Temperature3.C.Actual \	
AmbientConditions.AmbientHumidity.U.Actual	-0.427556
AmbientConditions.AmbientTemperature.U.Actual	0.330402
Machine4.Temperature1.C.Actual	NaN
Machine4.Temperature2.C.Actual	-0.264777
Machine4.Pressure.C.Actual	-0.075898
Machine4.Temperature3.C.Actual	1.000000
Machine4.Temperature4.C.Actual	-0.075898
Machine4.Temperature5.C.Actual	-0.047420
Machine4.ExitTemperature.U.Actual	0.090470
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN
Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	0.325039
Machine5.Temperature5.C.Actual	NaN
Machine5.Temperature6.C.Actual	0.206057
Machine5.ExitTemperature.U.Actual	-0.307190
Machine4.Temperature4.C.Actual \	
AmbientConditions.AmbientHumidity.U.Actual	0.037522
AmbientConditions.AmbientTemperature.U.Actual	-0.077463
Machine4.Temperature1.C.Actual	NaN
Machine4.Temperature2.C.Actual	-0.060130
Machine4.Pressure.C.Actual	1.000000
Machine4.Temperature3.C.Actual	-0.075898
Machine4.Temperature4.C.Actual	1.000000
Machine4.Temperature5.C.Actual	-0.000313
Machine4.ExitTemperature.U.Actual	-0.031819
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN
Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	-0.085581
Machine5.Temperature5.C.Actual	NaN
Machine5.Temperature6.C.Actual	-0.073525
Machine5.ExitTemperature.U.Actual	0.080503
Machine4.Temperature5.C.Actual \	

AmbientConditions.AmbientHumidity.U.Actual	0.147497
AmbientConditions.AmbientTemperature.U.Actual	-0.310889
Machine4.Temperature1.C.Actual	NaN
Machine4.Temperature2.C.Actual	0.378734
Machine4.Pressure.C.Actual	-0.000313
Machine4.Temperature3.C.Actual	-0.047420
Machine4.Temperature4.C.Actual	-0.000313
Machine4.Temperature5.C.Actual	1.000000
Machine4.ExitTemperature.U.Actual	0.162331
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN
Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	-0.025806
Machine5.Temperature5.C.Actual	NaN
Machine5.Temperature6.C.Actual	-0.282055
Machine5.ExitTemperature.U.Actual	0.014004
Machine4.ExitTemperature.U.Actual	
\	
AmbientConditions.AmbientHumidity.U.Actual	-0.003352
AmbientConditions.AmbientTemperature.U.Actual	0.005040
Machine4.Temperature1.C.Actual	NaN
Machine4.Temperature2.C.Actual	0.215612
Machine4.Pressure.C.Actual	-0.031819
Machine4.Temperature3.C.Actual	0.090470
Machine4.Temperature4.C.Actual	-0.031819
Machine4.Temperature5.C.Actual	0.162331
Machine4.ExitTemperature.U.Actual	1.000000
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN
Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	-0.006294
Machine5.Temperature5.C.Actual	NaN
Machine5.Temperature6.C.Actual	-0.056962
Machine5.ExitTemperature.U.Actual	0.081983
Machine5.Temperature1.C.Actual \	
AmbientConditions.AmbientHumidity.U.Actual	NaN
AmbientConditions.AmbientTemperature.U.Actual	NaN
Machine4.Temperature1.C.Actual	NaN
Machine4.Temperature2.C.Actual	NaN
Machine4.Pressure.C.Actual	NaN
Machine4.Temperature3.C.Actual	NaN
Machine4.Temperature4.C.Actual	NaN
Machine4.Temperature5.C.Actual	NaN
Machine4.ExitTemperature.U.Actual	NaN
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN

Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	NaN
Machine5.Temperature5.C.Actual	NaN
Machine5.Temperature6.C.Actual	NaN
Machine5.ExitTemperature.U.Actual	NaN
Machine5.Temperature2.C.Actual \	
AmbientConditions.AmbientHumidity.U.Actual	NaN
AmbientConditions.AmbientTemperature.U.Actual	NaN
Machine4.Temperature1.C.Actual	NaN
Machine4.Temperature2.C.Actual	NaN
Machine4.Pressure.C.Actual	NaN
Machine4.Temperature3.C.Actual	NaN
Machine4.Temperature4.C.Actual	NaN
Machine4.Temperature5.C.Actual	NaN
Machine4.ExitTemperature.U.Actual	NaN
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN
Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	NaN
Machine5.Temperature5.C.Actual	NaN
Machine5.Temperature6.C.Actual	NaN
Machine5.ExitTemperature.U.Actual	NaN
Machine5.Temperature3.C.Actual \	
AmbientConditions.AmbientHumidity.U.Actual	NaN
AmbientConditions.AmbientTemperature.U.Actual	NaN
Machine4.Temperature1.C.Actual	NaN
Machine4.Temperature2.C.Actual	NaN
Machine4.Pressure.C.Actual	NaN
Machine4.Temperature3.C.Actual	NaN
Machine4.Temperature4.C.Actual	NaN
Machine4.Temperature5.C.Actual	NaN
Machine4.ExitTemperature.U.Actual	NaN
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN
Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	NaN
Machine5.Temperature5.C.Actual	NaN
Machine5.Temperature6.C.Actual	NaN
Machine5.ExitTemperature.U.Actual	NaN
Machine5.Temperature4.C.Actual \	
AmbientConditions.AmbientHumidity.U.Actual	-0.871569
AmbientConditions.AmbientTemperature.U.Actual	0.763961
Machine4.Temperature1.C.Actual	NaN
Machine4.Temperature2.C.Actual	-0.230885
Machine4.Pressure.C.Actual	-0.085581

Machine4.Temperature3.C.Actual	0.325039
Machine4.Temperature4.C.Actual	-0.085581
Machine4.Temperature5.C.Actual	-0.025806
Machine4.ExitTemperature.U.Actual	-0.006294
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN
Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	1.000000
Machine5.Temperature5.C.Actual	NaN
Machine5.Temperature6.C.Actual	0.845014
Machine5.ExitTemperature.U.Actual	-0.673780
	Machine5.Temperature5.C.Actual \
AmbientConditions.AmbientHumidity.U.Actual	NaN
AmbientConditions.AmbientTemperature.U.Actual	NaN
Machine4.Temperature1.C.Actual	NaN
Machine4.Temperature2.C.Actual	NaN
Machine4.Pressure.C.Actual	NaN
Machine4.Temperature3.C.Actual	NaN
Machine4.Temperature4.C.Actual	NaN
Machine4.Temperature5.C.Actual	NaN
Machine4.ExitTemperature.U.Actual	NaN
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN
Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	NaN
Machine5.Temperature5.C.Actual	NaN
Machine5.Temperature6.C.Actual	NaN
Machine5.ExitTemperature.U.Actual	NaN
	Machine5.Temperature6.C.Actual \
AmbientConditions.AmbientHumidity.U.Actual	-0.874571
AmbientConditions.AmbientTemperature.U.Actual	0.917584
Machine4.Temperature1.C.Actual	NaN
Machine4.Temperature2.C.Actual	-0.271343
Machine4.Pressure.C.Actual	-0.073525
Machine4.Temperature3.C.Actual	0.206057
Machine4.Temperature4.C.Actual	-0.073525
Machine4.Temperature5.C.Actual	-0.282055
Machine4.ExitTemperature.U.Actual	-0.056962
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN
Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	0.845014
Machine5.Temperature5.C.Actual	NaN
Machine5.Temperature6.C.Actual	1.000000
Machine5.ExitTemperature.U.Actual	-0.574757

	Machine5.ExitTemperature.U.Actual	
AmbientConditions.AmbientHumidity.U.Actual		0.646153
AmbientConditions.AmbientTemperature.U.Actual		-0.506046
Machine4.Temperature1.C.Actual		NaN
Machine4.Temperature2.C.Actual		0.128764
Machine4.Pressure.C.Actual		0.080503
Machine4.Temperature3.C.Actual		-0.307190
Machine4.Temperature4.C.Actual		0.080503
Machine4.Temperature5.C.Actual		0.014004
Machine4.ExitTemperature.U.Actual		0.081983
Machine5.Temperature1.C.Actual		NaN
Machine5.Temperature2.C.Actual		NaN
Machine5.Temperature3.C.Actual		NaN
Machine5.Temperature4.C.Actual		-0.673780
Machine5.Temperature5.C.Actual		NaN
Machine5.Temperature6.C.Actual		-0.574757
Machine5.ExitTemperature.U.Actual		1.000000



```
[22]: # Feature Scaling for Model B
import pandas as pd
import numpy as np
from sklearn.preprocessing import StandardScaler
from sklearn.feature_selection import mutual_info_regression
import matplotlib.pyplot as plt

scaler = StandardScaler()
X_scaled = scaler.fit_transform(Input_BA)
y_scaled = scaler.fit_transform(Output_BA)

# Calculate mutual information for each output feature
mi_scores = []
for i in range(y_scaled.shape[1]):
    mi_scores.append(mutual_info_regression(X_scaled, y_scaled[:, i]))

# Average mutual information scores across all output features
mi_scores_avg = np.mean(mi_scores, axis=0)
mi_scores_series = pd.Series(mi_scores_avg, index=Input_BN).
    sort_values(ascending=False)

# Display feature ranking
print("Feature Ranking based on Mutual Information Scores for Model B:")
print(mi_scores_series)
```

Feature Ranking based on Mutual Information Scores for Model B:

Machine5.Temperature6.C.Actual	0.131528
AmbientConditions.AmbientHumidity.U.Actual	0.129552
AmbientConditions.AmbientTemperature.U.Actual	0.119162
Machine5.Temperature4.C.Actual	0.102538
Machine5.ExitTemperature.U.Actual	0.059323
Machine4.Temperature2.C.Actual	0.044639
Machine4.Temperature5.C.Actual	0.040969
Machine4.ExitTemperature.U.Actual	0.034056
Machine4.Temperature3.C.Actual	0.029043
Machine4.Pressure.C.Actual	0.025484
Machine5.Temperature5.C.Actual	0.021509
Machine4.Temperature4.C.Actual	0.019109
Machine5.Temperature3.C.Actual	0.019003
Machine5.Temperature1.C.Actual	0.016078
Machine4.Temperature1.C.Actual	0.012788
Machine5.Temperature2.C.Actual	0.009516

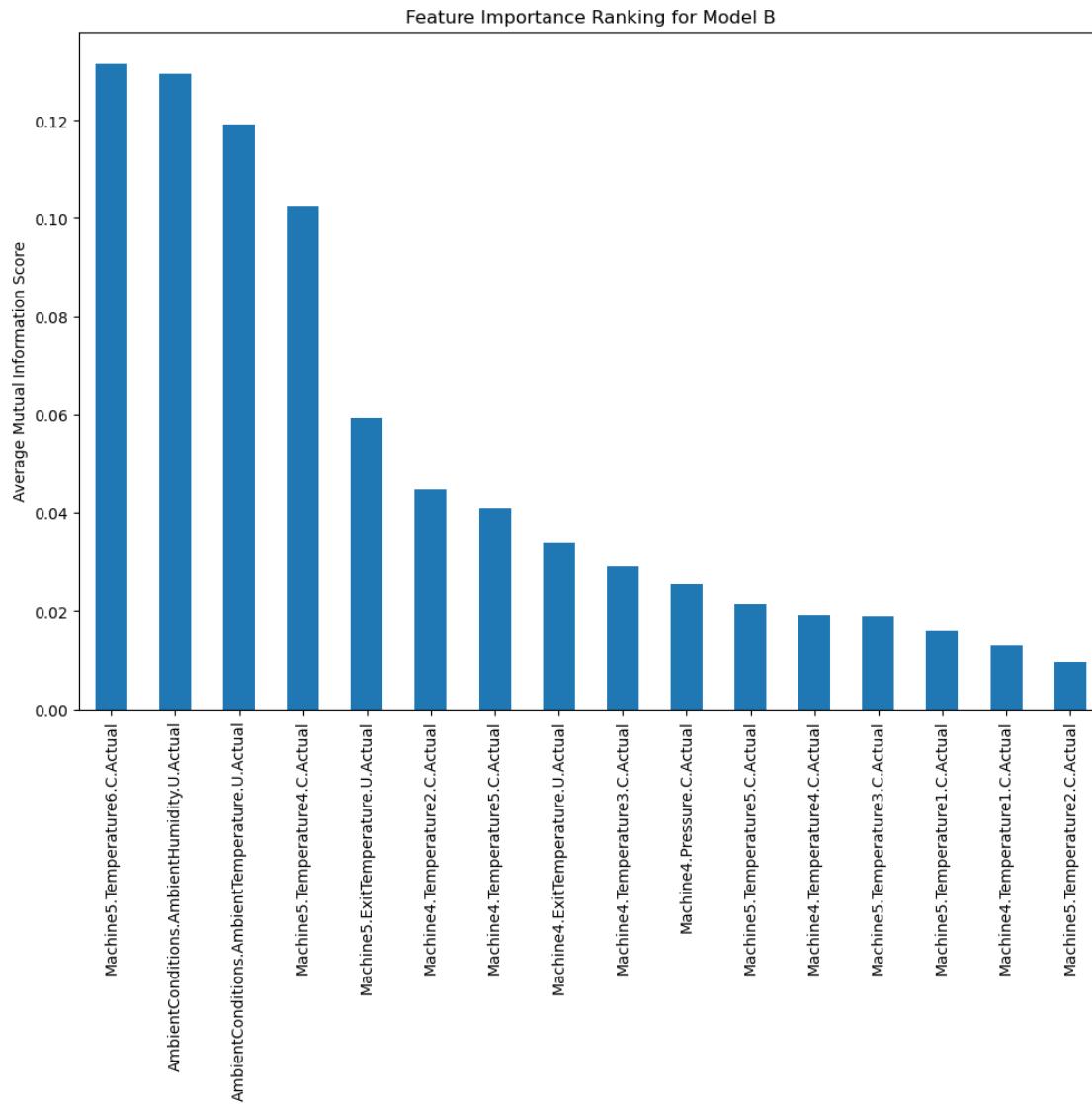
dtype: float64

```
[23]: # Plot the feature importance
plt.figure(figsize=(12, 8))
mi_scores_series.plot(kind='bar')
```

```

plt.title('Feature Importance Ranking for Model B')
plt.ylabel('Average Mutual Information Score')
plt.show()

```



[24] : #Feature Selection of Data for model C

```

INC = [0, 1, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63]
Input_C = Araw_data_clean.values[:, INC]
Input_CN = Araw_data_clean.columns[INC]
Input_CA = pd.DataFrame(data=Input_C, columns=Input_CN)
Input_CAN = pd.DataFrame(data=Input_C) #Non name
Output_CN = Araw_data_clean.columns[64:78]

```

```

Output_CA = Output_BA
print("Input for model C")
print(Input_CA.info())
print("Output for model C")
print(Output_CA.info())

```

Input for model C

<class 'pandas.core.frame.DataFrame'>

RangeIndex: 191 entries, 0 to 190

Data columns (total 25 columns):

#	Column	Non-Null Count	Dtype
0	AmbientConditions.AmbientHumidity.U.Actual	191 non-null	float64
1	AmbientConditions.AmbientTemperature.U.Actual	191 non-null	float64
2	Stage1.Output.Measurement0.U.Actual	191 non-null	float64
3	Stage1.Output.Measurement2.U.Actual	191 non-null	float64
4	Stage1.Output.Measurement3.U.Actual	191 non-null	float64
5	Stage1.Output.Measurement4.U.Actual	191 non-null	float64
6	Stage1.Output.Measurement8.U.Actual	191 non-null	float64
7	Stage1.Output.Measurement9.U.Actual	191 non-null	float64
8	Stage1.Output.Measurement10.U.Actual	191 non-null	float64
9	Stage1.Output.Measurement12.U.Actual	191 non-null	float64
10	Stage1.Output.Measurement13.U.Actual	191 non-null	float64
11	Machine4.Temperature1.C.Actual	191 non-null	float64
12	Machine4.Temperature2.C.Actual	191 non-null	float64
13	Machine4.Pressure.C.Actual	191 non-null	float64
14	Machine4.Temperature3.C.Actual	191 non-null	float64
15	Machine4.Temperature4.C.Actual	191 non-null	float64
16	Machine4.Temperature5.C.Actual	191 non-null	float64
17	Machine4.ExitTemperature.U.Actual	191 non-null	float64
18	Machine5.Temperature1.C.Actual	191 non-null	float64
19	Machine5.Temperature2.C.Actual	191 non-null	float64
20	Machine5.Temperature3.C.Actual	191 non-null	float64
21	Machine5.Temperature4.C.Actual	191 non-null	float64
22	Machine5.Temperature5.C.Actual	191 non-null	float64
23	Machine5.Temperature6.C.Actual	191 non-null	float64
24	Machine5.ExitTemperature.U.Actual	191 non-null	float64

dtypes: float64(25)

memory usage: 37.4 KB

None

Output for model C

<class 'pandas.core.frame.DataFrame'>

RangeIndex: 191 entries, 0 to 190

Data columns (total 14 columns):

#	Column	Non-Null Count	Dtype
0	Stage2.Output.Measurement0.U.Actual	191 non-null	float64
1	Stage2.Output.Measurement1.U.Actual	191 non-null	float64

```

2  Stage2.Output.Measurement2.U.Actual    191 non-null    float64
3  Stage2.Output.Measurement3.U.Actual    191 non-null    float64
4  Stage2.Output.Measurement5.U.Actual    191 non-null    float64
5  Stage2.Output.Measurement6.U.Actual    191 non-null    float64
6  Stage2.Output.Measurement7.U.Actual    191 non-null    float64
7  Stage2.Output.Measurement8.U.Actual    191 non-null    float64
8  Stage2.Output.Measurement9.U.Actual    191 non-null    float64
9  Stage2.Output.Measurement10.U.Actual   191 non-null    float64
10 Stage2.Output.Measurement11.U.Actual   191 non-null    float64
11 Stage2.Output.Measurement12.U.Actual   191 non-null    float64
12 Stage2.Output.Measurement13.U.Actual   191 non-null    float64
13 Stage2.Output.Measurement14.U.Actual   191 non-null    float64
dtypes: float64(14)
memory usage: 21.0 KB
None

```

```
[25]: #Pair wise Coraltion of Matrix of Model C
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt

# Assuming Araw_data_clean is already defined and cleaned as shown in the ↴
# provided code

# Feature Selection of Data for model C
INC = [0, 1, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, ↴
       57, 58, 59, 60, 61, 62, 63]
Input_C = Araw_data_clean.values[:, INC]
Input_CN = Araw_data_clean.columns[INC]
Input_CA = pd.DataFrame(data=Input_C, columns=Input_CN)

# Calculating the pairwise correlation matrix
correlation_matrix_C = Input_CA.corr()

# Displaying the correlation matrix
print("Pairwise Correlation Matrix for Model C:")
print(correlation_matrix_C)

# Plotting the correlation matrix as a heatmap
plt.figure(figsize=(16, 12))
sns.heatmap(correlation_matrix_C, annot=True, fmt=".2f", cmap='coolwarm', ↴
            linewidths=0.5)
plt.title("Pairwise Correlation Matrix for Model C")
plt.show()
```

```

Pairwise Correlation Matrix for Model C:
AmbientConditions.AmbientHumidity.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual

```

1.000000
AmbientConditions.AmbientTemperature.U.Actual
-0.909604
Stage1.Output.Measurement0.U.Actual
-0.496784
Stage1.Output.Measurement2.U.Actual
-0.048853
Stage1.Output.Measurement3.U.Actual
0.097087
Stage1.Output.Measurement4.U.Actual
-0.750915
Stage1.Output.Measurement8.U.Actual
0.050575
Stage1.Output.Measurement9.U.Actual
-0.322996
Stage1.Output.Measurement10.U.Actual
0.453538
Stage1.Output.Measurement12.U.Actual
-0.108517
Stage1.Output.Measurement13.U.Actual
-0.678806
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
0.390033
Machine4.Pressure.C.Actual
0.037522
Machine4.Temperature3.C.Actual
-0.427556
Machine4.Temperature4.C.Actual
0.037522
Machine4.Temperature5.C.Actual
0.147497
Machine4.ExitTemperature.U.Actual
-0.003352
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
-0.871569
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
-0.874571
Machine5.ExitTemperature.U.Actual

0.646153

AmbientConditions.AmbientTemperature.U.Actual \

AmbientConditions.AmbientHumidity.U.Actual

-0.909604

AmbientConditions.AmbientTemperature.U.Actual

1.000000

Stage1.Output.Measurement0.U.Actual

0.453721

Stage1.Output.Measurement2.U.Actual

-0.068267

Stage1.Output.Measurement3.U.Actual

0.025208

Stage1.Output.Measurement4.U.Actual

0.801083

Stage1.Output.Measurement8.U.Actual

0.064908

Stage1.Output.Measurement9.U.Actual

0.291684

Stage1.Output.Measurement10.U.Actual

-0.322694

Stage1.Output.Measurement12.U.Actual

0.034783

Stage1.Output.Measurement13.U.Actual

0.609633

Machine4.Temperature1.C.Actual

NaN

Machine4.Temperature2.C.Actual

-0.289789

Machine4.Pressure.C.Actual

-0.077463

Machine4.Temperature3.C.Actual

0.330402

Machine4.Temperature4.C.Actual

-0.077463

Machine4.Temperature5.C.Actual

-0.310889

Machine4.ExitTemperature.U.Actual

0.005040

Machine5.Temperature1.C.Actual

NaN

Machine5.Temperature2.C.Actual

NaN

Machine5.Temperature3.C.Actual

NaN

Machine5.Temperature4.C.Actual

0.763961

Machine5.Temperature5.C.Actual

NaN
Machine5.Temperature6.C.Actual
0.917584
Machine5.ExitTemperature.U.Actual
-0.506046

Stage1.Output.Measurement0.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
-0.496784
AmbientConditions.AmbientTemperature.U.Actual
0.453721
Stage1.Output.Measurement0.U.Actual
1.000000
Stage1.Output.Measurement2.U.Actual
0.236730
Stage1.Output.Measurement3.U.Actual
0.248221
Stage1.Output.Measurement4.U.Actual
0.300480
Stage1.Output.Measurement8.U.Actual
0.191022
Stage1.Output.Measurement9.U.Actual
0.142851
Stage1.Output.Measurement10.U.Actual
-0.252704
Stage1.Output.Measurement12.U.Actual
0.109461
Stage1.Output.Measurement13.U.Actual
0.312884
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
-0.178368
Machine4.Pressure.C.Actual
-0.036561
Machine4.Temperature3.C.Actual
0.108685
Machine4.Temperature4.C.Actual
-0.036561
Machine4.Temperature5.C.Actual
-0.143402
Machine4.ExitTemperature.U.Actual
0.035032
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual

NaN
Machine5.Temperature4.C.Actual
0.426050
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
0.426841
Machine5.ExitTemperature.U.Actual
-0.211087

Stage1.Output.Measurement2.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
-0.048853
AmbientConditions.AmbientTemperature.U.Actual
-0.068267
Stage1.Output.Measurement0.U.Actual
0.236730
Stage1.Output.Measurement2.U.Actual
1.000000
Stage1.Output.Measurement3.U.Actual
0.027383
Stage1.Output.Measurement4.U.Actual
-0.401079
Stage1.Output.Measurement8.U.Actual
0.210441
Stage1.Output.Measurement9.U.Actual
-0.033646
Stage1.Output.Measurement10.U.Actual
-0.159252
Stage1.Output.Measurement12.U.Actual
0.037673
Stage1.Output.Measurement13.U.Actual
0.107154
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
0.109876
Machine4.Pressure.C.Actual
0.109749
Machine4.Temperature3.C.Actual
0.046259
Machine4.Temperature4.C.Actual
0.109749
Machine4.Temperature5.C.Actual
0.059517
Machine4.ExitTemperature.U.Actual
0.127304
Machine5.Temperature1.C.Actual

NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
0.038809
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
-0.049667
Machine5.ExitTemperature.U.Actual
-0.051286

Stage1.Output.Measurement3.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.097087
AmbientConditions.AmbientTemperature.U.Actual
0.025208
Stage1.Output.Measurement0.U.Actual
0.248221
Stage1.Output.Measurement2.U.Actual
0.027383
Stage1.Output.Measurement3.U.Actual
1.000000
Stage1.Output.Measurement4.U.Actual
0.005994
Stage1.Output.Measurement8.U.Actual
0.120129
Stage1.Output.Measurement9.U.Actual
0.242689
Stage1.Output.Measurement10.U.Actual
0.093644
Stage1.Output.Measurement12.U.Actual
-0.075246
Stage1.Output.Measurement13.U.Actual
-0.029437
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
0.081897
Machine4.Pressure.C.Actual
-0.029577
Machine4.Temperature3.C.Actual
-0.178297
Machine4.Temperature4.C.Actual
-0.029577
Machine4.Temperature5.C.Actual

```
-0.134770
Machine4.ExitTemperature.U.Actual
0.114752
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
-0.108598
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
0.020558
Machine5.ExitTemperature.U.Actual
0.314138

Stage1.Output.Measurement4.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
-0.750915
AmbientConditions.AmbientTemperature.U.Actual
0.801083
Stage1.Output.Measurement0.U.Actual
0.300480
Stage1.Output.Measurement2.U.Actual
-0.401079
Stage1.Output.Measurement3.U.Actual
0.005994
Stage1.Output.Measurement4.U.Actual
1.000000
Stage1.Output.Measurement8.U.Actual
-0.085693
Stage1.Output.Measurement9.U.Actual
0.322250
Stage1.Output.Measurement10.U.Actual
-0.274138
Stage1.Output.Measurement12.U.Actual
0.036475
Stage1.Output.Measurement13.U.Actual
0.507659
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
-0.318913
Machine4.Pressure.C.Actual
-0.163627
Machine4.Temperature3.C.Actual
```

```
0.188847
Machine4.Temperature4.C.Actual
-0.163627
Machine4.Temperature5.C.Actual
-0.211842
Machine4.ExitTemperature.U.Actual
-0.034723
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
0.737535
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
0.825295
Machine5.ExitTemperature.U.Actual
-0.514990

Stage1.Output.Measurement8.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.050575
AmbientConditions.AmbientTemperature.U.Actual
0.064908
Stage1.Output.Measurement0.U.Actual
0.191022
Stage1.Output.Measurement2.U.Actual
0.210441
Stage1.Output.Measurement3.U.Actual
0.120129
Stage1.Output.Measurement4.U.Actual
-0.085693
Stage1.Output.Measurement8.U.Actual
1.000000
Stage1.Output.Measurement9.U.Actual
0.007847
Stage1.Output.Measurement10.U.Actual
0.167627
Stage1.Output.Measurement12.U.Actual
-0.070744
Stage1.Output.Measurement13.U.Actual
0.005321
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
```

```
0.173487
Machine4.Pressure.C.Actual
-0.002303
Machine4.Temperature3.C.Actual
-0.133811
Machine4.Temperature4.C.Actual
-0.002303
Machine4.Temperature5.C.Actual
-0.094333
Machine4.ExitTemperature.U.Actual
0.001352
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
-0.006446
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
0.013990
Machine5.ExitTemperature.U.Actual
0.189446

Stage1.Output.Measurement9.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
-0.322996
AmbientConditions.AmbientTemperature.U.Actual
0.291684
Stage1.Output.Measurement0.U.Actual
0.142851
Stage1.Output.Measurement2.U.Actual
-0.033646
Stage1.Output.Measurement3.U.Actual
0.242689
Stage1.Output.Measurement4.U.Actual
0.322250
Stage1.Output.Measurement8.U.Actual
0.007847
Stage1.Output.Measurement9.U.Actual
1.000000
Stage1.Output.Measurement10.U.Actual
-0.102886
Stage1.Output.Measurement12.U.Actual
0.102752
Stage1.Output.Measurement13.U.Actual
```

```
0.359623
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
-0.091156
Machine4.Pressure.C.Actual
-0.084159
Machine4.Temperature3.C.Actual
0.236932
Machine4.Temperature4.C.Actual
-0.084159
Machine4.Temperature5.C.Actual
-0.065902
Machine4.ExitTemperature.U.Actual
0.129077
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
0.391210
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
0.301558
Machine5.ExitTemperature.U.Actual
-0.229298

Stage1.Output.Measurement10.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.453538
AmbientConditions.AmbientTemperature.U.Actual
-0.322694
Stage1.Output.Measurement0.U.Actual
-0.252704
Stage1.Output.Measurement2.U.Actual
-0.159252
Stage1.Output.Measurement3.U.Actual
0.093644
Stage1.Output.Measurement4.U.Actual
-0.274138
Stage1.Output.Measurement8.U.Actual
0.167627
Stage1.Output.Measurement9.U.Actual
-0.102886
Stage1.Output.Measurement10.U.Actual
```

```
1.000000
Stage1.Output.Measurement12.U.Actual
-0.023077
Stage1.Output.Measurement13.U.Actual
-0.345015
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
0.119637
Machine4.Pressure.C.Actual
0.030193
Machine4.Temperature3.C.Actual
-0.073842
Machine4.Temperature4.C.Actual
0.030193
Machine4.Temperature5.C.Actual
-0.185124
Machine4.ExitTemperature.U.Actual
-0.167394
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
-0.361355
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
-0.298255
Machine5.ExitTemperature.U.Actual
0.322037

Stage1.Output.Measurement12.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
-0.108517
AmbientConditions.AmbientTemperature.U.Actual
0.034783
Stage1.Output.Measurement0.U.Actual
0.109461
Stage1.Output.Measurement2.U.Actual
0.037673
Stage1.Output.Measurement3.U.Actual
-0.075246
Stage1.Output.Measurement4.U.Actual
0.036475
Stage1.Output.Measurement8.U.Actual
```

```

-0.070744
Stage1.Output.Measurement9.U.Actual
0.102752
Stage1.Output.Measurement10.U.Actual
-0.023077
Stage1.Output.Measurement12.U.Actual
1.000000
Stage1.Output.Measurement13.U.Actual
0.177549
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
-0.217504
Machine4.Pressure.C.Actual
-0.024139
Machine4.Temperature3.C.Actual
0.085481
Machine4.Temperature4.C.Actual
-0.024139
Machine4.Temperature5.C.Actual
0.073921
Machine4.ExitTemperature.U.Actual
-0.032526
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
0.093231
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
0.045148
Machine5.ExitTemperature.U.Actual
0.051500

... \
AmbientConditions.AmbientHumidity.U.Actual ...
AmbientConditions.AmbientTemperature.U.Actual ...
Stage1.Output.Measurement0.U.Actual ...
Stage1.Output.Measurement2.U.Actual ...
Stage1.Output.Measurement3.U.Actual ...
Stage1.Output.Measurement4.U.Actual ...
Stage1.Output.Measurement8.U.Actual ...
Stage1.Output.Measurement9.U.Actual ...
Stage1.Output.Measurement10.U.Actual ...

```

Stage1.Output.Measurement12.U.Actual	...	
Stage1.Output.Measurement13.U.Actual	...	
Machine4.Temperature1.C.Actual	...	
Machine4.Temperature2.C.Actual	...	
Machine4.Pressure.C.Actual	...	
Machine4.Temperature3.C.Actual	...	
Machine4.Temperature4.C.Actual	...	
Machine4.Temperature5.C.Actual	...	
Machine4.ExitTemperature.U.Actual	...	
Machine5.Temperature1.C.Actual	...	
Machine5.Temperature2.C.Actual	...	
Machine5.Temperature3.C.Actual	...	
Machine5.Temperature4.C.Actual	...	
Machine5.Temperature5.C.Actual	...	
Machine5.Temperature6.C.Actual	...	
Machine5.ExitTemperature.U.Actual	...	
	Machine4.Temperature4.C.Actual	\
AmbientConditions.AmbientHumidity.U.Actual	0.037522	
AmbientConditions.AmbientTemperature.U.Actual	-0.077463	
Stage1.Output.Measurement0.U.Actual	-0.036561	
Stage1.Output.Measurement2.U.Actual	0.109749	
Stage1.Output.Measurement3.U.Actual	-0.029577	
Stage1.Output.Measurement4.U.Actual	-0.163627	
Stage1.Output.Measurement8.U.Actual	-0.002303	
Stage1.Output.Measurement9.U.Actual	-0.084159	
Stage1.Output.Measurement10.U.Actual	0.030193	
Stage1.Output.Measurement12.U.Actual	-0.024139	
Stage1.Output.Measurement13.U.Actual	0.002295	
Machine4.Temperature1.C.Actual	NaN	
Machine4.Temperature2.C.Actual	-0.060130	
Machine4.Pressure.C.Actual	1.000000	
Machine4.Temperature3.C.Actual	-0.075898	
Machine4.Temperature4.C.Actual	1.000000	
Machine4.Temperature5.C.Actual	-0.000313	
Machine4.ExitTemperature.U.Actual	-0.031819	
Machine5.Temperature1.C.Actual	NaN	
Machine5.Temperature2.C.Actual	NaN	
Machine5.Temperature3.C.Actual	NaN	
Machine5.Temperature4.C.Actual	-0.085581	
Machine5.Temperature5.C.Actual	NaN	
Machine5.Temperature6.C.Actual	-0.073525	
Machine5.ExitTemperature.U.Actual	0.080503	
	Machine4.Temperature5.C.Actual	\
AmbientConditions.AmbientHumidity.U.Actual	0.147497	
AmbientConditions.AmbientTemperature.U.Actual	-0.310889	
Stage1.Output.Measurement0.U.Actual	-0.143402	

Stage1.Output.Measurement2.U.Actual	0.059517
Stage1.Output.Measurement3.U.Actual	-0.134770
Stage1.Output.Measurement4.U.Actual	-0.211842
Stage1.Output.Measurement8.U.Actual	-0.094333
Stage1.Output.Measurement9.U.Actual	-0.065902
Stage1.Output.Measurement10.U.Actual	-0.185124
Stage1.Output.Measurement12.U.Actual	0.073921
Stage1.Output.Measurement13.U.Actual	-0.056410
Machine4.Temperature1.C.Actual	NaN
Machine4.Temperature2.C.Actual	0.378734
Machine4.Pressure.C.Actual	-0.000313
Machine4.Temperature3.C.Actual	-0.047420
Machine4.Temperature4.C.Actual	-0.000313
Machine4.Temperature5.C.Actual	1.000000
Machine4.ExitTemperature.U.Actual	0.162331
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN
Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	-0.025806
Machine5.Temperature5.C.Actual	NaN
Machine5.Temperature6.C.Actual	-0.282055
Machine5.ExitTemperature.U.Actual	0.014004
Machine4.ExitTemperature.U.Actual	
\	
AmbientConditions.AmbientHumidity.U.Actual	-0.003352
AmbientConditions.AmbientTemperature.U.Actual	0.005040
Stage1.Output.Measurement0.U.Actual	0.035032
Stage1.Output.Measurement2.U.Actual	0.127304
Stage1.Output.Measurement3.U.Actual	0.114752
Stage1.Output.Measurement4.U.Actual	-0.034723
Stage1.Output.Measurement8.U.Actual	0.001352
Stage1.Output.Measurement9.U.Actual	0.129077
Stage1.Output.Measurement10.U.Actual	-0.167394
Stage1.Output.Measurement12.U.Actual	-0.032526
Stage1.Output.Measurement13.U.Actual	0.077948
Machine4.Temperature1.C.Actual	NaN
Machine4.Temperature2.C.Actual	0.215612
Machine4.Pressure.C.Actual	-0.031819
Machine4.Temperature3.C.Actual	0.090470
Machine4.Temperature4.C.Actual	-0.031819
Machine4.Temperature5.C.Actual	0.162331
Machine4.ExitTemperature.U.Actual	1.000000
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN
Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	-0.006294
Machine5.Temperature5.C.Actual	NaN

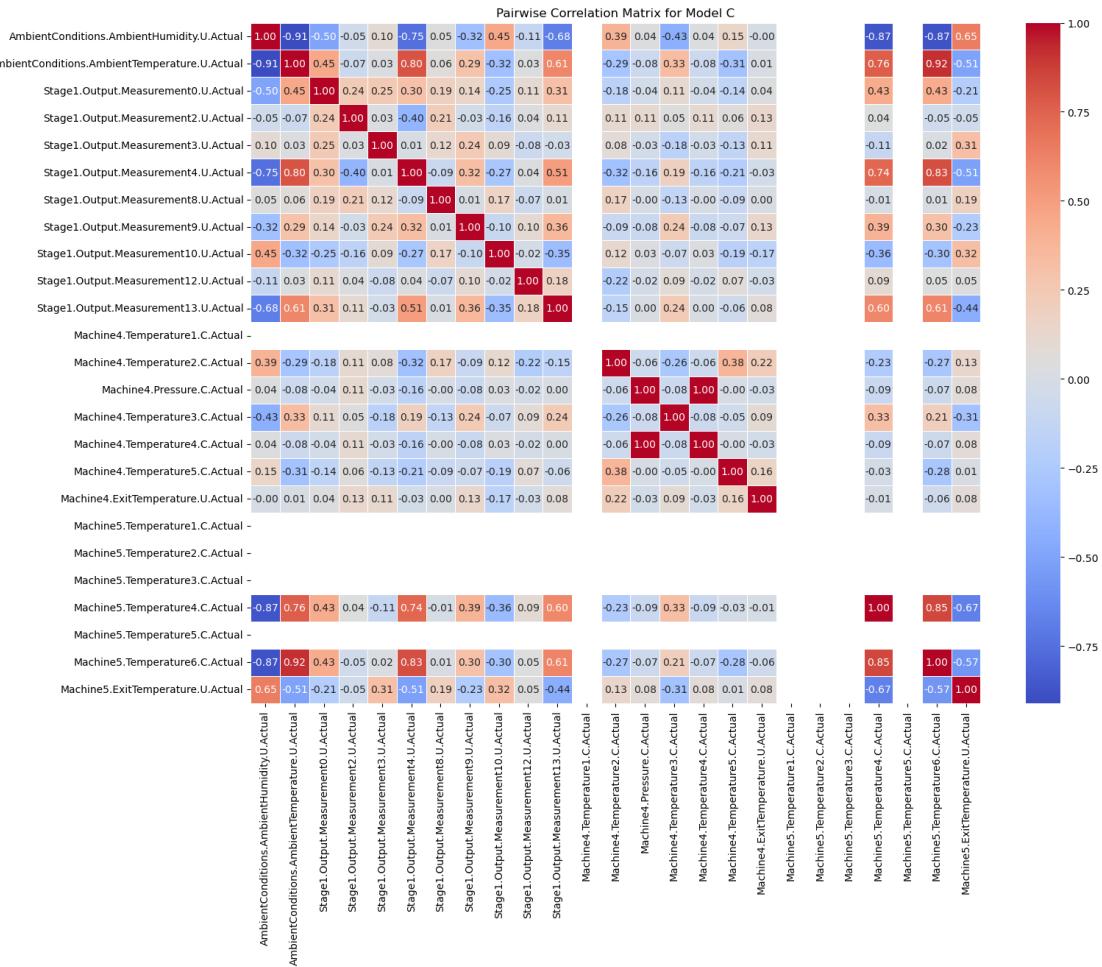
Machine5.Temperature6.C.Actual	-0.056962
Machine5.ExitTemperature.U.Actual	0.081983
	Machine5.Temperature1.C.Actual \
AmbientConditions.AmbientHumidity.U.Actual	NaN
AmbientConditions.AmbientTemperature.U.Actual	NaN
Stage1.Output.Measurement0.U.Actual	NaN
Stage1.Output.Measurement2.U.Actual	NaN
Stage1.Output.Measurement3.U.Actual	NaN
Stage1.Output.Measurement4.U.Actual	NaN
Stage1.Output.Measurement8.U.Actual	NaN
Stage1.Output.Measurement9.U.Actual	NaN
Stage1.Output.Measurement10.U.Actual	NaN
Stage1.Output.Measurement12.U.Actual	NaN
Stage1.Output.Measurement13.U.Actual	NaN
Machine4.Temperature1.C.Actual	NaN
Machine4.Temperature2.C.Actual	NaN
Machine4.Pressure.C.Actual	NaN
Machine4.Temperature3.C.Actual	NaN
Machine4.Temperature4.C.Actual	NaN
Machine4.Temperature5.C.Actual	NaN
Machine4.ExitTemperature.U.Actual	NaN
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN
Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	NaN
Machine5.Temperature5.C.Actual	NaN
Machine5.Temperature6.C.Actual	NaN
Machine5.ExitTemperature.U.Actual	NaN
	Machine5.Temperature2.C.Actual \
AmbientConditions.AmbientHumidity.U.Actual	NaN
AmbientConditions.AmbientTemperature.U.Actual	NaN
Stage1.Output.Measurement0.U.Actual	NaN
Stage1.Output.Measurement2.U.Actual	NaN
Stage1.Output.Measurement3.U.Actual	NaN
Stage1.Output.Measurement4.U.Actual	NaN
Stage1.Output.Measurement8.U.Actual	NaN
Stage1.Output.Measurement9.U.Actual	NaN
Stage1.Output.Measurement10.U.Actual	NaN
Stage1.Output.Measurement12.U.Actual	NaN
Stage1.Output.Measurement13.U.Actual	NaN
Machine4.Temperature1.C.Actual	NaN
Machine4.Temperature2.C.Actual	NaN
Machine4.Pressure.C.Actual	NaN
Machine4.Temperature3.C.Actual	NaN
Machine4.Temperature4.C.Actual	NaN
Machine4.Temperature5.C.Actual	NaN

Machine4.ExitTemperature.U.Actual	NaN
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN
Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	NaN
Machine5.Temperature5.C.Actual	NaN
Machine5.Temperature6.C.Actual	NaN
Machine5.ExitTemperature.U.Actual	NaN
Machine5.Temperature3.C.Actual \	
AmbientConditions.AmbientHumidity.U.Actual	NaN
AmbientConditions.AmbientTemperature.U.Actual	NaN
Stage1.Output.Measurement0.U.Actual	NaN
Stage1.Output.Measurement2.U.Actual	NaN
Stage1.Output.Measurement3.U.Actual	NaN
Stage1.Output.Measurement4.U.Actual	NaN
Stage1.Output.Measurement8.U.Actual	NaN
Stage1.Output.Measurement9.U.Actual	NaN
Stage1.Output.Measurement10.U.Actual	NaN
Stage1.Output.Measurement12.U.Actual	NaN
Stage1.Output.Measurement13.U.Actual	NaN
Machine4.Temperature1.C.Actual	NaN
Machine4.Temperature2.C.Actual	NaN
Machine4.Pressure.C.Actual	NaN
Machine4.Temperature3.C.Actual	NaN
Machine4.Temperature4.C.Actual	NaN
Machine4.Temperature5.C.Actual	NaN
Machine4.ExitTemperature.U.Actual	NaN
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN
Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	NaN
Machine5.Temperature5.C.Actual	NaN
Machine5.Temperature6.C.Actual	NaN
Machine5.ExitTemperature.U.Actual	NaN
Machine5.Temperature4.C.Actual \	
AmbientConditions.AmbientHumidity.U.Actual	-0.871569
AmbientConditions.AmbientTemperature.U.Actual	0.763961
Stage1.Output.Measurement0.U.Actual	0.426050
Stage1.Output.Measurement2.U.Actual	0.038809
Stage1.Output.Measurement3.U.Actual	-0.108598
Stage1.Output.Measurement4.U.Actual	0.737535
Stage1.Output.Measurement8.U.Actual	-0.006446
Stage1.Output.Measurement9.U.Actual	0.391210
Stage1.Output.Measurement10.U.Actual	-0.361355
Stage1.Output.Measurement12.U.Actual	0.093231
Stage1.Output.Measurement13.U.Actual	0.603441

Machine4.Temperature1.C.Actual	NaN
Machine4.Temperature2.C.Actual	-0.230885
Machine4.Pressure.C.Actual	-0.085581
Machine4.Temperature3.C.Actual	0.325039
Machine4.Temperature4.C.Actual	-0.085581
Machine4.Temperature5.C.Actual	-0.025806
Machine4.ExitTemperature.U.Actual	-0.006294
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN
Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	1.000000
Machine5.Temperature5.C.Actual	NaN
Machine5.Temperature6.C.Actual	0.845014
Machine5.ExitTemperature.U.Actual	-0.673780
Machine5.Temperature5.C.Actual \	
AmbientConditions.AmbientHumidity.U.Actual	NaN
AmbientConditions.AmbientTemperature.U.Actual	NaN
Stage1.Output.Measurement0.U.Actual	NaN
Stage1.Output.Measurement2.U.Actual	NaN
Stage1.Output.Measurement3.U.Actual	NaN
Stage1.Output.Measurement4.U.Actual	NaN
Stage1.Output.Measurement8.U.Actual	NaN
Stage1.Output.Measurement9.U.Actual	NaN
Stage1.Output.Measurement10.U.Actual	NaN
Stage1.Output.Measurement12.U.Actual	NaN
Stage1.Output.Measurement13.U.Actual	NaN
Machine4.Temperature1.C.Actual	NaN
Machine4.Temperature2.C.Actual	NaN
Machine4.Pressure.C.Actual	NaN
Machine4.Temperature3.C.Actual	NaN
Machine4.Temperature4.C.Actual	NaN
Machine4.Temperature5.C.Actual	NaN
Machine4.ExitTemperature.U.Actual	NaN
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN
Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	NaN
Machine5.Temperature5.C.Actual	NaN
Machine5.Temperature6.C.Actual	NaN
Machine5.ExitTemperature.U.Actual	NaN
Machine5.Temperature6.C.Actual \	
AmbientConditions.AmbientHumidity.U.Actual	-0.874571
AmbientConditions.AmbientTemperature.U.Actual	0.917584
Stage1.Output.Measurement0.U.Actual	0.426841
Stage1.Output.Measurement2.U.Actual	-0.049667
Stage1.Output.Measurement3.U.Actual	0.020558

Stage1.Output.Measurement4.U.Actual	0.825295
Stage1.Output.Measurement8.U.Actual	0.013990
Stage1.Output.Measurement9.U.Actual	0.301558
Stage1.Output.Measurement10.U.Actual	-0.298255
Stage1.Output.Measurement12.U.Actual	0.045148
Stage1.Output.Measurement13.U.Actual	0.612867
Machine4.Temperature1.C.Actual	NaN
Machine4.Temperature2.C.Actual	-0.271343
Machine4.Pressure.C.Actual	-0.073525
Machine4.Temperature3.C.Actual	0.206057
Machine4.Temperature4.C.Actual	-0.073525
Machine4.Temperature5.C.Actual	-0.282055
Machine4.ExitTemperature.U.Actual	-0.056962
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN
Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	0.845014
Machine5.Temperature5.C.Actual	NaN
Machine5.Temperature6.C.Actual	1.000000
Machine5.ExitTemperature.U.Actual	-0.574757
Machine5.ExitTemperature.U.Actual	
AmbientConditions.AmbientHumidity.U.Actual	0.646153
AmbientConditions.AmbientTemperature.U.Actual	-0.506046
Stage1.Output.Measurement0.U.Actual	-0.211087
Stage1.Output.Measurement2.U.Actual	-0.051286
Stage1.Output.Measurement3.U.Actual	0.314138
Stage1.Output.Measurement4.U.Actual	-0.514990
Stage1.Output.Measurement8.U.Actual	0.189446
Stage1.Output.Measurement9.U.Actual	-0.229298
Stage1.Output.Measurement10.U.Actual	0.322037
Stage1.Output.Measurement12.U.Actual	0.051500
Stage1.Output.Measurement13.U.Actual	-0.440771
Machine4.Temperature1.C.Actual	NaN
Machine4.Temperature2.C.Actual	0.128764
Machine4.Pressure.C.Actual	0.080503
Machine4.Temperature3.C.Actual	-0.307190
Machine4.Temperature4.C.Actual	0.080503
Machine4.Temperature5.C.Actual	0.014004
Machine4.ExitTemperature.U.Actual	0.081983
Machine5.Temperature1.C.Actual	NaN
Machine5.Temperature2.C.Actual	NaN
Machine5.Temperature3.C.Actual	NaN
Machine5.Temperature4.C.Actual	-0.673780
Machine5.Temperature5.C.Actual	NaN
Machine5.Temperature6.C.Actual	-0.574757
Machine5.ExitTemperature.U.Actual	1.000000

[25 rows x 25 columns]



```
[26]: # Feature Scaling for Model C
import pandas as pd
import numpy as np
from sklearn.preprocessing import StandardScaler
from sklearn.feature_selection import mutual_info_regression
import matplotlib.pyplot as plt

scaler = StandardScaler()
X_scaled = scaler.fit_transform(Input_CA)
y_scaled = scaler.fit_transform(Output_CA)

# Calculate mutual information for each output feature
mi_scores = []
for i in range(y_scaled.shape[1]):
    mi_scores.append(mutual_info_regression(X_scaled, y_scaled[:, i]))
```

```

# Average mutual information scores across all output features
mi_scores_avg = np.mean(mi_scores, axis=0)
mi_scores_series = pd.Series(mi_scores_avg, index=Input_CN).
    ↪sort_values(ascending=False)

# Display feature ranking
print("Feature Ranking based on Mutual Information Scores for Model C:")
print(mi_scores_series)

```

Feature Ranking based on Mutual Information Scores for Model C:

Machine5.Temperature6.C.Actual	0.137703
AmbientConditions.AmbientHumidity.U.Actual	0.116796
AmbientConditions.AmbientTemperature.U.Actual	0.102936
Machine5.Temperature4.C.Actual	0.100720
Stage1.Output.Measurement4.U.Actual	0.071130
Machine5.ExitTemperature.U.Actual	0.066886
Machine4.Temperature5.C.Actual	0.046185
Stage1.Output.Measurement13.U.Actual	0.044918
Stage1.Output.Measurement10.U.Actual	0.044590
Stage1.Output.Measurement8.U.Actual	0.043526
Stage1.Output.Measurement2.U.Actual	0.043464
Machine4.Temperature2.C.Actual	0.042488
Machine4.ExitTemperature.U.Actual	0.039025
Stage1.Output.Measurement9.U.Actual	0.037375
Stage1.Output.Measurement3.U.Actual	0.032980
Stage1.Output.Measurement12.U.Actual	0.029810
Machine4.Temperature3.C.Actual	0.027019
Machine4.Pressure.C.Actual	0.026605
Stage1.Output.Measurement0.U.Actual	0.026202
Machine4.Temperature4.C.Actual	0.020763
Machine5.Temperature2.C.Actual	0.018110
Machine5.Temperature1.C.Actual	0.016617
Machine5.Temperature3.C.Actual	0.014338
Machine4.Temperature1.C.Actual	0.012878
Machine5.Temperature5.C.Actual	0.008018

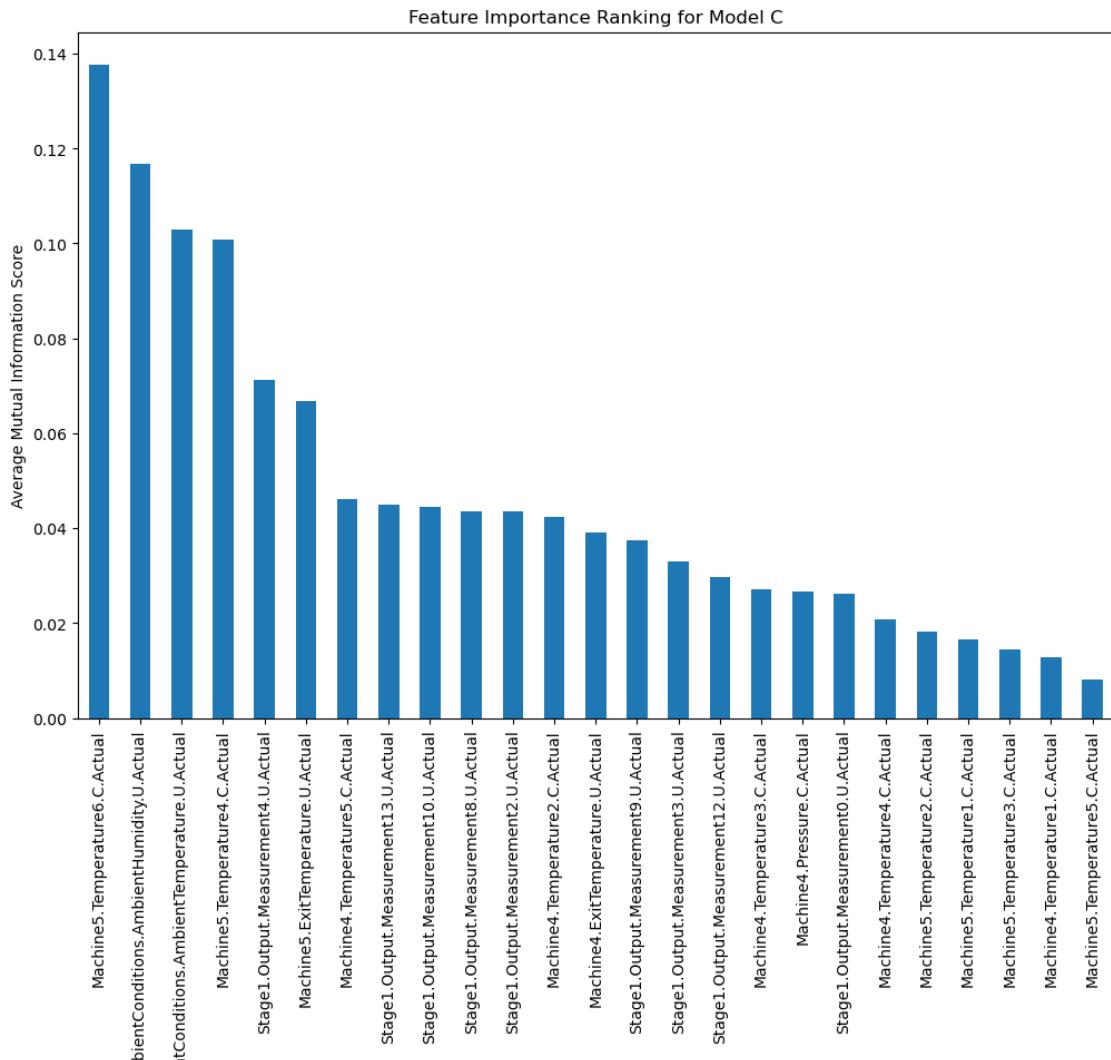
dtype: float64

[27]:

```

# Plot the feature importance
plt.figure(figsize=(12, 8))
mi_scores_series.plot(kind='bar')
plt.title('Feature Importance Ranking for Model C')
plt.ylabel('Average Mutual Information Score')
plt.show()

```



```
[28]: import pandas as pd
import numpy as np
import statsmodels.api as sm

# Feature Selection of Data for model A
Input_A = Araw_data_clean.values[:, 0:41]
Input_AN = Araw_data_clean.columns[0:41]
Input_AA = pd.DataFrame(data=Input_A, columns=Input_AN)

Output_A = Araw_data_clean.values[:, 41:50]
Output_AN = Araw_data_clean.columns[41:50]
Output_AA = pd.DataFrame(data=Output_A, columns=Output_AN)
```

```

print("Input for model A")
print(Input_AA.info())
print("Output for model A")
print(Output_AA.info())

# Calculate p-values
p_values_A = pd.DataFrame(index=Input_AN, columns=Output_AN)

for output in Output_AN:
    y = Output_AA[output]
    for feature in Input_AN:
        X = Input_AA[feature]
        X = sm.add_constant(X) # Adds a constant term to the predictor
        model = sm.OLS(y, X).fit()
        if len(model.pvalues) > 1:
            p_values_A.loc[feature, output] = model.pvalues[1]
        else:
            p_values_A.loc[feature, output] = np.nan # Assign NaN if p-value
            ↵is not available

print("P-values for Model A:")
print(p_values_A)

```

Input for model A

<class 'pandas.core.frame.DataFrame'>

RangeIndex: 191 entries, 0 to 190

Data columns (total 41 columns):

#	Column	Non-Null Count	Dtype	
0	AmbientConditions.AmbientHumidity.U.Actual	191	non-null	float64
1	AmbientConditions.AmbientTemperature.U.Actual	191	non-null	float64
2	Machine1.RawMaterial.Property1	191	non-null	float64
3	Machine1.RawMaterial.Property2	191	non-null	float64
4	Machine1.RawMaterial.Property3	191	non-null	float64
5	Machine1.RawMaterial.Property4	191	non-null	float64
6	Machine1.RawMaterialFeederParameter.U.Actual	191	non-null	float64
7	Machine1.Zone1Temperature.C.Actual	191	non-null	float64
8	Machine1.Zone2Temperature.C.Actual	191	non-null	float64
9	Machine1.MotorAmperage.U.Actual	191	non-null	float64
10	Machine1.MotorRPM.C.Actual	191	non-null	float64
11	Machine1.MaterialPressure.U.Actual	191	non-null	float64
12	Machine1.MaterialTemperature.U.Actual	191	non-null	float64
13	Machine1.ExitZoneTemperature.C.Actual	191	non-null	float64
14	Machine2.RawMaterial.Property1	191	non-null	float64
15	Machine2.RawMaterial.Property2	191	non-null	float64
16	Machine2.RawMaterial.Property3	191	non-null	float64
17	Machine2.RawMaterial.Property4	191	non-null	float64
18	Machine2.RawMaterialFeederParameter.U.Actual	191	non-null	float64

```

19 Machine2.Zone1Temperature.C.Actual           191 non-null   float64
20 Machine2.Zone2Temperature.C.Actual           191 non-null   float64
21 Machine2.MotorAmperage.U.Actual             191 non-null   float64
22 Machine2.MotorRPM.C.Actual                 191 non-null   float64
23 Machine2.MaterialPressure.U.Actual          191 non-null   float64
24 Machine2.MaterialTemperature.U.Actual        191 non-null   float64
25 Machine2.ExitZoneTemperature.C.Actual        191 non-null   float64
26 Machine3.RawMaterial.Property1              191 non-null   float64
27 Machine3.RawMaterial.Property2              191 non-null   float64
28 Machine3.RawMaterial.Property3              191 non-null   float64
29 Machine3.RawMaterial.Property4              191 non-null   float64
30 Machine3.RawMaterialFeederParameter.U.Actual 191 non-null   float64
31 Machine3.Zone1Temperature.C.Actual           191 non-null   float64
32 Machine3.Zone2Temperature.C.Actual           191 non-null   float64
33 Machine3.MotorAmperage.U.Actual             191 non-null   float64
34 Machine3.MotorRPM.C.Actual                 191 non-null   float64
35 Machine3.MaterialPressure.U.Actual          191 non-null   float64
36 Machine3.MaterialTemperature.U.Actual        191 non-null   float64
37 Machine3.ExitZoneTemperature.C.Actual        191 non-null   float64
38 FirstStage.CombinerOperation.Temperature1.U.Actual 191 non-null   float64
39 FirstStage.CombinerOperation.Temperature2.U.Actual 191 non-null   float64
40 FirstStage.CombinerOperation.Temperature3.C.Actual 191 non-null   float64
dtypes: float64(41)
memory usage: 61.3 KB
None
Output for model A
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 191 entries, 0 to 190
Data columns (total 9 columns):
 #   Column                Non-Null Count  Dtype  
--- 
 0   Stage1.Output.Measurement0.U.Actual      191 non-null   float64
 1   Stage1.Output.Measurement2.U.Actual      191 non-null   float64
 2   Stage1.Output.Measurement3.U.Actual      191 non-null   float64
 3   Stage1.Output.Measurement4.U.Actual      191 non-null   float64
 4   Stage1.Output.Measurement8.U.Actual      191 non-null   float64
 5   Stage1.Output.Measurement9.U.Actual      191 non-null   float64
 6   Stage1.Output.Measurement10.U.Actual     191 non-null   float64
 7   Stage1.Output.Measurement12.U.Actual     191 non-null   float64
 8   Stage1.Output.Measurement13.U.Actual     191 non-null   float64
dtypes: float64(9)
memory usage: 13.6 KB
None
P-values for Model A:
Stage1.Output.Measurement0.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.0
AmbientConditions.AmbientTemperature.U.Actual

```

```
0.0
Machine1.RawMaterial.Property1
NaN
Machine1.RawMaterial.Property2
NaN
Machine1.RawMaterial.Property3
NaN
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
0.010317
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
0.544957
Machine1.MotorAmperage.U.Actual
0.918504
Machine1.MotorRPM.C.Actual
0.0
Machine1.MaterialPressure.U.Actual
0.70966
Machine1.MaterialTemperature.U.Actual
0.0
Machine1.ExitZoneTemperature.C.Actual
0.340094
Machine2.RawMaterial.Property1
NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
0.014727
Machine2.Zone1Temperature.C.Actual
0.200979
Machine2.Zone2Temperature.C.Actual
0.70865
Machine2.MotorAmperage.U.Actual
0.094542
Machine2.MotorRPM.C.Actual
0.116867
Machine2.MaterialPressure.U.Actual
0.709658
Machine2.MaterialTemperature.U.Actual
0.002696
Machine2.ExitZoneTemperature.C.Actual
```

```
0.615491
Machine3.RawMaterial.Property1
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
0.138744
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual
0.12893
Machine3.MotorAmperage.U.Actual
0.839546
Machine3.MotorRPM.C.Actual
0.0
Machine3.MaterialPressure.U.Actual
0.000001
Machine3.MaterialTemperature.U.Actual
0.000011
Machine3.ExitZoneTemperature.C.Actual
NaN
FirstStage.CombinerOperation.Temperature1.U.Actual
0.00197
FirstStage.CombinerOperation.Temperature2.U.Actual
0.00011
FirstStage.CombinerOperation.Temperature3.C.Actual
0.218111

Stage1.Output.Measurement2.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.502141
AmbientConditions.AmbientTemperature.U.Actual
0.348051
Machine1.RawMaterial.Property1
NaN
Machine1.RawMaterial.Property2
NaN
Machine1.RawMaterial.Property3
NaN
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
0.528929
Machine1.Zone1Temperature.C.Actual
```

Nan
Machine1.Zone2Temperature.C.Actual
0.418428
Machine1.MotorAmperage.U.Actual
0.153788
Machine1.MotorRPM.C.Actual
0.768772
Machine1.MaterialPressure.U.Actual
0.044547
Machine1.MaterialTemperature.U.Actual
0.157085
Machine1.ExitZoneTemperature.C.Actual
0.073197
Machine2.RawMaterial.Property1
Nan
Machine2.RawMaterial.Property2
Nan
Machine2.RawMaterial.Property3
Nan
Machine2.RawMaterial.Property4
Nan
Machine2.RawMaterialFeederParameter.U.Actual
0.435457
Machine2.Zone1Temperature.C.Actual
0.70019
Machine2.Zone2Temperature.C.Actual
0.859098
Machine2.MotorAmperage.U.Actual
0.330009
Machine2.MotorRPM.C.Actual
0.592292
Machine2.MaterialPressure.U.Actual
0.404805
Machine2.MaterialTemperature.U.Actual
0.83932
Machine2.ExitZoneTemperature.C.Actual
0.000129
Machine3.RawMaterial.Property1
Nan
Machine3.RawMaterial.Property2
Nan
Machine3.RawMaterial.Property3
Nan
Machine3.RawMaterial.Property4
Nan
Machine3.RawMaterialFeederParameter.U.Actual
0.312433
Machine3.Zone1Temperature.C.Actual

Nan
Machine3.Zone2Temperature.C.Actual
0.065473
Machine3.MotorAmperage.U.Actual
0.868346
Machine3.MotorRPM.C.Actual
0.067812
Machine3.MaterialPressure.U.Actual
0.033163
Machine3.MaterialTemperature.U.Actual
0.393621
Machine3.ExitZoneTemperature.C.Actual
Nan
FirstStage.CombinerOperation.Temperature1.U.Actual
0.452983
FirstStage.CombinerOperation.Temperature2.U.Actual
0.445082
FirstStage.CombinerOperation.Temperature3.C.Actual
0.293732

Stage1.Output.Measurement3.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.181509
AmbientConditions.AmbientTemperature.U.Actual
0.729227
Machine1.RawMaterial.Property1
Nan
Machine1.RawMaterial.Property2
Nan
Machine1.RawMaterial.Property3
Nan
Machine1.RawMaterial.Property4
Nan
Machine1.RawMaterialFeederParameter.U.Actual
0.855757
Machine1.Zone1Temperature.C.Actual
Nan
Machine1.Zone2Temperature.C.Actual
0.000144
Machine1.MotorAmperage.U.Actual
0.877238
Machine1.MotorRPM.C.Actual
0.122975
Machine1.MaterialPressure.U.Actual
0.172076
Machine1.MaterialTemperature.U.Actual
0.384279
Machine1.ExitZoneTemperature.C.Actual

0.362512
Machine2.RawMaterial.Property1
NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
0.225096
Machine2.Zone1Temperature.C.Actual
0.162393
Machine2.Zone2Temperature.C.Actual
0.949825
Machine2.MotorAmperage.U.Actual
0.870855
Machine2.MotorRPM.C.Actual
0.427663
Machine2.MaterialPressure.U.Actual
0.644313
Machine2.MaterialTemperature.U.Actual
0.321406
Machine2.ExitZoneTemperature.C.Actual
0.09075
Machine3.RawMaterial.Property1
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
0.561031
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual
0.004341
Machine3.MotorAmperage.U.Actual
0.980945
Machine3.MotorRPM.C.Actual
0.003822
Machine3.MaterialPressure.U.Actual
0.02411
Machine3.MaterialTemperature.U.Actual
0.000107
Machine3.ExitZoneTemperature.C.Actual

NaN
FirstStage.CombinerOperation.Temperature1.U.Actual
0.060721
FirstStage.CombinerOperation.Temperature2.U.Actual
0.183539
FirstStage.CombinerOperation.Temperature3.C.Actual
0.173407

Stage1.Output.Measurement4.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.0
AmbientConditions.AmbientTemperature.U.Actual
0.0
Machine1.RawMaterial.Property1
NaN
Machine1.RawMaterial.Property2
NaN
Machine1.RawMaterial.Property3
NaN
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
0.669733
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
0.917065
Machine1.MotorAmperage.U.Actual
0.872764
Machine1.MotorRPM.C.Actual
0.0
Machine1.MaterialPressure.U.Actual
0.160038
Machine1.MaterialTemperature.U.Actual
0.0
Machine1.ExitZoneTemperature.C.Actual
0.726968
Machine2.RawMaterial.Property1
NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
0.00567
Machine2.Zone1Temperature.C.Actual

```
0.008131
Machine2.Zone2Temperature.C.Actual
0.201132
Machine2.MotorAmperage.U.Actual
0.763437
Machine2.MotorRPM.C.Actual
0.083781
Machine2.MaterialPressure.U.Actual
0.744995
Machine2.MaterialTemperature.U.Actual
0.000182
Machine2.ExitZoneTemperature.C.Actual
0.027605
Machine3.RawMaterial.Property1
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
0.04878
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual
0.0
Machine3.MotorAmperage.U.Actual
0.693007
Machine3.MotorRPM.C.Actual
0.0
Machine3.MaterialPressure.U.Actual
0.000148
Machine3.MaterialTemperature.U.Actual
0.000007
Machine3.ExitZoneTemperature.C.Actual
NaN
FirstStage.CombinerOperation.Temperature1.U.Actual
0.000041
FirstStage.CombinerOperation.Temperature2.U.Actual
0.0
FirstStage.CombinerOperation.Temperature3.C.Actual
0.239512

Stage1.Output.Measurement8.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.487169
AmbientConditions.AmbientTemperature.U.Actual
```

```
0.372341
Machine1.RawMaterial.Property1
NaN
Machine1.RawMaterial.Property2
NaN
Machine1.RawMaterial.Property3
NaN
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
0.714618
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
0.003153
Machine1.MotorAmperage.U.Actual
0.216206
Machine1.MotorRPM.C.Actual
0.812346
Machine1.MaterialPressure.U.Actual
0.134984
Machine1.MaterialTemperature.U.Actual
0.715822
Machine1.ExitZoneTemperature.C.Actual
0.045101
Machine2.RawMaterial.Property1
NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
0.862438
Machine2.Zone1Temperature.C.Actual
0.61892
Machine2.Zone2Temperature.C.Actual
0.55601
Machine2.MotorAmperage.U.Actual
0.07293
Machine2.MotorRPM.C.Actual
0.591607
Machine2.MaterialPressure.U.Actual
0.104272
Machine2.MaterialTemperature.U.Actual
0.170804
Machine2.ExitZoneTemperature.C.Actual
```

```
0.5576
Machine3.RawMaterial.Property1
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
0.958716
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual
0.54122
Machine3.MotorAmperage.U.Actual
0.355902
Machine3.MotorRPM.C.Actual
0.144902
Machine3.MaterialPressure.U.Actual
0.001196
Machine3.MaterialTemperature.U.Actual
0.000018
Machine3.ExitZoneTemperature.C.Actual
NaN
FirstStage.CombinerOperation.Temperature1.U.Actual
0.011584
FirstStage.CombinerOperation.Temperature2.U.Actual
0.044393
FirstStage.CombinerOperation.Temperature3.C.Actual
0.044353

Stage1.Output.Measurement9.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.000005
AmbientConditions.AmbientTemperature.U.Actual
0.000042
Machine1.RawMaterial.Property1
NaN
Machine1.RawMaterial.Property2
NaN
Machine1.RawMaterial.Property3
NaN
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
0.502063
Machine1.Zone1Temperature.C.Actual
```

Nan
Machine1.Zone2Temperature.C.Actual
0.163869
Machine1.MotorAmperage.U.Actual
0.419355
Machine1.MotorRPM.C.Actual
0.000008
Machine1.MaterialPressure.U.Actual
0.117523
Machine1.MaterialTemperature.U.Actual
0.000001
Machine1.ExitZoneTemperature.C.Actual
0.002067
Machine2.RawMaterial.Property1
Nan
Machine2.RawMaterial.Property2
Nan
Machine2.RawMaterial.Property3
Nan
Machine2.RawMaterial.Property4
Nan
Machine2.RawMaterialFeederParameter.U.Actual
0.833128
Machine2.Zone1Temperature.C.Actual
0.083183
Machine2.Zone2Temperature.C.Actual
0.893072
Machine2.MotorAmperage.U.Actual
0.82482
Machine2.MotorRPM.C.Actual
0.073471
Machine2.MaterialPressure.U.Actual
0.691521
Machine2.MaterialTemperature.U.Actual
0.000472
Machine2.ExitZoneTemperature.C.Actual
0.462462
Machine3.RawMaterial.Property1
Nan
Machine3.RawMaterial.Property2
Nan
Machine3.RawMaterial.Property3
Nan
Machine3.RawMaterial.Property4
Nan
Machine3.RawMaterialFeederParameter.U.Actual
0.351768
Machine3.Zone1Temperature.C.Actual

Nan
Machine3.Zone2Temperature.C.Actual
0.456598
Machine3.MotorAmperage.U.Actual
0.038369
Machine3.MotorRPM.C.Actual
0.000032
Machine3.MaterialPressure.U.Actual
0.057077
Machine3.MaterialTemperature.U.Actual
0.052508
Machine3.ExitZoneTemperature.C.Actual
Nan
FirstStage.CombinerOperation.Temperature1.U.Actual
0.911972
FirstStage.CombinerOperation.Temperature2.U.Actual
0.707468
FirstStage.CombinerOperation.Temperature3.C.Actual
0.010052

Stage1.Output.Measurement10.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.0
AmbientConditions.AmbientTemperature.U.Actual
0.000005
Machine1.RawMaterial.Property1
Nan
Machine1.RawMaterial.Property2
Nan
Machine1.RawMaterial.Property3
Nan
Machine1.RawMaterial.Property4
Nan
Machine1.RawMaterialFeederParameter.U.Actual
0.769608
Machine1.Zone1Temperature.C.Actual
Nan
Machine1.Zone2Temperature.C.Actual
0.055112
Machine1.MotorAmperage.U.Actual
0.122263
Machine1.MotorRPM.C.Actual
0.0
Machine1.MaterialPressure.U.Actual
0.020922
Machine1.MaterialTemperature.U.Actual
0.0
Machine1.ExitZoneTemperature.C.Actual

0.675557
Machine2.RawMaterial.Property1
NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
0.283842
Machine2.Zone1Temperature.C.Actual
0.555815
Machine2.Zone2Temperature.C.Actual
0.895229
Machine2.MotorAmperage.U.Actual
0.704239
Machine2.MotorRPM.C.Actual
0.695811
Machine2.MaterialPressure.U.Actual
0.354622
Machine2.MaterialTemperature.U.Actual
0.009578
Machine2.ExitZoneTemperature.C.Actual
0.081885
Machine3.RawMaterial.Property1
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
0.037818
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual
0.903061
Machine3.MotorAmperage.U.Actual
0.273188
Machine3.MotorRPM.C.Actual
0.0
Machine3.MaterialPressure.U.Actual
0.0
Machine3.MaterialTemperature.U.Actual
0.452482
Machine3.ExitZoneTemperature.C.Actual

NaN
FirstStage.CombinerOperation.Temperature1.U.Actual
0.01728
FirstStage.CombinerOperation.Temperature2.U.Actual
0.000792
FirstStage.CombinerOperation.Temperature3.C.Actual
0.811151

Stage1.Output.Measurement12.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.135097
AmbientConditions.AmbientTemperature.U.Actual
0.632867
Machine1.RawMaterial.Property1
NaN
Machine1.RawMaterial.Property2
NaN
Machine1.RawMaterial.Property3
NaN
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
0.878834
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
0.014547
Machine1.MotorAmperage.U.Actual
0.550292
Machine1.MotorRPM.C.Actual
0.093758
Machine1.MaterialPressure.U.Actual
0.228108
Machine1.MaterialTemperature.U.Actual
0.822809
Machine1.ExitZoneTemperature.C.Actual
0.274703
Machine2.RawMaterial.Property1
NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
0.73953
Machine2.Zone1Temperature.C.Actual

0.417592
Machine2.Zone2Temperature.C.Actual
0.59307
Machine2.MotorAmperage.U.Actual
0.541187
Machine2.MotorRPM.C.Actual
0.414846
Machine2.MaterialPressure.U.Actual
0.751083
Machine2.MaterialTemperature.U.Actual
0.885518
Machine2.ExitZoneTemperature.C.Actual
0.340301
Machine3.RawMaterial.Property1
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
0.222374
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual
0.224613
Machine3.MotorAmperage.U.Actual
0.904011
Machine3.MotorRPM.C.Actual
0.004052
Machine3.MaterialPressure.U.Actual
0.054464
Machine3.MaterialTemperature.U.Actual
0.011967
Machine3.ExitZoneTemperature.C.Actual
NaN
FirstStage.CombinerOperation.Temperature1.U.Actual
0.115707
FirstStage.CombinerOperation.Temperature2.U.Actual
0.080179
FirstStage.CombinerOperation.Temperature3.C.Actual
0.990356

Stage1.Output.Measurement13.U.Actual
AmbientConditions.AmbientHumidity.U.Actual
0.0
AmbientConditions.AmbientTemperature.U.Actual

```
0.0
Machine1.RawMaterial.Property1
NaN
Machine1.RawMaterial.Property2
NaN
Machine1.RawMaterial.Property3
NaN
Machine1.RawMaterial.Property4
NaN
Machine1.RawMaterialFeederParameter.U.Actual
0.294994
Machine1.Zone1Temperature.C.Actual
NaN
Machine1.Zone2Temperature.C.Actual
0.531281
Machine1.MotorAmperage.U.Actual
0.524981
Machine1.MotorRPM.C.Actual
0.0
Machine1.MaterialPressure.U.Actual
0.927838
Machine1.MaterialTemperature.U.Actual
0.0
Machine1.ExitZoneTemperature.C.Actual
0.468311
Machine2.RawMaterial.Property1
NaN
Machine2.RawMaterial.Property2
NaN
Machine2.RawMaterial.Property3
NaN
Machine2.RawMaterial.Property4
NaN
Machine2.RawMaterialFeederParameter.U.Actual
0.089113
Machine2.Zone1Temperature.C.Actual
0.006139
Machine2.Zone2Temperature.C.Actual
0.470505
Machine2.MotorAmperage.U.Actual
0.573066
Machine2.MotorRPM.C.Actual
0.330711
Machine2.MaterialPressure.U.Actual
0.369207
Machine2.MaterialTemperature.U.Actual
0.000111
Machine2.ExitZoneTemperature.C.Actual
```

```

0.628343
Machine3.RawMaterial.Property1
NaN
Machine3.RawMaterial.Property2
NaN
Machine3.RawMaterial.Property3
NaN
Machine3.RawMaterial.Property4
NaN
Machine3.RawMaterialFeederParameter.U.Actual
0.04784
Machine3.Zone1Temperature.C.Actual
NaN
Machine3.Zone2Temperature.C.Actual
0.415911
Machine3.MotorAmperage.U.Actual
0.170092
Machine3.MotorRPM.C.Actual
0.0
Machine3.MaterialPressure.U.Actual
0.0
Machine3.MaterialTemperature.U.Actual
0.000007
Machine3.ExitZoneTemperature.C.Actual
NaN
FirstStage.CombinerOperation.Temperature1.U.Actual
0.000526
FirstStage.CombinerOperation.Temperature2.U.Actual
0.000002
FirstStage.CombinerOperation.Temperature3.C.Actual
0.704783

```

```

[29]: import statsmodels.api as sm
import pandas as pd
import numpy as np

# Define a range of significance levels to test
significance_levels = np.arange(0.01, 0.11, 0.01)

# Store the number of selected features for each significance level and output ↴variable
results = pd.DataFrame(index=Output_AN, columns=significance_levels)

# Feature selection and evaluation for each significance level
for significance_level in significance_levels:
    print(f"*****Testing significance level:{significance_level}*****")

```

```

# Loop through each output column
for n in range(len(Output_AN)):
    Yi = Output_AA.values[:, n] # Select the current output column
    cols = list(Input_AAN.columns) # Initialize the list of input features
    pmax = 1 # Initialize the maximum p-value

    # Perform backward elimination
    while len(cols) > 0:
        X_1 = Input_AAN[cols] # Subset the input features
        X_1 = sm.add_constant(X_1) # Add a constant term for the intercept
        model = sm.OLS(Yi, X_1).fit() # Fit the OLS regression model
        p_values = model.pvalues.iloc[1:] # Get p-values excluding the
        ↵constant term
        pmax = p_values.max() # Find the maximum p-value
        feature_with_p_max = p_values.idxmax() # Identify the feature with
        ↵the maximum p-value

        # Check if the maximum p-value is above the significance level
        if pmax > significance_level:
            cols.remove(feature_with_p_max) # Remove the least significant
        ↵feature
        else:
            break # Stop if all p-values are below the significance level

    selected_features = cols # Get the selected features
    # Record the number of selected features
    results.loc[Output_AN[n], significance_level] = len(selected_features)
    # Print the results for this significance level
    print(Output_AN[n], " Total features:", len(Input_AN), " Selected"
    ↵features:", len(selected_features))

# Display the results for all tested significance levels
print("\nResults for various significance levels:")
print(results)

```

```

*****Testing significance level:
0.01*****
Stage1.Output.Measurement0.U.Actual  Total features: 41  Selected features: 19
Stage1.Output.Measurement2.U.Actual  Total features: 41  Selected features: 20
Stage1.Output.Measurement3.U.Actual  Total features: 41  Selected features: 21
Stage1.Output.Measurement4.U.Actual  Total features: 41  Selected features: 20
Stage1.Output.Measurement8.U.Actual  Total features: 41  Selected features: 16
Stage1.Output.Measurement9.U.Actual  Total features: 41  Selected features: 2
Stage1.Output.Measurement10.U.Actual Total features: 41  Selected features: 2
Stage1.Output.Measurement12.U.Actual Total features: 41  Selected features: 17
Stage1.Output.Measurement13.U.Actual Total features: 41  Selected features: 1

```



```

Stage1.Output.Measurement10.U.Actual  Total features: 41  Selected features: 6
Stage1.Output.Measurement12.U.Actual  Total features: 41  Selected features: 18
Stage1.Output.Measurement13.U.Actual  Total features: 41  Selected features: 3

```

Results for various significance levels:

	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	\
Stage1.Output.Measurement0.U.Actual	19	19	19	19	19	20	20	22	
Stage1.Output.Measurement2.U.Actual	20	20	20	20	20	20	20	20	
Stage1.Output.Measurement3.U.Actual	21	21	21	21	21	21	21	21	
Stage1.Output.Measurement4.U.Actual	20	20	20	20	20	20	20	21	
Stage1.Output.Measurement8.U.Actual	16	18	20	20	20	22	22	22	
Stage1.Output.Measurement9.U.Actual	2	2	5	5	5	5	6	8	
Stage1.Output.Measurement10.U.Actual	2	2	4	4	4	4	4	6	
Stage1.Output.Measurement12.U.Actual	17	17	17	17	18	18	18	18	
Stage1.Output.Measurement13.U.Actual	1	1	3	3	3	3	3	3	
	0.09	0.10							
Stage1.Output.Measurement0.U.Actual	22	22							
Stage1.Output.Measurement2.U.Actual	22	23							
Stage1.Output.Measurement3.U.Actual	21	21							
Stage1.Output.Measurement4.U.Actual	22	22							
Stage1.Output.Measurement8.U.Actual	22	22							
Stage1.Output.Measurement9.U.Actual	8	9							
Stage1.Output.Measurement10.U.Actual	6	6							
Stage1.Output.Measurement12.U.Actual	18	18							
Stage1.Output.Measurement13.U.Actual	3	3							

```

[30]: import statsmodels.api as sm
import pandas as pd

# Feature selection and prediction for model A
print("*****Prediction Model A (Stage\u20d71)*****")
for n in range(len(Output_AN)):
    Yi = Output_AA.values[:, n]
    # Backward Elimination for feature selection
    cols = list(Input_AAN.columns)
    pmax = 1
    while len(cols) > 0:
        X_1 = Input_AAN[cols]
        X_1 = sm.add_constant(X_1)
        model = sm.OLS(Yi, X_1).fit()
        p_values = model.pvalues.iloc[1:]  # Exclude p-value for constant
        pmax = p_values.max()
        feature_with_p_max = p_values.idxmax()
        if pmax > 0.05:
            cols.remove(feature_with_p_max)

```

```

        else:
            break
    selected_features = cols
    print(Output_AN[n], "      Total features:", len(Input_AN), " Selected\u202a
    ↵features:", len(selected_features))

*****Prediction Model A (Stage
1)*****
Stage1.Output.Measurement0.U.Actual      Total features: 41 Selected features:
19
Stage1.Output.Measurement2.U.Actual      Total features: 41 Selected features:
20
Stage1.Output.Measurement3.U.Actual      Total features: 41 Selected features:
21
Stage1.Output.Measurement4.U.Actual      Total features: 41 Selected features:
20
Stage1.Output.Measurement8.U.Actual      Total features: 41 Selected features:
20
Stage1.Output.Measurement9.U.Actual      Total features: 41 Selected features:
5
Stage1.Output.Measurement10.U.Actual     Total features: 41 Selected features:
4
Stage1.Output.Measurement12.U.Actual     Total features: 41 Selected features:
18
Stage1.Output.Measurement13.U.Actual     Total features: 41 Selected features:
3

```

[31]:

```

print("*****Slitting the data into train and
    ↵test*****")

```

```

x_selected = Input_AA.values[:, selected_features]
x_train, x_test, y_train, y_test = train_test_split(x_selected, Yi, test_size=0.
    ↵3)

```

```

*****Slitting the data into train and
test*****

```

[32]:

```

# SVM
# Import necessary libraries
from sklearn.pipeline import make_pipeline
from sklearn.preprocessing import StandardScaler
from sklearn.svm import SVR
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
import matplotlib.pyplot as plt
import numpy as np

# Create the SVM pipeline

```

```

svr_poly = make_pipeline(StandardScaler(), SVR(C=1.0, epsilon=0.2,
    ↪kernel='poly', degree=3))
svr_poly = svr_poly.fit(x_train, y_train)
predictions = svr_poly.predict(x_test)

# Calculate errors
MSE = mean_squared_error(y_test, predictions)
RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_test, predictions)
R2 = r2_score(y_test, predictions) # Calculate R-squared

# Print errors
print("Root Mean Squared Error (RMSE): ", RMSE)
print("Mean Absolute Error (MAE): ", MAE)
print("R-squared (R2): ", R2) # Print R-squared

# Plot results: Actual vs Predicted using range if index is not available
x_axis = range(len(y_test)) # Create a range for the x-axis equal to the
↪length of y_test

# plt.figure(figsize=(15, 6))
# plt.plot(x_axis, y_test, color='blue', label='Actual')
# plt.plot(x_axis, predictions, color='orange', linestyle='--', ↪
↪label='Predicted')
# plt.title('SVM-Poly Predictions vs Actual')
# plt.xlabel('Index')
# plt.ylabel('Value')
# plt.legend()
# plt.show()

# Residual Plot
residuals = y_test - predictions
plt.figure(figsize=(15, 6))
plt.plot(x_axis, residuals, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')
plt.show()

# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_test, predictions, color='purple', alpha=0.6)
plt.plot([min(y_test), max(y_test)], [min(y_test), max(y_test)], color='black',
    ↪linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')

```

```

plt.ylabel('Predicted Values')
plt.show()

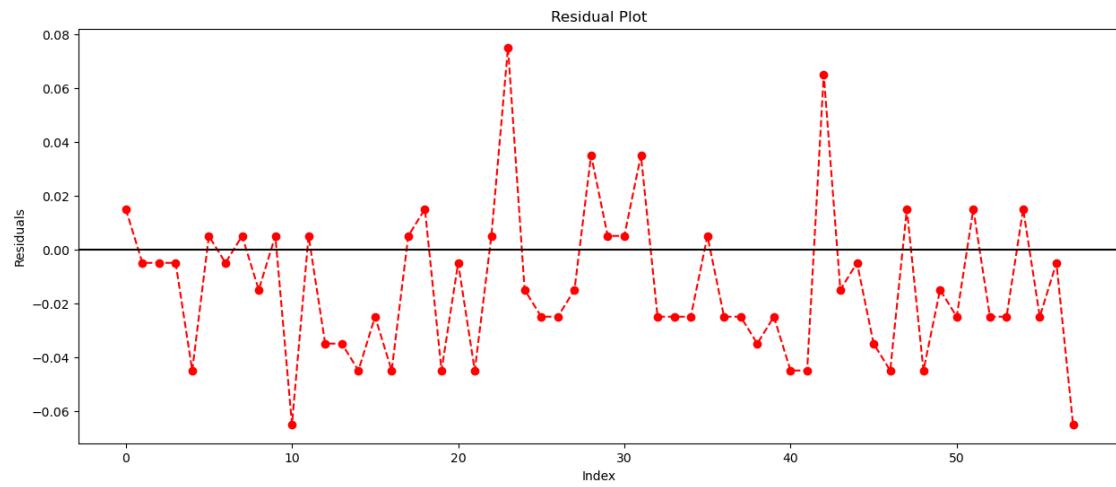
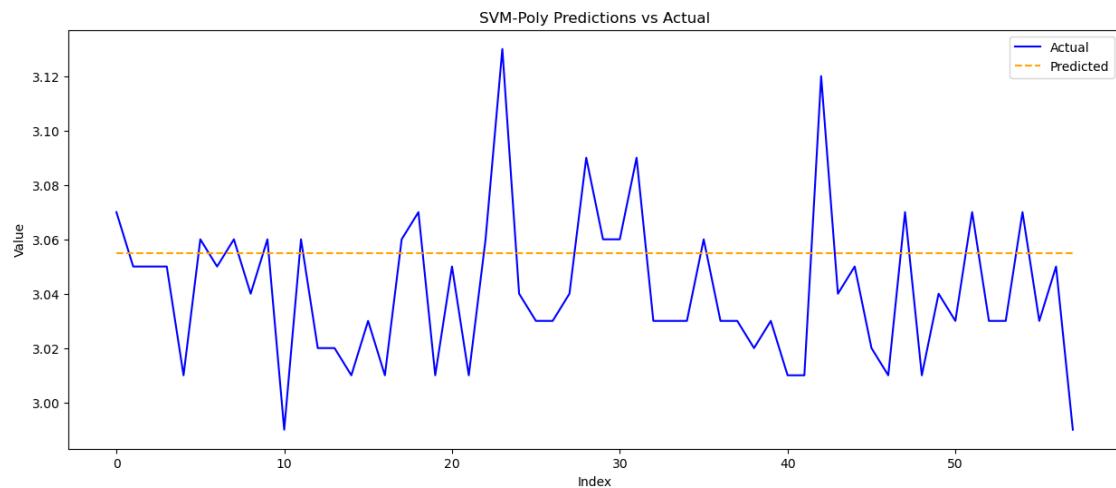
# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residuals, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

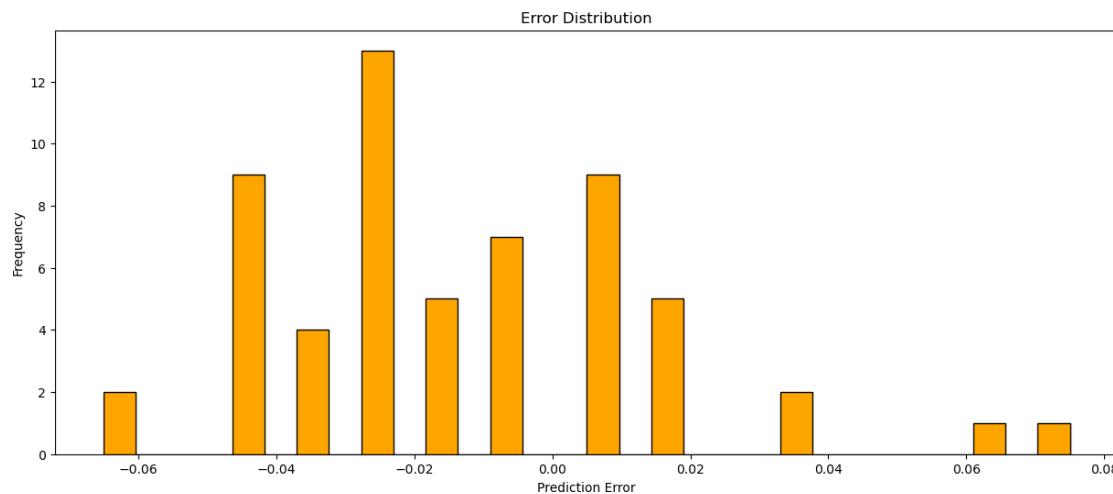
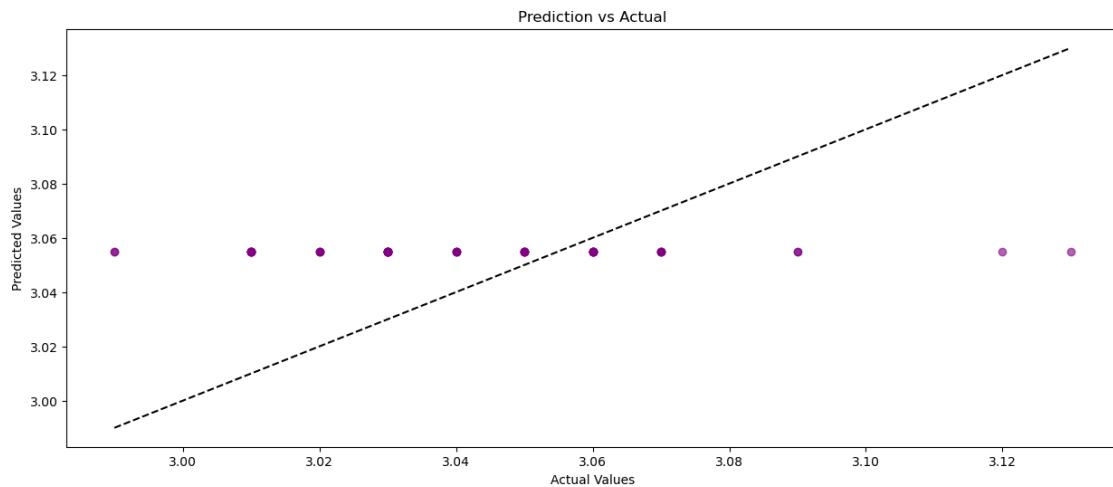
```

Root Mean Squared Error (RMSE): 0.03069595053602922

Mean Absolute Error (MAE): 0.02482758620689669

R-squared (R2): -0.23753562643970727





```
[33]: # Decision Tree
```

```
import numpy as np
import matplotlib.pyplot as plt
from sklearn.tree import DecisionTreeRegressor, plot_tree
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
from sklearn.model_selection import train_test_split

# Create and fit the Decision Tree model
clf = DecisionTreeRegressor(max_features='auto')
clf = clf.fit(x_train, y_train)
predictions = clf.predict(x_test)
```

```

# Calculate errors
MSE = mean_squared_error(y_test, predictions)
RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_test, predictions)
R2 = r2_score(y_test, predictions) # Calculate R-squared

# Print errors
print("Root Mean Squared Error (RMSE): ", RMSE)
print("Mean Absolute Error (MAE): ", MAE)
print("R-squared (R2): ", R2) # Print R-squared value

# Plot results: Actual vs Predicted using range if index is not available
x_axis = range(len(y_test)) # Create a range for the x-axis equal to the ↴
                             ↴length of y_test

# plt.figure(figsize=(15, 6))
# plt.plot(x_axis, y_test, color='blue', label='Actual')
# plt.plot(x_axis, predictions, color='orange', linestyle='--', ↴
#          ↴label='Predicted')
# plt.title('Decision Tree Predictions vs Actual')
# plt.xlabel('Index')
# plt.ylabel('Value')
# plt.legend()
# plt.show()

# Residual Plot
residuals = y_test - predictions
plt.figure(figsize=(15, 6))
plt.plot(x_axis, residuals, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')
plt.show()

# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_test, predictions, color='purple', alpha=0.6)
plt.plot([min(y_test), max(y_test)], [min(y_test), max(y_test)], color='black', ↴
          ↴linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

# Error Distribution Plot
plt.figure(figsize=(15, 6))

```

```

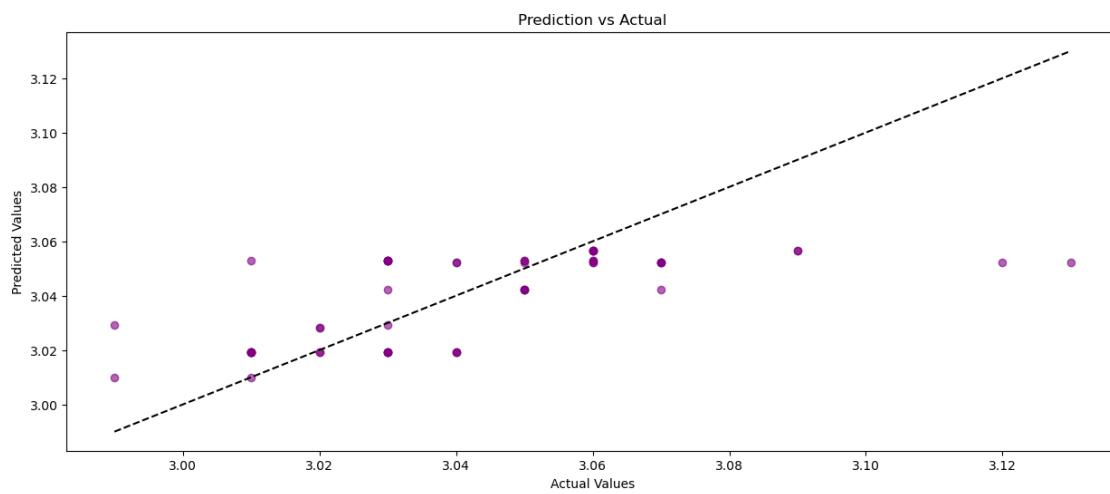
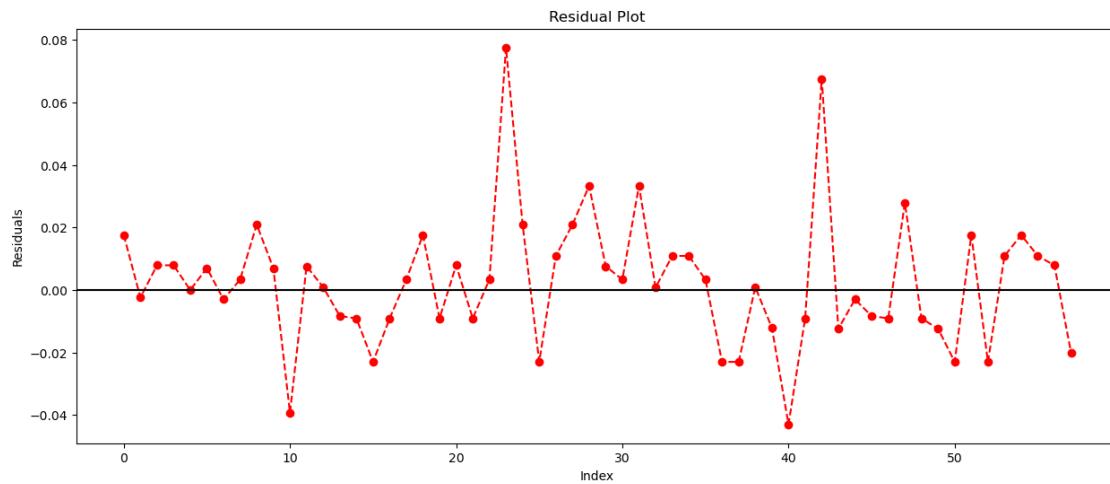
plt.hist(residuals, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

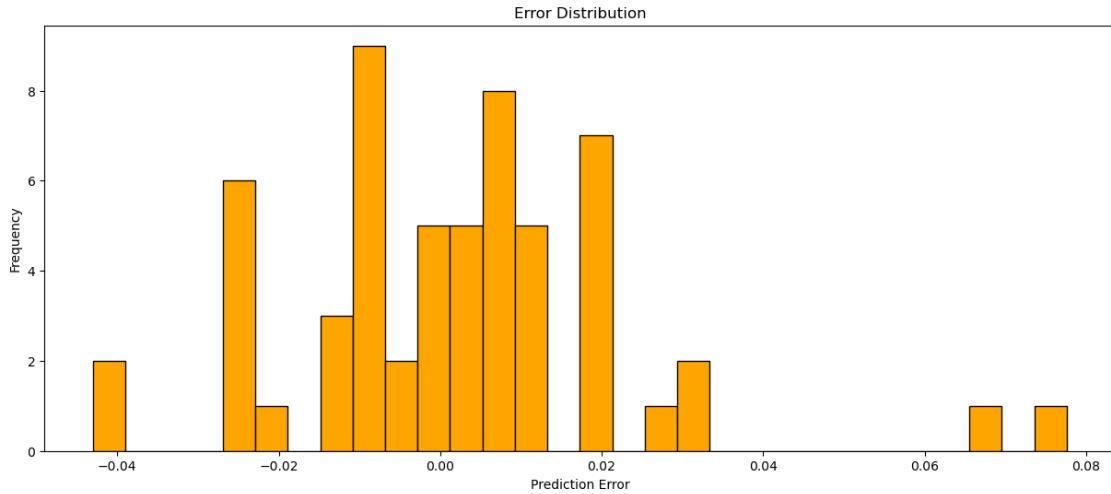
```

Root Mean Squared Error (RMSE): 0.02093314881310046

Mean Absolute Error (MAE): 0.0150570037947534

R-squared (R2): 0.42447438273749316





```
[34]: # K-Nearest Neighbors
# Import necessary libraries
from sklearn.neighbors import KNeighborsRegressor
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
import matplotlib.pyplot as plt
import numpy as np

# Create and fit the KNN model
knn = KNeighborsRegressor(n_neighbors=5, weights='distance', algorithm='auto',
                           leaf_size=30, p=2,
                           metric='minkowski', metric_params=None, n_jobs=None)
knn = knn.fit(x_train, y_train)
predictions = knn.predict(x_test)

# Calculate errors
MSE = mean_squared_error(y_test, predictions)
RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_test, predictions)
R2 = r2_score(y_test, predictions) # Calculate R-squared

# Print errors
print("Root Mean Squared Error (RMSE): ", RMSE)
print("Mean Absolute Error (MAE): ", MAE)
print("R-squared (R2): ", R2) # Print R-squared value

# Plot results: Actual vs Predicted using range if index is not available
x_axis = range(len(y_test)) # Create a range for the x-axis equal to the
                           # length of y_test

# plt.figure(figsize=(15, 6))
```

```

# plt.plot(x_axis, y_test, color='blue', label='Actual')
# plt.plot(x_axis, predictions, color='orange', linestyle='--', label='Predicted')
# plt.title('KNN Predictions vs Actual')
# plt.xlabel('Index')
# plt.ylabel('Value')
# plt.legend()
# plt.show()

# Residual Plot
residuals = y_test - predictions
plt.figure(figsize=(15, 6))
plt.plot(x_axis, residuals, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')
plt.show()

# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_test, predictions, color='purple', alpha=0.6)
plt.plot([min(y_test), max(y_test)], [min(y_test), max(y_test)], color='black', linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

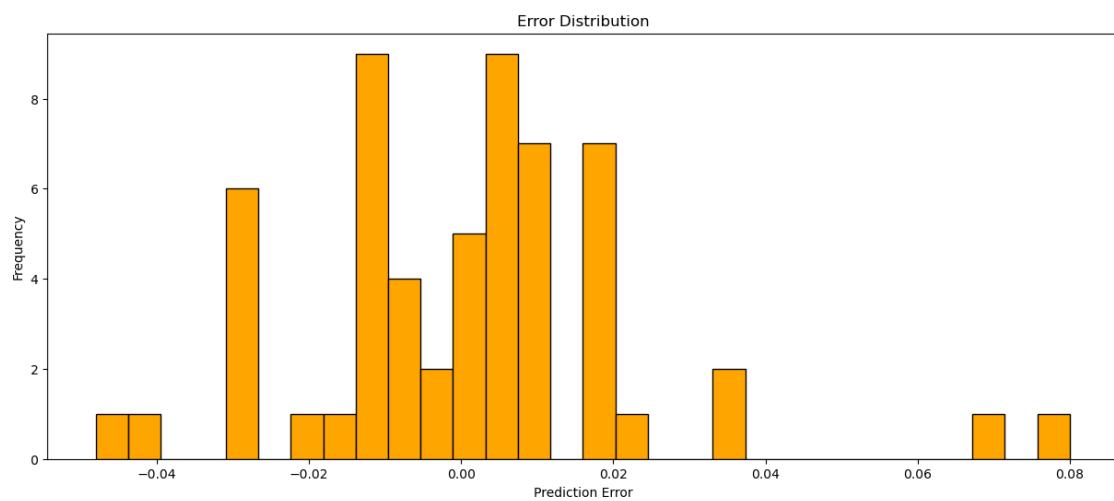
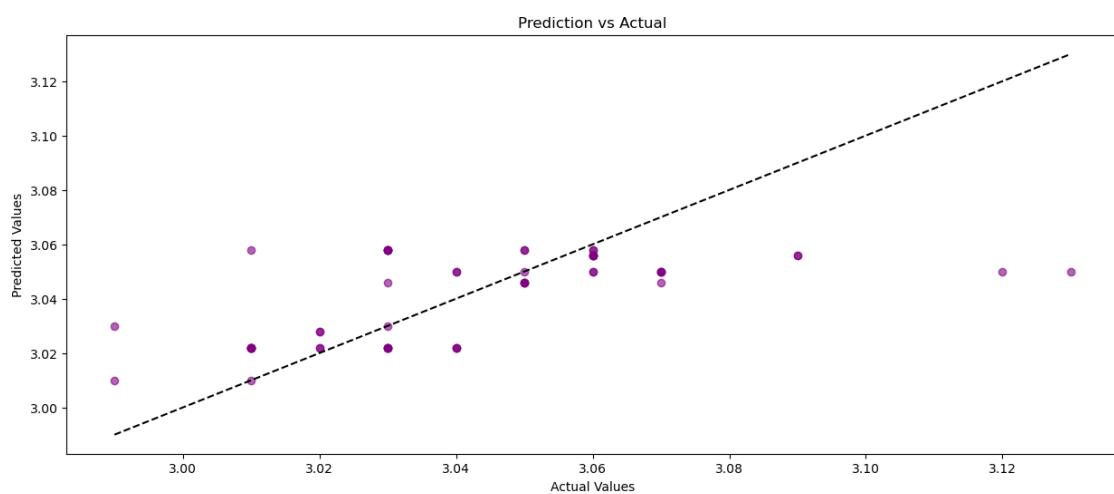
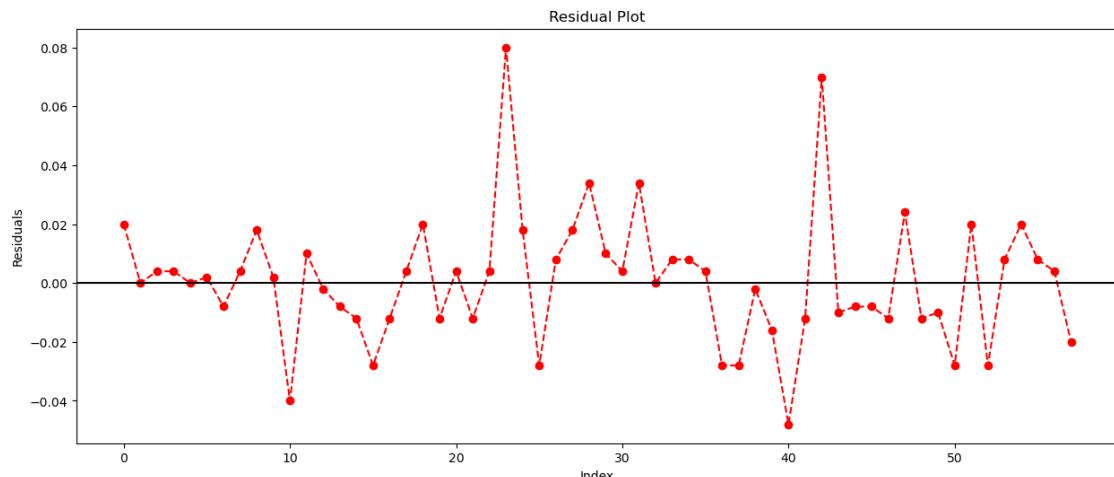
# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residuals, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

```

Root Mean Squared Error (RMSE): 0.022037585448814262

Mean Absolute Error (MAE): 0.01565517241379302

R-squared (R2): 0.36214266192949374



```
[35]: # Random Forest

from sklearn.ensemble import RandomForestRegressor
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
import matplotlib.pyplot as plt
import numpy as np

# Create and fit the Random Forest model
rf = RandomForestRegressor(n_estimators=100, random_state=42) # You can adjust
    ↪n_estimators and other hyperparameters
rf = rf.fit(x_train, y_train)
predictions = rf.predict(x_test)

# Calculate errors
MSE = mean_squared_error(y_test, predictions)
RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_test, predictions)
R2 = r2_score(y_test, predictions) # Calculate R-squared

# Print errors
print("Root Mean Squared Error (RMSE): ", RMSE)
print("Mean Absolute Error (MAE): ", MAE)
print("R-squared (R2): ", R2) # Print R-squared value

# Plot results: Actual vs Predicted using range if index is not available
x_axis = range(len(y_test)) # Create a range for the x-axis equal to the
    ↪length of y_test
# plt.figure(figsize=(15, 6))
# plt.plot(x_axis, y_test, color='blue', label='Actual')
# plt.plot(x_axis, predictions, color='orange', linestyle='--', ↪
    ↪label='Predicted')
# plt.title('Random Forest Predictions vs Actual')
# plt.xlabel('Index')
# plt.ylabel('Value')
# plt.legend()
# plt.show()

# Residual Plot
residuals = y_test - predictions
plt.figure(figsize=(15, 6))
plt.plot(x_axis, residuals, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
```

```

plt.ylabel('Residuals')
plt.show()

# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_test, predictions, color='purple', alpha=0.6)
plt.plot([min(y_test), max(y_test)], [min(y_test), max(y_test)], color='black',  

         linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residuals, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

# Feature Importance Plot
importances = rf.feature_importances_
indices = np.argsort(importances)[::-1]
feature_names = Input_AA.columns[selected_features] # Assume  

↳ 'selected_features' is a list of indices

plt.figure(figsize=(15, 6))
plt.title("Feature Importances")
plt.bar(range(x_train.shape[1]), importances[indices], color="r",  

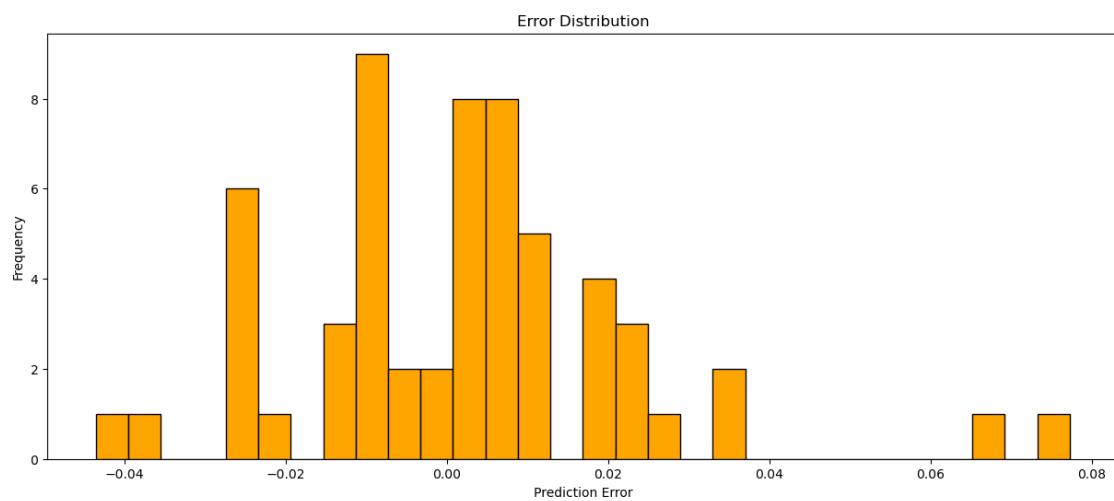
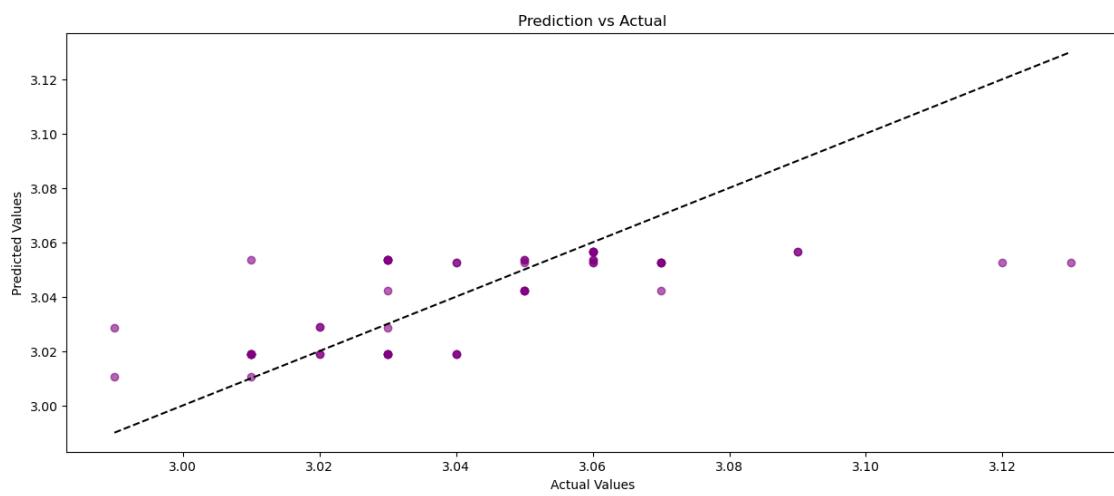
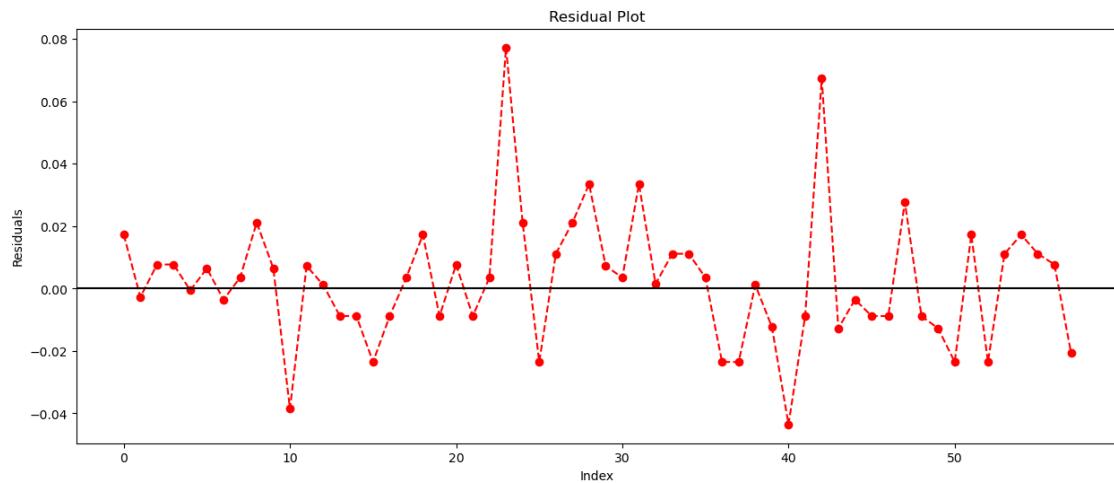
        align="center")
plt.xticks(range(x_train.shape[1]), feature_names[indices], rotation=90)
plt.xlim([-1, x_train.shape[1]])
plt.show()

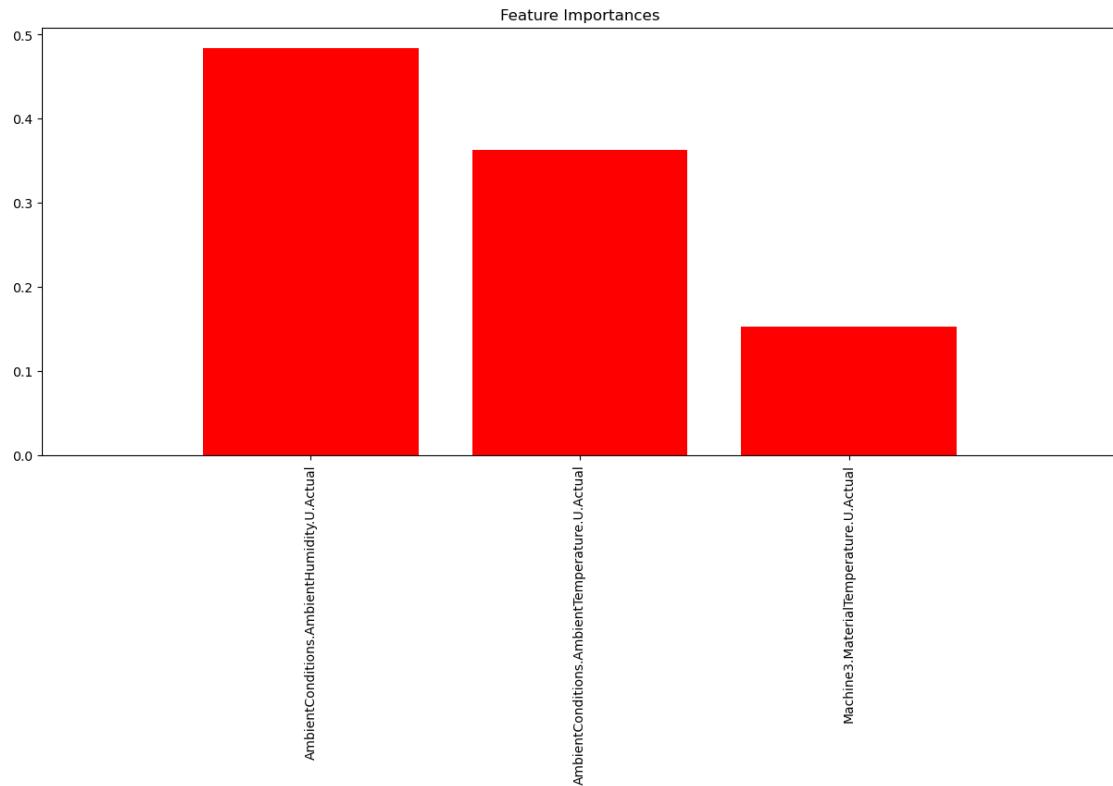
```

Root Mean Squared Error (RMSE): 0.02096399910533415

Mean Absolute Error (MAE): 0.015147979528655028

R-squared (R2): 0.4227767674403047





```
[36]: # Gradient Boosting
from sklearn.ensemble import GradientBoostingRegressor
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
import matplotlib.pyplot as plt
import numpy as np

# Create and fit the Gradient Boosting model
gbm = GradientBoostingRegressor(n_estimators=100, learning_rate=0.1, max_depth=3, random_state=42)
gbm.fit(x_train, y_train)
predictions = gbm.predict(x_test)

# Calculate errors
MSE = mean_squared_error(y_test, predictions)
RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_test, predictions)
R2 = r2_score(y_test, predictions) # Calculate R-squared

# Print errors
```

```

print("Root Mean Squared Error: ", RMSE)
print("Mean Absolute Error: ", MAE)
print("R-squared (R2): ", R2) # Print R-squared value

# Plot results: Actual vs Predicted using range if index is not available
x_axis = range(len(y_test)) # Create a range for the x-axis equal to the
                             # length of y_test
plt.figure(figsize=(15, 6))
plt.plot(x_axis, y_test, color='blue', label='Actual')
plt.plot(x_axis, predictions, color='orange', linestyle='--', label='Predicted')
plt.title('Gradient Boosting Machine Predictions vs Actual')
plt.xlabel('Index')
plt.ylabel('Value')
plt.legend()
plt.show()

# Residual Plot
residuals = y_test - predictions
plt.figure(figsize=(15, 6))
plt.plot(x_axis, residuals, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')
plt.show()

# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_test, predictions, color='purple', alpha=0.6)
plt.plot([min(y_test), max(y_test)], [min(y_test), max(y_test)], color='black',
         linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residuals, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

# Feature Importance Plot
importances = gbm.feature_importances_
indices = np.argsort(importances)[::-1]

```

```

feature_names = Input_AA.columns[selected_features] # Assuming
    ↪selected_features is a list of indices

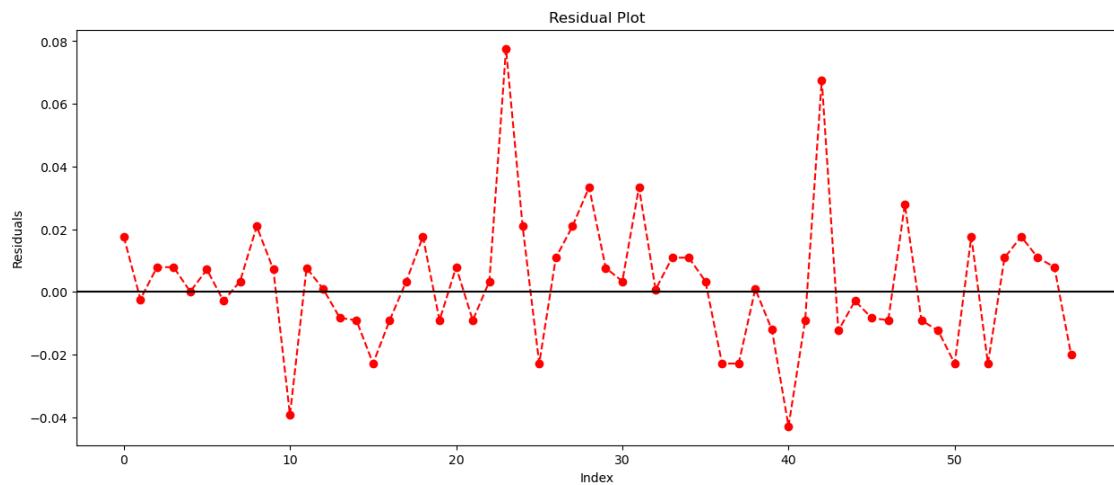
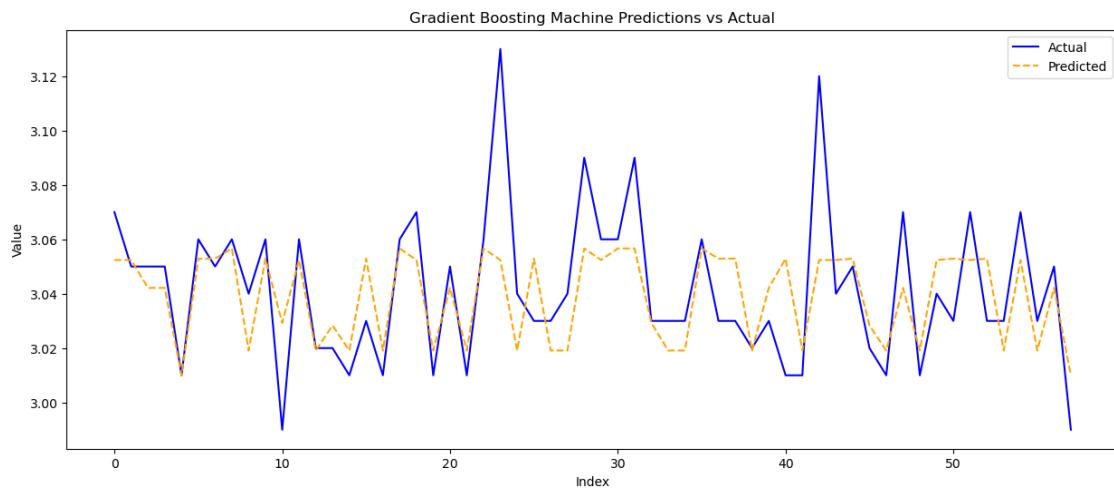
plt.figure(figsize=(15, 6))
plt.title("Feature Importances")
plt.bar(range(x_train.shape[1]), importances[indices], color="r",
    ↪align="center")
plt.xticks(range(x_train.shape[1]), feature_names[indices], rotation=90)
plt.xlim([-1, x_train.shape[1]])
plt.show()

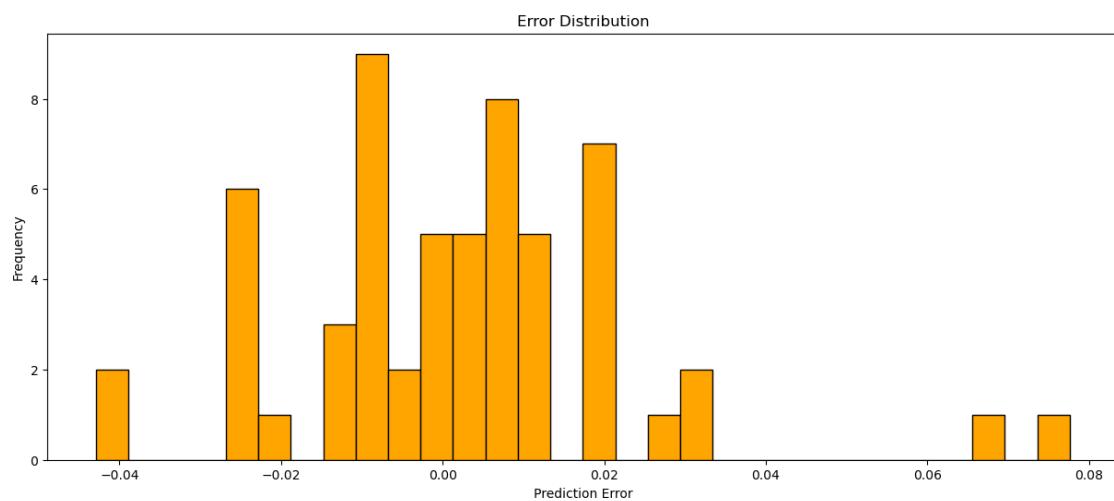
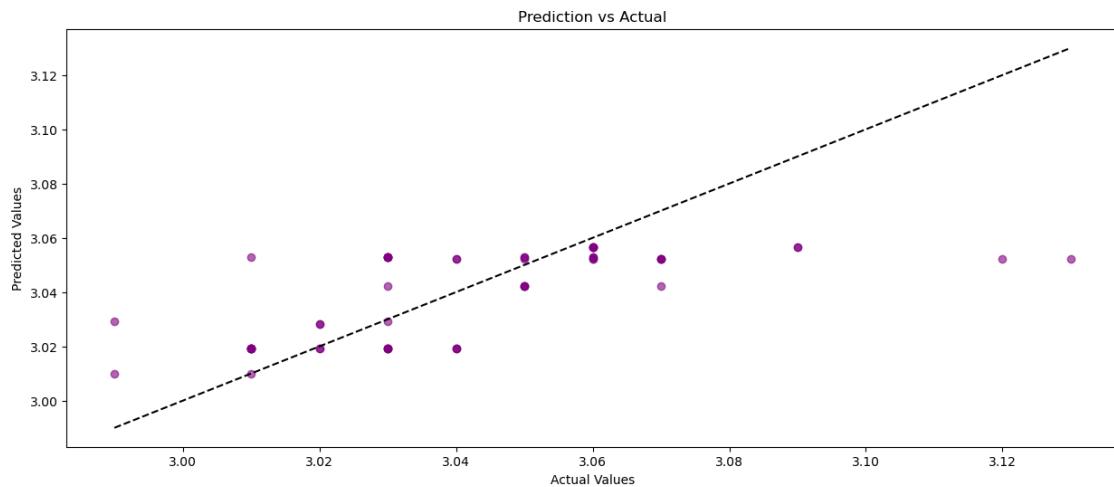
```

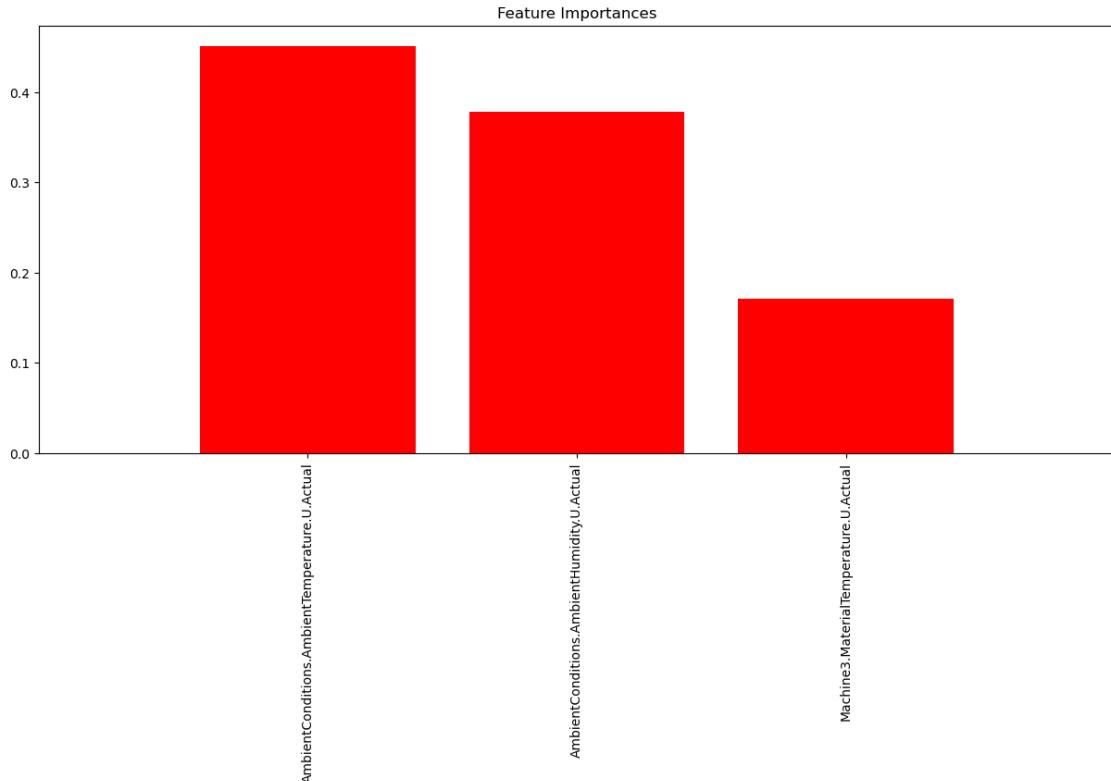
Root Mean Squared Error: 0.020921114435966354

Mean Absolute Error: 0.015045669604439068

R-squared (R2): 0.4251359269227437







```
[37]: # RNN
import numpy as np
import pandas as pd
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, LSTM
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
from sklearn.model_selection import train_test_split
import matplotlib.pyplot as plt

x_train_rnn = np.array(x_train).reshape((x_train.shape[0], x_train.shape[1], 1))
x_test_rnn = np.array(x_test).reshape((x_test.shape[0], x_test.shape[1], 1))

# Build the RNN model
model = Sequential([
    LSTM(50, activation='relu', input_shape=(x_train_rnn.shape[1], 1)), # Can use LSTM instead of SimpleRNN
    Dense(1)
])
model.compile(optimizer='adam', loss='mse')
```

```

# Train the model
model.fit(x_train_rnn, y_train, epochs=50, verbose=0)

# Predictions
predictions = model.predict(x_test_rnn).flatten() # Flatten to match y_test's
    ↪shape if needed

# Calculate errors
MSE = mean_squared_error(y_test, predictions)
RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_test, predictions)
R2 = r2_score(y_test, predictions) # Calculate R-squared

# Print errors
print("RNN Model RMSE: ", RMSE)
print("RNN Model MAE: ", MAE)
print("RNN Model R-squared: ", R2) # Print R-squared value

# Plot results: Actual vs Predicted
x_axis = range(len(y_test)) # Create a range for the x-axis equal to the
    ↪length of y_test
plt.figure(figsize=(15, 6))
plt.plot(x_axis, y_test, color='blue', label='Actual')
plt.plot(x_axis, predictions, color='orange', linestyle='--', label='Predicted')
plt.title('RNN Predictions vs Actual')
plt.xlabel('Index')
plt.ylabel('Value')
plt.legend()
plt.show()

# Residual Plot
residuals = y_test - predictions
plt.figure(figsize=(15, 6))
plt.plot(x_axis, residuals, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')
plt.show()

# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_test, predictions, color='purple', alpha=0.6)
plt.plot([min(y_test), max(y_test)], [min(y_test), max(y_test)], color='black',
    ↪linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')

```

```

plt.ylabel('Predicted Values')
plt.show()

# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residuals, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

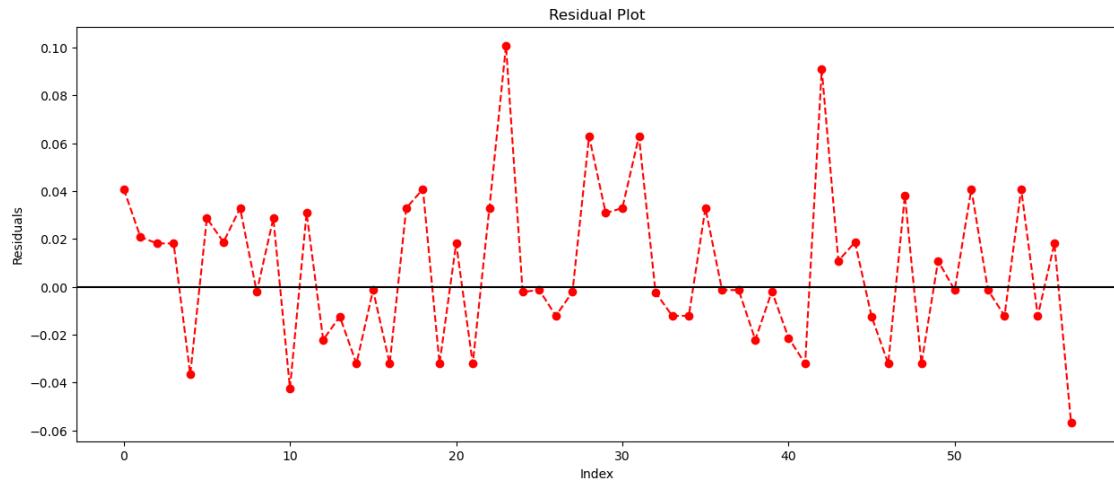
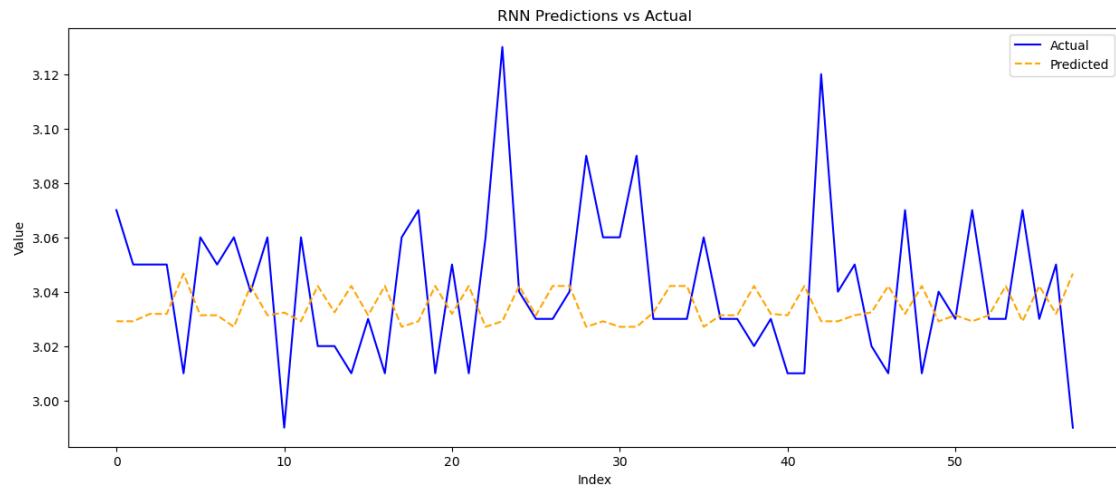
```

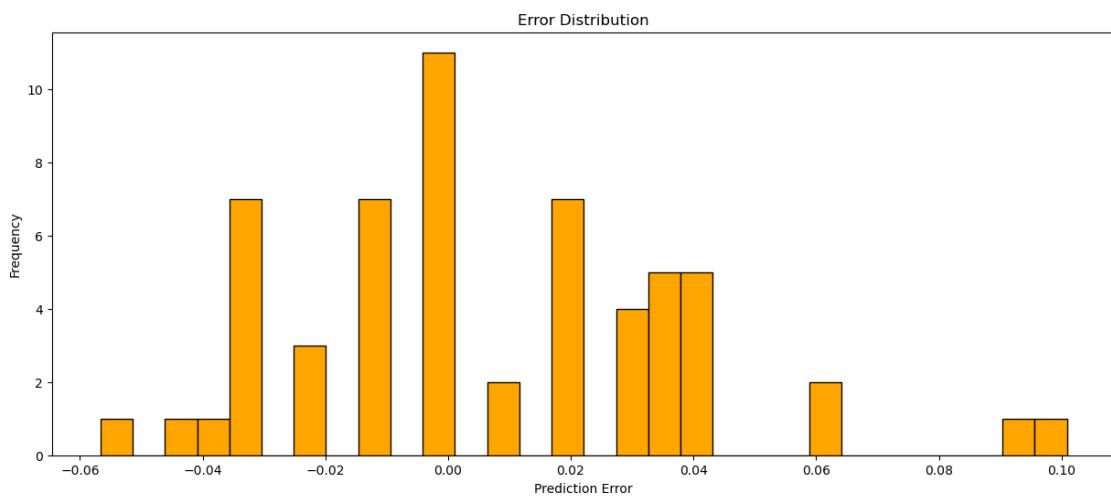
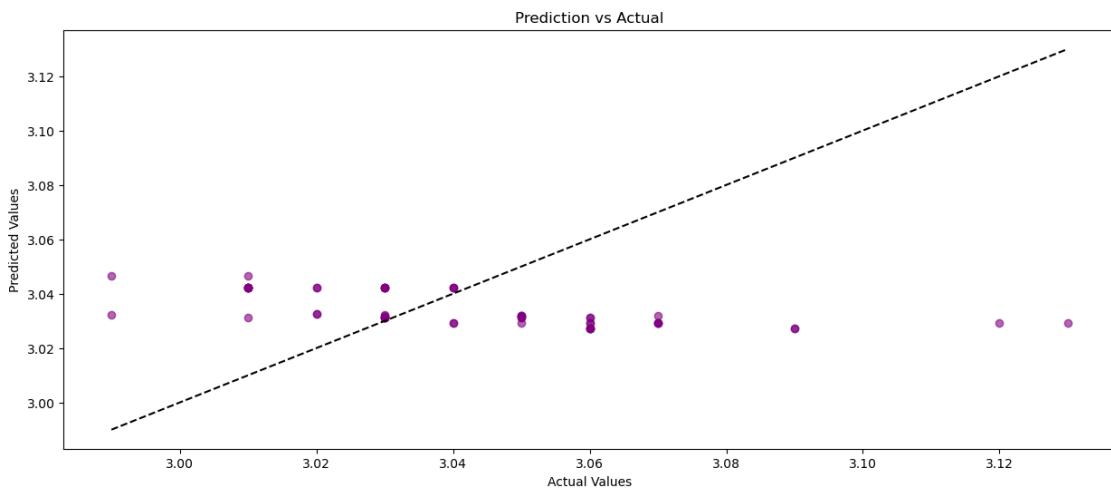
2/2 [=====] - 1s 7ms/step

RNN Model RMSE: 0.03275006169209571

RNN Model MAE: 0.02560892746366307

RNN Model R-squared: -0.4087041125102684





```
[38]: # LSTM
import numpy as np
import pandas as pd
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, LSTM
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
from sklearn.model_selection import train_test_split
import matplotlib.pyplot as plt

x_train_lstm = x_train.reshape((x_train.shape[0], x_train.shape[1], 1))
x_test_lstm = x_test.reshape((x_test.shape[0], x_test.shape[1], 1))
```

```

# Build the LSTM model
model = Sequential([
    LSTM(50, activation='relu', input_shape=(x_train_lstm.shape[1], 1)),
    Dense(1)
])

model.compile(optimizer='adam', loss='mse')

# Train the model
model.fit(x_train_lstm, y_train, epochs=50, verbose=0)

# Predictions
predictions = model.predict(x_test_lstm).flatten() # Flatten predictions to
#match y_test's shape

# Calculate errors
MSE = mean_squared_error(y_test, predictions)
RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_test, predictions)
R2 = r2_score(y_test, predictions) # Calculate R-squared

# Print errors
print("LSTM Model RMSE: ", RMSE)
print("LSTM Model MAE: ", MAE)
print("LSTM Model R-squared: ", R2) # Print R-squared value

# Plot results: Actual vs Predicted
x_axis = range(len(y_test)) # Create a range for the x-axis equal to the
#length of y_test
plt.figure(figsize=(15, 6))
plt.plot(x_axis, y_test, color='blue', label='Actual')
plt.plot(x_axis, predictions, color='orange', linestyle='--', label='Predicted')
plt.title('LSTM Predictions vs Actual')
plt.xlabel('Index')
plt.ylabel('Value')
plt.legend()
plt.show()

# Residual Plot
residuals = y_test - predictions
plt.figure(figsize=(15, 6))
plt.plot(x_axis, residuals, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')

```

```

plt.show()

# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_test, predictions, color='purple', alpha=0.6)
plt.plot([min(y_test), max(y_test)], [min(y_test), max(y_test)], color='black',  

         linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residuals, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

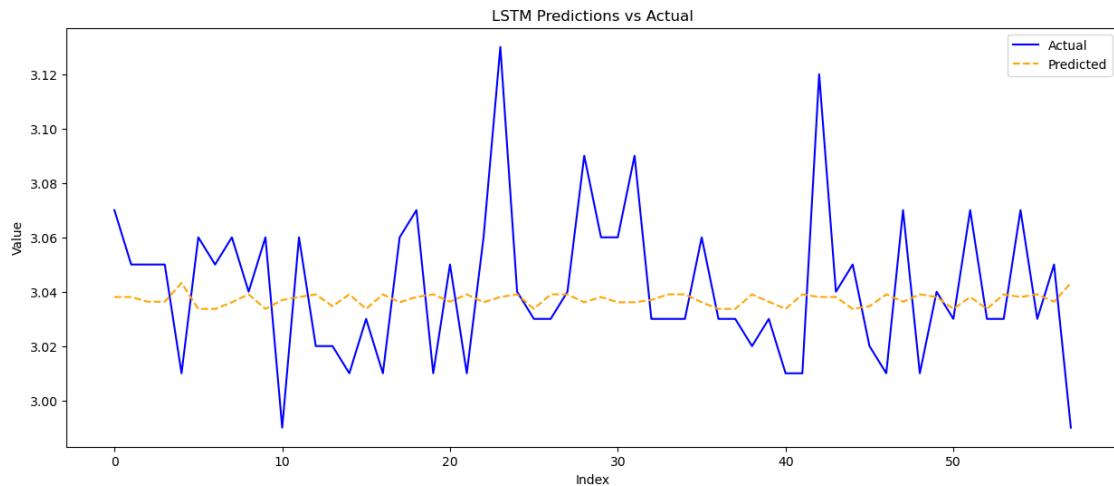
```

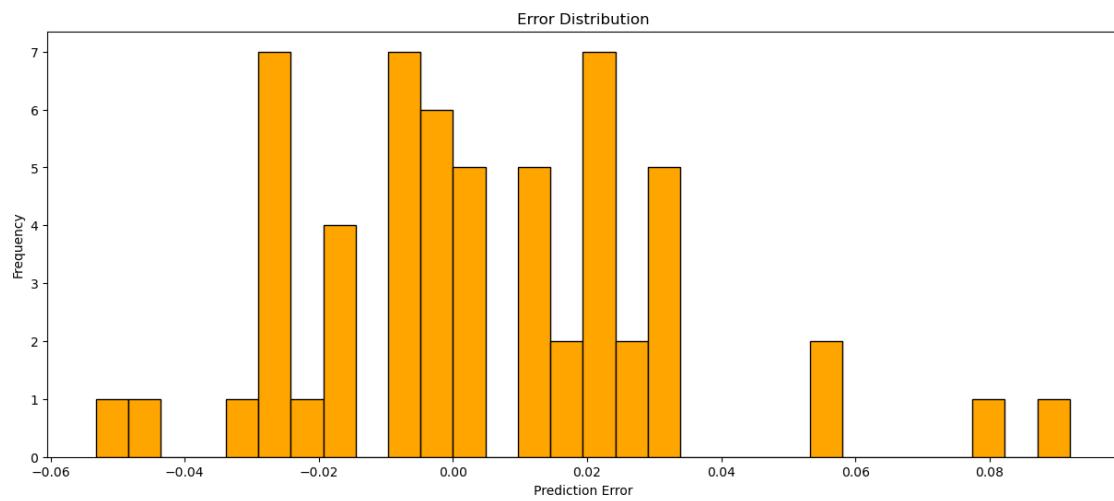
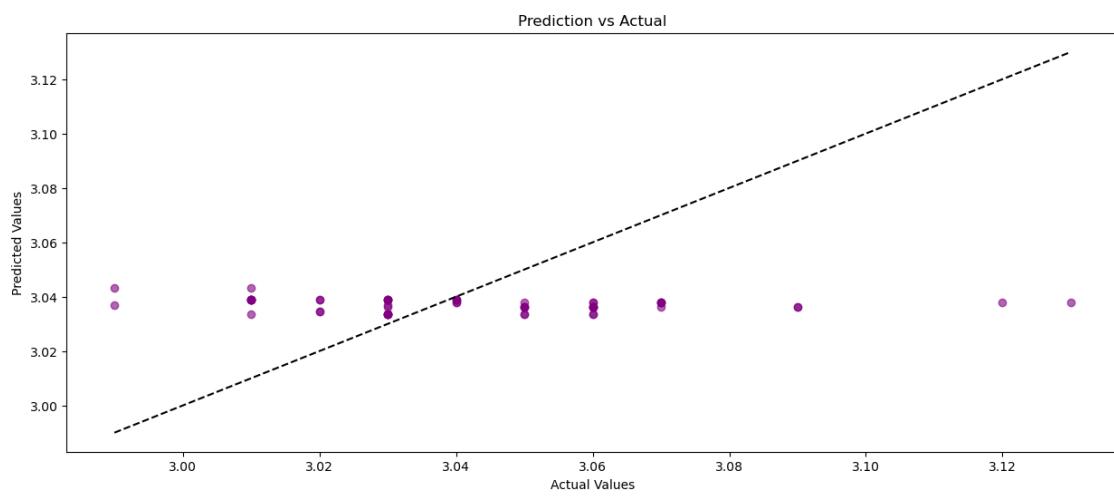
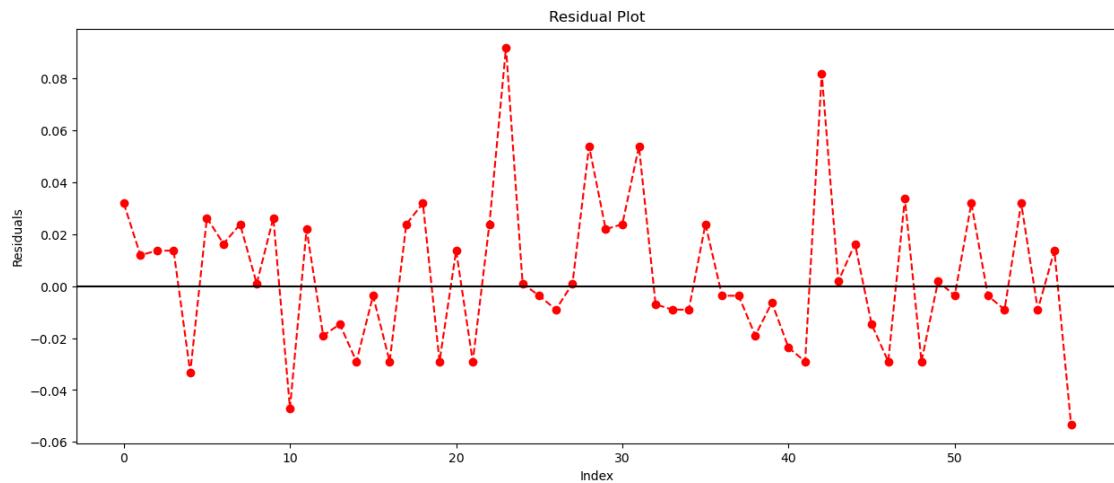
2/2 [=====] - 1s 9ms/step

LSTM Model RMSE: 0.028515973492325278

LSTM Model MAE: 0.02195494059858655

LSTM Model R-squared: -0.06800169583385363





```
[120]: #hyperparameter Tuning for GBM
from sklearn.model_selection import GridSearchCV

# Define the parameter grid
param_grid = {
    'n_estimators': [100, 200, 300],
    'learning_rate': [0.01, 0.05, 0.1],
    'max_depth': [3, 4, 5],
    'min_samples_split': [2, 5, 10],
    'min_samples_leaf': [1, 2, 4],
    'subsample': [0.8, 0.9, 1.0]
}

# Initialize the GridSearchCV object
grid_search = GridSearchCV(estimator=GradientBoostingRegressor(random_state=42),
                           param_grid=param_grid, cv=5, n_jobs=-1, scoring='neg_mean_squared_error')

# Fit to the data
grid_search.fit(x_train, y_train)

# Best parameters found by GridSearchCV
best_params = grid_search.best_params_
print(f"Best parameters: {best_params}")
```

Best parameters: {'learning_rate': 0.1, 'max_depth': 5, 'min_samples_leaf': 4, 'min_samples_split': 2, 'n_estimators': 100, 'subsample': 0.8}

```
[121]: # Gradient Boosting hyperparameter tuning
from sklearn.ensemble import GradientBoostingRegressor
from sklearn.metrics import mean_squared_error, mean_absolute_error,
                           mean_absolute_percentage_error
import matplotlib.pyplot as plt
import numpy as np

# Create and fit the Gradient Boosting model with best parameters
best_params = {
    'learning_rate': 0.1,
    'max_depth': 5,
    'min_samples_leaf': 4,
    'min_samples_split': 2,
    'n_estimators': 100,
    'subsample': 0.8
}
gbm = GradientBoostingRegressor(**best_params, random_state=42)
```

```

gbm.fit(x_train, y_train)
predictions = gbm.predict(x_test)

# Calculate errors
MSE = mean_squared_error(y_test, predictions)
MAE = mean_absolute_error(y_test, predictions)
MAPE = mean_absolute_percentage_error(y_test, predictions)

# Print errors
print("Mean Squared Error: ", MSE)
print("Mean Absolute Error: ", MAE)
print("Mean Absolute Percentage Error: ", MAPE)

# Plot results: Actual vs Predicted using range if index is not available
x_axis = range(len(y_test)) # Create a range for the x-axis equal to the
length of y_test

plt.figure(figsize=(15, 6))
plt.plot(x_axis, y_test, color='blue', label='Actual')
plt.plot(x_axis, predictions, color='orange', linestyle='--', label='Predicted')
plt.title('Gradient Boosting Machine Predictions vs Actual')
plt.xlabel('Index')
plt.ylabel('Value')
plt.legend()
plt.show()

# Plot MAPE
plt.figure(figsize=(6, 4))
plt.bar(['MAPE'], [MAPE], color='green')
plt.title('Mean Absolute Percentage Error (MAPE)')
plt.ylabel('MAPE')
plt.show()

# Residual Plot
residuals = y_test - predictions
plt.figure(figsize=(15, 6))
plt.plot(x_axis, residuals, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')
plt.show()

# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_test, predictions, color='purple', alpha=0.6)

```

```

plt.plot([min(y_test), max(y_test)], [min(y_test), max(y_test)], color='black', u
    ↪ linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residuals, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

# Feature Importance Plot
importances = gbm.feature_importances_
indices = np.argsort(importances)[::-1]
feature_names = Input_AA.columns[selected_features] # Assuming
    ↪selected_features is a list of indices

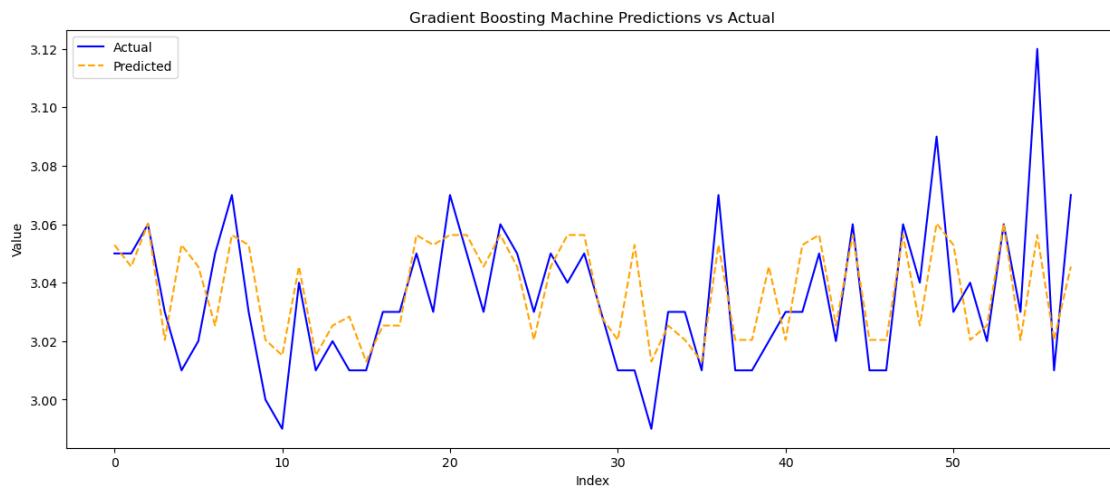
plt.figure(figsize=(15, 6))
plt.title("Feature Importances")
plt.bar(range(x_train.shape[1]), importances[indices], color="r", u
    ↪align="center")
plt.xticks(range(x_train.shape[1]), feature_names[indices], rotation=90)
plt.xlim([-1, x_train.shape[1]])
plt.show()

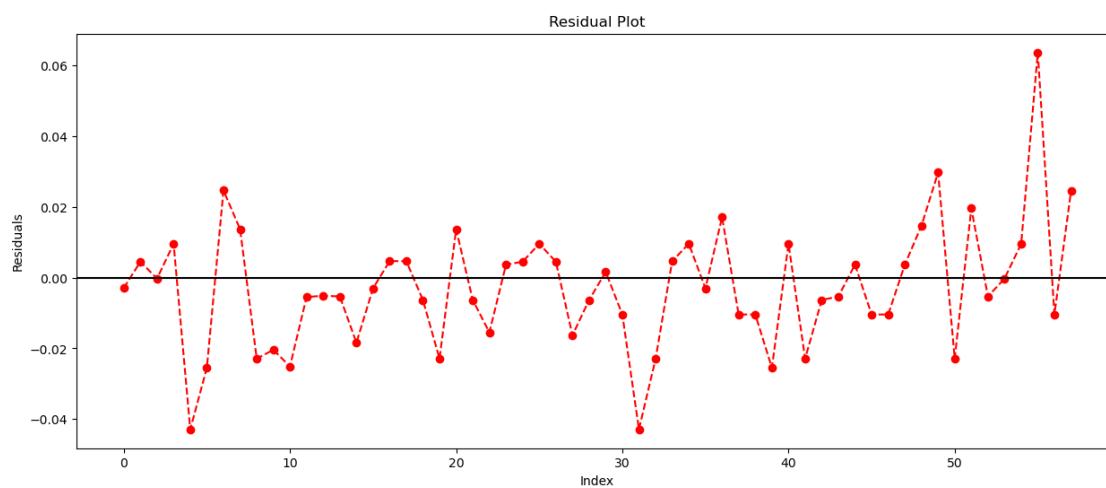
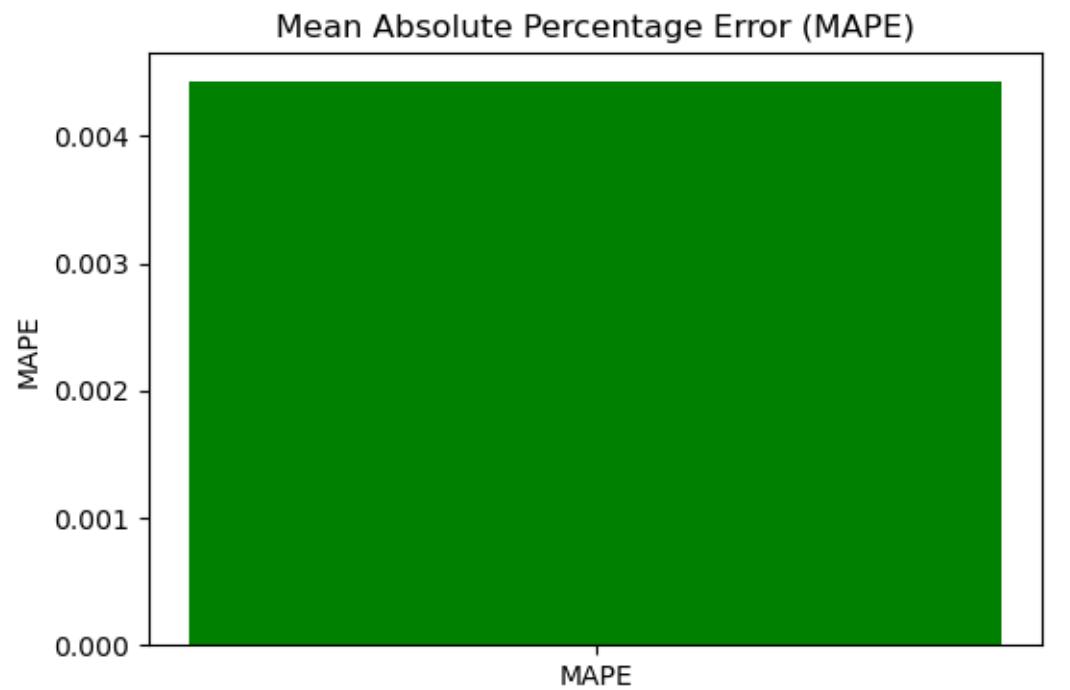
```

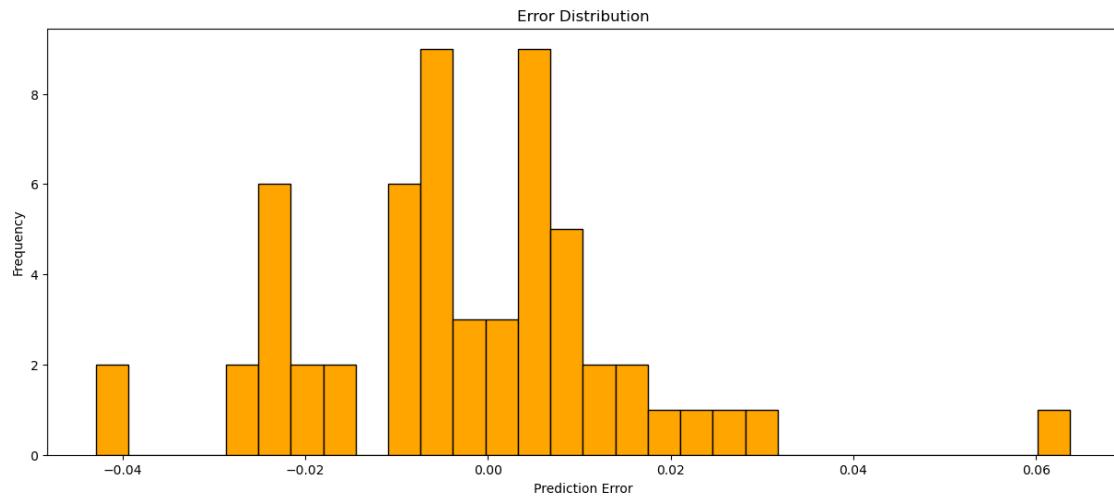
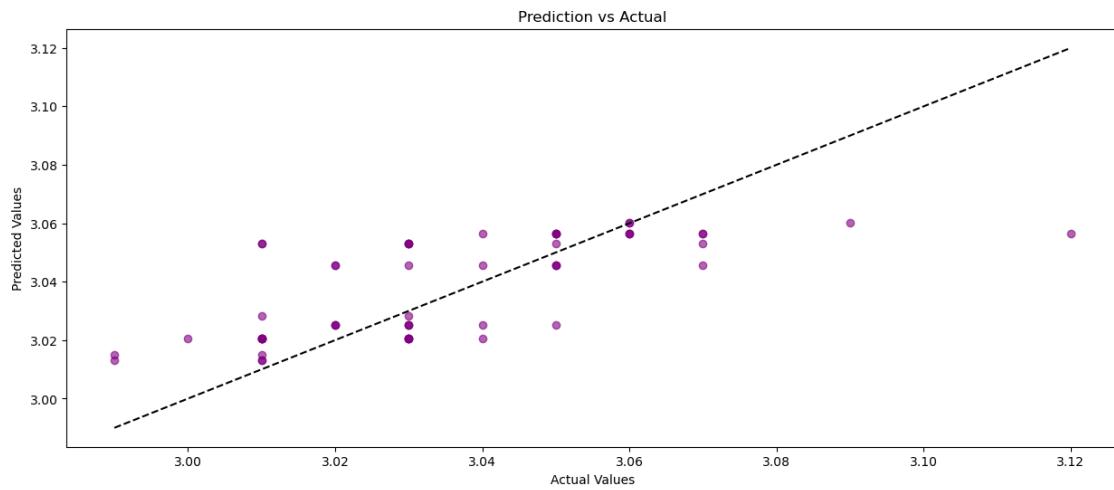
Mean Squared Error: 0.00031947439989231055

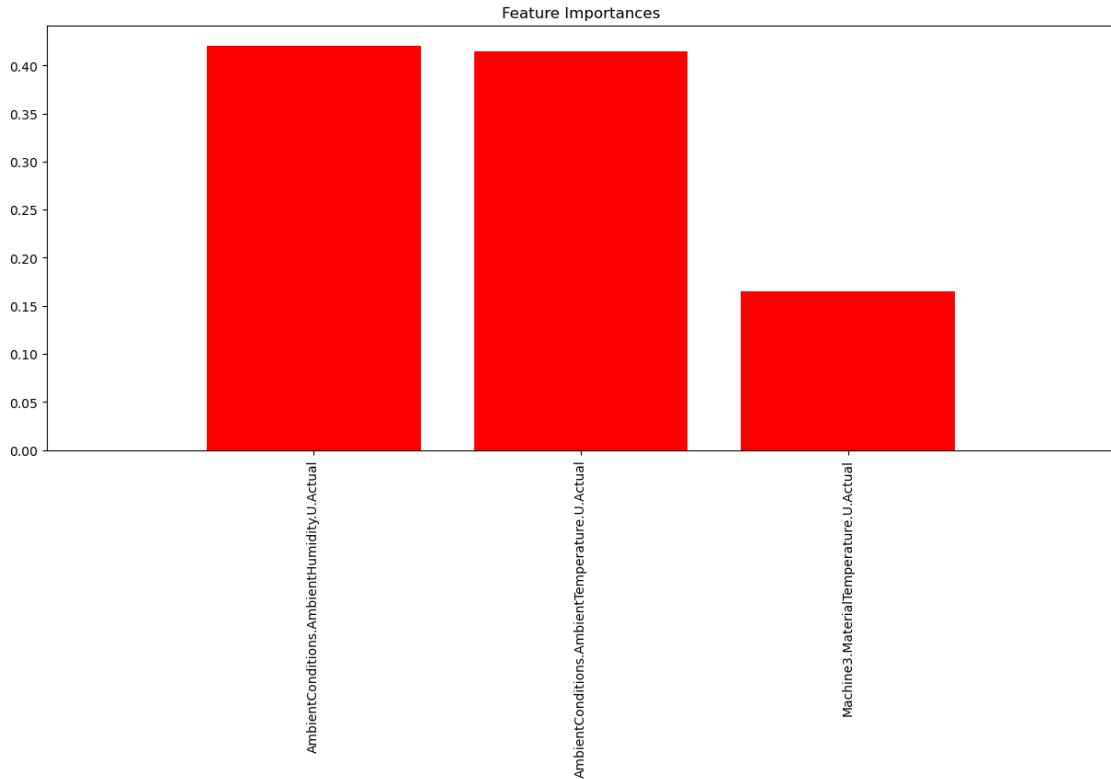
Mean Absolute Error: 0.013457061253118806

Mean Absolute Percentage Error: 0.00443106891843395









[39]: #Model B

[40]: # Calculate p-values

```
p_values_B = pd.DataFrame(index=Input_BN, columns=Output_BN)

for output in Output_BN:
    y = Output_BA[output]
    for feature in Input_BN:
        X = Input_BA[feature]
        X = sm.add_constant(X) # Adds a constant term to the predictor
        model = sm.OLS(y, X).fit()
        if len(model.pvalues) > 1:
            p_values_B.loc[feature, output] = model.pvalues[1]
        else:
            p_values_B.loc[feature, output] = np.nan # Assign NaN if p-value ↴ is not available

print("P-values for Model B:")
print(p_values_B)
```

P-values for Model B:
Stage2.Output.Measurement0.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual

```
0.004422
AmbientConditions.AmbientTemperature.U.Actual
0.016075
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
0.039164
Machine4.Pressure.C.Actual
0.04783
Machine4.Temperature3.C.Actual
0.844182
Machine4.Temperature4.C.Actual
0.04783
Machine4.Temperature5.C.Actual
0.188164
Machine4.ExitTemperature.U.Actual
0.137895
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
0.049268
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
0.028203
Machine5.ExitTemperature.U.Actual
0.035274

Stage2.Output.Measurement1.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.002035
AmbientConditions.AmbientTemperature.U.Actual
0.000379
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
0.540683
Machine4.Pressure.C.Actual
0.434085
Machine4.Temperature3.C.Actual
0.001762
Machine4.Temperature4.C.Actual
0.434085
Machine4.Temperature5.C.Actual
```

```
0.088635
Machine4.ExitTemperature.U.Actual
0.085212
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
0.110698
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
0.196004
Machine5.ExitTemperature.U.Actual
0.284918

Stage2.Output.Measurement2.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.025388
AmbientConditions.AmbientTemperature.U.Actual
0.005333
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
0.38857
Machine4.Pressure.C.Actual
0.234235
Machine4.Temperature3.C.Actual
0.004936
Machine4.Temperature4.C.Actual
0.234235
Machine4.Temperature5.C.Actual
0.012215
Machine4.ExitTemperature.U.Actual
0.293985
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
0.886684
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
```

```
0.58934
Machine5.ExitTemperature.U.Actual
0.70145

Stage2.Output.Measurement3.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.000016
AmbientConditions.AmbientTemperature.U.Actual
0.000029
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
0.72266
Machine4.Pressure.C.Actual
0.0258
Machine4.Temperature3.C.Actual
0.119172
Machine4.Temperature4.C.Actual
0.0258
Machine4.Temperature5.C.Actual
0.171217
Machine4.ExitTemperature.U.Actual
0.278477
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
0.0
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
0.0
Machine5.ExitTemperature.U.Actual
0.0

Stage2.Output.Measurement5.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.008135
AmbientConditions.AmbientTemperature.U.Actual
0.035566
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
0.686838
Machine4.Pressure.C.Actual
```

```
0.186696
Machine4.Temperature3.C.Actual
0.068676
Machine4.Temperature4.C.Actual
0.186696
Machine4.Temperature5.C.Actual
0.962808
Machine4.ExitTemperature.U.Actual
0.860067
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
0.008366
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
0.034283
Machine5.ExitTemperature.U.Actual
0.13402

Stage2.Output.Measurement6.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.311154
AmbientConditions.AmbientTemperature.U.Actual
0.323324
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
0.820072
Machine4.Pressure.C.Actual
0.121834
Machine4.Temperature3.C.Actual
0.015022
Machine4.Temperature4.C.Actual
0.121834
Machine4.Temperature5.C.Actual
0.369985
Machine4.ExitTemperature.U.Actual
0.692779
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
```

NaN
Machine5.Temperature4.C.Actual
0.175491
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
0.149356
Machine5.ExitTemperature.U.Actual
0.265141

Stage2.Output.Measurement7.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.054356
AmbientConditions.AmbientTemperature.U.Actual
0.092091
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
0.16014
Machine4.Pressure.C.Actual
0.773824
Machine4.Temperature3.C.Actual
0.092116
Machine4.Temperature4.C.Actual
0.773824
Machine4.Temperature5.C.Actual
0.216501
Machine4.ExitTemperature.U.Actual
0.281873
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
0.000199
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
0.041909
Machine5.ExitTemperature.U.Actual
0.250245

Stage2.Output.Measurement8.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.348291
AmbientConditions.AmbientTemperature.U.Actual

```
0.535444
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
0.696491
Machine4.Pressure.C.Actual
0.380843
Machine4.Temperature3.C.Actual
0.234017
Machine4.Temperature4.C.Actual
0.380843
Machine4.Temperature5.C.Actual
0.619041
Machine4.ExitTemperature.U.Actual
0.689603
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
0.209786
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
0.348093
Machine5.ExitTemperature.U.Actual
0.63703

Stage2.Output.Measurement9.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.0
AmbientConditions.AmbientTemperature.U.Actual
0.000003
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
0.010625
Machine4.Pressure.C.Actual
0.009963
Machine4.Temperature3.C.Actual
0.019265
Machine4.Temperature4.C.Actual
0.009963
Machine4.Temperature5.C.Actual
0.785958
Machine4.ExitTemperature.U.Actual
```

```
0.027871
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
0.000365
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
0.000112
Machine5.ExitTemperature.U.Actual
0.058909

Stage2.Output.Measurement10.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.000929
AmbientConditions.AmbientTemperature.U.Actual
0.004736
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
0.914754
Machine4.Pressure.C.Actual
0.182462
Machine4.Temperature3.C.Actual
0.008481
Machine4.Temperature4.C.Actual
0.182462
Machine4.Temperature5.C.Actual
0.738095
Machine4.ExitTemperature.U.Actual
0.430002
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
0.0
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
0.000199
Machine5.ExitTemperature.U.Actual
```

0.000096

Stage2.Output.Measurement11.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.466649
AmbientConditions.AmbientTemperature.U.Actual
0.188464
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
0.269977
Machine4.Pressure.C.Actual
0.358216
Machine4.Temperature3.C.Actual
0.226666
Machine4.Temperature4.C.Actual
0.358216
Machine4.Temperature5.C.Actual
0.389227
Machine4.ExitTemperature.U.Actual
0.555416
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
0.016298
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
0.021169
Machine5.ExitTemperature.U.Actual
0.205491

Stage2.Output.Measurement12.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.10148
AmbientConditions.AmbientTemperature.U.Actual
0.285444
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
0.331634
Machine4.Pressure.C.Actual
0.805189
Machine4.Temperature3.C.Actual

```
0.963472
Machine4.Temperature4.C.Actual
0.805189
Machine4.Temperature5.C.Actual
0.338107
Machine4.ExitTemperature.U.Actual
0.427892
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
0.029074
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
0.129414
Machine5.ExitTemperature.U.Actual
0.727636

Stage2.Output.Measurement13.U.Actual \
AmbientConditions.AmbientHumidity.U.Actual
0.018716
AmbientConditions.AmbientTemperature.U.Actual
0.032781
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
0.981267
Machine4.Pressure.C.Actual
0.255167
Machine4.Temperature3.C.Actual
0.021503
Machine4.Temperature4.C.Actual
0.255167
Machine4.Temperature5.C.Actual
0.072787
Machine4.ExitTemperature.U.Actual
0.046698
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
```

```
0.006715
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
0.033314
Machine5.ExitTemperature.U.Actual
0.003008

Stage2.Output.Measurement14.U.Actual
AmbientConditions.AmbientHumidity.U.Actual
0.074954
AmbientConditions.AmbientTemperature.U.Actual
0.018802
Machine4.Temperature1.C.Actual
NaN
Machine4.Temperature2.C.Actual
0.49764
Machine4.Pressure.C.Actual
0.792807
Machine4.Temperature3.C.Actual
0.356219
Machine4.Temperature4.C.Actual
0.792807
Machine4.Temperature5.C.Actual
0.536519
Machine4.ExitTemperature.U.Actual
0.42042
Machine5.Temperature1.C.Actual
NaN
Machine5.Temperature2.C.Actual
NaN
Machine5.Temperature3.C.Actual
NaN
Machine5.Temperature4.C.Actual
0.623754
Machine5.Temperature5.C.Actual
NaN
Machine5.Temperature6.C.Actual
0.610274
Machine5.ExitTemperature.U.Actual
0.276219
```

```
[41]: import statsmodels.api as sm
import pandas as pd
import numpy as np

# Define a range of significance levels to test
```

```

significance_levels = np.arange(0.01, 0.11, 0.01)

# Store the number of selected features for each significance level and output
# variable
results = pd.DataFrame(index=Output_BN, columns=significance_levels)

# Feature selection and evaluation for each significance level
for significance_level in significance_levels:
    print(f"*****Testing significance level:{significance_level}*****")

    # Loop through each output column
    for n in range(len(Output_BN)):
        Yi = Output_BA.values[:, n] # Select the current output column
        cols = list(Input_BAN.columns) # Initialize the list of input features
        pmax = 1 # Initialize the maximum p-value

        # Perform backward elimination
        while len(cols) > 0:
            X_1 = Input_BAN[cols] # Subset the input features
            X_1 = sm.add_constant(X_1) # Add a constant term for the intercept
            model = sm.OLS(Yi, X_1).fit() # Fit the OLS regression model
            p_values = model.pvalues.iloc[1:] # Get p-values excluding the
            # constant term
            pmax = p_values.max() # Find the maximum p-value
            feature_with_p_max = p_values.idxmax() # Identify the feature with
            # the maximum p-value

            # Check if the maximum p-value is above the significance level
            if pmax > significance_level:
                cols.remove(feature_with_p_max) # Remove the least significant
                # feature
            else:
                break # Stop if all p-values are below the significance level

            selected_features = cols # Get the selected features
            # Record the number of selected features
            results.loc[Output_BN[n], significance_level] = len(selected_features)
            # Print the results for this significance level
            print(Output_BN[n], " Total features:", len(Input_BN), " Selected",
            # features:", len(selected_features))

    # Display the results for all tested significance levels
print("\nResults for various significance levels:")
print(results)

```

*****Testing significance level:

0.0999999999999999*****

Stage2.Output.Measurement0.U.Actual	Total features: 16	Selected features: 8
Stage2.Output.Measurement1.U.Actual	Total features: 16	Selected features: 3
Stage2.Output.Measurement2.U.Actual	Total features: 16	Selected features: 4
Stage2.Output.Measurement3.U.Actual	Total features: 16	Selected features: 12
Stage2.Output.Measurement5.U.Actual	Total features: 16	Selected features: 1
Stage2.Output.Measurement6.U.Actual	Total features: 16	Selected features: 8
Stage2.Output.Measurement7.U.Actual	Total features: 16	Selected features: 4
Stage2.Output.Measurement8.U.Actual	Total features: 16	Selected features: 7
Stage2.Output.Measurement9.U.Actual	Total features: 16	Selected features: 13
Stage2.Output.Measurement10.U.Actual	Total features: 16	Selected features: 8
Stage2.Output.Measurement11.U.Actual	Total features: 16	Selected features: 8
Stage2.Output.Measurement12.U.Actual	Total features: 16	Selected features: 6
Stage2.Output.Measurement13.U.Actual	Total features: 16	Selected features: 2
Stage2.Output.Measurement14.U.Actual	Total features: 16	Selected features: 2

Results for various significance levels:

	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	\
Stage2.Output.Measurement0.U.Actual	6	6	6	8	8	8	8	8	
Stage2.Output.Measurement1.U.Actual	3	3	3	3	3	3	3	3	
Stage2.Output.Measurement2.U.Actual	3	3	4	4	4	4	4	4	
Stage2.Output.Measurement3.U.Actual	8	8	10	10	10	10	10	10	
Stage2.Output.Measurement5.U.Actual	1	1	1	1	1	1	1	1	
Stage2.Output.Measurement6.U.Actual	0	1	8	8	8	8	8	8	
Stage2.Output.Measurement7.U.Actual	2	2	2	2	3	3	3	4	
Stage2.Output.Measurement8.U.Actual	6	6	6	6	6	6	6	7	
Stage2.Output.Measurement9.U.Actual	8	10	10	10	10	10	11	13	
Stage2.Output.Measurement10.U.Actual	7	7	7	7	8	8	8	8	
Stage2.Output.Measurement11.U.Actual	7	8	8	8	8	8	8	8	
Stage2.Output.Measurement12.U.Actual	6	6	6	6	6	6	6	6	
Stage2.Output.Measurement13.U.Actual	1	1	2	2	2	2	2	2	
Stage2.Output.Measurement14.U.Actual	2	2	2	2	2	2	2	2	

	0.09	0.10
Stage2.Output.Measurement0.U.Actual	8	8
Stage2.Output.Measurement1.U.Actual	3	3
Stage2.Output.Measurement2.U.Actual	4	4
Stage2.Output.Measurement3.U.Actual	12	12
Stage2.Output.Measurement5.U.Actual	1	1
Stage2.Output.Measurement6.U.Actual	8	8
Stage2.Output.Measurement7.U.Actual	4	4
Stage2.Output.Measurement8.U.Actual	7	7
Stage2.Output.Measurement9.U.Actual	13	13
Stage2.Output.Measurement10.U.Actual	8	8
Stage2.Output.Measurement11.U.Actual	8	8
Stage2.Output.Measurement12.U.Actual	6	6
Stage2.Output.Measurement13.U.Actual	2	2
Stage2.Output.Measurement14.U.Actual	2	2

```
[42]: import statsmodels.api as sm
import pandas as pd

# Feature selection and prediction for model B
print("*****Prediction Model B (Stage 2)*****")
for n in range(len(Output_BN)):
    YBi = Output_BA.values[:, n]
    # Backward Elimination for feature selection
    cols = list(Input_BAN.columns)
    pmax = 1
    while len(cols) > 0:
        X_1 = Input_BAN[cols]
        X_1 = sm.add_constant(X_1)
        model = sm.OLS(Yi, X_1).fit()
        p_values = model.pvalues.iloc[1:] # Exclude p-value for constant
        pmax = p_values.max()
        feature_with_p_max = p_values.idxmax()
        if pmax > 0.05:
            cols.remove(feature_with_p_max)
        else:
            break
    selected_featuresB = cols
    print(Output_BN[n], "Total features:", len(Input_BN), "Selected features:", len(selected_featuresB))

*****Prediction Model B (Stage 2)*****
Stage2.Output.Measurement0.U.Actual      Total features: 16 Selected features: 2
Stage2.Output.Measurement1.U.Actual      Total features: 16 Selected features: 2
Stage2.Output.Measurement2.U.Actual      Total features: 16 Selected features: 2
Stage2.Output.Measurement3.U.Actual      Total features: 16 Selected features: 2
Stage2.Output.Measurement5.U.Actual      Total features: 16 Selected features: 2
Stage2.Output.Measurement6.U.Actual      Total features: 16 Selected features: 2
Stage2.Output.Measurement7.U.Actual      Total features: 16 Selected features: 2
Stage2.Output.Measurement8.U.Actual      Total features: 16 Selected features: 2
Stage2.Output.Measurement9.U.Actual      Total features: 16 Selected features: 2
Stage2.Output.Measurement10.U.Actual     Total features: 16 Selected features: 2
```

```

Stage2.Output.Measurement11.U.Actual      Total features: 16 Selected features:
2
Stage2.Output.Measurement12.U.Actual      Total features: 16 Selected features:
2
Stage2.Output.Measurement13.U.Actual      Total features: 16 Selected features:
2
Stage2.Output.Measurement14.U.Actual      Total features: 16 Selected features:
2

```

```
[43]: print("*****Slitting the data into train and test FOR MODEL B*****")
x_selectedB = Input_BA.values[:, selected_features]
x_trainB, x_testB, y_trainB, y_testB = train_test_split(x_selectedB, YBi, test_size=0.3)
```

*****Slitting the data into train and test FOR MODEL B*****

```
[44]: # SVM-poly
from sklearn.pipeline import make_pipeline
from sklearn.preprocessing import StandardScaler
from sklearn.svm import SVR
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
from sklearn.model_selection import train_test_split
import matplotlib.pyplot as plt
import numpy as np

# Assuming Input_BA and selected_featuresB are already defined, and YBi is your target variable
x_selectedB = Input_BA.values[:, selected_features]
x_trainB, x_testB, y_trainB, y_testB = train_test_split(x_selectedB, YBi, test_size=0.3)

# Create the SVM pipeline
svr_polyB = make_pipeline(StandardScaler(), SVR(C=1.0, epsilon=0.2, kernel='poly', degree=3))
svr_polyB = svr_polyB.fit(x_trainB, y_trainB)
predictions = svr_polyB.predict(x_testB)

# Calculate errors
MSE = mean_squared_error(y_testB, predictions)
RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_testB, predictions)
R2 = r2_score(y_testB, predictions) # Calculate R-squared

# Print errors
print("SVM-Poly Model RMSE: ", RMSE)
```

```

print("SVM-Poly Model MAE: ", MAE)
print("SVM-Poly Model R-squared: ", R2) # Print R-squared value

# Plot results: Actual vs Predicted using range if index is not available
x_axis = range(len(y_testB)) # Create a range for the x-axis equal to the
                             # length of y_testB
plt.figure(figsize=(15, 6))
plt.plot(x_axis, y_testB, color='blue', label='Actual')
plt.plot(x_axis, predictions, color='orange', linestyle='--', label='Predicted')
plt.title('SVM-Poly Predictions vs Actual')
plt.xlabel('Index')
plt.ylabel('Value')
plt.legend()
plt.show()

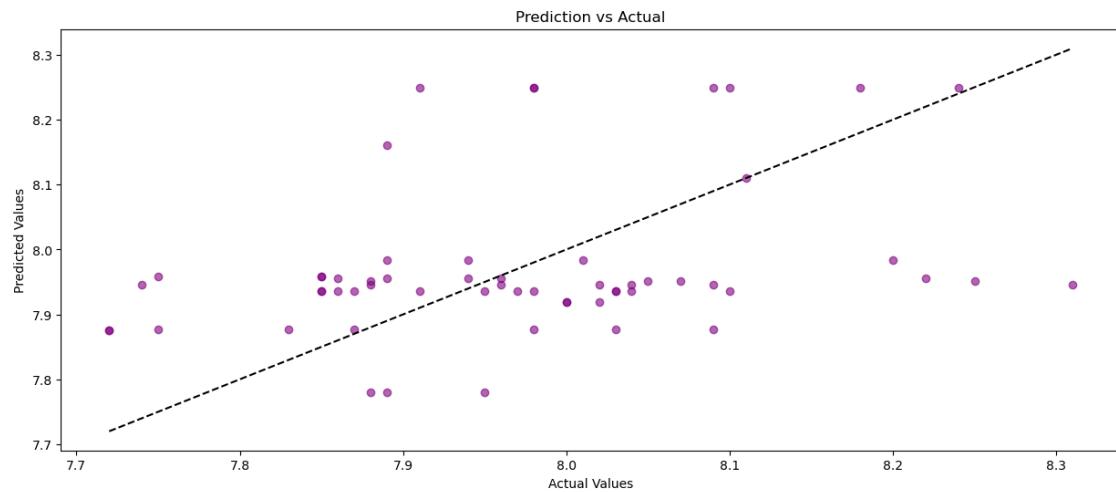
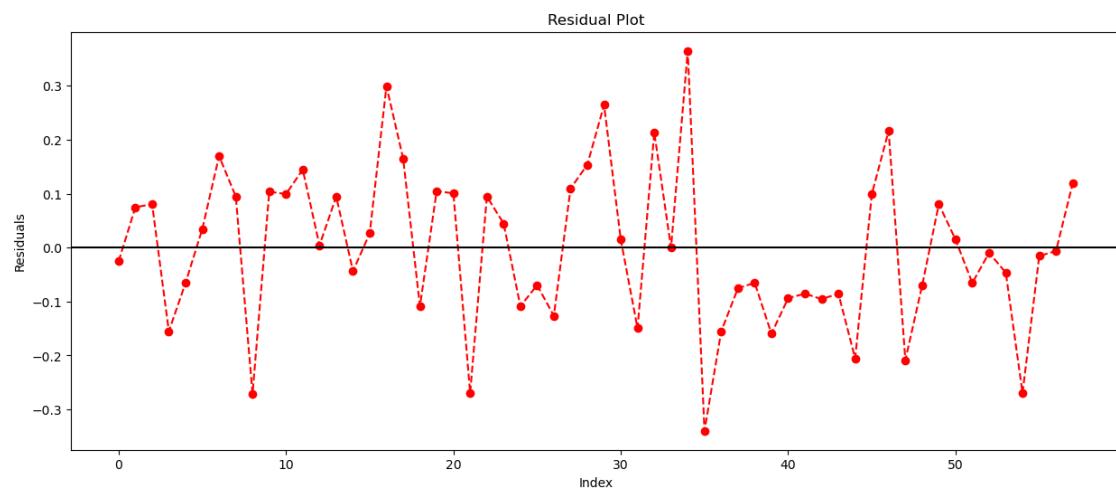
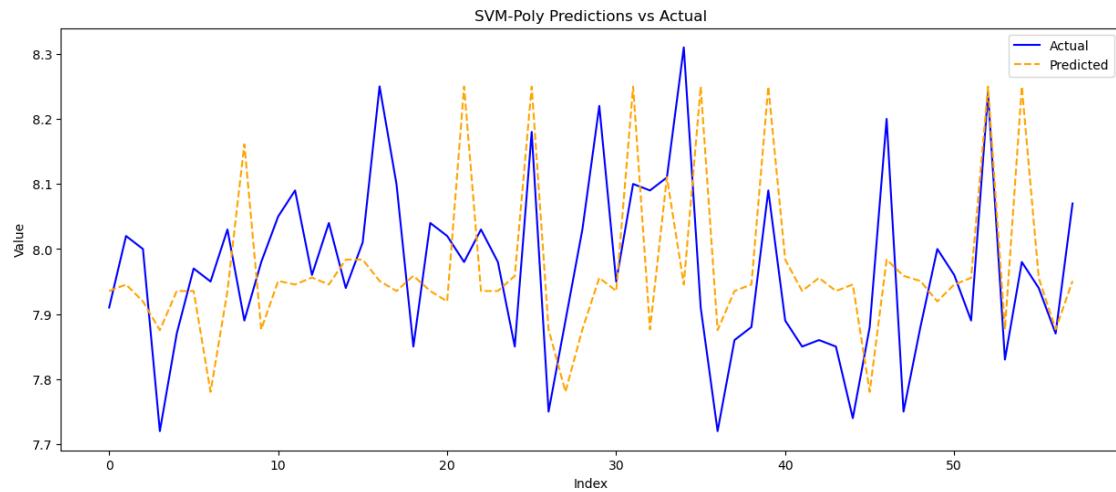
# Residual Plot
residuals = y_testB - predictions
plt.figure(figsize=(15, 6))
plt.plot(x_axis, residuals, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')
plt.show()

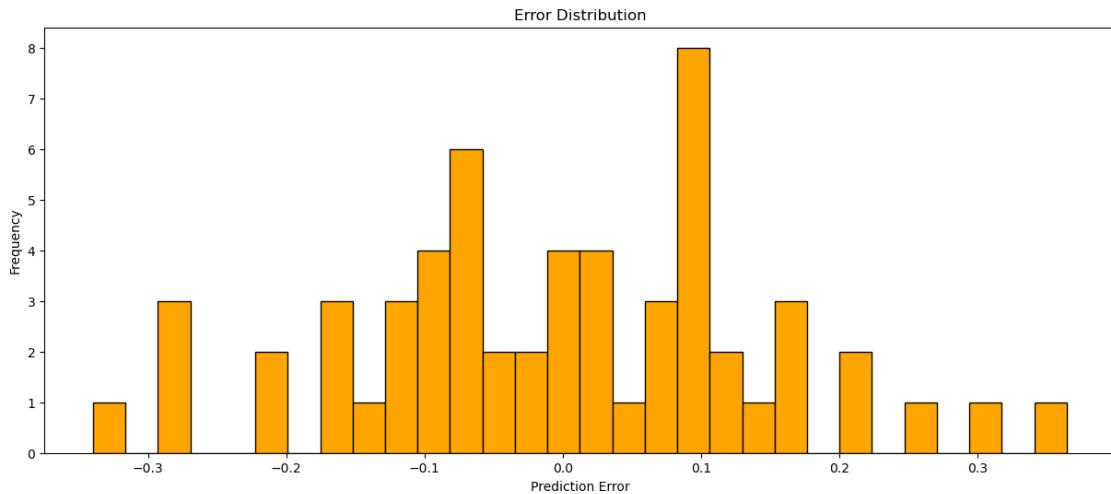
# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_testB, predictions, color='purple', alpha=0.6)
plt.plot([min(y_testB), max(y_testB)], [min(y_testB), max(y_testB)], color='black', linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residuals, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

```

SVM-Poly Model RMSE: 0.1458897599990144
 SVM-Poly Model MAE: 0.11781366468952026
 SVM-Poly Model R-squared: -0.20462032700491206





```
[45]: # Decision Tree
from sklearn.tree import DecisionTreeRegressor, plot_tree
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
import matplotlib.pyplot as plt
import numpy as np

# Assuming x_trainB, x_testB, y_trainB, y_testB have been defined earlier in
# your workflow
# Create and fit the Decision Tree model
clfB = DecisionTreeRegressor(max_features='auto')
clfB = clfB.fit(x_trainB, y_trainB)
predictionsB = clfB.predict(x_testB)

# Calculate errors
MSE = mean_squared_error(y_testB, predictionsB)
RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_testB, predictionsB)
R2 = r2_score(y_testB, predictionsB) # Calculate R-squared

# Print errors
print("Decision Tree Model RMSE: ", RMSE)
print("Decision Tree Model MAE: ", MAE)
print("Decision Tree Model R-squared: ", R2) # Print R-squared value

# Plot results: Actual vs Predicted using range if index is not available
x_axisB = range(len(y_testB)) # Create a range for the x-axis equal to the
# length of y_testB
```

```

plt.figure(figsize=(15, 6))
plt.plot(x_axisB, y_testB, color='blue', label='Actual')
plt.plot(x_axisB, predictionsB, color='orange', linestyle='--', □
    ↪label='Predicted')
plt.title('Decision Tree Predictions vs Actual')
plt.xlabel('Index')
plt.ylabel('Value')
plt.legend()
plt.show()

# Residual Plot
residuals = y_testB - predictionsB
plt.figure(figsize=(15, 6))
plt.plot(x_axisB, residuals, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')
plt.show()

# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_testB, predictionsB, color='purple', alpha=0.6)
plt.plot([min(y_testB), max(y_testB)], [min(y_testB), max(y_testB)], □
    ↪color='black', linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residuals, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

# Feature Importance Plot
importances = clfB.feature_importances_
indices = np.argsort(importances)[::-1]
feature_names = Input_AA.columns[selected_featuresB] # Assuming □
    ↪selected_featuresB is a list of indices

plt.figure(figsize=(15, 6))
plt.title("Feature Importances")

```

```

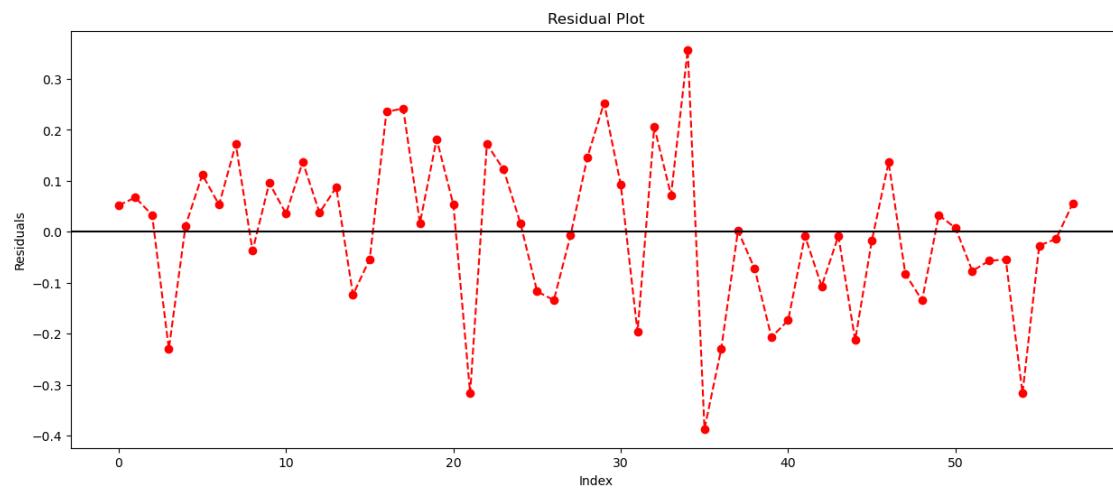
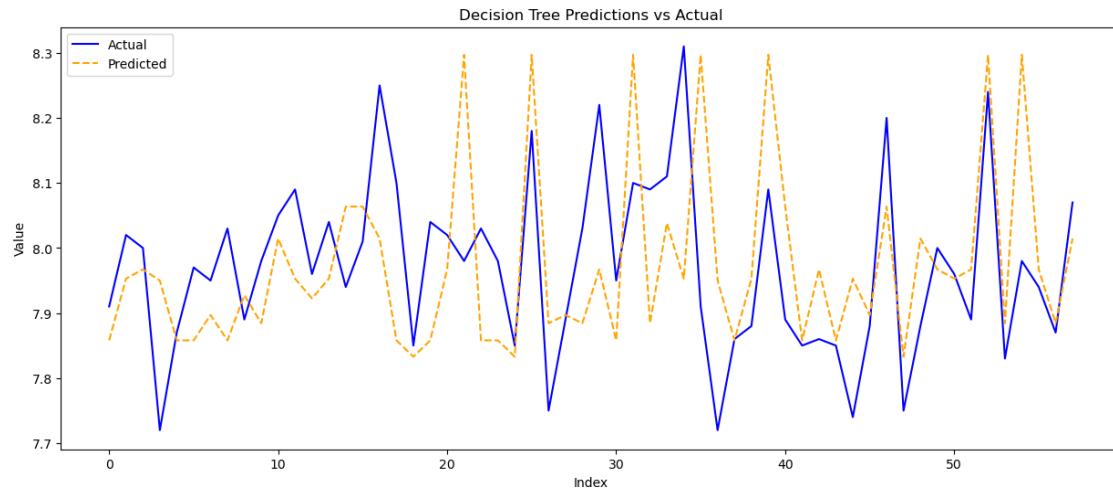
plt.bar(range(x_trainB.shape[1]), importances[indices], color="r", u
      ↪align="center")
plt.xticks(range(x_trainB.shape[1]), feature_names[indices], rotation=90)
plt.xlim([-1, x_trainB.shape[1]])
plt.show()

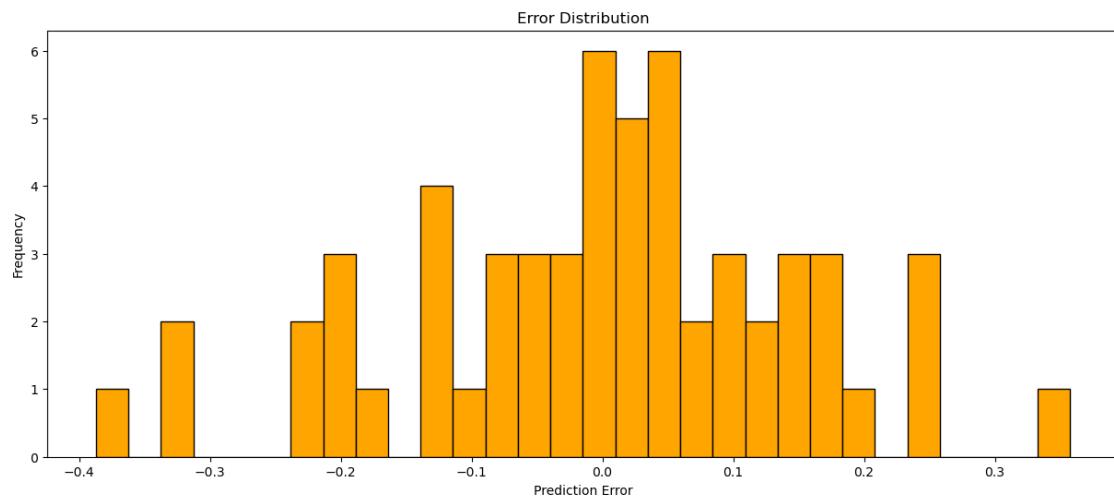
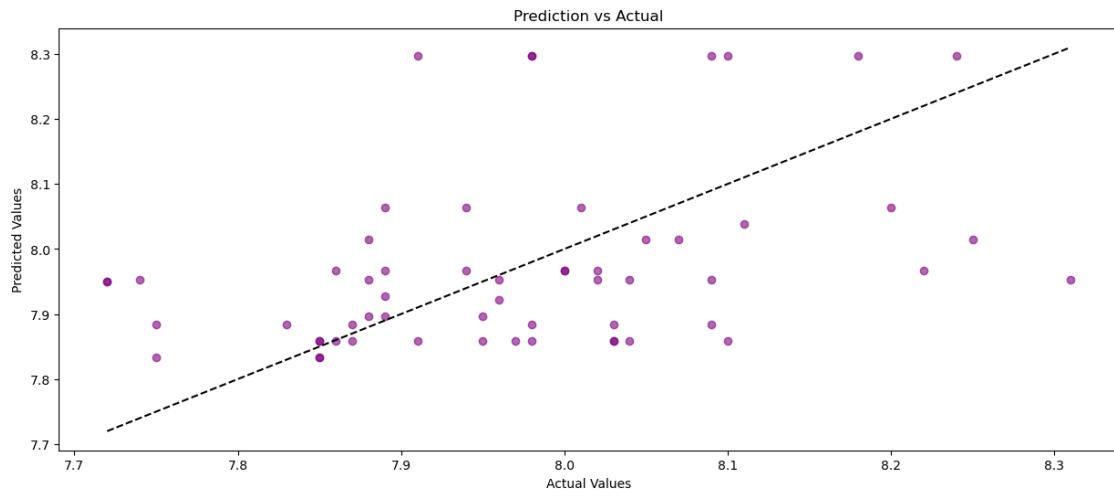
```

Decision Tree Model RMSE: 0.14961536635193087

Decision Tree Model MAE: 0.11548522167487683

Decision Tree Model R-squared: -0.2669310158481957







```
[46]: # KNN
from sklearn.neighbors import KNeighborsRegressor
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
import matplotlib.pyplot as plt
import numpy as np

# Create and fit the KNN model using the specified train and test datasets
knnB = KNeighborsRegressor(n_neighbors=5, weights='distance', algorithm='auto',
                           leaf_size=30, p=2,
                           metric='minkowski', metric_params=None, n_jobs=None)
knnB = knnB.fit(x_trainB, y_trainB)
predictionsB = knnB.predict(x_testB)

# Calculate errors
MSE = mean_squared_error(y_testB, predictionsB)
RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_testB, predictionsB)
R2 = r2_score(y_testB, predictionsB) # Calculate R-squared

# Print accuracy and errors
print("KNN Model RMSE: ", RMSE)
print("KNN Model MAE: ", MAE)
```

```

print("KNN Model R-squared: ", R2) # Print R-squared value

# Plot results: Actual vs Predicted using range if index is not available
x_axisB = range(len(y_testB)) # Create a range for the x-axis equal to the
                             # length of y_testB
plt.figure(figsize=(15, 6))
plt.plot(x_axisB, y_testB, color='blue', label='Actual')
plt.plot(x_axisB, predictionsB, color='orange', linestyle='--', label='Predicted')
plt.title('KNN Predictions vs Actual')
plt.xlabel('Index')
plt.ylabel('Value')
plt.legend()
plt.show()

# Residual Plot
residuals = y_testB - predictionsB
plt.figure(figsize=(15, 6))
plt.plot(x_axisB, residuals, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')
plt.show()

# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_testB, predictionsB, color='purple', alpha=0.6)
plt.plot([min(y_testB), max(y_testB)], [min(y_testB), max(y_testB)], color='black', linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

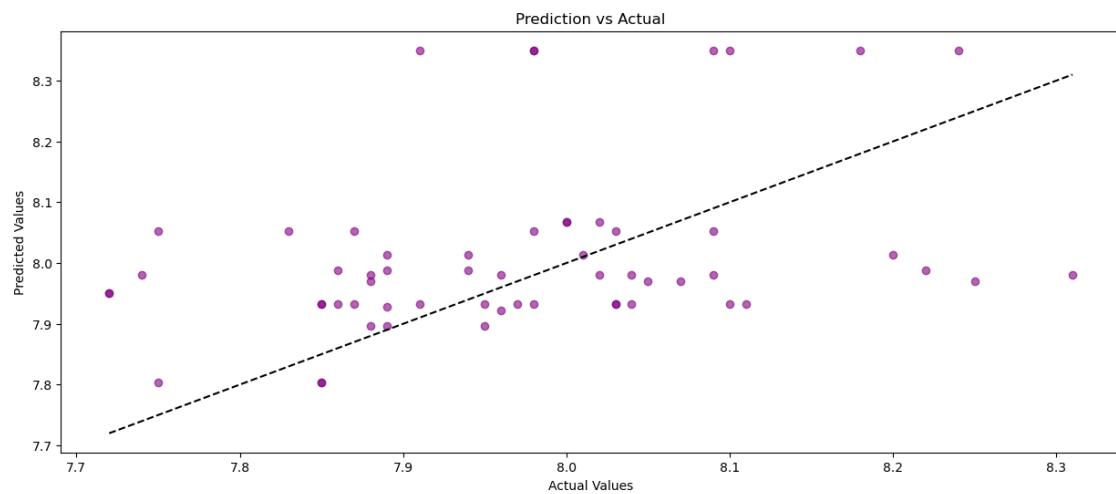
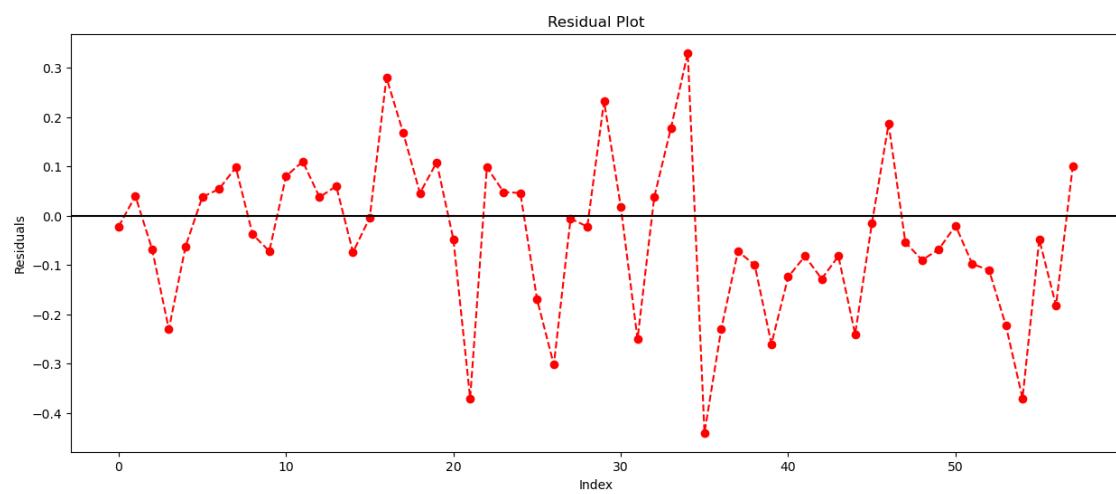
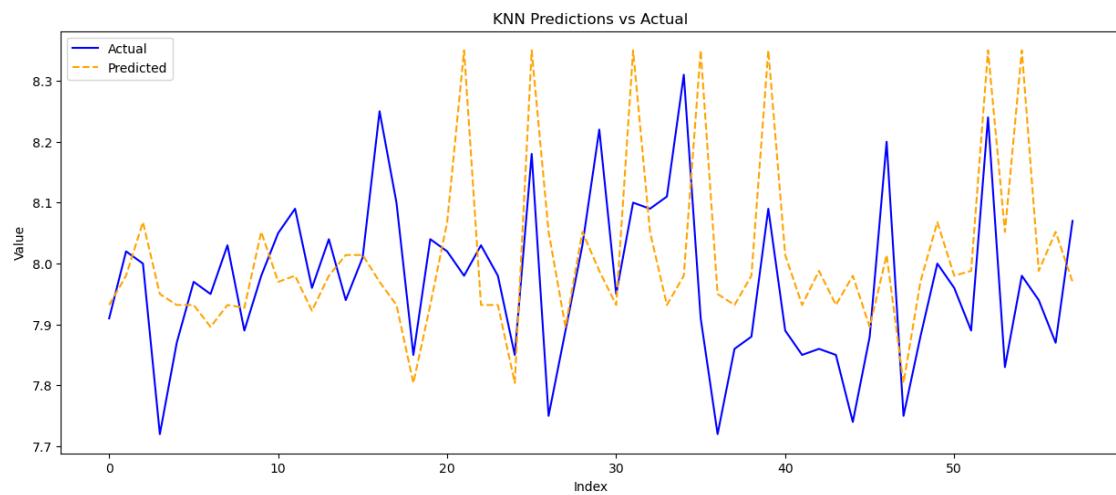
# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residuals, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

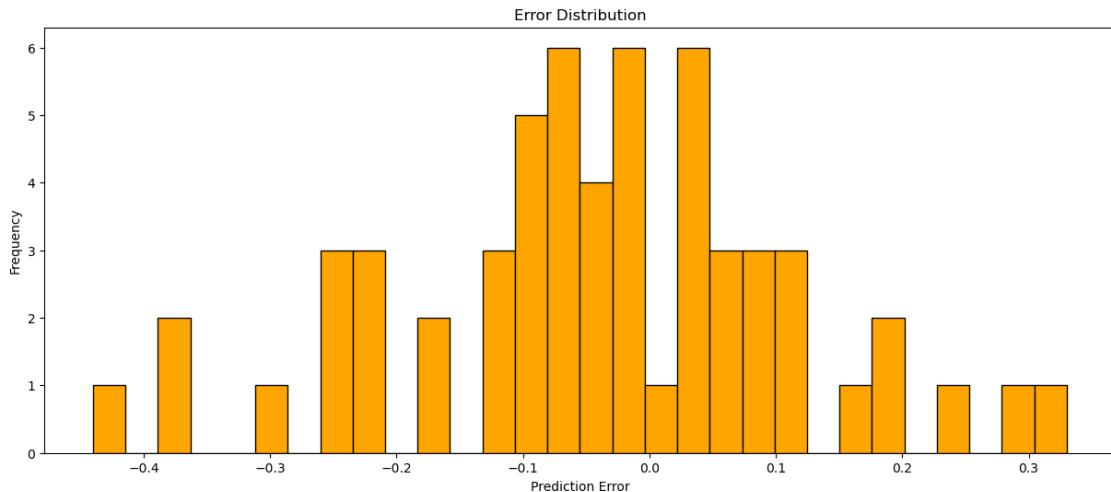
```

KNN Model RMSE: 0.16093672455454297

KNN Model MAE: 0.12356896551724147

KNN Model R-squared: -0.4659220718477446





```
[47]: # Random Forest
from sklearn.ensemble import RandomForestRegressor
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
import matplotlib.pyplot as plt
import numpy as np
from sklearn.model_selection import train_test_split

# Assuming Input_AA and YBi are already defined, and 'selected_featuresB' is
# the index list of selected features
x_selectedB = Input_AA.values[:, selected_featuresB]
x_trainB, x_testB, y_trainB, y_testB = train_test_split(x_selectedB, YBi,
    test_size=0.3, random_state=42)

# Create and fit the Random Forest model
rf = RandomForestRegressor(n_estimators=100, random_state=42) # You can adjust
# n_estimators and other hyperparameters
rf = rf.fit(x_trainB, y_trainB)
predictionsB = rf.predict(x_testB)

# Calculate errors
MSE = mean_squared_error(y_testB, predictionsB)
RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_testB, predictionsB)
R2 = r2_score(y_testB, predictionsB) # Calculate R-squared

# Print errors
print("Random Forest Model RMSE: ", RMSE)
```

```

print("Random Forest Model MAE: ", MAE)
print("Random Forest Model R-squared: ", R2) # Print R-squared value

# Plot results: Actual vs Predicted using range if index is not available
x_axisB = range(len(y_testB)) # Create a range for the x-axis equal to the
                                # length of y_testB
plt.figure(figsize=(15, 6))
plt.plot(x_axisB, y_testB, color='blue', label='Actual')
plt.plot(x_axisB, predictionsB, color='orange', linestyle='--', label='Predicted')
plt.title('Random Forest Predictions vs Actual')
plt.xlabel('Index')
plt.ylabel('Value')
plt.legend()
plt.show()

# Residual Plot
residualsB = y_testB - predictionsB
plt.figure(figsize=(15, 6))
plt.plot(x_axisB, residualsB, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')
plt.show()

# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_testB, predictionsB, color='purple', alpha=0.6)
plt.plot([min(y_testB), max(y_testB)], [min(y_testB), max(y_testB)], color='black', linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residualsB, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

# Feature Importance Plot
importances = rf.feature_importances_
indices = np.argsort(importances)[::-1]

```

```

feature_names = Input_AA.columns[selected_featuresB] # Assuming
    ↪selected_featuresB is a list of indices

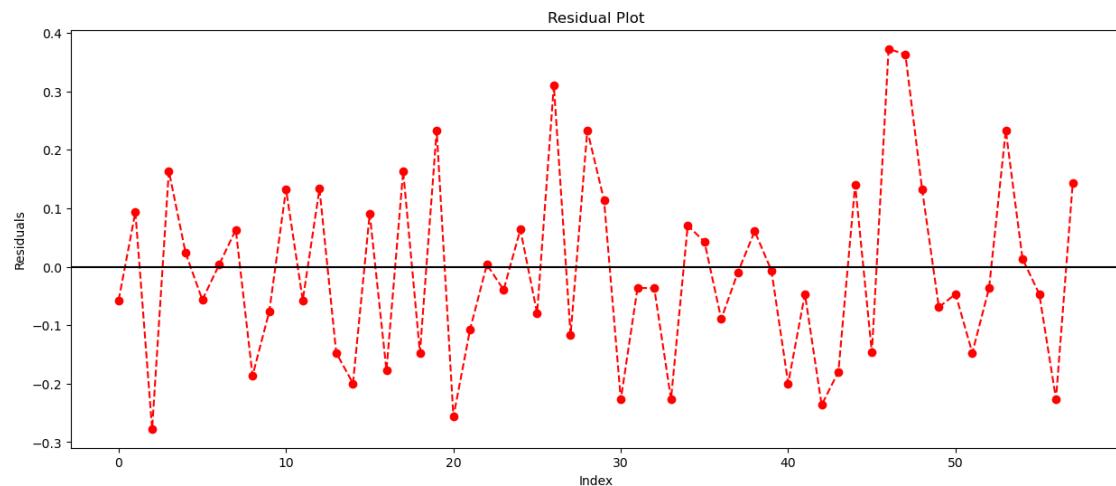
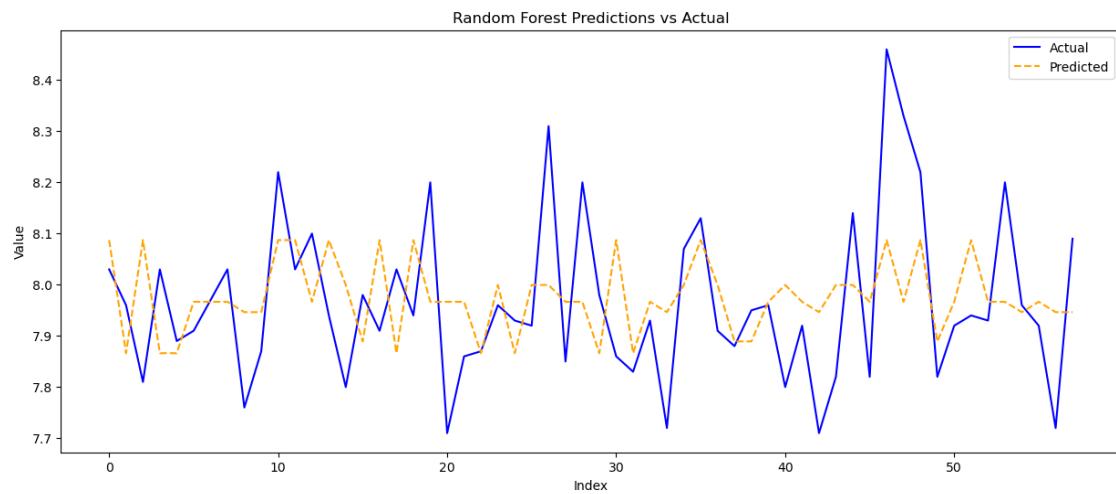
plt.figure(figsize=(15, 6))
plt.title("Feature Importances")
plt.bar(range(x_trainB.shape[1]), importances[indices], color="r",
    ↪align="center")
plt.xticks(range(x_trainB.shape[1]), feature_names[indices], rotation=90)
plt.xlim([-1, x_trainB.shape[1]])
plt.show()

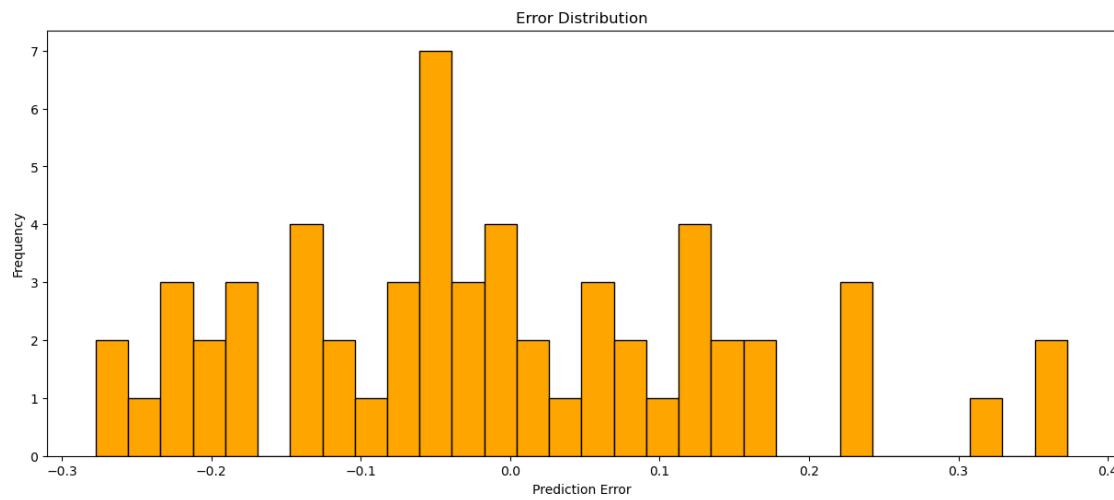
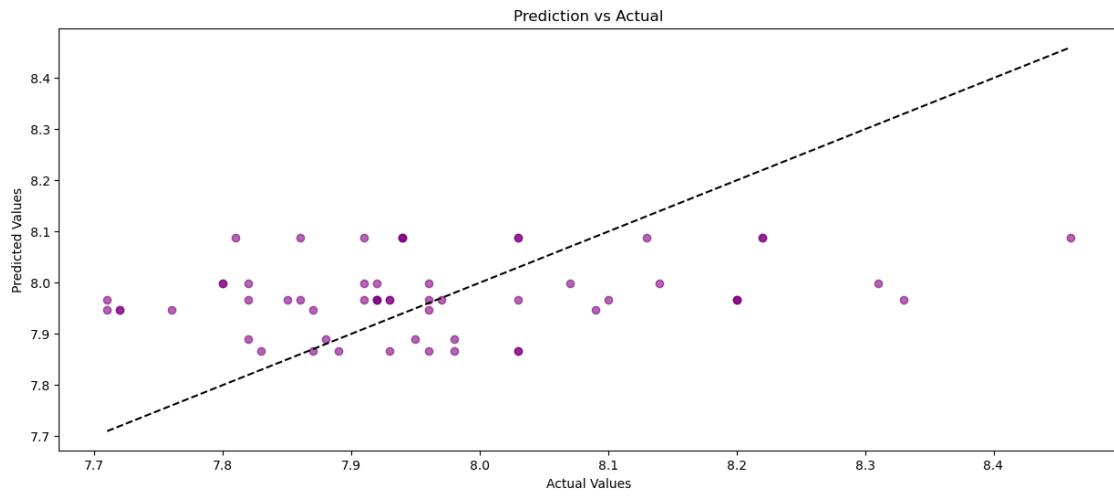
```

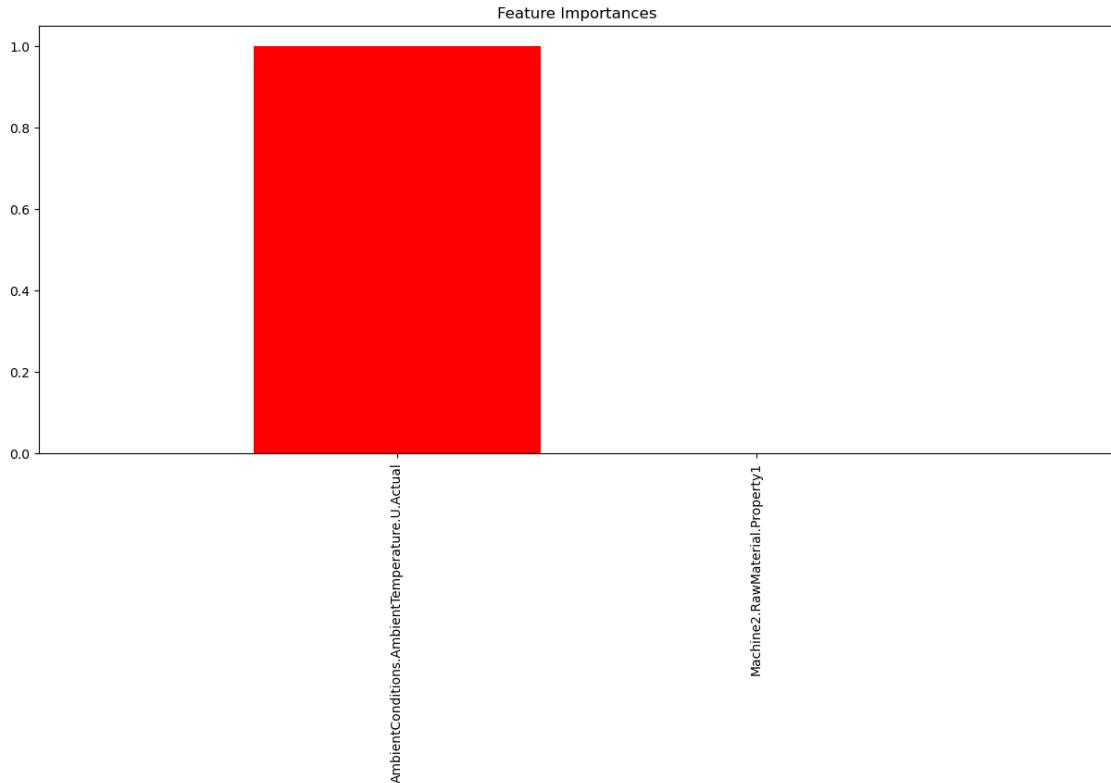
Random Forest Model RMSE: 0.15627222257068682

Random Forest Model MAE: 0.12752305072979989

Random Forest Model R-squared: 0.0288181890445548







```
[48]: # Gradient Boosting
from sklearn.ensemble import GradientBoostingRegressor
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
import matplotlib.pyplot as plt
import numpy as np
from sklearn.model_selection import train_test_split

# Assuming Input_AA and YBi are already defined, and 'selected_featuresB' is
# the index list of selected features
x_selectedB = Input_AA.values[:, selected_featuresB]
x_trainB, x_testB, y_trainB, y_testB = train_test_split(x_selectedB, YBi,
# test_size=0.3, random_state=42)

# Create and fit the Gradient Boosting model
gbm = GradientBoostingRegressor(n_estimators=100, learning_rate=0.1,
# max_depth=3, random_state=42)
gbm.fit(x_trainB, y_trainB)
predictionsB = gbm.predict(x_testB)

# Calculate errors
MSE = mean_squared_error(y_testB, predictionsB)
```

```

RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_testB, predictionsB)
R2 = r2_score(y_testB, predictionsB) # Calculate R-squared

# Print errors
print("Gradient Boosting Model RMSE: ", RMSE)
print("Gradient Boosting Model MAE: ", MAE)
print("Gradient Boosting Model R-squared: ", R2) # Print R-squared value

# Plot results: Actual vs Predicted using range if index is not available
x_axisB = range(len(y_testB)) # Create a range for the x-axis equal to the
                             # length of y_testB
plt.figure(figsize=(15, 6))
plt.plot(x_axisB, y_testB, color='blue', label='Actual')
plt.plot(x_axisB, predictionsB, color='orange', linestyle='--', label='Predicted')
plt.title('Gradient Boosting Predictions vs Actual')
plt.xlabel('Index')
plt.ylabel('Value')
plt.legend()
plt.show()

# Residual Plot
residualsB = y_testB - predictionsB
plt.figure(figsize=(15, 6))
plt.plot(x_axisB, residualsB, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')
plt.show()

# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_testB, predictionsB, color='purple', alpha=0.6)
plt.plot([min(y_testB), max(y_testB)], [min(y_testB), max(y_testB)], color='black', linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residualsB, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')

```

```

plt.ylabel('Frequency')
plt.show()

# Feature Importance Plot
importances = gbm.feature_importances_
indices = np.argsort(importances)[::-1]
feature_names = Input_AA.columns[selected_featuresB] # Assuming
↳ selected_featuresB is a list of indices

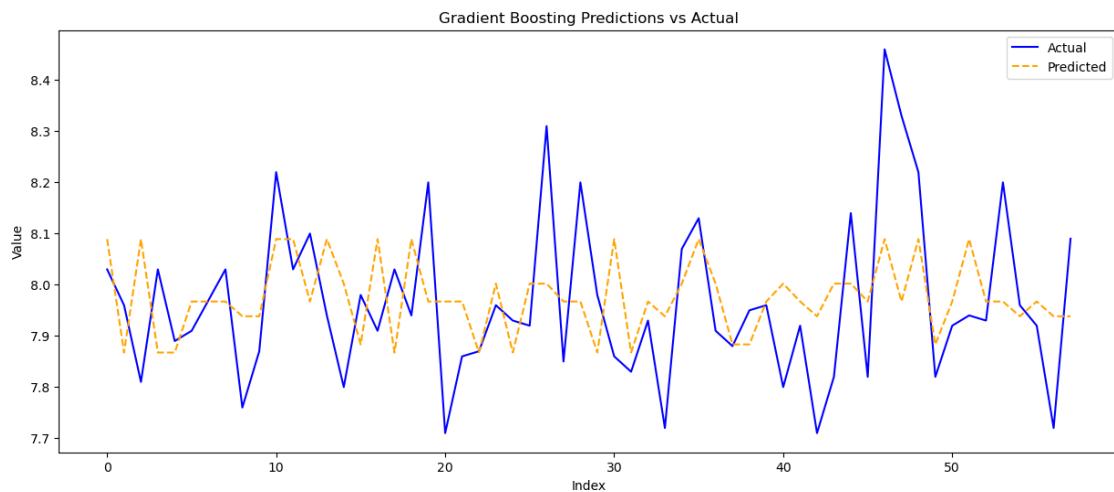
plt.figure(figsize=(15, 6))
plt.title("Feature Importances")
plt.bar(range(x_trainB.shape[1]), importances[indices], color="r",
↳ align="center")
plt.xticks(range(x_trainB.shape[1]), feature_names[indices], rotation=90)
plt.xlim([-1, x_trainB.shape[1]])
plt.show()

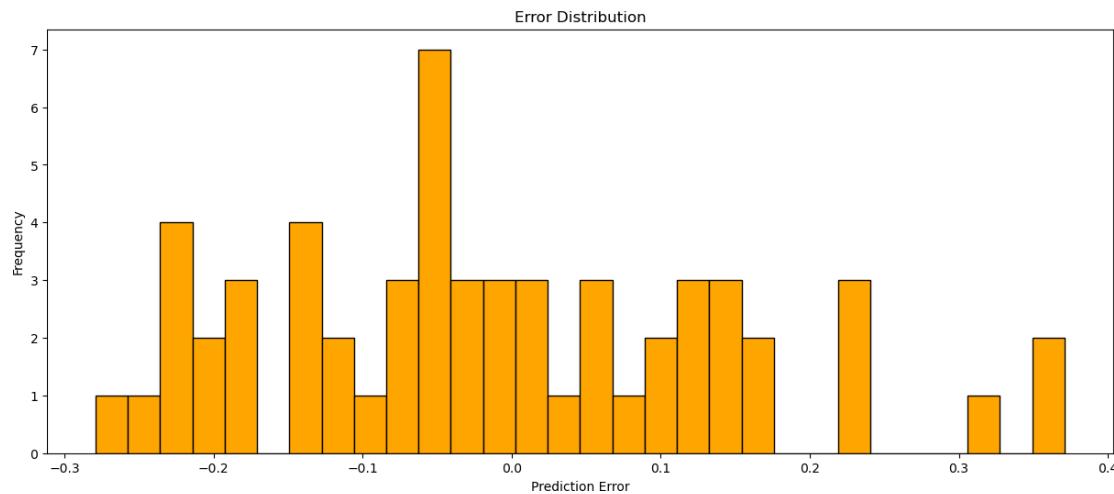
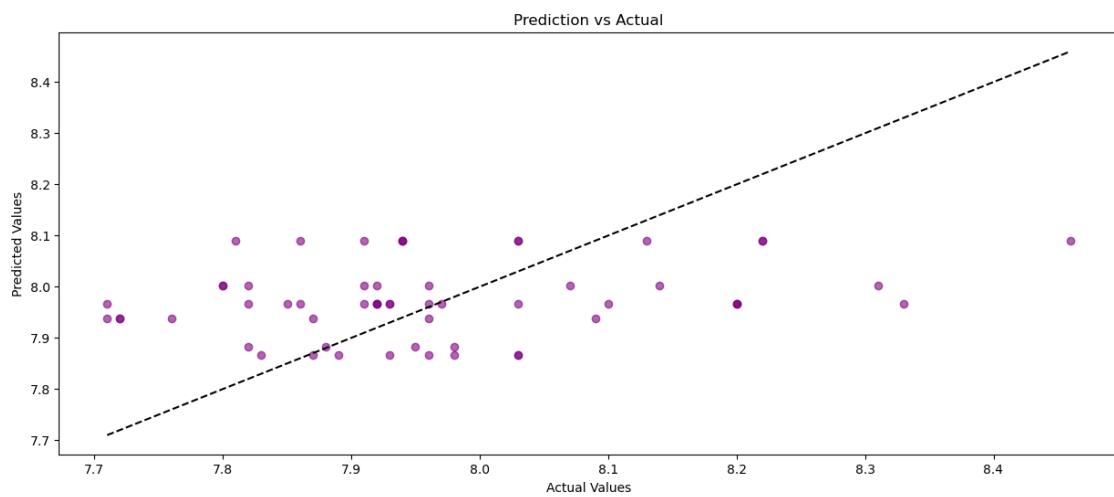
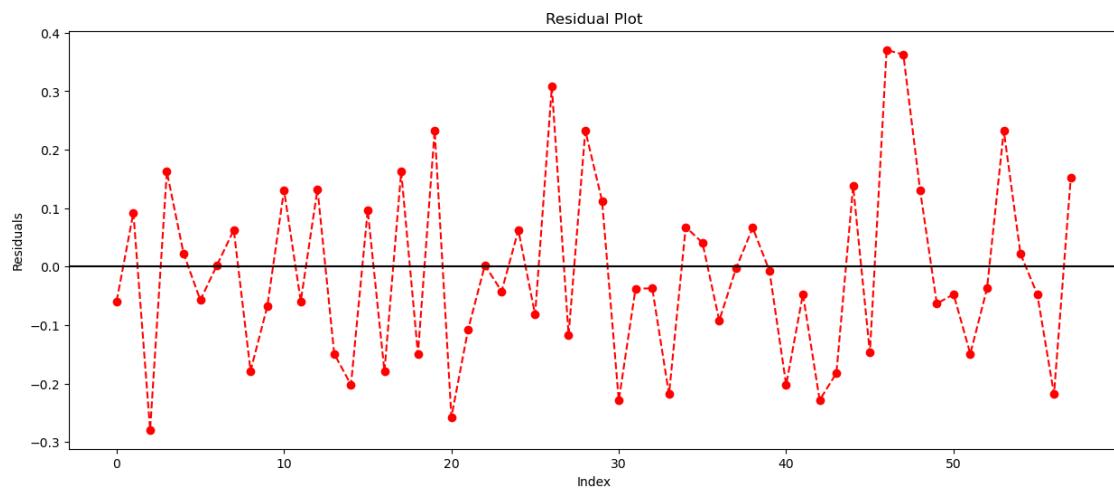
```

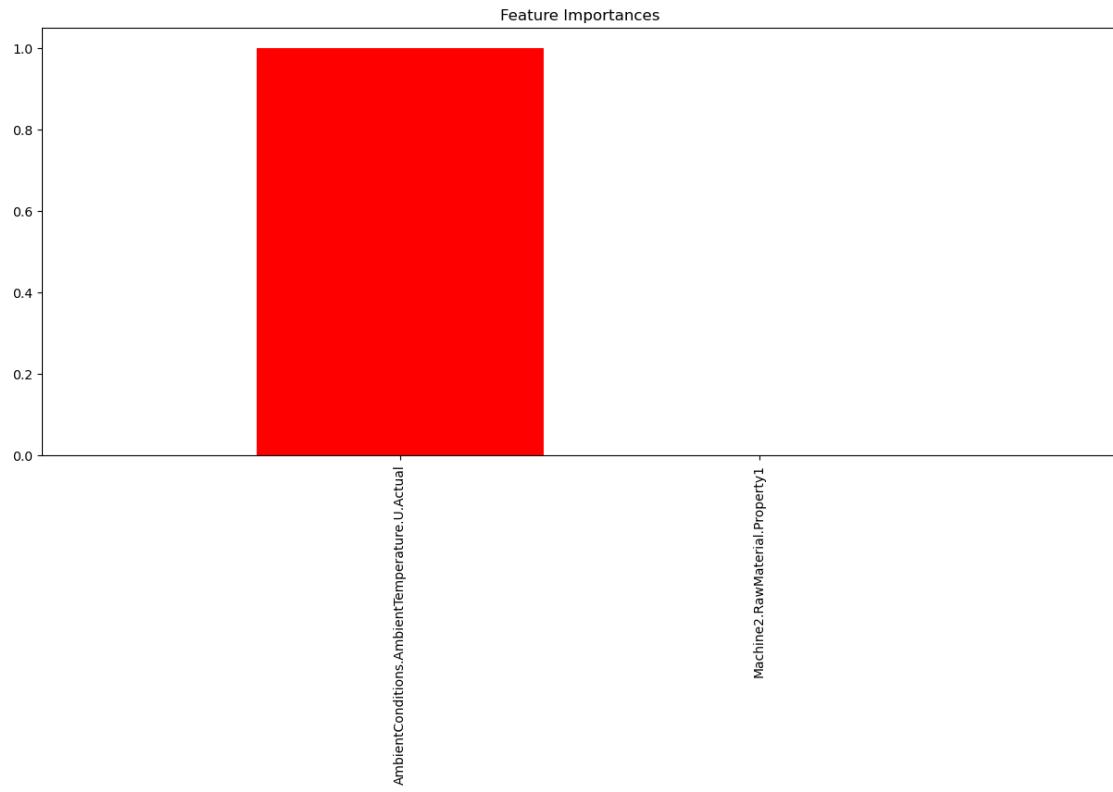
Gradient Boosting Model RMSE: 0.15573749094565373

Gradient Boosting Model MAE: 0.127279012997464

Gradient Boosting Model R-squared: 0.03545318934313779







```
[49]: # RNN
import numpy as np
import pandas as pd
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, LSTM
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
import matplotlib.pyplot as plt

# Reshape input data for RNN input
x_train_rnn = x_trainB.reshape((x_trainB.shape[0], x_trainB.shape[1], 1))
x_test_rnn = x_testB.reshape((x_testB.shape[0], x_testB.shape[1], 1))

# Build the RNN model
model = Sequential([
    LSTM(50, activation='relu', input_shape=(x_train_rnn.shape[1], 1)), # LSTM layer
    Dense(1)
])
```

```

model.compile(optimizer='adam', loss='mse')

# Train the model
model.fit(x_train_rnn, y_trainB, epochs=50, verbose=0)

# Predictions
predictionsB = model.predict(x_test_rnn).flatten()

# Calculate errors
MSE = mean_squared_error(y_testB, predictionsB)
RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_testB, predictionsB)
R2 = r2_score(y_testB, predictionsB) # Calculate R-squared

# Print errors
print("RNN Model MSE: ", MSE)
print("RNN Model RMSE: ", RMSE)
print("RNN Model MAE: ", MAE)
print("RNN Model R-squared: ", R2) # Print R-squared value

# Plot results: Actual vs Predicted
x_axisB = range(len(y_testB)) # Create a range for the x-axis equal to the
length of y_testB
plt.figure(figsize=(15, 6))
plt.plot(x_axisB, y_testB, color='blue', label='Actual')
plt.plot(x_axisB, predictionsB, color='orange', linestyle='--', l
label='Predicted')
plt.title('RNN Predictions vs Actual')
plt.xlabel('Index')
plt.ylabel('Value')
plt.legend()
plt.show()

# Residual Plot
residualsB = y_testB - predictionsB
plt.figure(figsize=(15, 6))
plt.plot(x_axisB, residualsB, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')
plt.show()

# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_testB, predictionsB, color='purple', alpha=0.6)

```

```

plt.plot([min(y_testB), max(y_testB)], [min(y_testB), max(y_testB)], color='black', linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residualsB, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

```

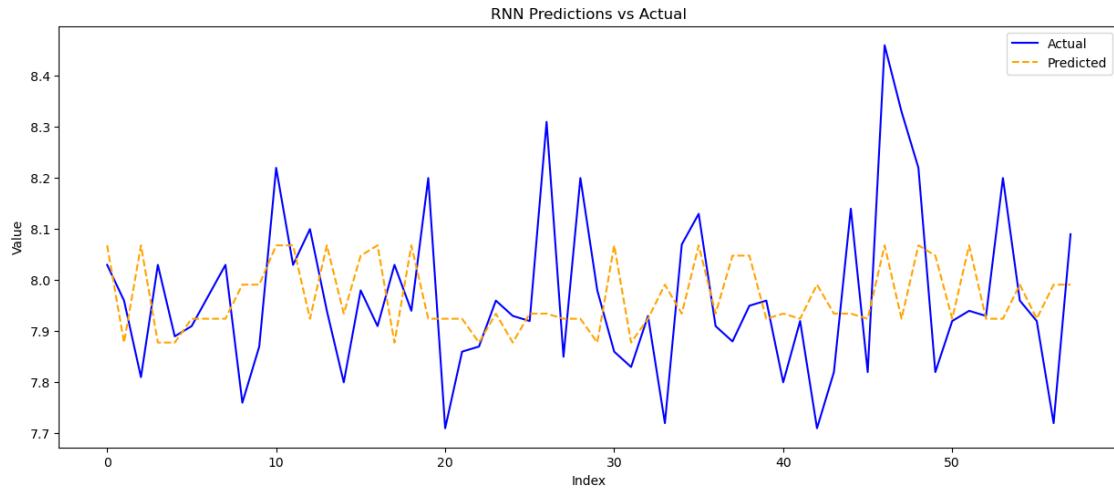
2/2 [=====] - 1s 7ms/step

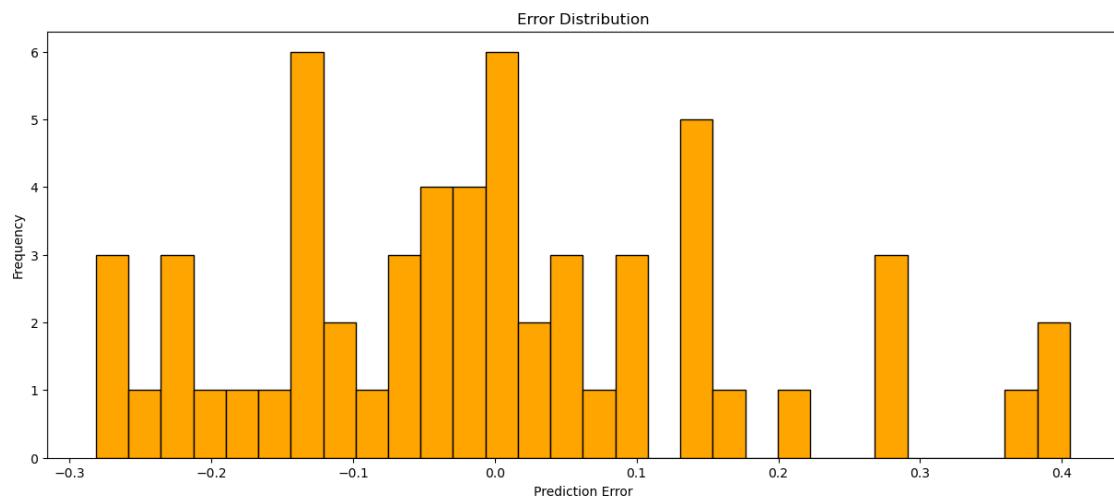
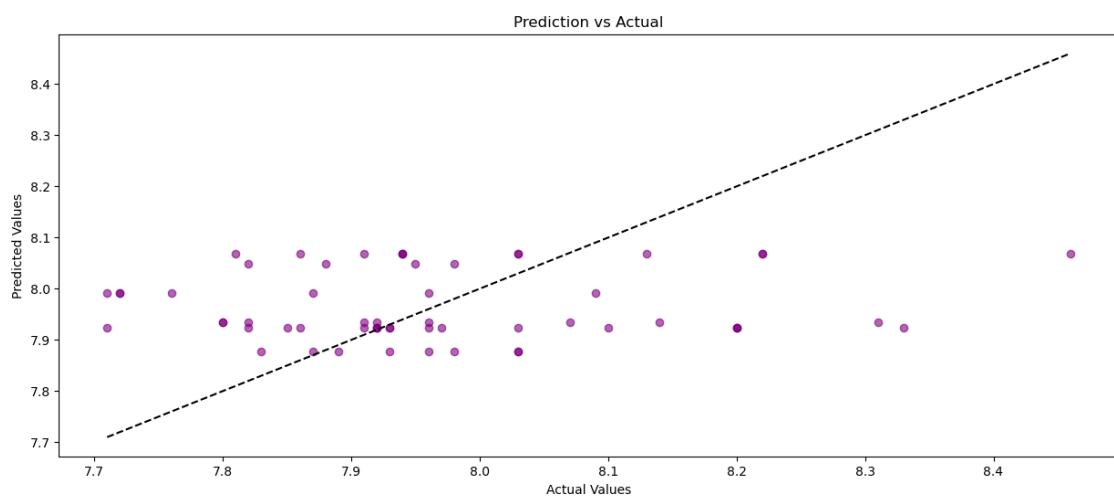
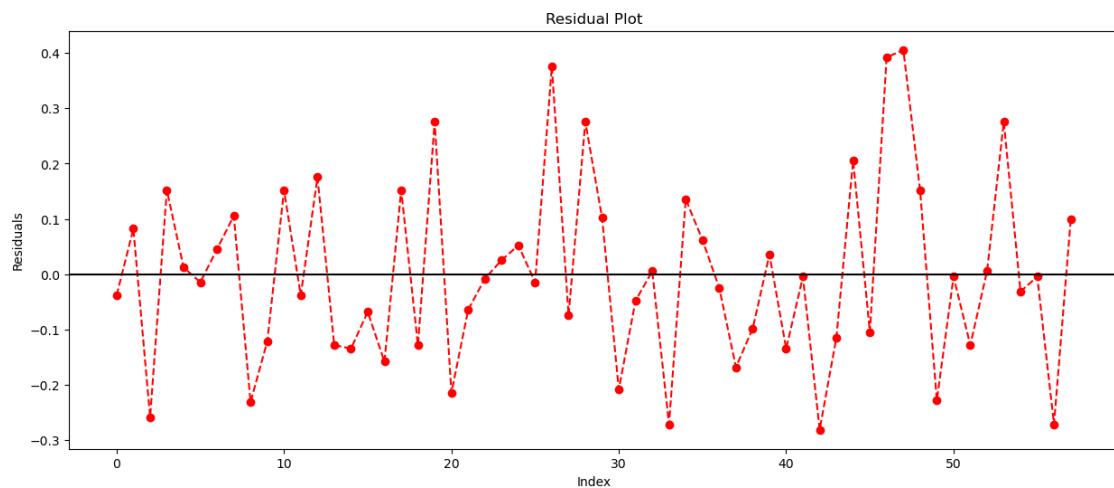
RNN Model MSE: 0.027857198718331023

RNN Model RMSE: 0.16690475942384334

RNN Model MAE: 0.13060627444037073

RNN Model R-squared: -0.1078332721180455





```
[50]: # LSTM
import numpy as np
import pandas as pd
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, LSTM
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
import matplotlib.pyplot as plt

# Reshape input data for LSTM input
x_train_lstm = x_trainB.reshape((x_trainB.shape[0], x_trainB.shape[1], 1))
x_test_lstm = x_testB.reshape((x_testB.shape[0], x_testB.shape[1], 1))

# Build the LSTM model
model = Sequential([
    LSTM(50, activation='relu', input_shape=(x_train_lstm.shape[1], 1)),
    Dense(1)
])

model.compile(optimizer='adam', loss='mse')

# Train the model
model.fit(x_train_lstm, y_trainB, epochs=50, verbose=0)

# Predictions
predictionsB = model.predict(x_test_lstm).flatten()

# Calculate errors
MSE = mean_squared_error(y_testB, predictionsB)
RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_testB, predictionsB)
R2 = r2_score(y_testB, predictionsB) # Calculate R-squared

# Print errors
print("LSTM Model MSE: ", MSE)
print("LSTM Model RMSE: ", RMSE)
print("LSTM Model MAE: ", MAE)
print("LSTM Model R-squared: ", R2) # Print R-squared value

# Plot results: Actual vs Predicted
x_axisB = range(len(y_testB)) # Create a range for the x-axis equal to the
# length of y_testB
plt.figure(figsize=(15, 6))
plt.plot(x_axisB, y_testB, color='blue', label='Actual')
```

```

plt.plot(x_axisB, predictionsB, color='orange', linestyle='--', □
         ↳label='Predicted')
plt.title('LSTM Predictions vs Actual')
plt.xlabel('Index')
plt.ylabel('Value')
plt.legend()
plt.show()

# Residual Plot
residualsB = y_testB - predictionsB
plt.figure(figsize=(15, 6))
plt.plot(x_axisB, residualsB, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')
plt.show()

# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_testB, predictionsB, color='purple', alpha=0.6)
plt.plot([min(y_testB), max(y_testB)], [min(y_testB), max(y_testB)], □
         ↳color='black', linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residualsB, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

```

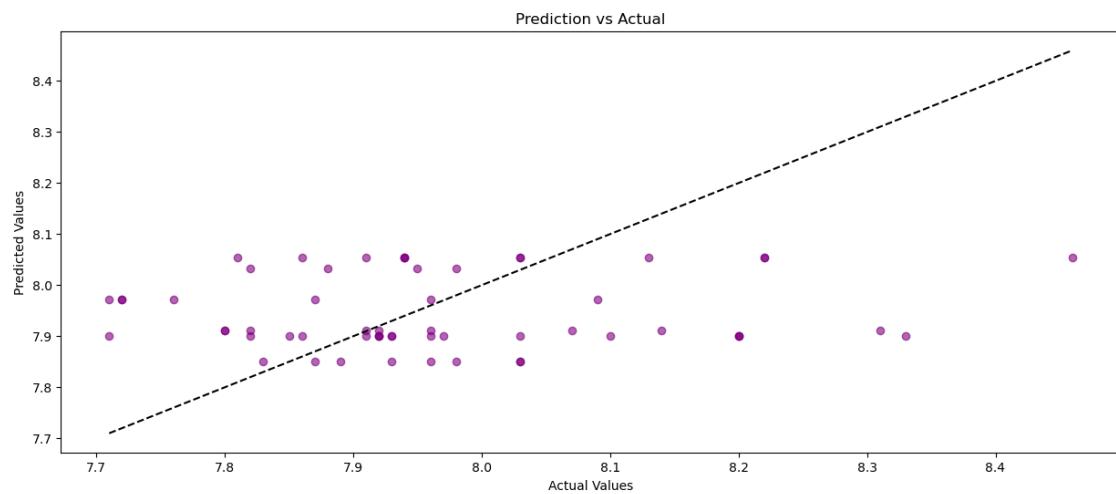
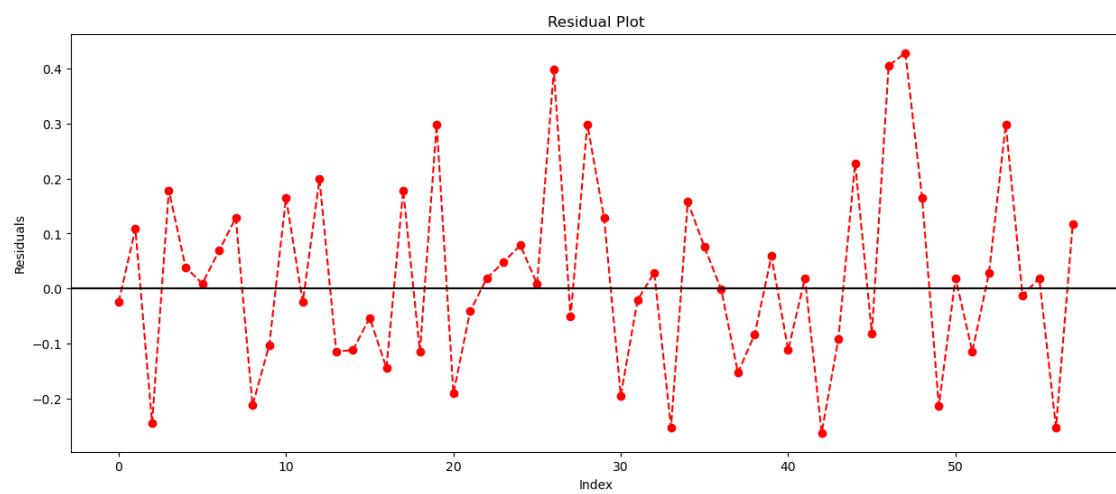
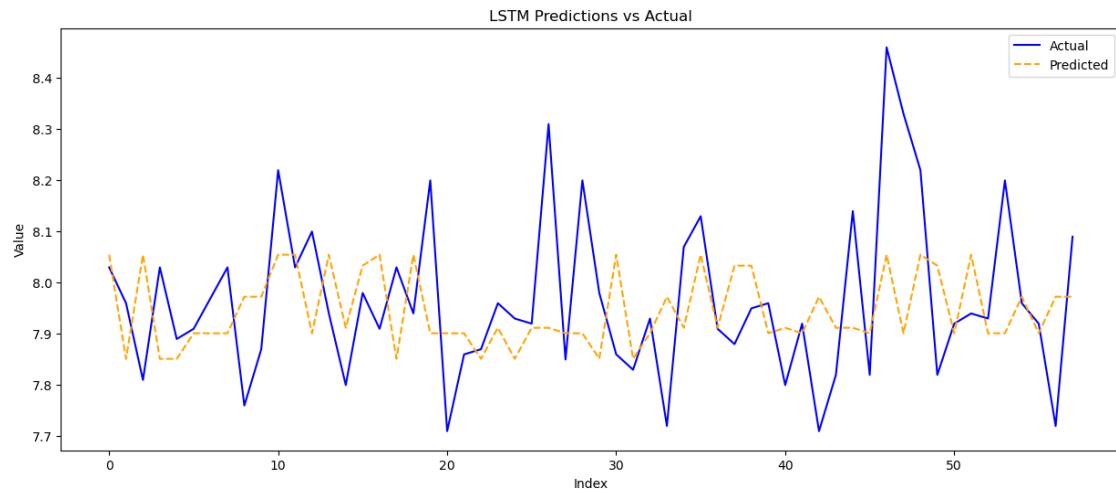
2/2 [=====] - 1s 6ms/step

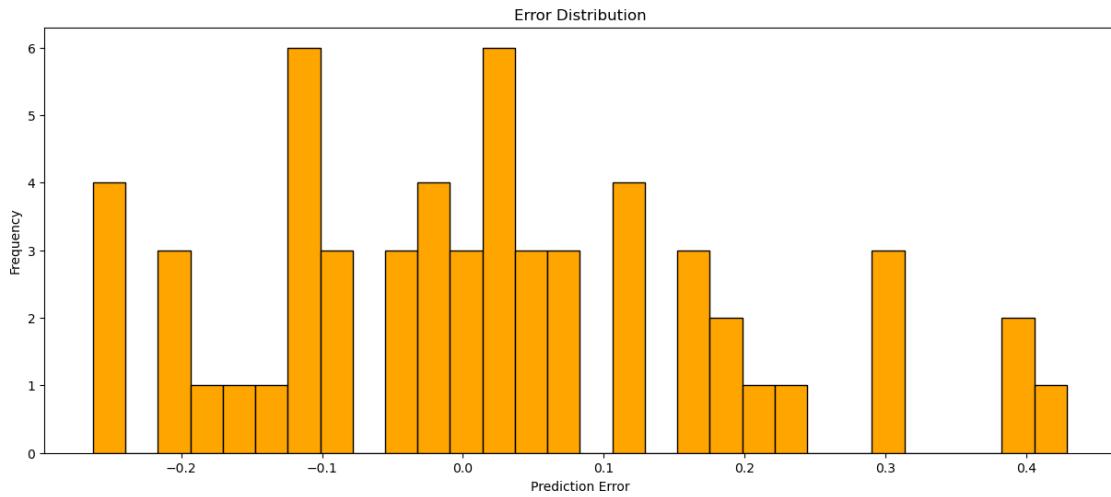
LSTM Model MSE: 0.028747924107895124

LSTM Model RMSE: 0.1695521279957734

LSTM Model MAE: 0.13247430735620955

LSTM Model R-squared: -0.1432559013944803





```
[51]: # MODEL C
```

```
[52]: import statsmodels.api as sm
import pandas as pd
import numpy as np

# Define a range of significance levels to test
significance_levels = np.arange(0.01, 0.11, 0.01)

# Store the number of selected features for each significance level and output variable
results = pd.DataFrame(index=Output_CN, columns=significance_levels)

# Feature selection and evaluation for each significance level
for significance_level in significance_levels:
    print(f"*****Testing significance level:{significance_level}*****")
    # Loop through each output column
    for n in range(len(Output_CN)):
        YCi = Output_CA.values[:, n] # Select the current output column
        cols = list(Input_CAN.columns) # Initialize the list of input features
        pmax = 1 # Initialize the maximum p-value

        # Perform backward elimination
        while len(cols) > 0:
            X_1 = Input_CAN[cols] # Subset the input features
```

```

X_1 = sm.add_constant(X_1) # Add a constant term for the intercept
model = sm.OLS(YCi, X_1).fit() # Fit the OLS regression model
p_values = model.pvalues.iloc[1:] # Get p-values excluding the
↪constant term
pmax = p_values.max() # Find the maximum p-value
feature_with_p_max = p_values.idxmax() # Identify the feature with
↪the maximum p-value

# Check if the maximum p-value is above the significance level
if pmax > significance_level:
    cols.remove(feature_with_p_max) # Remove the least significant
↪feature
else:
    break # Stop if all p-values are below the significance level

selected_featuresC = cols # Get the selected features
# Record the number of selected features
results.loc[Output_CN[n], significance_level] = len(selected_featuresC)
# Print the results for this significance level
print(Output_CN[n], " Total features:", len(Input_CN), " Selected
↪features:", len(selected_featuresC))

# Display the results for all tested significance levels
print("\nResults for various significance levels:")
print(results)

```

```

*****Testing significance level:
0.01*****
Stage2.Output.Measurement0.U.Actual Total features: 25 Selected features: 6
Stage2.Output.Measurement1.U.Actual Total features: 25 Selected features: 3
Stage2.Output.Measurement2.U.Actual Total features: 25 Selected features: 3
Stage2.Output.Measurement3.U.Actual Total features: 25 Selected features: 8
Stage2.Output.Measurement5.U.Actual Total features: 25 Selected features: 1
Stage2.Output.Measurement6.U.Actual Total features: 25 Selected features: 0
Stage2.Output.Measurement7.U.Actual Total features: 25 Selected features: 2
Stage2.Output.Measurement8.U.Actual Total features: 25 Selected features: 0
Stage2.Output.Measurement9.U.Actual Total features: 25 Selected features: 10
Stage2.Output.Measurement10.U.Actual Total features: 25 Selected features: 7
Stage2.Output.Measurement11.U.Actual Total features: 25 Selected features: 7
Stage2.Output.Measurement12.U.Actual Total features: 25 Selected features: 6
Stage2.Output.Measurement13.U.Actual Total features: 25 Selected features: 1
Stage2.Output.Measurement14.U.Actual Total features: 25 Selected features: 9
*****Testing significance level:
0.02*****
Stage2.Output.Measurement0.U.Actual Total features: 25 Selected features: 6
Stage2.Output.Measurement1.U.Actual Total features: 25 Selected features: 4
Stage2.Output.Measurement2.U.Actual Total features: 25 Selected features: 3

```


Results for various significance levels:

0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 \

Stage2.Output.Measurement0.U.Actual	6	6	6	8	9	9	9	9
Stage2.Output.Measurement1.U.Actual	3	4	4	4	4	10	10	10

Stage2.Output.Measurement2.U.Actual	3	3	4	4	4	4	5	5
Stage2.Output.Measurement3.U.Actual	8	8	10	10	10	10	14	14
Stage2.Output.Measurement5.U.Actual	1	2	2	2	2	2	2	2
Stage2.Output.Measurement6.U.Actual	0	1	8	8	9	9	9	9
Stage2.Output.Measurement7.U.Actual	2	2	2	2	3	3	3	4
Stage2.Output.Measurement8.U.Actual	0	0	0	0	0	0	0	0
Stage2.Output.Measurement9.U.Actual	10	10	10	12	12	12	13	13
Stage2.Output.Measurement10.U.Actual	7	9	9	9	10	10	12	12
Stage2.Output.Measurement11.U.Actual	7	8	8	8	8	8	8	8
Stage2.Output.Measurement12.U.Actual	6	6	6	6	6	6	6	6
Stage2.Output.Measurement13.U.Actual	1	1	2	2	2	2	2	2
Stage2.Output.Measurement14.U.Actual	9	9	10	10	10	10	10	10
	0.09	0.10						
Stage2.Output.Measurement0.U.Actual	9	9						
Stage2.Output.Measurement1.U.Actual	10	10						
Stage2.Output.Measurement2.U.Actual	5	5						
Stage2.Output.Measurement3.U.Actual	14	14						
Stage2.Output.Measurement5.U.Actual	2	2						
Stage2.Output.Measurement6.U.Actual	9	9						
Stage2.Output.Measurement7.U.Actual	4	4						
Stage2.Output.Measurement8.U.Actual	0	2						
Stage2.Output.Measurement9.U.Actual	13	13						
Stage2.Output.Measurement10.U.Actual	12	12						
Stage2.Output.Measurement11.U.Actual	8	8						
Stage2.Output.Measurement12.U.Actual	6	6						
Stage2.Output.Measurement13.U.Actual	2	2						
Stage2.Output.Measurement14.U.Actual	10	10						

```
[53]: import statsmodels.api as sm
import pandas as pd

# Feature selection and prediction for model C
print("*****Prediction Model C (Stage 1)*****")
for n in range(len(Output_CN)):
    YCi = Output_CA.values[:, n]
    # Backward Elimination for feature selection
    cols = list(Input_CAN.columns)
    pmax = 1
    while len(cols) > 0:
        X_1 = Input_CAN[cols]
        X_1 = sm.add_constant(X_1)
        model = sm.OLS(Yi, X_1).fit()
        p_values = model.pvalues.iloc[1:] # Exclude p-value for constant
        pmax = p_values.max()
        feature_with_p_max = p_values.idxmax()
```

```

    if pmax > 0.05:
        cols.remove(feature_with_p_max)
    else:
        break
selected_featuresC = cols
print(Output_CN[n], "      Total features:", len(Input_CN), " Selected\u202a
˓→features:", len(selected_featuresC))

```

*****Prediction Model C (Stage
3)*****

Stage2.Output.Measurement0.U.Actual 10	Total features: 25 Selected features:
Stage2.Output.Measurement1.U.Actual 10	Total features: 25 Selected features:
Stage2.Output.Measurement2.U.Actual 10	Total features: 25 Selected features:
Stage2.Output.Measurement3.U.Actual 10	Total features: 25 Selected features:
Stage2.Output.Measurement5.U.Actual 10	Total features: 25 Selected features:
Stage2.Output.Measurement6.U.Actual 10	Total features: 25 Selected features:
Stage2.Output.Measurement7.U.Actual 10	Total features: 25 Selected features:
Stage2.Output.Measurement8.U.Actual 10	Total features: 25 Selected features:
Stage2.Output.Measurement9.U.Actual 10	Total features: 25 Selected features:
Stage2.Output.Measurement10.U.Actual 10	Total features: 25 Selected features:
Stage2.Output.Measurement11.U.Actual 10	Total features: 25 Selected features:
Stage2.Output.Measurement12.U.Actual 10	Total features: 25 Selected features:
Stage2.Output.Measurement13.U.Actual 10	Total features: 25 Selected features:
Stage2.Output.Measurement14.U.Actual 10	Total features: 25 Selected features:

[54]: print("*****Slitting the data into train and test for\u202a
˓→Model C*****")

```

x_selected = Input_CA.values[:, selected_featuresC]
x_trainC, x_testC, y_trainC, y_testC = train_test_split(x_selected, YCi, u
˓→test_size=0.3)

```

*****Slitting the data into train and test for Model
C*****

```
[58]: # SVM poly
from sklearn.pipeline import make_pipeline
from sklearn.preprocessing import StandardScaler
from sklearn.svm import SVR
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
import matplotlib.pyplot as plt
import numpy as np

# Create the SVM pipeline using the specified train and test data
svr_polyC = make_pipeline(StandardScaler(), SVR(C=1.0, epsilon=0.2,
    kernel='poly', degree=3))
svr_polyC = svr_polyC.fit(x_trainC, y_trainC)
predictionsC = svr_polyC.predict(x_testC)

# Calculate errors
MSE = mean_squared_error(y_testC, predictionsC)
RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_testC, predictionsC)
R2 = r2_score(y_testC, predictionsC) # Calculate R-squared

# Print accuracy and errors
#print("SVM-Poly Model MSE: ", MSE)
print("SVM-Poly Model RMSE: ", RMSE)
print("SVM-Poly Model MAE: ", MAE)
print("SVM-Poly Model R-squared: ", R2) # Print R-squared value

# Plot results: Actual vs Predicted using range if index is not available
x_axisC = range(len(y_testC)) # Create a range for the x-axis equal to the
    #length of y_testC
plt.figure(figsize=(15, 6))
plt.plot(x_axisC, y_testC, color='blue', label='Actual')
plt.plot(x_axisC, predictionsC, color='orange', linestyle='--',
    label='Predicted')
plt.title('SVM-Poly Predictions vs Actual')
plt.xlabel('Index')
plt.ylabel('Value')
plt.legend()
plt.show()

# Residual Plot
residualsC = y_testC - predictionsC
plt.figure(figsize=(15, 6))
plt.plot(x_axisC, residualsC, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')
```

```

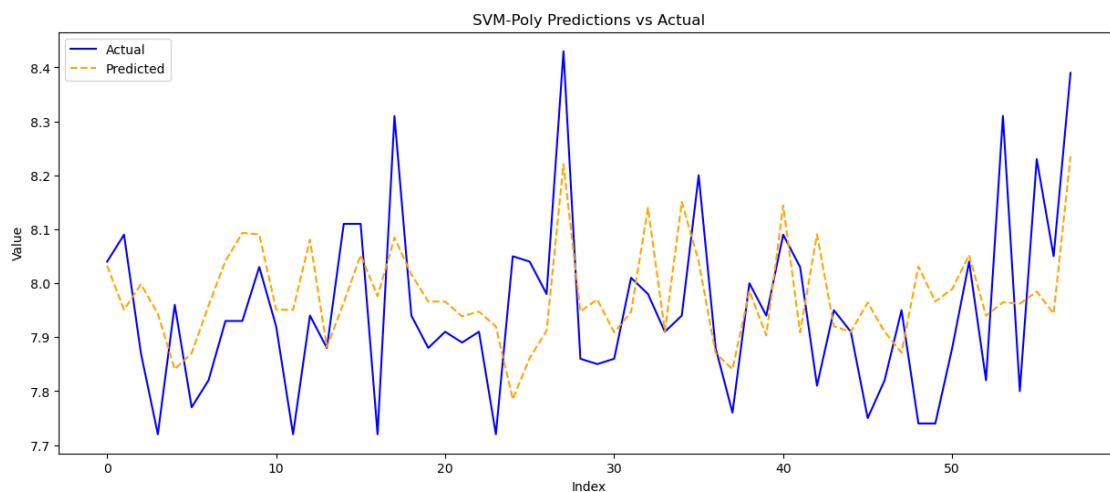
plt.show()

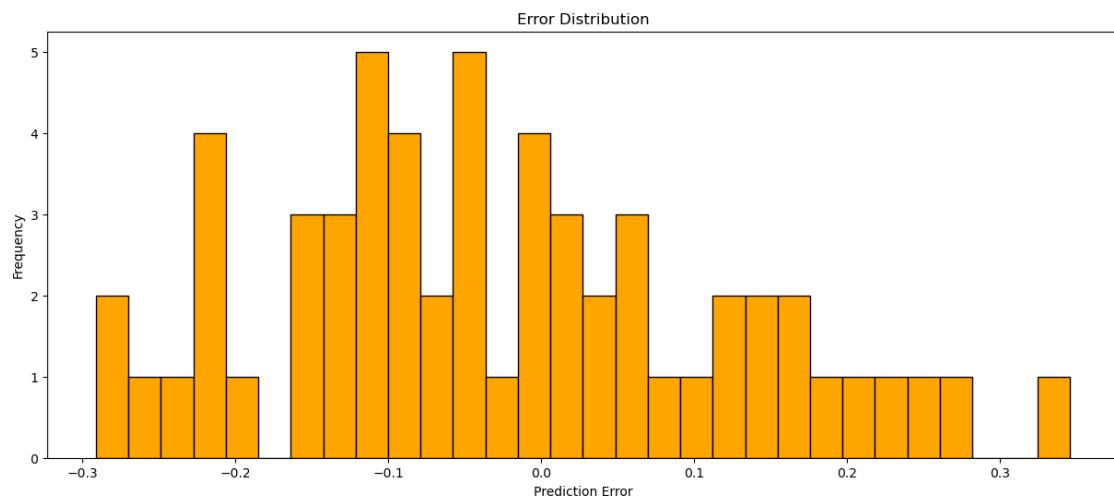
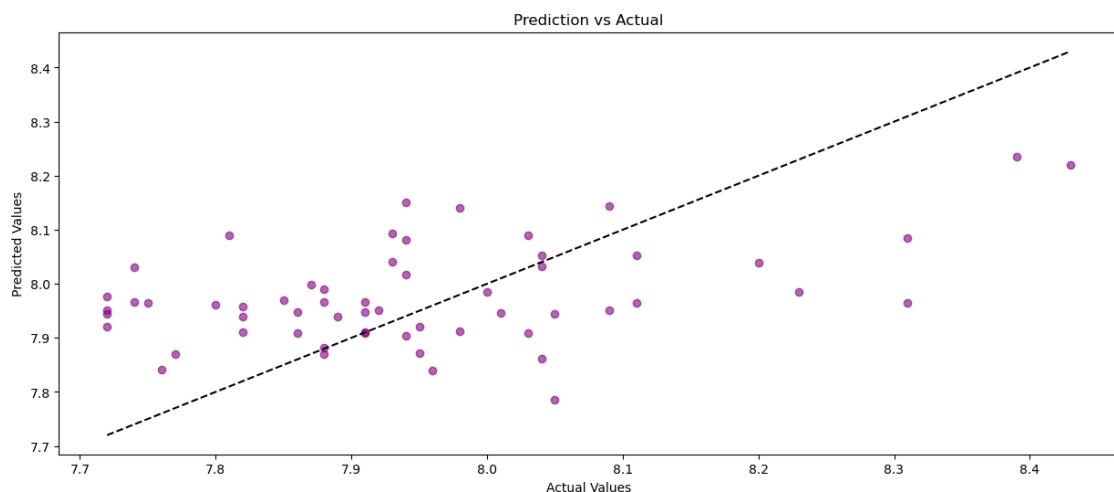
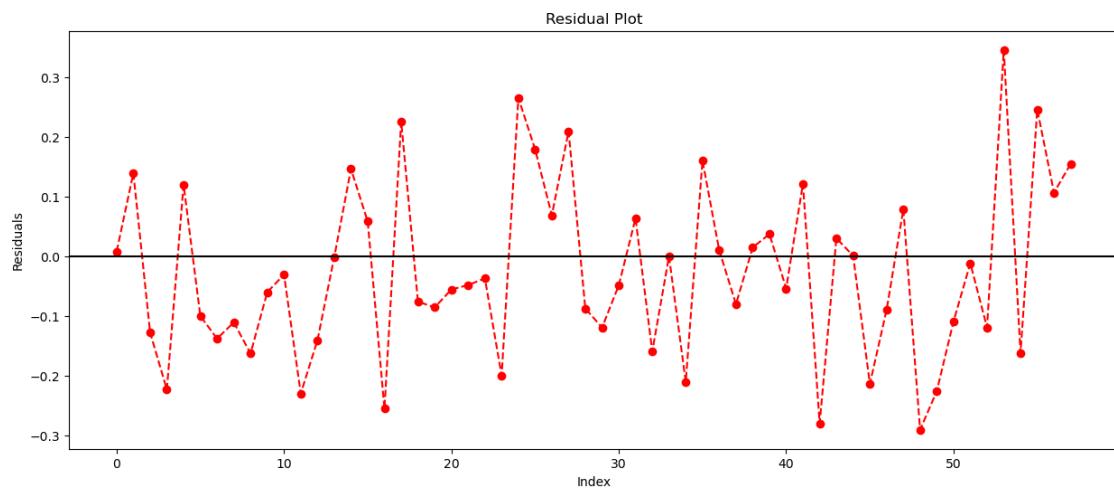
# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_testC, predictionsC, color='purple', alpha=0.6)
plt.plot([min(y_testC), max(y_testC)], [min(y_testC), max(y_testC)], color='black', linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residualsC, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

```

SVM-Poly Model RMSE: 0.14916265378857527
SVM-Poly Model MAE: 0.12309935230296884
SVM-Poly Model R-squared: 0.16474006281043319





```
[59]: # Decision Tree
from sklearn.tree import DecisionTreeRegressor, plot_tree
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
import matplotlib.pyplot as plt
import numpy as np

# Create and fit the Decision Tree model
clfC = DecisionTreeRegressor(max_features='auto')
clfC = clfC.fit(x_trainC, y_trainC)
predictionsC = clfC.predict(x_testC)

# Calculate errors
MSE = mean_squared_error(y_testC, predictionsC)
RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_testC, predictionsC)
R2 = r2_score(y_testC, predictionsC) # Calculate R-squared

# Print errors
#print("Decision Tree Model MSE: ", MSE)
print("Decision Tree Model RMSE: ", RMSE)
print("Decision Tree Model MAE: ", MAE)
print("Decision Tree Model R-squared: ", R2) # Print R-squared value

# Plot results: Actual vs Predicted using range if index is not available
x_axisC = range(len(y_testC)) # Create a range for the x-axis equal to the length of y_testC
# plt.figure(figsize=(15, 6))
# plt.plot(x_axisC, y_testC, color='blue', label='Actual')
# plt.plot(x_axisC, predictionsC, color='orange', linestyle='--', label='Predicted')
# plt.title('Decision Tree Predictions vs Actual')
# plt.xlabel('Index')
# plt.ylabel('Value')
# plt.legend()
# plt.show()

# Residual Plot
residualsC = y_testC - predictionsC
plt.figure(figsize=(15, 6))
plt.plot(x_axisC, residualsC, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')
```

```

plt.show()

# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_testC, predictionsC, color='purple', alpha=0.6)
plt.plot([min(y_testC), max(y_testC)], [min(y_testC), max(y_testC)],  

         color='black', linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residualsC, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

# Feature Importance Plot
importances = clfC.feature_importances_
indices = np.argsort(importances)[::-1]
feature_names = Input_AA.columns[selected_featuresC] # Assuming  

selected_featuresC is a list of indices

plt.figure(figsize=(15, 6))
plt.title("Feature Importances")
plt.bar(range(x_trainC.shape[1]), importances[indices], color="r",  

        align="center")
plt.xticks(range(x_trainC.shape[1]), feature_names[indices], rotation=90)
plt.xlim([-1, x_trainC.shape[1]])
plt.show()

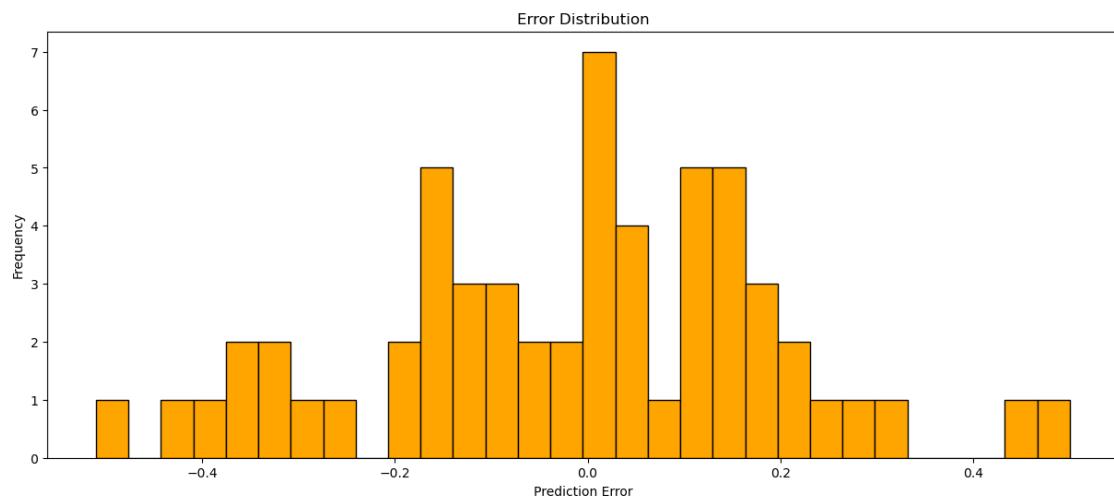
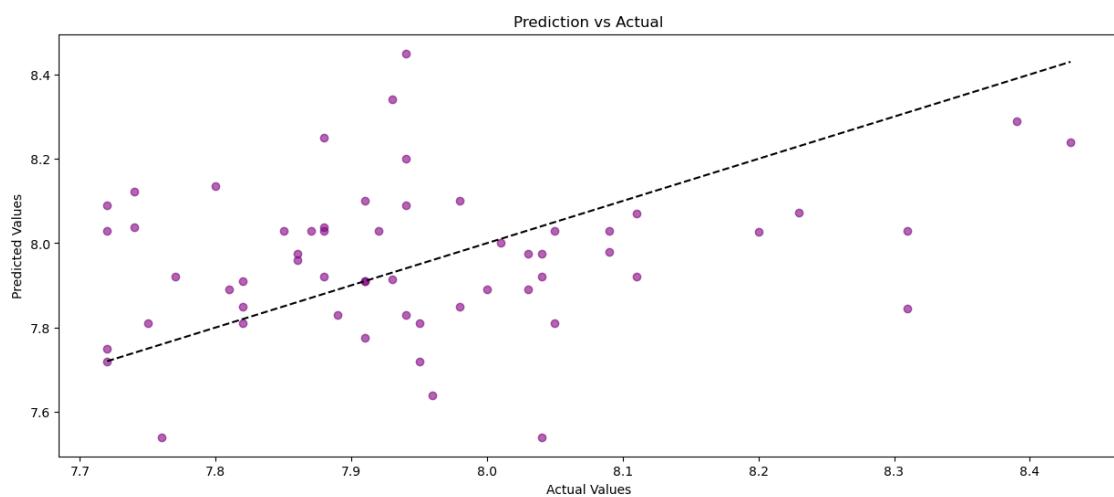
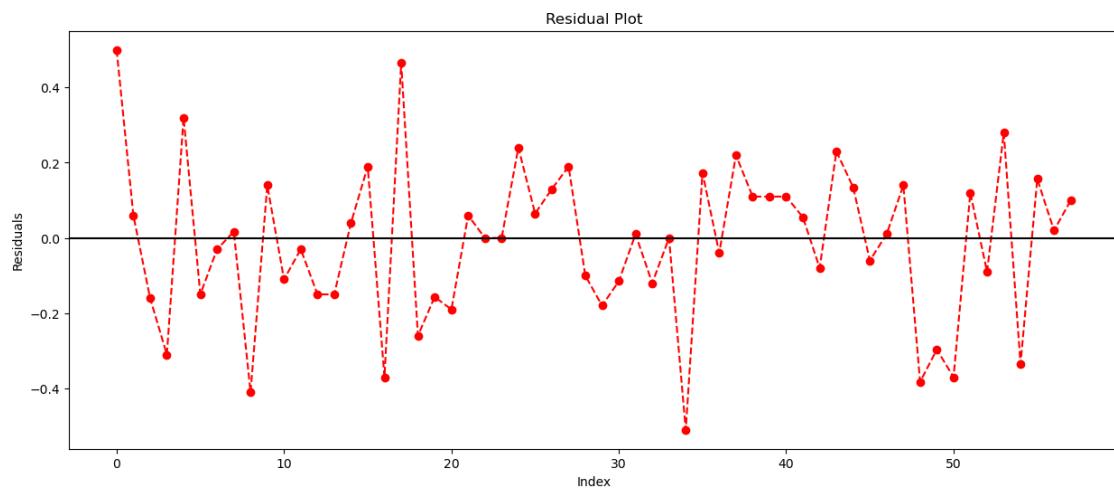
# Visualize the Decision Tree
plt.figure(figsize=(20, 10))
plot_tree(clfC, filled=True, feature_names=feature_names, rounded=True)
plt.title('Decision Tree Structure')
plt.show()

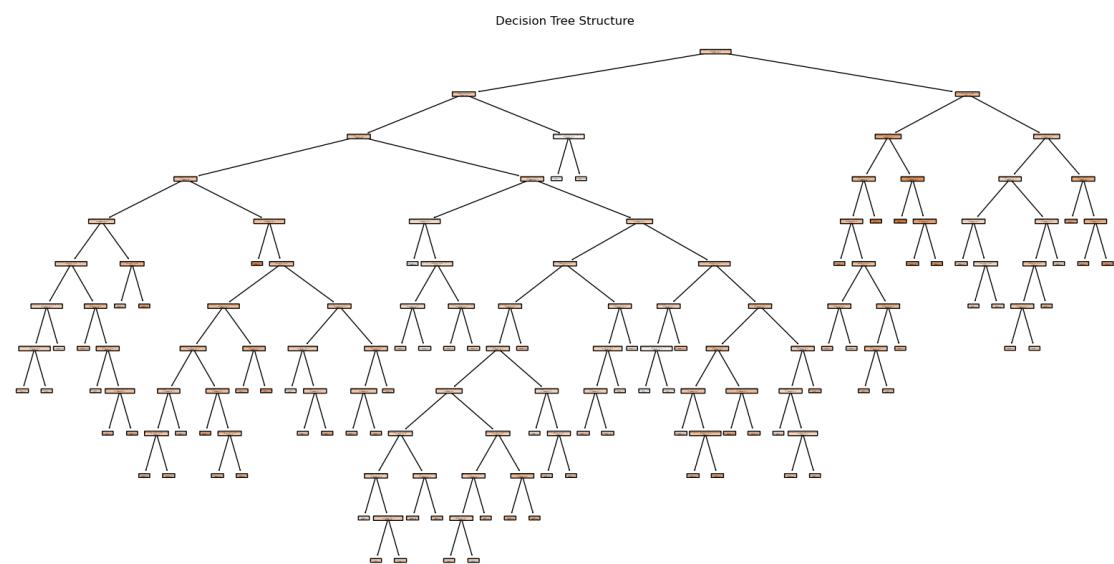
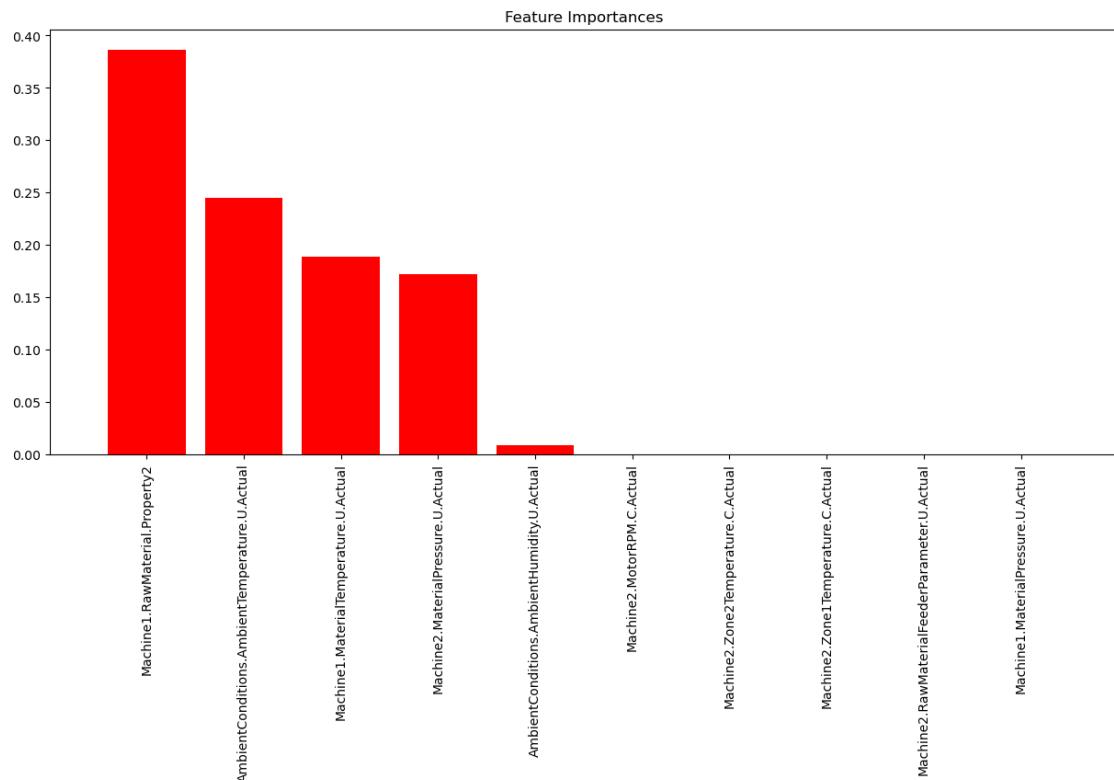
```

Decision Tree Model RMSE: 0.20985538831259815

Decision Tree Model MAE: 0.16469827586206878

Decision Tree Model R-squared: -0.6532620543880188





```
[60]: # KNN
from sklearn.neighbors import KNeighborsRegressor
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
import matplotlib.pyplot as plt
import numpy as np

# Create and fit the KNN model using the specified train and test datasets
knnC = KNeighborsRegressor(n_neighbors=5, weights='distance', algorithm='auto',
                           leaf_size=30, p=2,
                           metric='minkowski', metric_params=None, n_jobs=None)
knnC = knnC.fit(x_trainC, y_trainC)
predictionsC = knnC.predict(x_testC)

# Calculate errors
MSE = mean_squared_error(y_testC, predictionsC)
RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_testC, predictionsC)
R2 = r2_score(y_testC, predictionsC) # Calculate R-squared

# Print accuracy and errors
# print("KNN Model MSE: ", MSE)
print("KNN Model RMSE: ", RMSE)
print("KNN Model MAE: ", MAE)
print("KNN Model R-squared: ", R2) # Print R-squared value

# Plot results: Actual vs Predicted using range if index is not available
x_axisC = range(len(y_testC)) # Create a range for the x-axis equal to the
                               # length of y_testC
# plt.figure(figsize=(15, 6))
# plt.plot(x_axisC, y_testC, color='blue', label='Actual')
# plt.plot(x_axisC, predictionsC, color='orange', linestyle='--', 
#           label='Predicted')
# plt.title('KNN Predictions vs Actual')
# plt.xlabel('Index')
# plt.ylabel('Value')
# plt.legend()
# plt.show()

# Residual Plot
residualsC = y_testC - predictionsC
plt.figure(figsize=(15, 6))
plt.plot(x_axisC, residualsC, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')
plt.show()
```

```

# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_testC, predictionsC, color='purple', alpha=0.6)
plt.plot([min(y_testC), max(y_testC)], [min(y_testC), max(y_testC)], color='black', linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

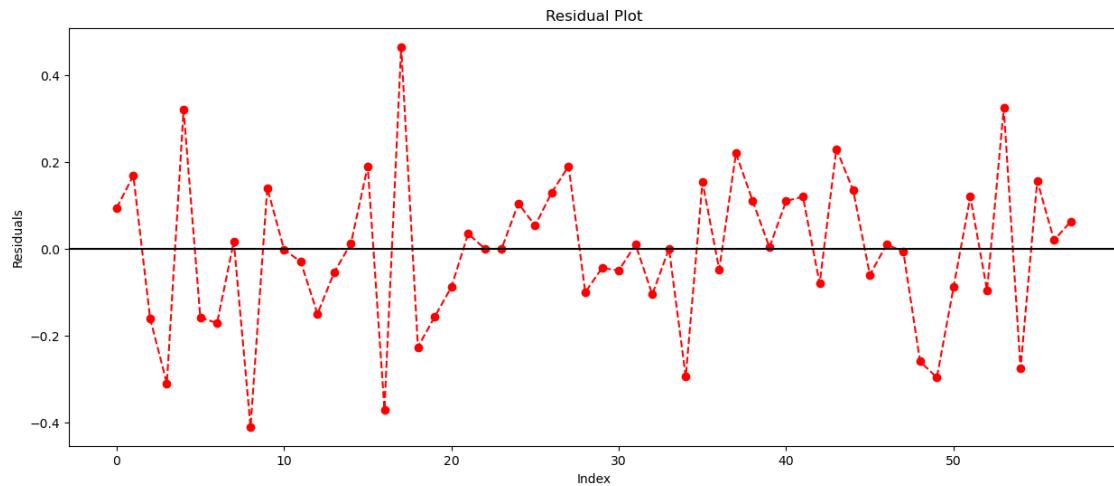
# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residualsC, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

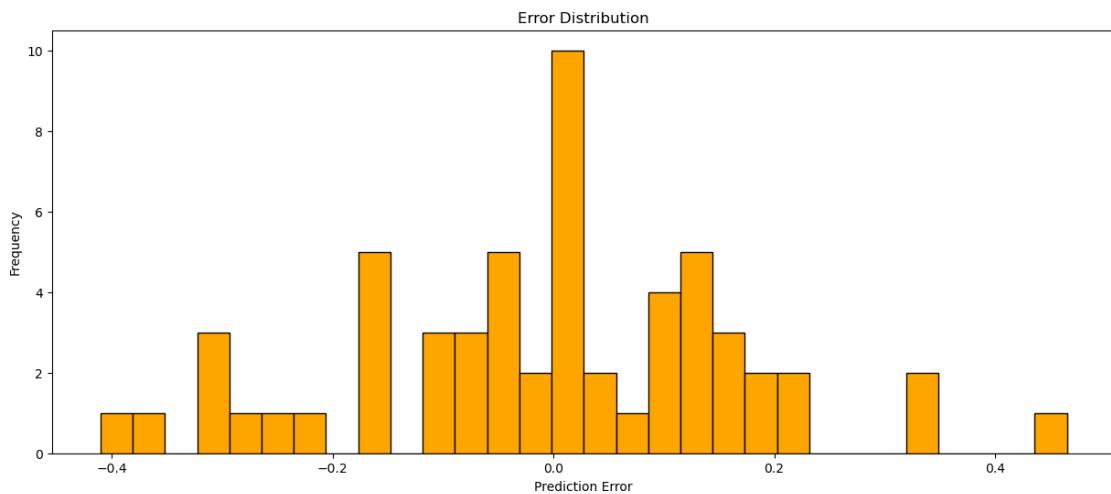
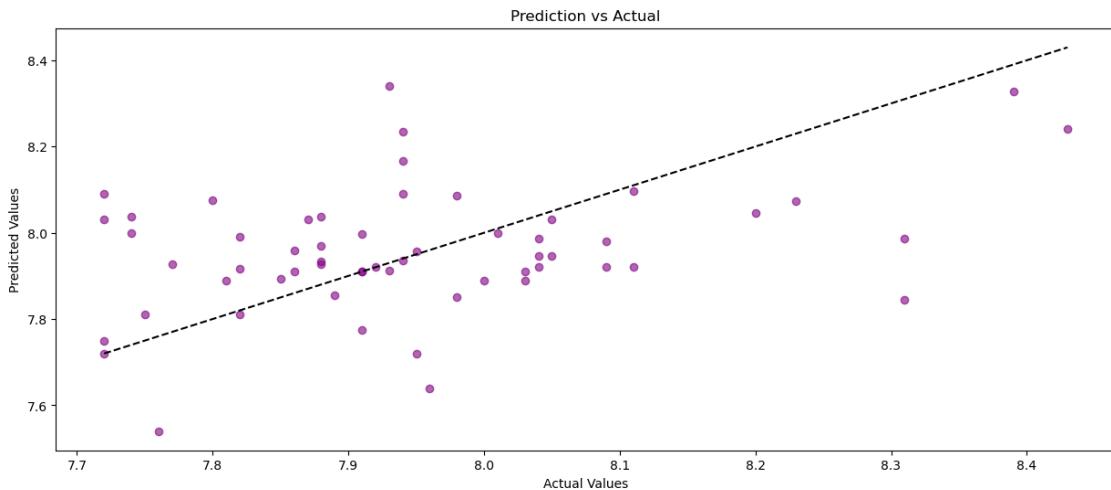
```

KNN Model RMSE: 0.17492286437908017

KNN Model MAE: 0.13444442821682426

KNN Model R-squared: -0.14866822902240462





```
[64]: # Random Forest
from sklearn.ensemble import RandomForestRegressor
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
import matplotlib.pyplot as plt
import numpy as np
from sklearn.model_selection import train_test_split

# Assuming Input_CA and YCi are already defined, and 'selected_featuresC' is
# the index list of selected features
x_selectedC = Input_CA.values[:, selected_featuresC]
x_trainC, x_testC, y_trainC, y_testC = train_test_split(x_selectedC, YCi,
# test_size=0.3, random_state=42)
```

```

# Create and fit the Random Forest model
rfC = RandomForestRegressor(n_estimators=100, random_state=42) # You can ↵
    ↵adjust n_estimators and other hyperparameters
rfC = rfC.fit(x_trainC, y_trainC)
predictionsC = rfC.predict(x_testC)

# Calculate errors
MSE = mean_squared_error(y_testC, predictionsC)
RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_testC, predictionsC)
R2 = r2_score(y_testC, predictionsC) # Calculate R-squared

# Print errors
# print("Random Forest Model MSE: ", MSE)
print("Random Forest Model RMSE: ", RMSE)
print("Random Forest Model MAE: ", MAE)
print("Random Forest Model R-squared: ", R2) # Print R-squared value

# Plot results: Actual vs Predicted using range if index is not available
# x_axisC = range(len(y_testC)) # Create a range for the x-axis equal to the ↵
    ↵length of y_testC
# plt.figure(figsize=(15, 6))
# plt.plot(x_axisC, y_testC, color='blue', label='Actual')
# plt.plot(x_axisC, predictionsC, color='orange', linestyle='--', ↵
    ↵label='Predicted')
# plt.title('Random Forest Predictions vs Actual')
# plt.xlabel('Index')
# plt.ylabel('Value')
# plt.legend()
# plt.show()

# Residual Plot
residualsC = y_testC - predictionsC
plt.figure(figsize=(15, 6))
plt.plot(x_axisC, residualsC, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')
plt.show()

# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_testC, predictionsC, color='purple', alpha=0.6)
plt.plot([min(y_testC), max(y_testC)], [min(y_testC), max(y_testC)], ↵
    ↵color='black', linestyle='--')
plt.title('Prediction vs Actual')

```

```

plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residualsC, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

# Feature Importance Plot
importances = rfc.feature_importances_
indices = np.argsort(importances)[::-1]
feature_names = Input_CA.columns[selected_featuresC] # Assuming
# selected_featuresC is a list of indices

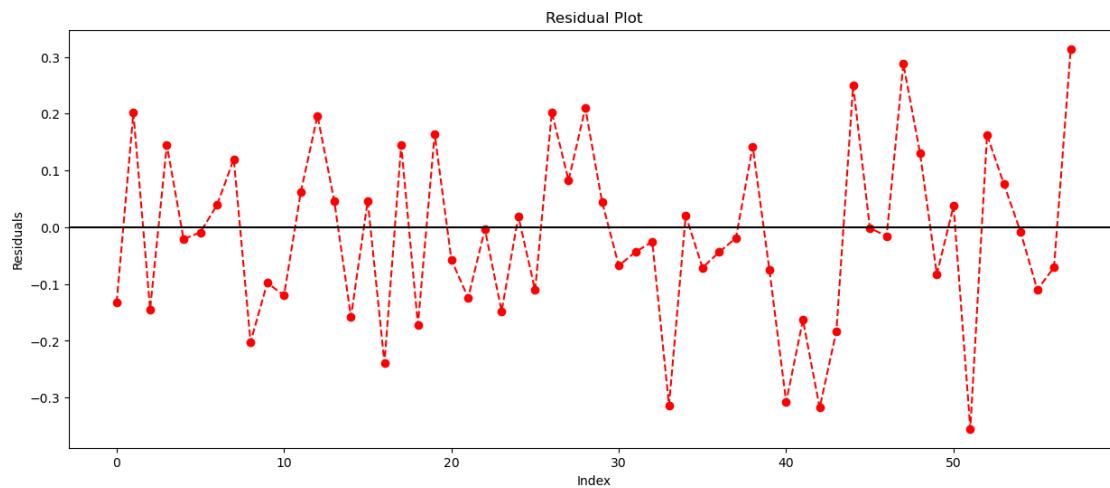
plt.figure(figsize=(15, 6))
plt.title("Feature Importances")
plt.bar(range(x_trainC.shape[1]), importances[indices], color="r",
align="center")
plt.xticks(range(x_trainC.shape[1]), feature_names[indices], rotation=90)
plt.xlim([-1, x_trainC.shape[1]])
plt.show()

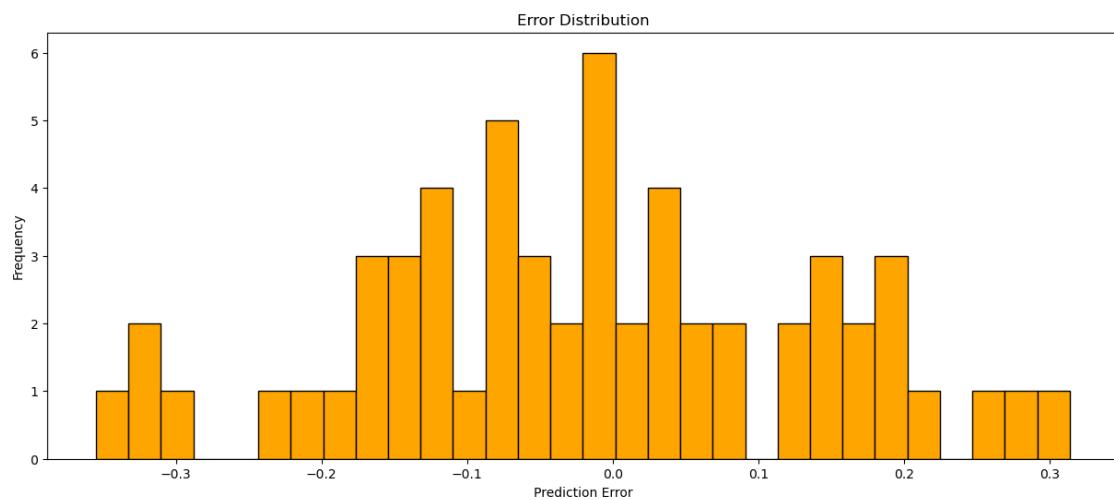
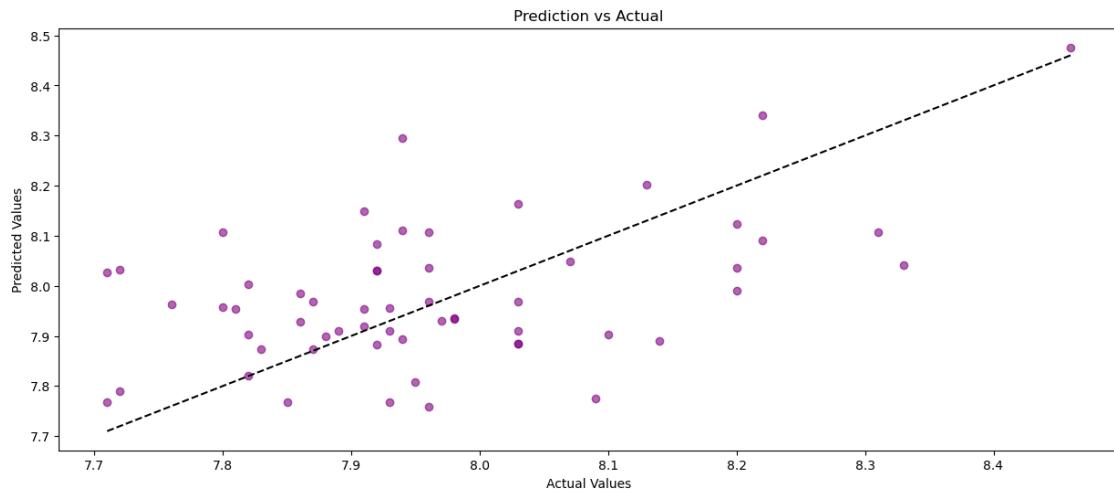
```

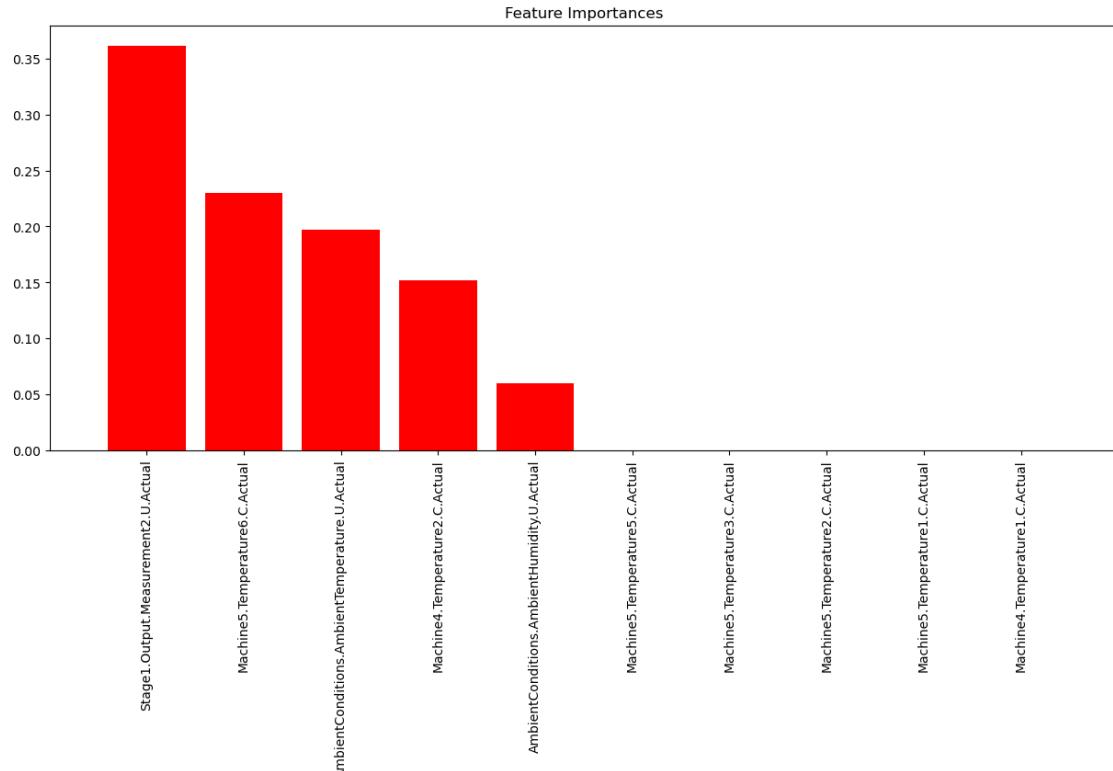
Random Forest Model RMSE: 0.1539055486475413

Random Forest Model MAE: 0.12343329999502294

Random Forest Model R-squared: 0.05801168186853889







```
[62]: # Gradient Boosting Machine Predictions
from sklearn.ensemble import GradientBoostingRegressor
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
import matplotlib.pyplot as plt
import numpy as np
from sklearn.model_selection import train_test_split

# Assuming Input_CA and YCi are already defined, and 'selected_featuresC' is
# the index list of selected features
x_selectedC = Input_CA.values[:, selected_featuresC]
x_trainC, x_testC, y_trainC, y_testC = train_test_split(x_selectedC, YCi,
#test_size=0.3, random_state=42)

# Create and fit the Gradient Boosting model
gbmC = GradientBoostingRegressor(n_estimators=100, learning_rate=0.1,
#max_depth=3, random_state=42)
gbmC.fit(x_trainC, y_trainC)
predictionsC = gbmC.predict(x_testC)

# Calculate errors
MSE = mean_squared_error(y_testC, predictionsC)
RMSE = np.sqrt(MSE)
```

```

MAE = mean_absolute_error(y_testC, predictionsC)
R2 = r2_score(y_testC, predictionsC) # Calculate R-squared

# Print accuracy and errors
#print("Gradient Boosting Model MSE: ", MSE)
print("Gradient Boosting Model RMSE: ", RMSE)
print("Gradient Boosting Model MAE: ", MAE)
print("Gradient Boosting Model R-squared: ", R2) # Print R-squared value

# Plot results: Actual vs Predicted using range if index is not available
# x_axisC = range(len(y_testC)) # Create a range for the x-axis equal to the
# length of y_testC
# plt.figure(figsize=(15, 6))
# plt.plot(x_axisC, y_testC, color='blue', label='Actual')
# plt.plot(x_axisC, predictionsC, color='orange', linestyle='--', label='Predicted')
# plt.title('Gradient Boosting Machine Predictions vs Actual')
# plt.xlabel('Index')
# plt.ylabel('Value')
# plt.legend()
# plt.show()

# Residual Plot
residualsC = y_testC - predictionsC
plt.figure(figsize=(15, 6))
plt.plot(x_axisC, residualsC, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')
plt.show()

# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_testC, predictionsC, color='purple', alpha=0.6)
plt.plot([min(y_testC), max(y_testC)], [min(y_testC), max(y_testC)], color='black', linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residualsC, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')

```

```

plt.ylabel('Frequency')
plt.show()

# Feature Importance Plot
importances = gbmC.feature_importances_
indices = np.argsort(importances)[::-1]
feature_names = Input_CA.columns[selected_featuresC] # Assuming
↳ selected_featuresC is a list of indices

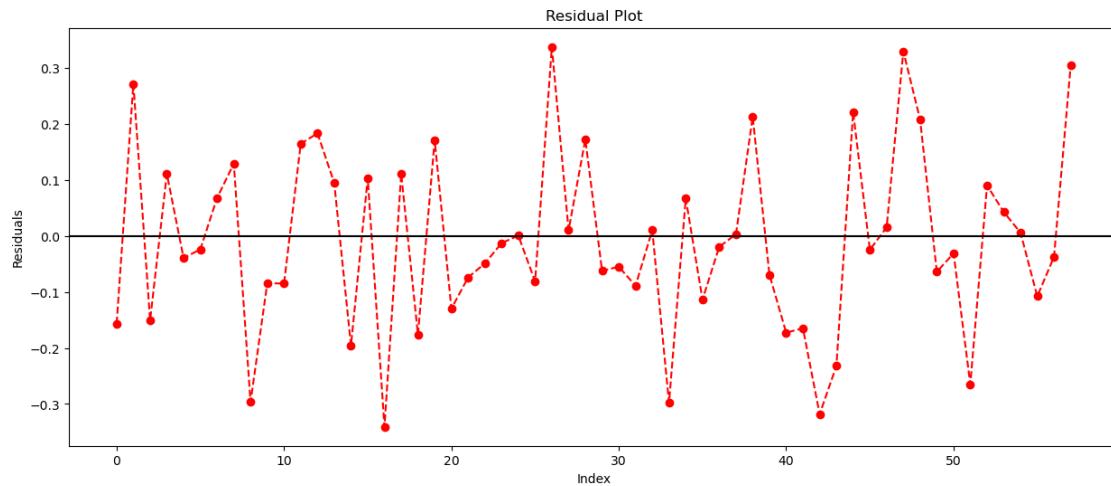
plt.figure(figsize=(15, 6))
plt.title("Feature Importances")
plt.bar(range(x_trainC.shape[1]), importances[indices], color="r",
↳ align="center")
plt.xticks(range(x_trainC.shape[1]), feature_names[indices], rotation=90)
plt.xlim([-1, x_trainC.shape[1]])
plt.show()

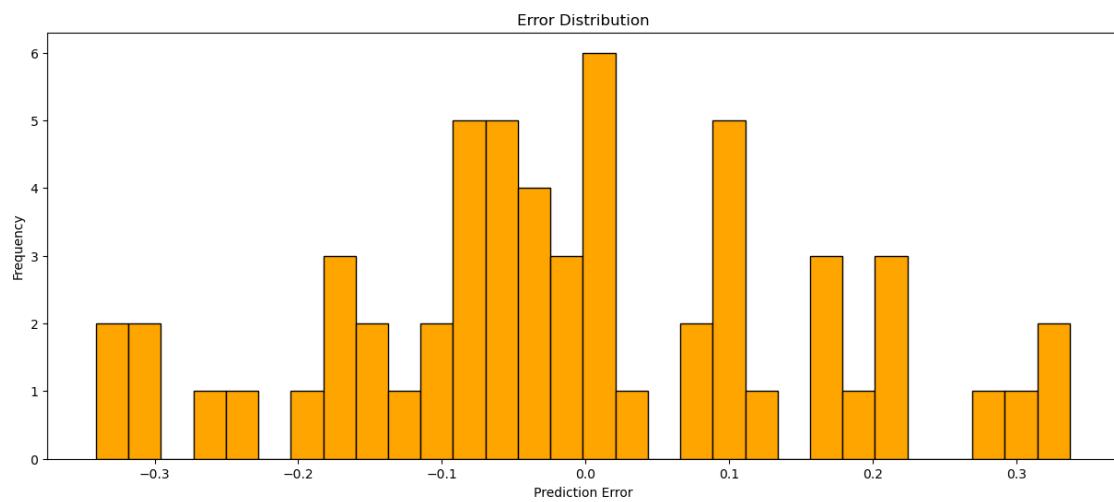
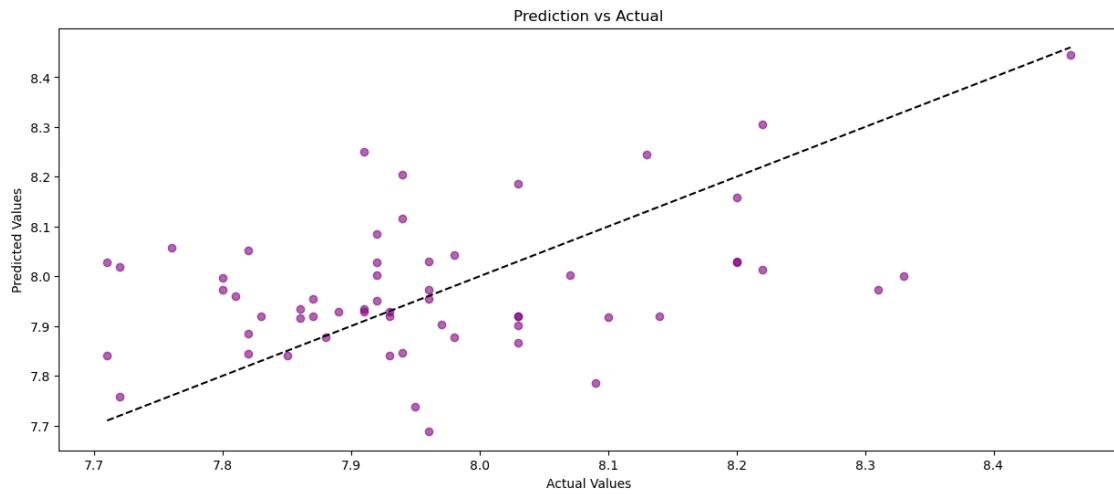
```

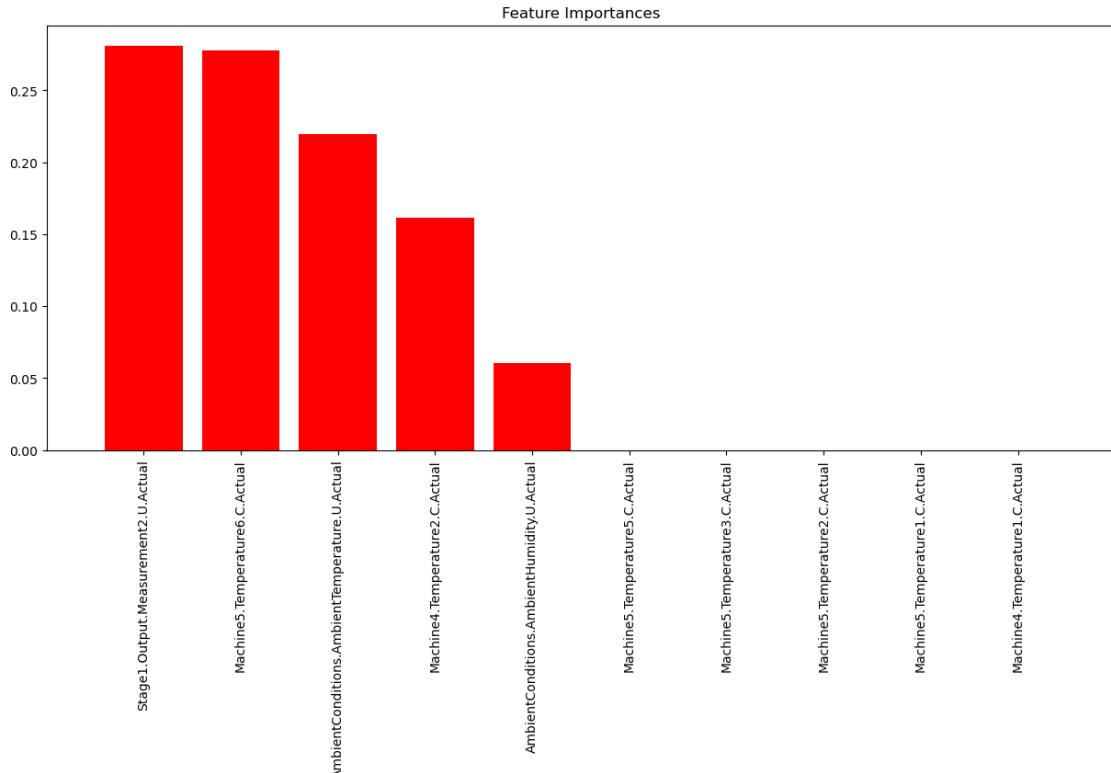
Gradient Boosting Model RMSE: 0.16174000834885044

Gradient Boosting Model MAE: 0.12857196085575426

Gradient Boosting Model R-squared: -0.04033182564733795







```
[66]: # RNN with LSTM for Regression
import numpy as np
import pandas as pd
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, LSTM
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split

# Assuming Input_CA and selected_featuresC have been used to split the data:
x_selectedC = Input_CA.values[:, selected_featuresC]
x_trainC, x_testC, y_trainC, y_testC = train_test_split(x_selectedC, YCi, test_size=0.3)

# Reshape input data for RNN input
x_train_rnn = x_trainC.reshape((x_trainC.shape[0], x_trainC.shape[1], 1))
x_test_rnn = x_testC.reshape((x_testC.shape[0], x_testC.shape[1], 1))

# Build the RNN model
model = Sequential([
    ...]
```

```

        LSTM(50, activation='relu', input_shape=(x_train_rnn.shape[1], 1)), # LSTM
    ↵layer
    Dense(1)
])

model.compile(optimizer='adam', loss='mse')

# Train the model
model.fit(x_train_rnn, y_trainC, epochs=50, verbose=0)

# Predictions
predictions = model.predict(x_test_rnn).flatten()

# Calculate errors and metrics
MSE = mean_squared_error(y_testC, predictions)
RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_testC, predictions)
R2 = r2_score(y_testC, predictions) # Calculate R-squared

# Print errors and metrics
# print("RNN Model MSE: ", MSE)
print("RNN Model RMSE: ", RMSE)
print("RNN Model MAE: ", MAE)
print("RNN Model R-squared: ", R2) # Print R-squared value

# Plot results: Actual vs Predicted
# x_axis = range(len(y_testC)) # Create a range for the x-axis equal to the
    ↵length of y_testC
# plt.figure(figsize=(15, 6))
# plt.plot(x_axis, y_testC, color='blue', label='Actual')
# plt.plot(x_axis, predictions, color='orange', linestyle='--', ↵
    ↵label='Predicted')
# plt.title('RNN Predictions vs Actual')
# plt.xlabel('Index')
# plt.ylabel('Value')
# plt.legend()
# plt.show()

# Residual Plot
residuals = y_testC - predictions
plt.figure(figsize=(15, 6))
plt.plot(x_axis, residuals, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')
plt.ylabel('Residuals')
plt.show()

```

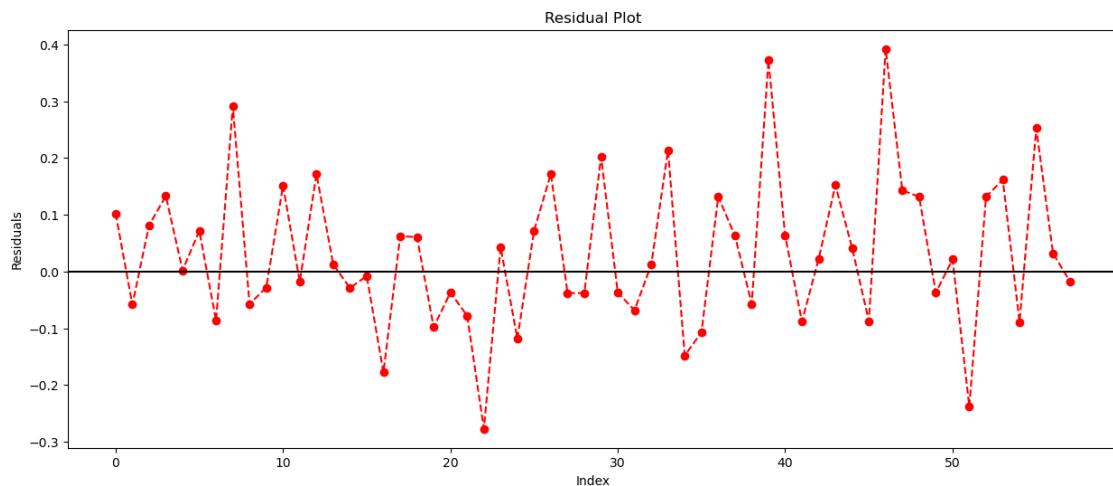
```

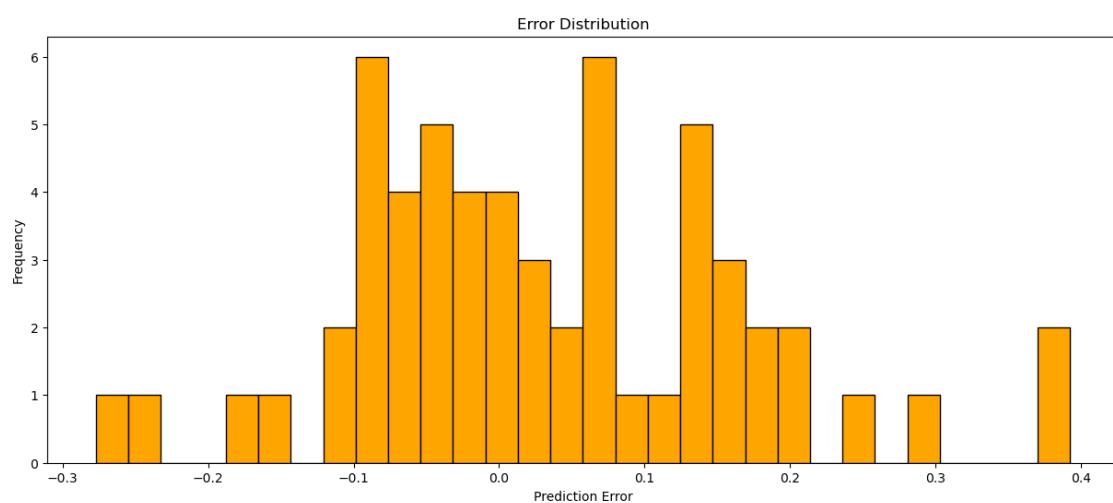
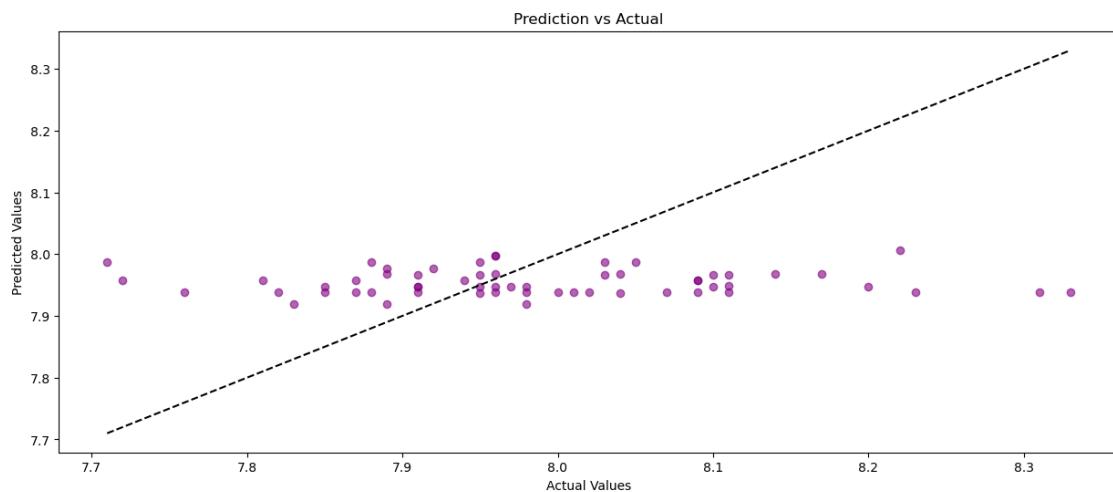
# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_testC, predictions, color='purple', alpha=0.6)
plt.plot([min(y_testC), max(y_testC)], [min(y_testC), max(y_testC)], color='black', linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residuals, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

```

WARNING:tensorflow:6 out of the last 11 calls to <function Model.make_predict_function.<locals>.predict_function at 0x000001D42BA569D0> triggered tf.function retracing. Tracing is expensive and the excessive number of tracings could be due to (1) creating @tf.function repeatedly in a loop, (2) passing tensors with different shapes, (3) passing Python objects instead of tensors. For (1), please define your @tf.function outside of the loop. For (2), @tf.function has reduce_retracing=True option that can avoid unnecessary retracing. For (3), please refer to
https://www.tensorflow.org/guide/function#controlling_retracing and
https://www.tensorflow.org/api_docs/python/tf/function for more details.
 2/2 [=====] - 0s 8ms/step
 RNN Model RMSE: 0.13651257935427755
 RNN Model MAE: 0.10499357552363951
 RNN Model R-squared: -0.07902418723607973





```
[67]: # LSTM for Regression
import numpy as np
import pandas as pd
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, LSTM
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split

x_train_lstm = x_trainC.reshape((x_trainC.shape[0], x_trainC.shape[1], 1))
```

```

x_test_lstm = x_testC.reshape((x_testC.shape[0], x_testC.shape[1], 1))

# Build the LSTM model
model = Sequential([
    LSTM(50, activation='relu', input_shape=(x_train_lstm.shape[1], 1)),
    Dense(1)
])

model.compile(optimizer='adam', loss='mse')

# Train the model
model.fit(x_train_lstm, y_trainC, epochs=50, verbose=0)

# Predictions
predictions = model.predict(x_test_lstm).flatten()

# Calculate errors and metrics
MSE = mean_squared_error(y_testC, predictions)
RMSE = np.sqrt(MSE)
MAE = mean_absolute_error(y_testC, predictions)
R2 = r2_score(y_testC, predictions) # Calculate R-squared

# Print errors and metrics
print("LSTM Model MSE: ", MSE)
print("LSTM Model RMSE: ", RMSE)
print("LSTM Model MAE: ", MAE)
print("LSTM Model R-squared: ", R2) # Print R-squared value

# Plot results: Actual vs Predicted
x_axis = range(len(y_testC)) # Create a range for the x-axis equal to the length of y_testC
plt.figure(figsize=(15, 6))
plt.plot(x_axis, y_testC, color='blue', label='Actual')
plt.plot(x_axis, predictions, color='orange', linestyle='--', label='Predicted')
plt.title('LSTM Predictions vs Actual')
plt.xlabel('Index')
plt.ylabel('Value')
plt.legend()
plt.show()

# Residual Plot
residuals = y_testC - predictions
plt.figure(figsize=(15, 6))
plt.plot(x_axis, residuals, color='red', linestyle='--', marker='o')
plt.axhline(y=0, color='black', linestyle='--')
plt.title('Residual Plot')
plt.xlabel('Index')

```

```

plt.ylabel('Residuals')
plt.show()

# Prediction vs Actual Plot
plt.figure(figsize=(15, 6))
plt.scatter(y_testC, predictions, color='purple', alpha=0.6)
plt.plot([min(y_testC), max(y_testC)], [min(y_testC), max(y_testC)], color='black', linestyle='--')
plt.title('Prediction vs Actual')
plt.xlabel('Actual Values')
plt.ylabel('Predicted Values')
plt.show()

# Error Distribution Plot
plt.figure(figsize=(15, 6))
plt.hist(residuals, bins=30, color='orange', edgecolor='black')
plt.title('Error Distribution')
plt.xlabel('Prediction Error')
plt.ylabel('Frequency')
plt.show()

```

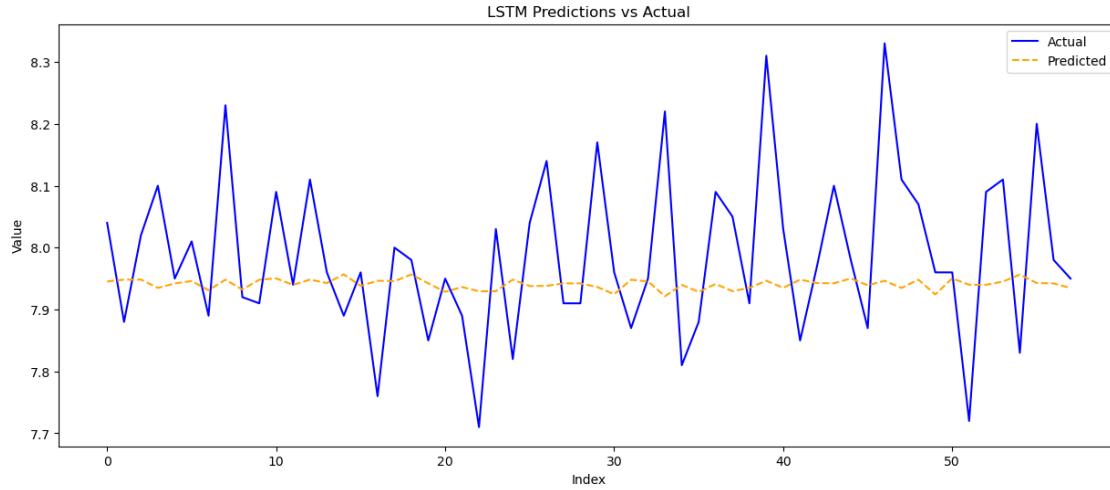
2/2 [=====] - 0s 5ms/step

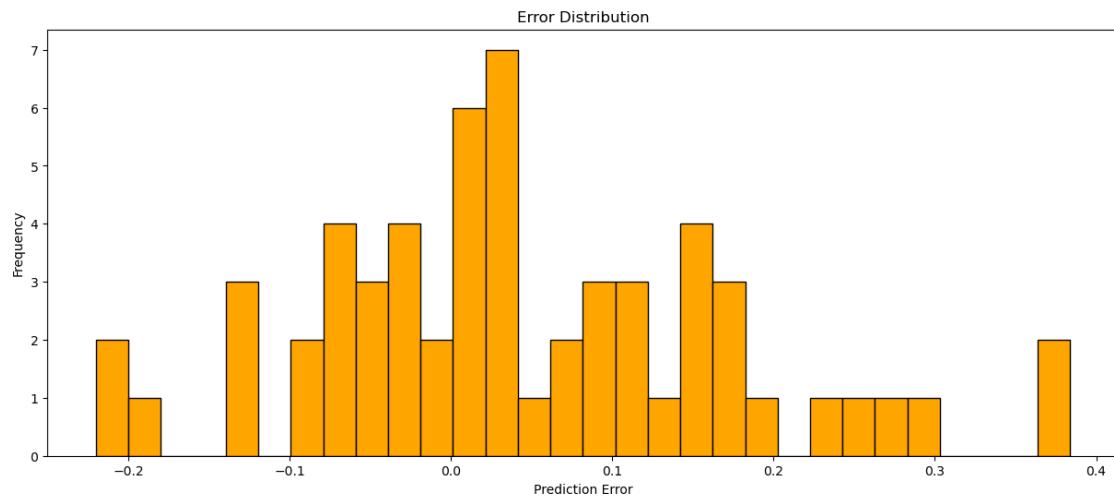
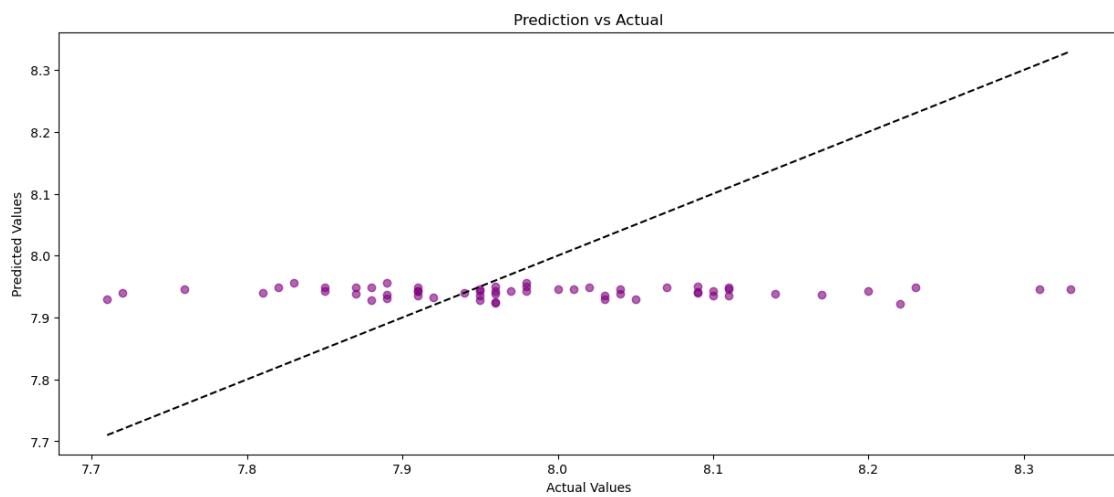
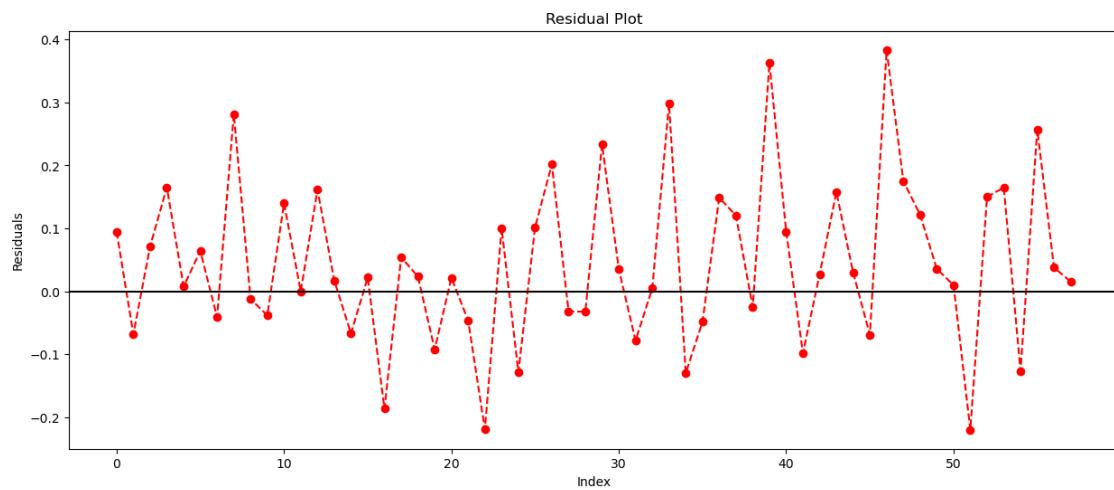
LSTM Model MSE: 0.019423571563830424

LSTM Model RMSE: 0.13936847406723812

LSTM Model MAE: 0.1060928568346747

LSTM Model R-squared: -0.12464362229988568





```
[68]: import matplotlib.pyplot as plt
import numpy as np

# Data from the table
models = [
    "Gradient Boosting Machines (GBMs)",
    "Decision trees",
    "Random Forest",
    "KNN",
    "LSTM",
    "SVM",
    "Recurrent Neural Networks (RNNs)"
]

rmse = [
    0.016640671,
    0.016638317,
    0.016583164,
    0.016454745,
    0.022266277,
    0.032430297,
    0.024276634
]

mae = [
    0.013125976,
    0.013123150,
    0.013006474,
    0.012965517,
    0.017613920,
    0.026551724,
    0.020573005
]

r_square = [
    0.425135927,
    0.424474383,
    0.422776767,
    0.362142662,
    -0.068001696,
    -0.237535626,
    -0.408704113
]
```

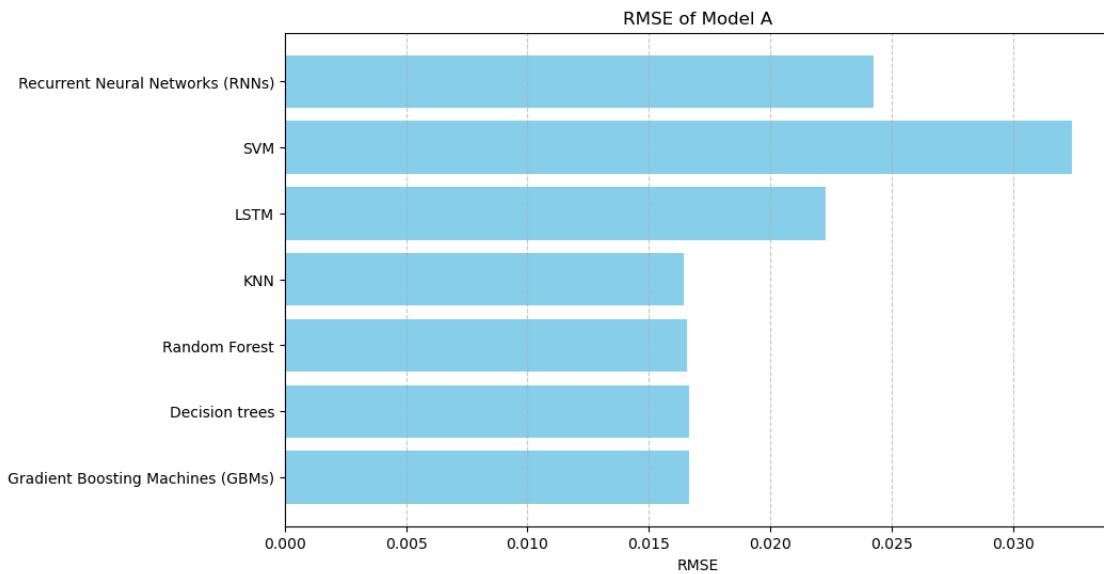
```

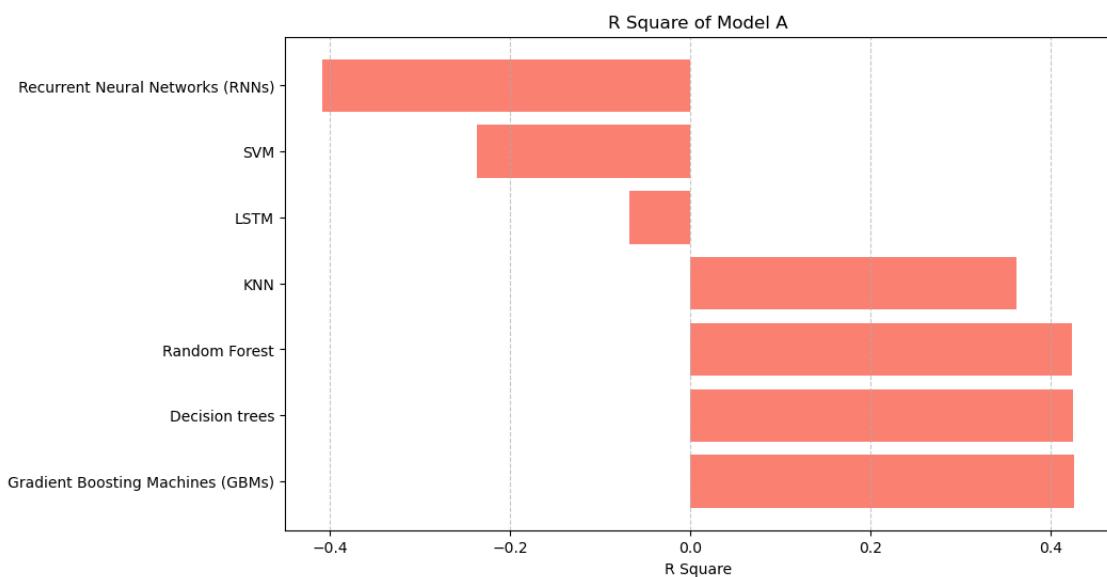
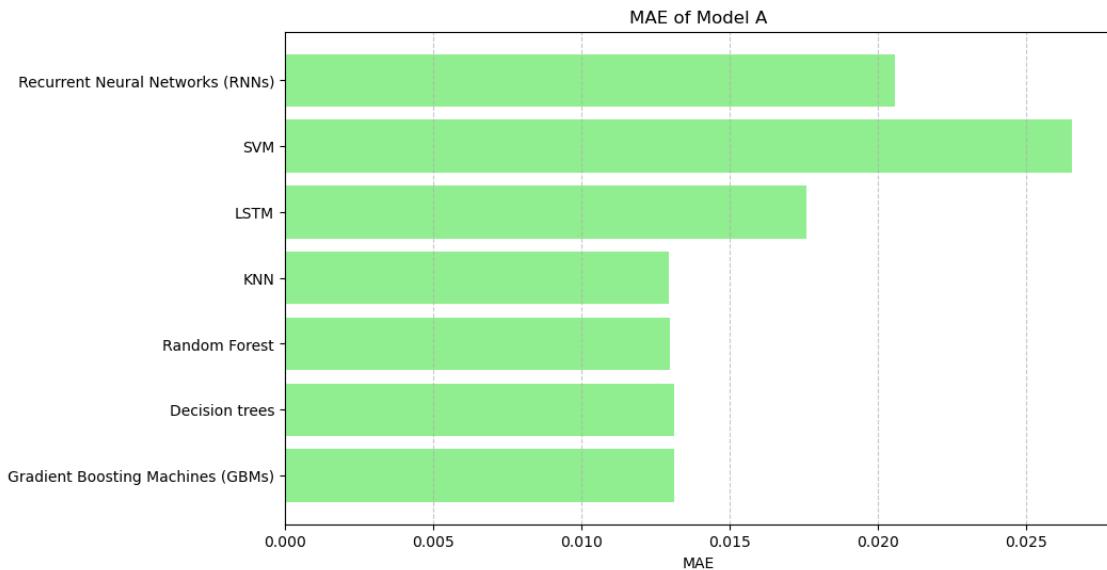
# Plot RMSE
plt.figure(figsize=(10, 6))
plt.barh(models, rmse, color='skyblue')
plt.xlabel('RMSE')
plt.title('RMSE of Model A')
plt.grid(axis='x', linestyle='--', alpha=0.7)
plt.show()

# Plot MAE
plt.figure(figsize=(10, 6))
plt.barh(models, mae, color='lightgreen')
plt.xlabel('MAE')
plt.title('MAE of Model A')
plt.grid(axis='x', linestyle='--', alpha=0.7)
plt.show()

# Plot R Square
plt.figure(figsize=(10, 6))
plt.barh(models, r_square, color='salmon')
plt.xlabel('R Square')
plt.title('R Square of Model A')
plt.grid(axis='x', linestyle='--', alpha=0.7)
plt.show()

```





```
[70]: import matplotlib.pyplot as plt
import numpy as np

# Data from Model B table
models_b = [
    "Gradient Boosting Machines (GBMs)",
    "Random Forest",
    "Recurrent Neural Networks (RNNs)",
```

```

    "LSTM",
    "SVM",
    "Decision trees",
    "KNN"
]

rmse_b = [
    0.155737491,
    0.136188764,
    0.128284086,
    0.162735338,
    0.146459802,
    0.133844340,
    0.136188764
]

mae_b = [
    0.127279013,
    0.127523051,
    0.155737491,
    0.125109669,
    0.114902777,
    0.103050629,
    0.107413793
]

r_square_b = [
    0.035453189,
    0.028818189,
    -0.107833272,
    -0.143255901,
    -0.204620327,
    -0.266931016,
    -0.465922072
]

# Plot RMSE for Model B
plt.figure(figsize=(10, 6))
plt.barh(models_b, rmse_b, color='skyblue')
plt.xlabel('RMSE')
plt.title('RMSE of (Model B)')
plt.grid(axis='x', linestyle='--', alpha=0.7)
plt.show()

# Plot MAE for Model B
plt.figure(figsize=(10, 6))
plt.barh(models_b, mae_b, color='lightgreen')

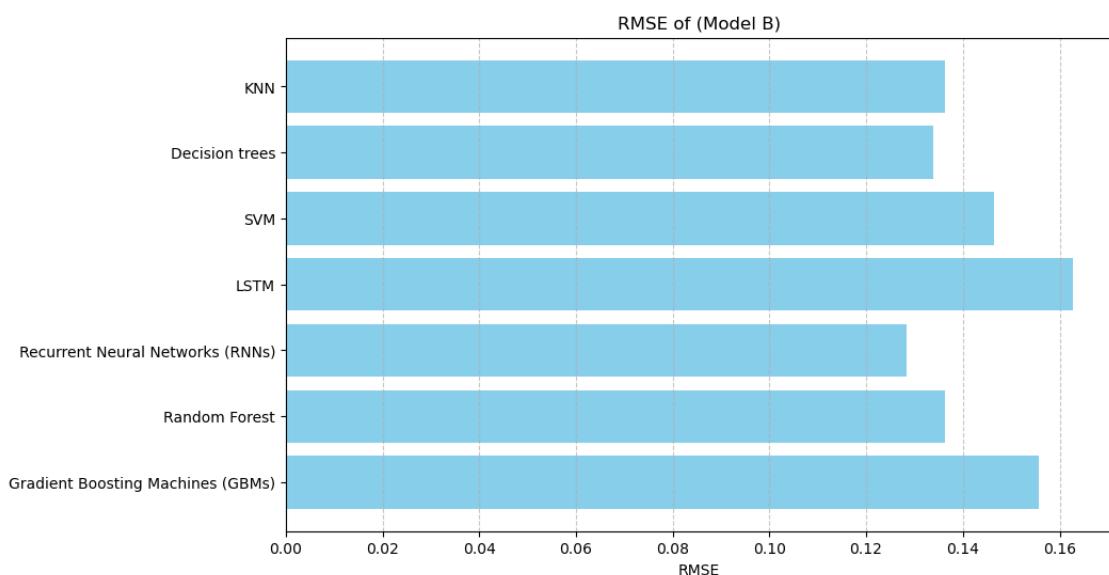
```

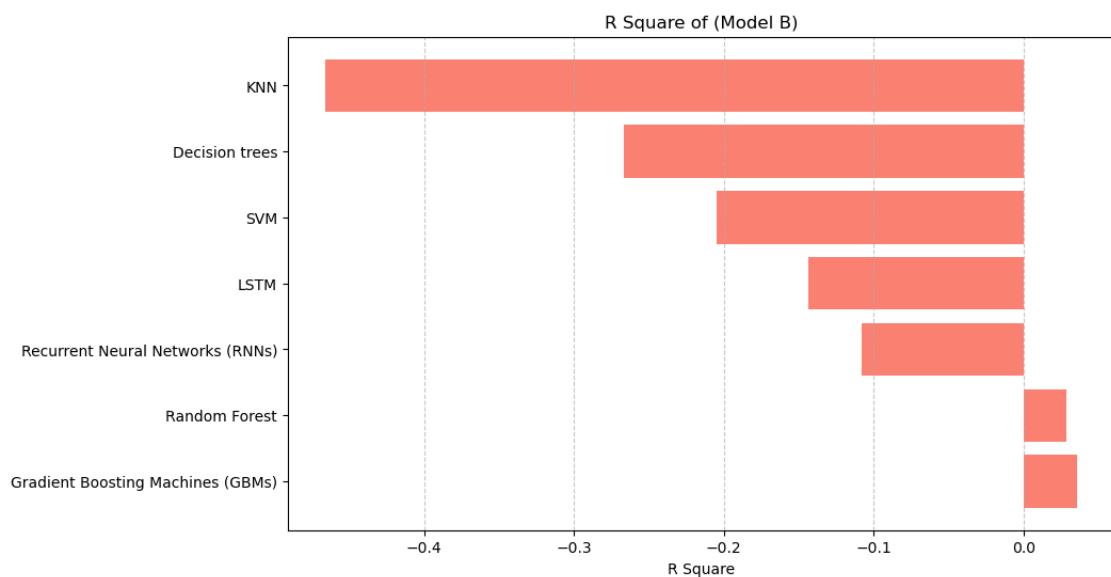
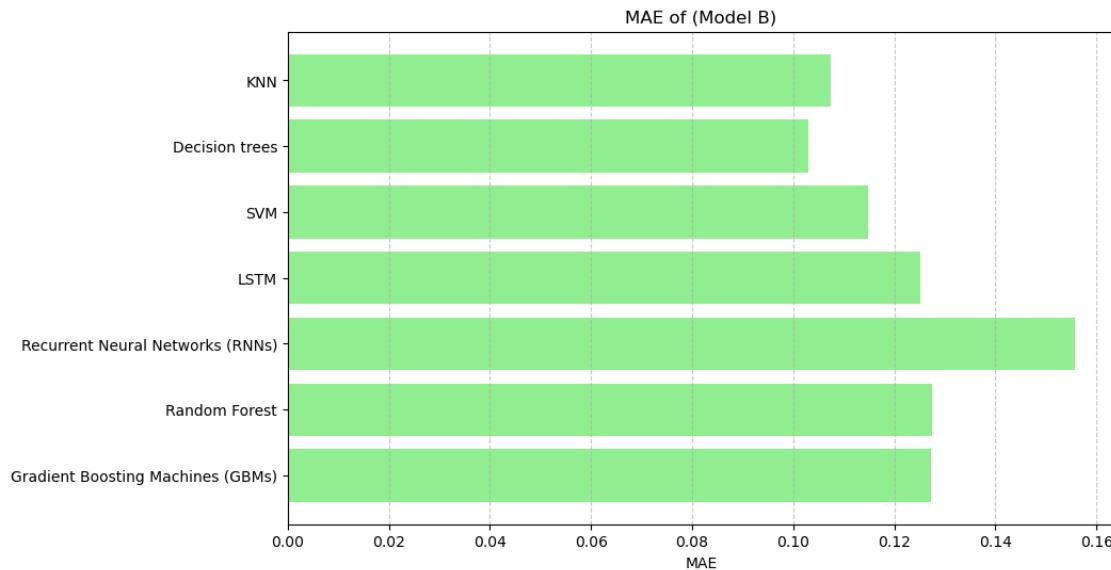
```

plt.xlabel('MAE')
plt.title('MAE of (Model B)')
plt.grid(axis='x', linestyle='--', alpha=0.7)
plt.show()

# Plot R Square for Model B
plt.figure(figsize=(10, 6))
plt.barh(models_b, r_square_b, color='salmon')
plt.xlabel('R Square')
plt.title('R Square of (Model B)')
plt.grid(axis='x', linestyle='--', alpha=0.7)
plt.show()

```





```
[71]: import matplotlib.pyplot as plt
import numpy as np

# Data from Model C table
models_c = [
    "SVM",
    "Random Forest",
    "Gradient Boosting Machines (GBMs)",
```

```

"Recurrent Neural Networks (RNNs)",
"LSTM",
"KNN",
"Decision trees"
]

rmse_c = [
0.178938004,
0.153905549,
0.161740008,
0.224147748,
0.219762408,
0.176847079,
0.185515330
]

mae_c = [
0.138179041,
0.123433300,
0.128571961,
0.168732614,
0.159230490,
0.137335376,
0.144908046
]

r_square_c = [
0.164740063,
0.058011682,
-0.040331826,
-0.079024187,
-0.124643622,
-0.148668229,
-0.653262054
]

# Plot RMSE for Model C
plt.figure(figsize=(10, 6))
plt.barh(models_c, rmse_c, color='skyblue')
plt.xlabel('RMSE')
plt.title('RMSE of (Model C)')
plt.grid(axis='x', linestyle='--', alpha=0.7)
plt.show()

# Plot MAE for Model C
plt.figure(figsize=(10, 6))
plt.barh(models_c, mae_c, color='lightgreen')

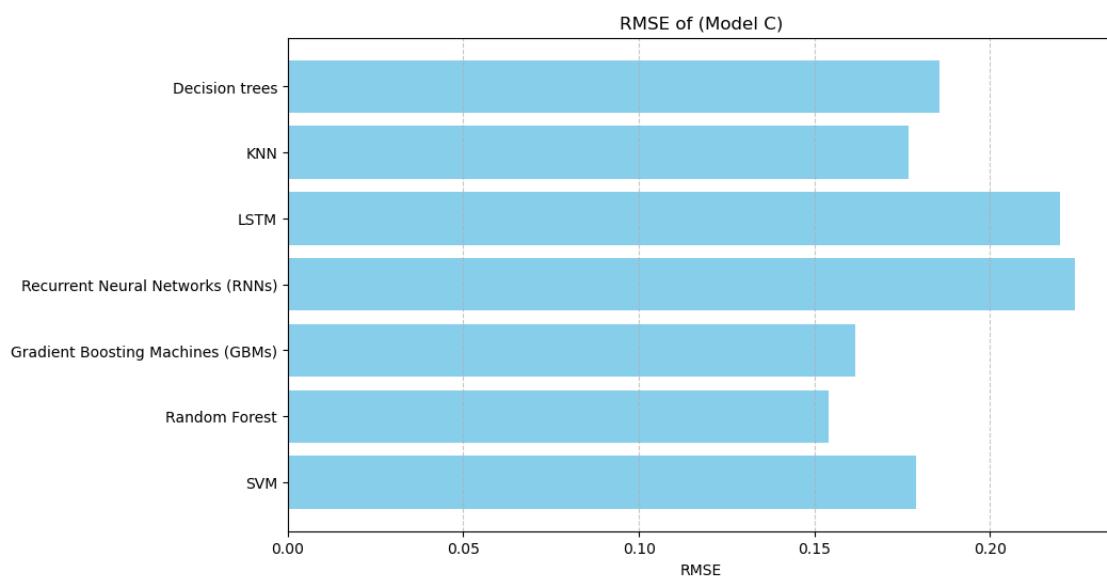
```

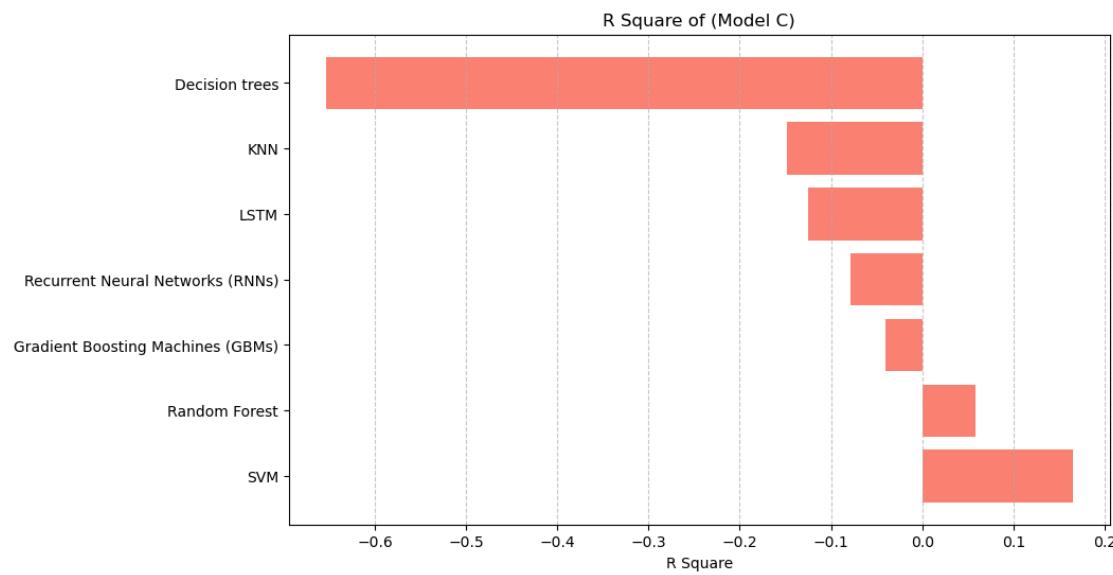
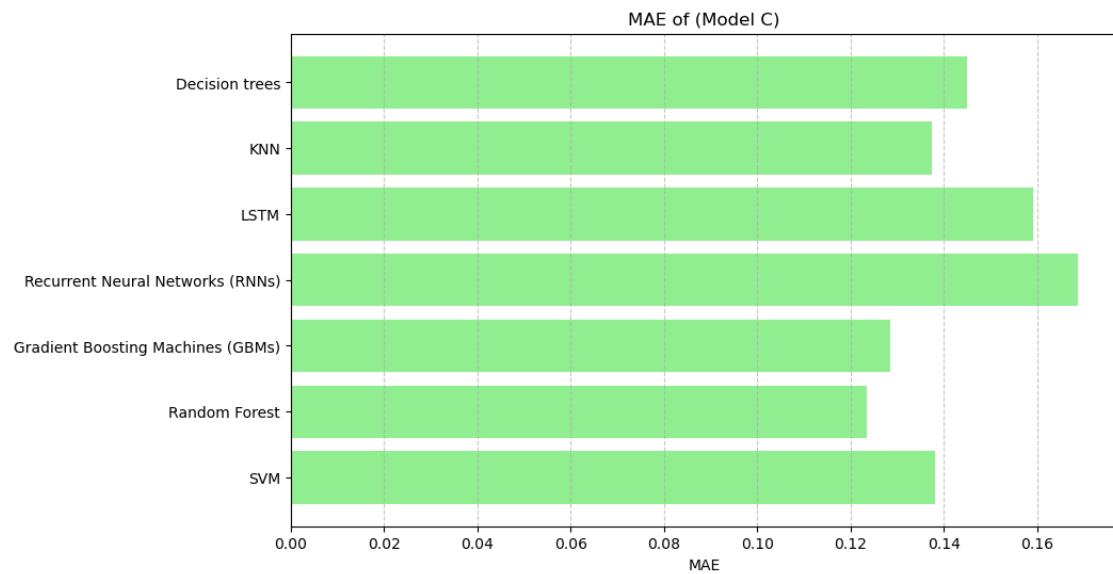
```

plt.xlabel('MAE')
plt.title('MAE of (Model C)')
plt.grid(axis='x', linestyle='--', alpha=0.7)
plt.show()

# Plot R Square for Model C
plt.figure(figsize=(10, 6))
plt.barh(models_c, r_square_c, color='salmon')
plt.xlabel('R Square')
plt.title('R Square of (Model C)')
plt.grid(axis='x', linestyle='--', alpha=0.7)
plt.show()

```





[]: