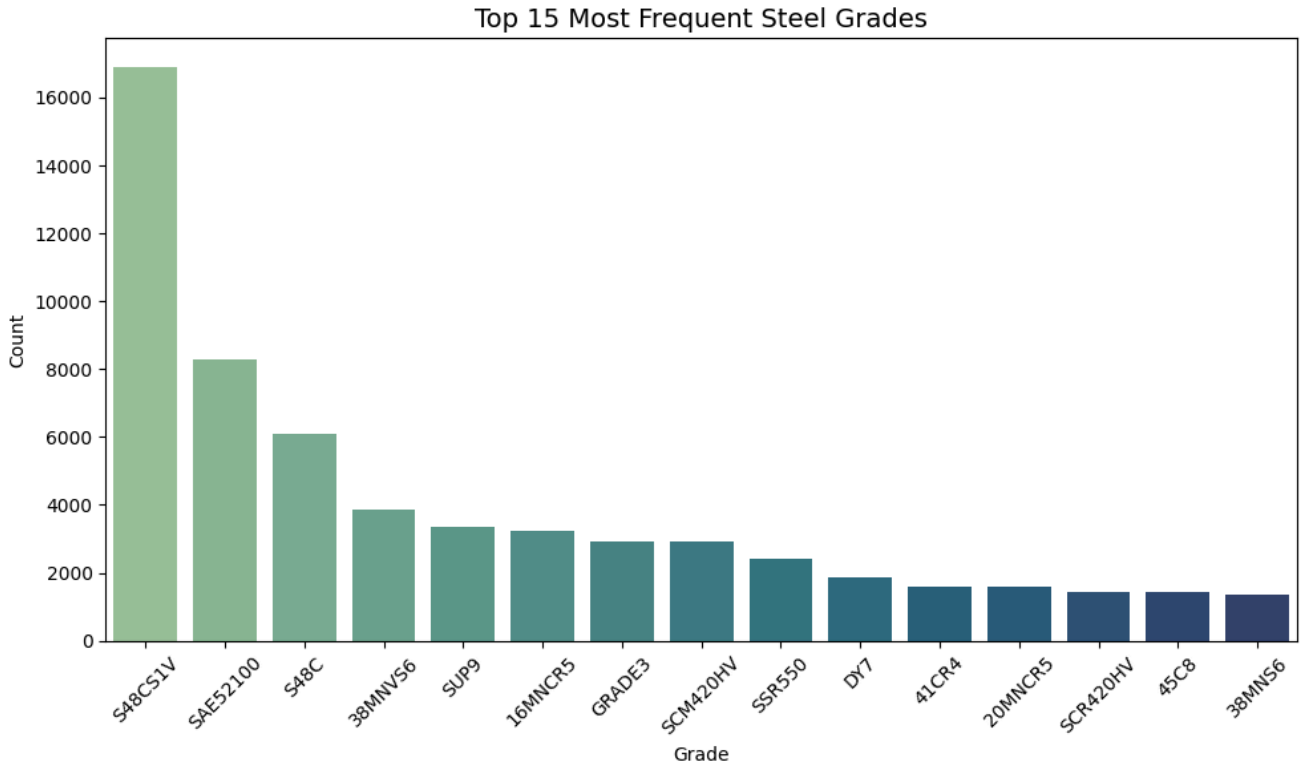
```
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt

# Load sheets
heat_df = pd.read_excel("/content/GRADE_PRODUCT_MIX.xlsx", sheet_name="HEAT_MASTER")
grade_df = pd.read_excel("/content/GRADE_PRODUCT_MIX.xlsx", sheet_name="GRADE_MASTER")

# Merge on Grade (FK → PK)
merged_df = pd.merge(heat_df, grade_df, on='GRADE', how='left')
```

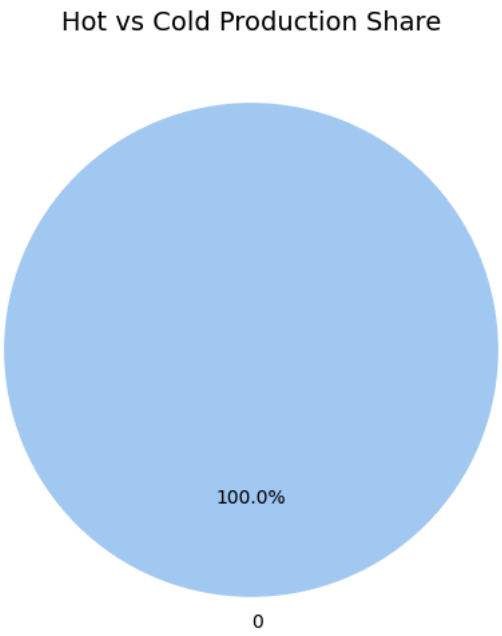
UNIVARIANT ANALYSIS

```
# GRADE — Frequency Distribution
# Goal: See which steel grades are most common.
plt.figure(figsize=(10,6))
top_grades = merged_df['GRADE'].value_counts().head(15)
sns.barplot(x=top_grades.index, y=top_grades.values, palette='crest')
plt.title("Top 15 Most Frequent Steel Grades", fontsize=14)
plt.xlabel("Grade")
plt.ylabel("Count")
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```

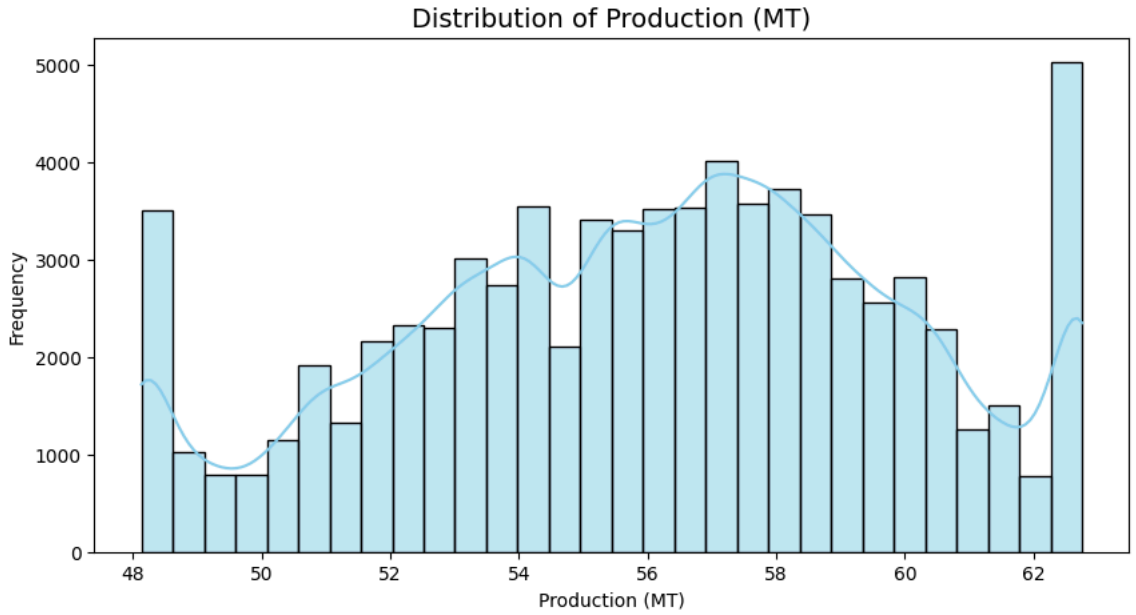
```
/tmp/ipython-input-2831103479.py:5: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set

  sns.barplot(x=top_grades.index, y=top_grades.values, palette='crest')
```

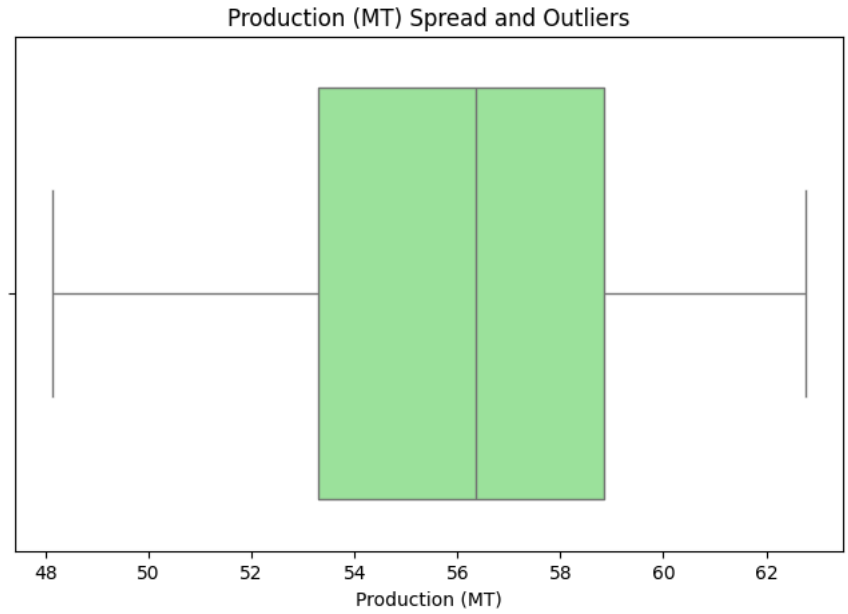



```
# HOT_COLD — Production Type Mix
# Goal: See share of hot vs cold production.
plt.figure(figsize=(6,6))
merged_df['HOT_COLD'].value_counts().plot.pie(
    autopct='%1.1f%%', colors=sns.color_palette('pastel'), startangle=90
)
plt.title("Hot vs Cold Production Share", fontsize=14)
plt.ylabel("")
plt.show()
```

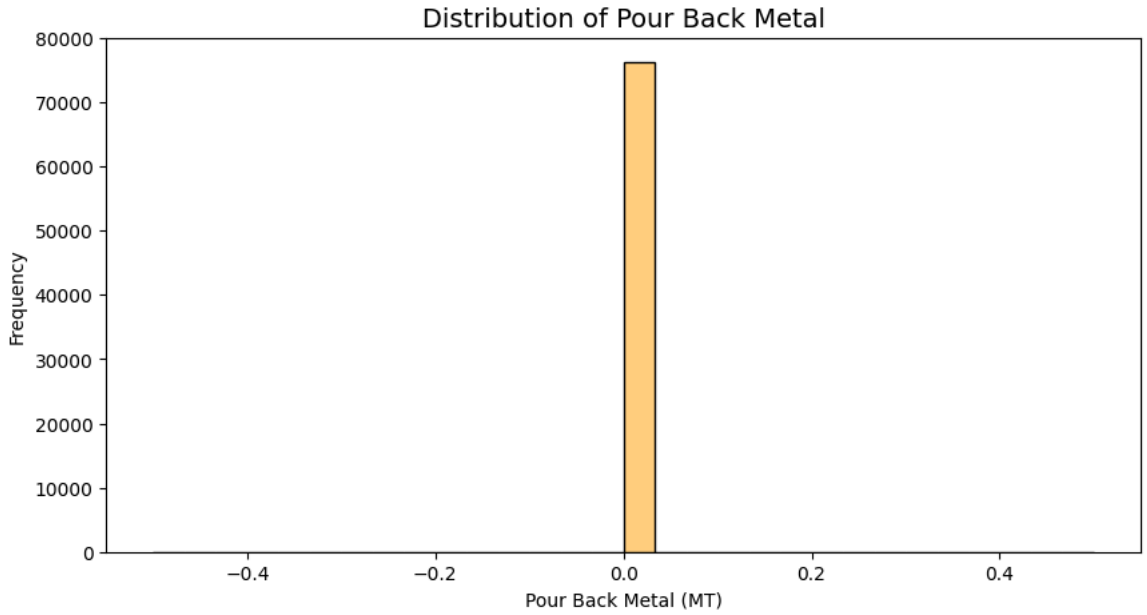



```
# Production (MT) – Distribution
# Goal: Understand average production and outliers.
plt.figure(figsize=(10,5))
sns.histplot(merged_df['Production (MT)'], kde=True, color='skyblue', bins=30)
plt.title("Distribution of Production (MT)", fontsize=14)
plt.xlabel("Production (MT)")
plt.ylabel("Frequency")
plt.show()

plt.figure(figsize=(8,5))
sns.boxplot(x=merged_df['Production (MT)'], color='lightgreen')
plt.title("Production (MT) Spread and Outliers")
plt.xlabel("Production (MT)")
plt.show()
```

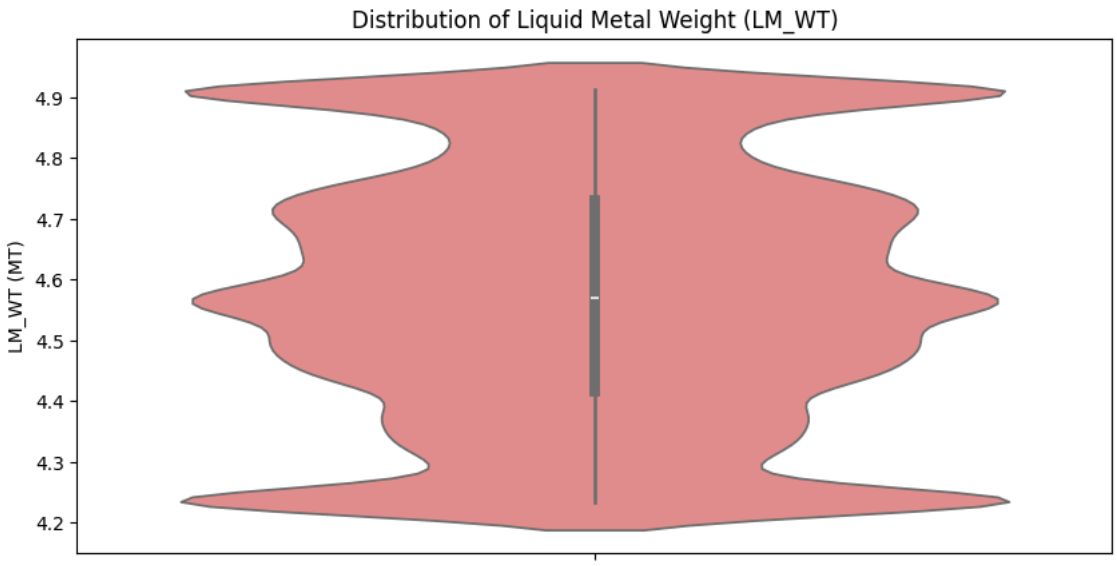





```
# Pour_Back_Metal – Process Recovery
# Goal: See how much metal is poured back on average.
plt.figure(figsize=(10,5))
sns.histplot(merged_df['Pour_Back_Metal'], kde=True, bins=30, color='orange')
plt.title("Distribution of Pour Back Metal", fontsize=14)
plt.xlabel("Pour Back Metal (MT)")
plt.ylabel("Frequency")
plt.show()
```

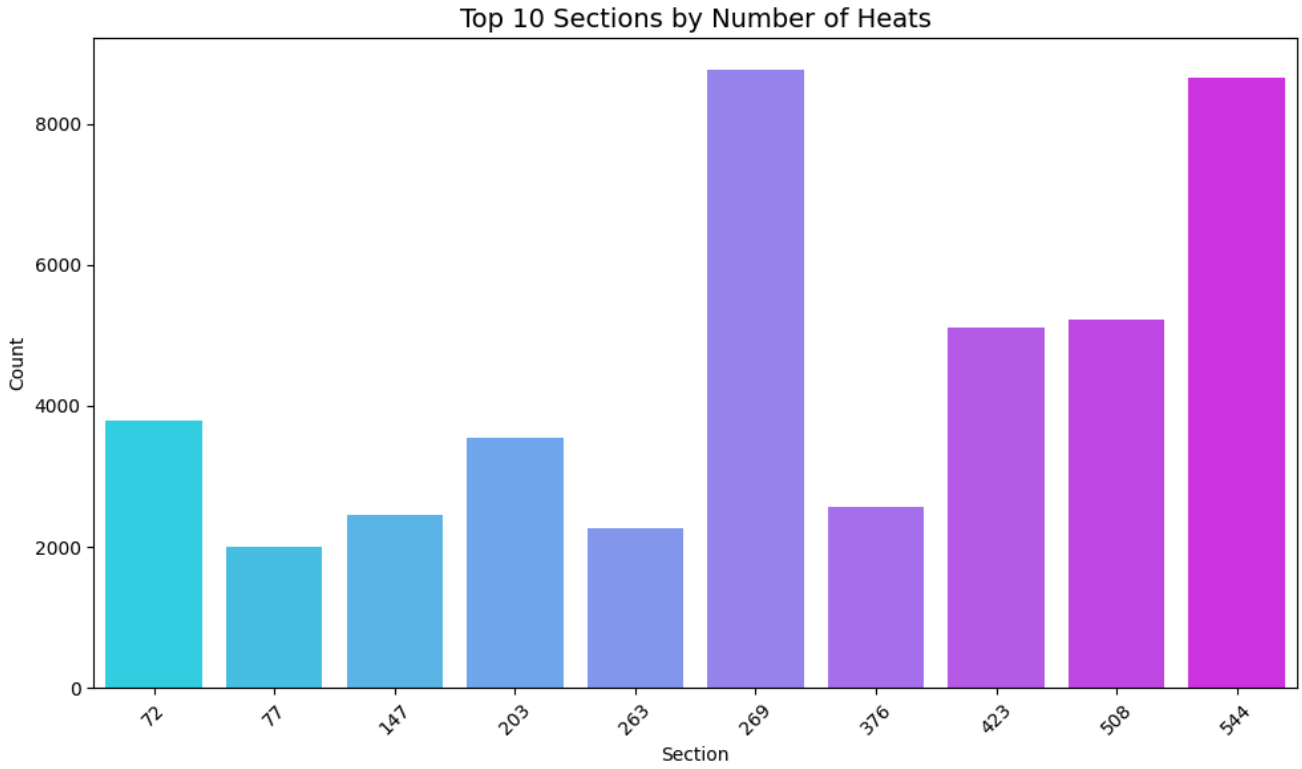



```
# LM_WT — Liquid Metal Weight Distribution
# Goal: Variation in metal weight per heat.
plt.figure(figsize=(10,5))
sns.violinplot(y='LM_WT', data=merged_df, color='lightcoral')
plt.title("Distribution of Liquid Metal Weight (LM_WT)")
plt.ylabel("LM_WT (MT)")
plt.show()
```



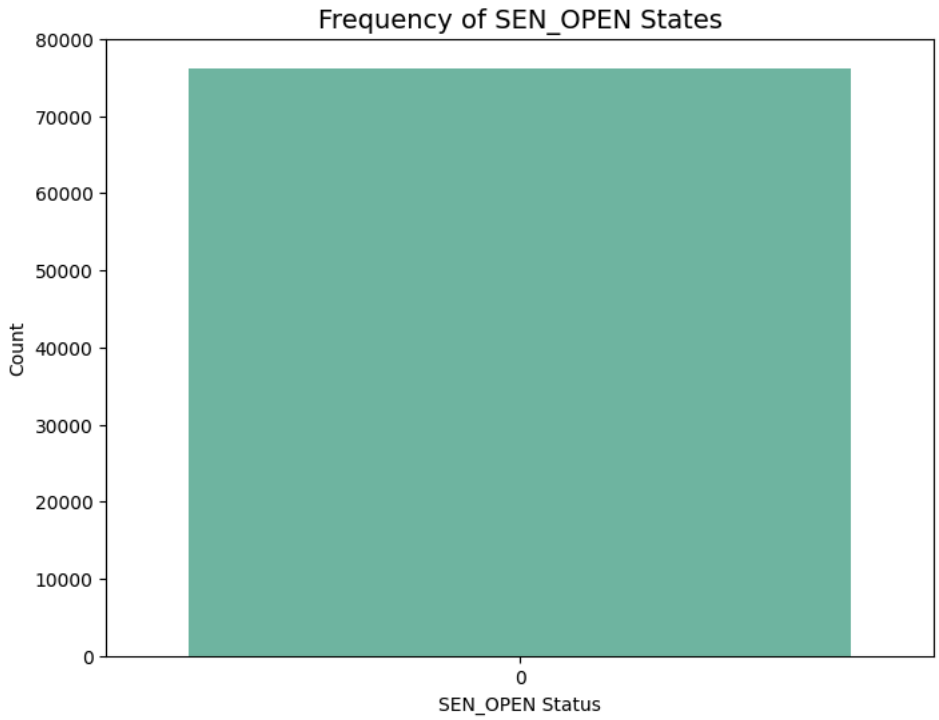

```
# SECTION — Production by Section
# Goal: Identify which section contributes most.
plt.figure(figsize=(10,6))
section_counts = merged_df['SECTION'].value_counts().head(10)
sns.barplot(x=section_counts.index, y=section_counts.values, palette='cool')
plt.title("Top 10 Sections by Number of Heats", fontsize=14)
plt.xlabel("Section")
plt.ylabel("Count")
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```

```
/tmp/ipython-input-3652185239.py:5: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set

  sns.barplot(x=section_counts.index, y=section_counts.values, palette='cool')
```




```
# SEN_OPEN – Operational Frequency
# Goal: Check if SEN openings are consistent.
plt.figure(figsize=(8,6))
sns.countplot(x='SEN_OPEN', data=merged_df, palette='Set2')
plt.title("Frequency of SEN_OPEN States", fontsize=14)
plt.xlabel("SEN_OPEN Status")
plt.ylabel("Count")
plt.show()
```

```
/tmp/ipython-input-1748194203.py:4: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set

  sns.countplot(x='SEN_OPEN', data=merged_df, palette='Set2')
```

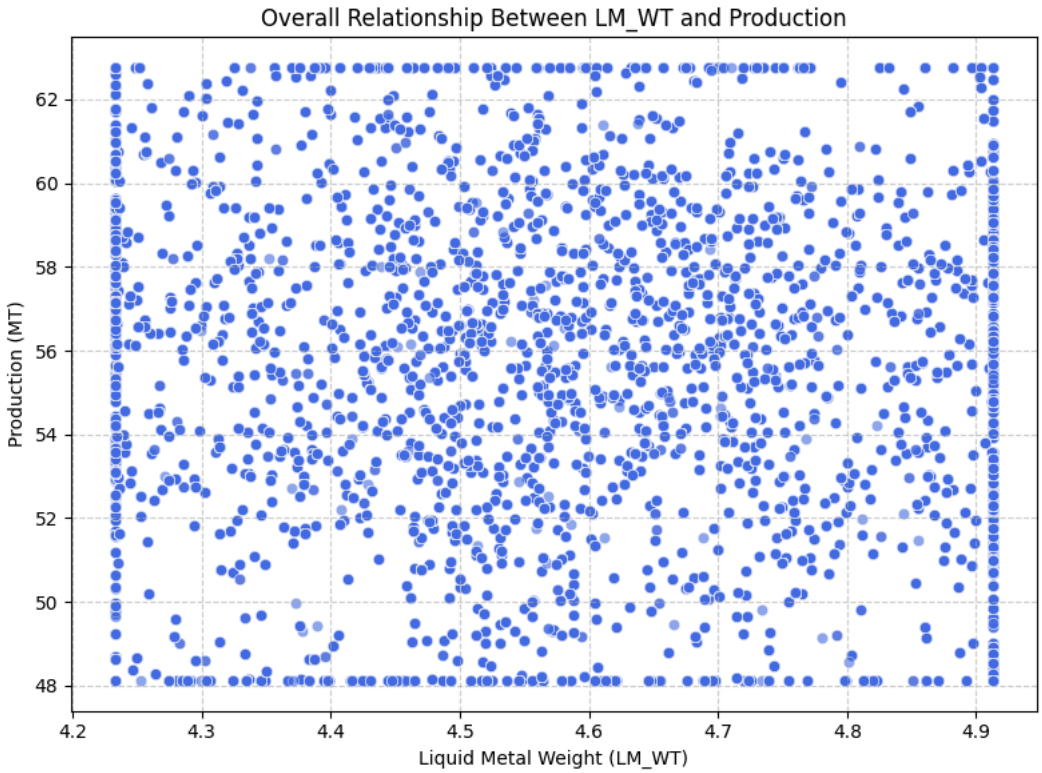


```
# SECTION_IC — Frequency Distribution

# Goal: Understand variation in internal code or section index.
plt.figure(figsize=(10,6))
sns.countplot(x='SECTION_IC', data=merged_df, palette='viridis')
plt.title("Distribution of SECTION_IC Values", fontsize=14)
plt.xlabel("SECTION_IC")
plt.ylabel("Count")
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```

```
/tmp/ipython-input-3989999945.py:5: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set

  sns.countplot(x='SECTION_IC', data=merged_df, palette='viridis')
```

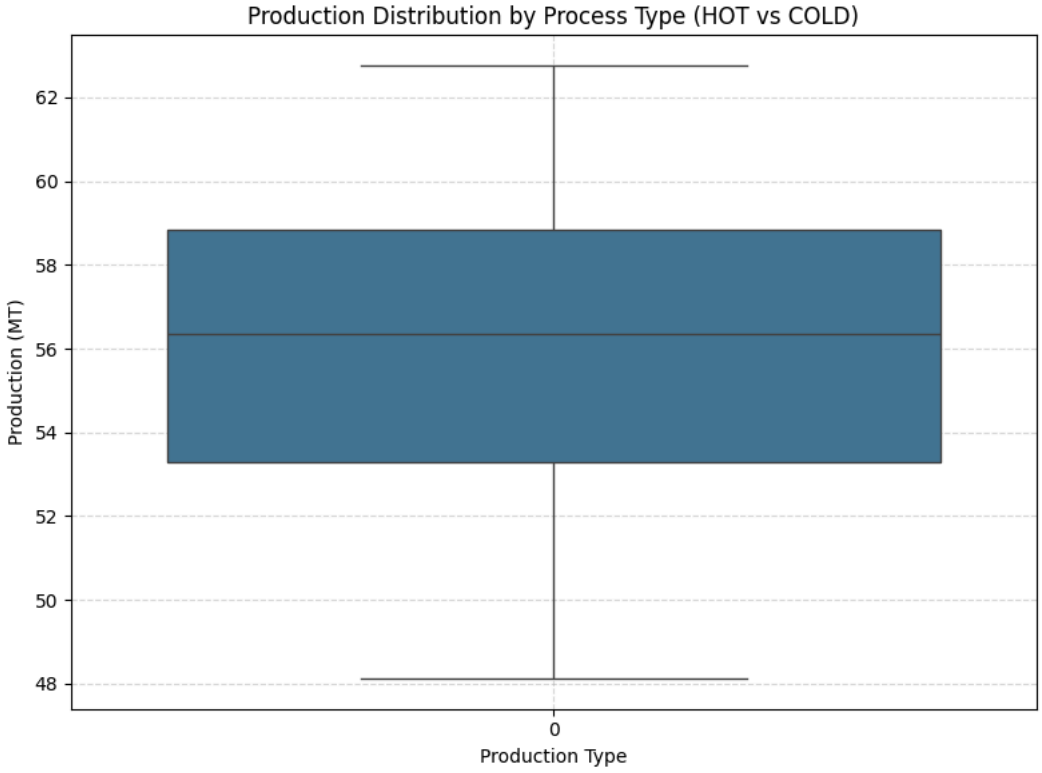
Bivariate Analysis

```
#LM_WT vs Production (MT)


plt.figure(figsize=(8,6))
sns.scatterplot(data=merged_df, x='LM_WT', y='Production (MT)', color='royalblue', alpha=0.6)
plt.title("Overall Relationship Between LM_WT and Production")
plt.xlabel("Liquid Metal Weight (LM_WT)")
plt.ylabel("Production (MT)")
plt.grid(True, linestyle='--', alpha=0.6)
plt.tight_layout()
plt.show()
```



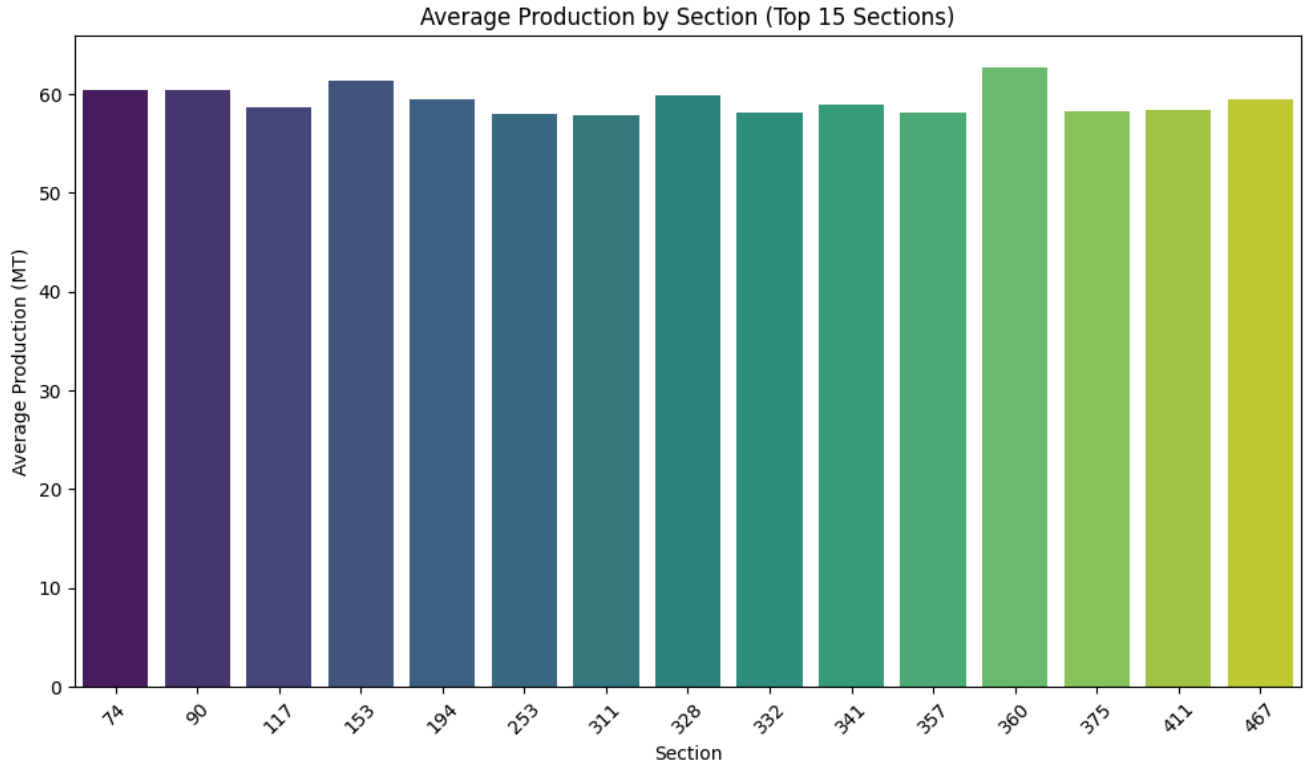

```
#  HOT_COLD vs Production (MT)

plt.figure(figsize=(8,6))
sns.boxplot(data=merged_df, x='HOT_COLD', y='Production (MT)', palette='mako')
plt.title("Production Distribution by Process Type (HOT vs COLD)")
plt.xlabel("Production Type")
plt.ylabel("Production (MT)")
plt.grid(True, linestyle='--', alpha=0.5)
plt.tight_layout()
plt.show()
```

```
/tmp/ipython-input-939156510.py:5: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set

  sns.boxplot(data=merged_df, x='HOT_COLD', y='Production (MT)', palette='mako')
```

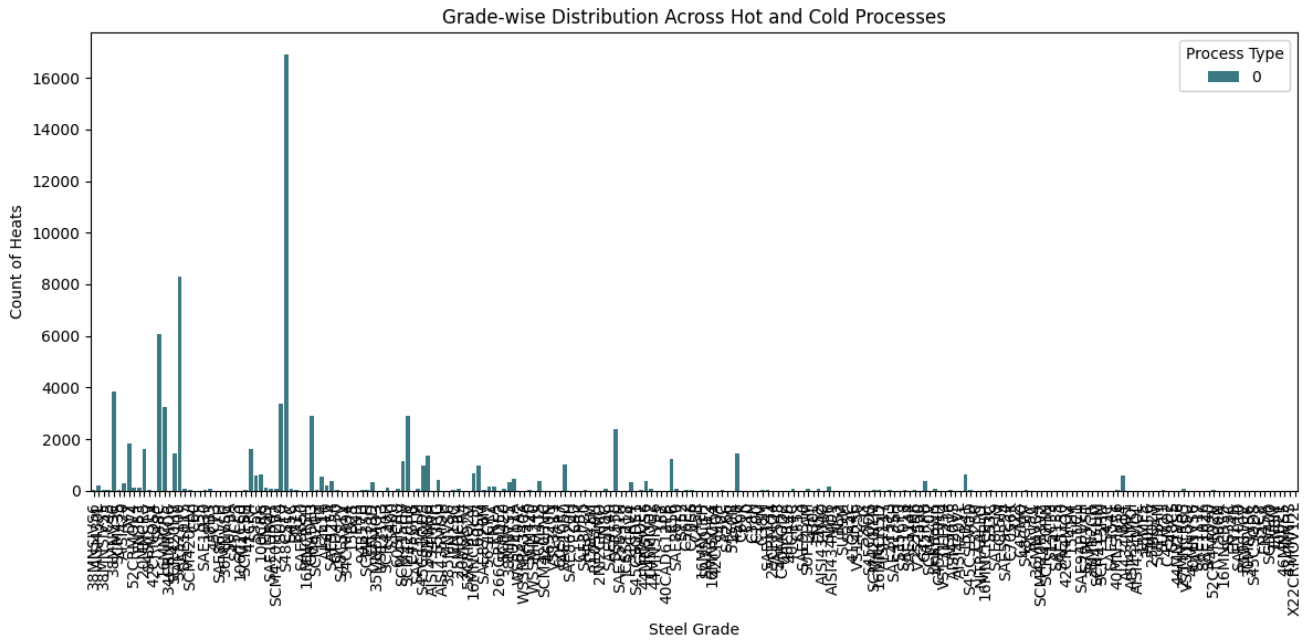


```
# SECTION vs Production (MT)

section_prod = merged_df.groupby('SECTION')['Production (MT)'].mean().sort_values(ascending=False).head(15)
plt.figure(figsize=(10,6))
sns.barplot(x=section_prod.index, y=section_prod.values, palette='viridis')
plt.title("Average Production by Section (Top 15 Sections)")
plt.xlabel("Section")
plt.ylabel("Average Production (MT)")
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```

```
/tmp/ipython-input-3719066492.py:6: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set

  sns.barplot(x=section_prod.index, y=section_prod.values, palette='viridis')
```

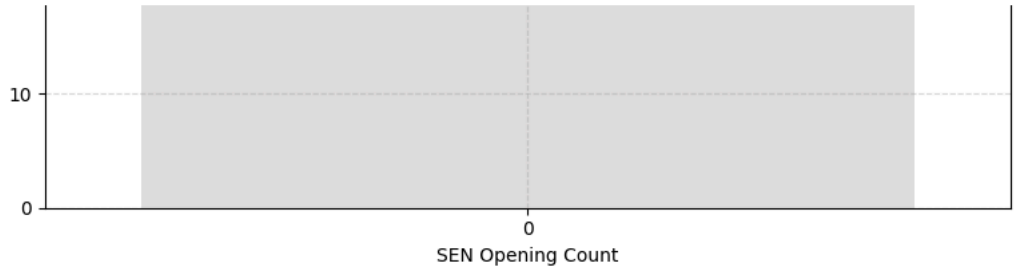



```
#  GRADE vs HOT_COLD (Categorical Relationship)

plt.figure(figsize=(12,6))
sns.countplot(data=merged_df, x='GRADE', hue='HOT_COLD', palette='crest')
plt.title("Grade-wise Distribution Across Hot and Cold Processes")
plt.xlabel("Steel Grade")
plt.ylabel("Count of Heats")
plt.xticks(rotation=90)
plt.legend(title='Process Type')
plt.tight_layout()
plt.show()
```

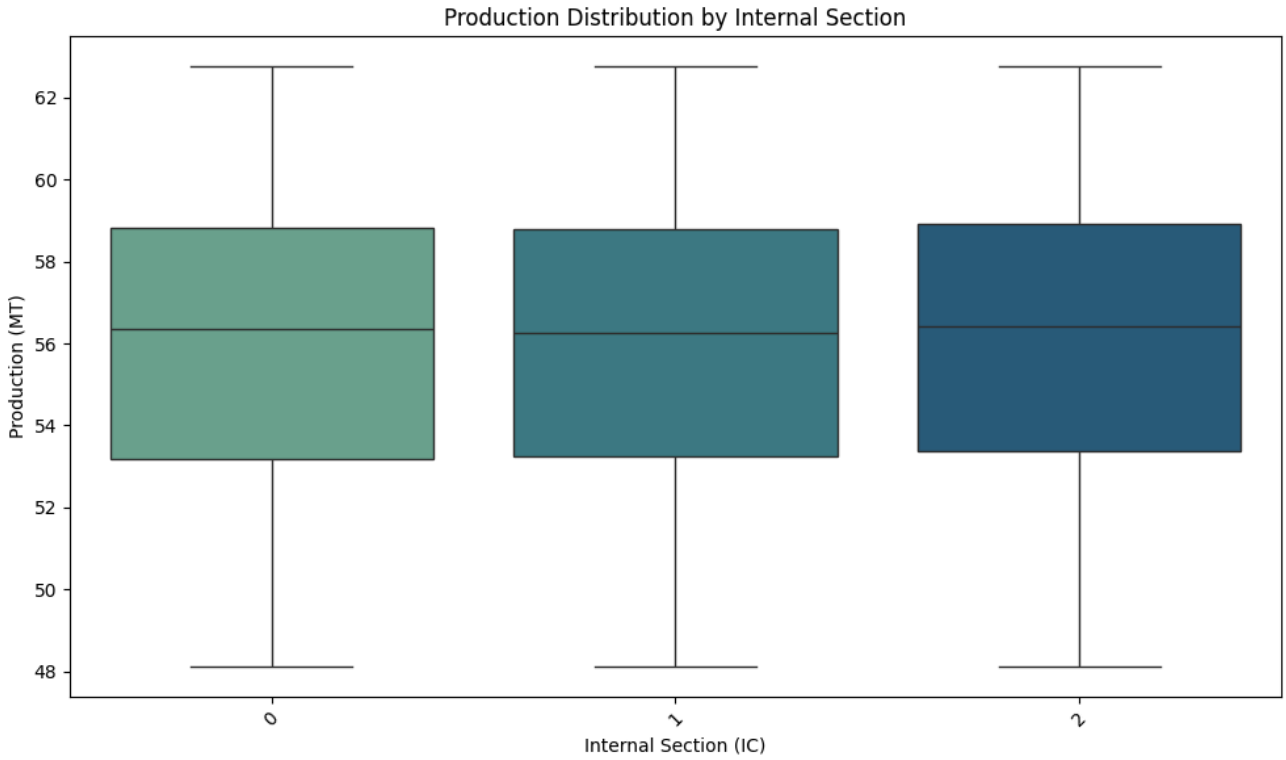



```
#  SEN_OPEN vs Production (MT)

plt.figure(figsize=(8,6))
sns.barplot(data=merged_df, x='SEN_OPEN', y='Production (MT)', palette='coolwarm')
plt.title("Impact of SEN Opening on Production")
plt.xlabel("SEN Opening Count")
plt.ylabel("Average Production (MT)")
plt.grid(True, linestyle='--', alpha=0.5)
plt.tight_layout()
plt.show()
```

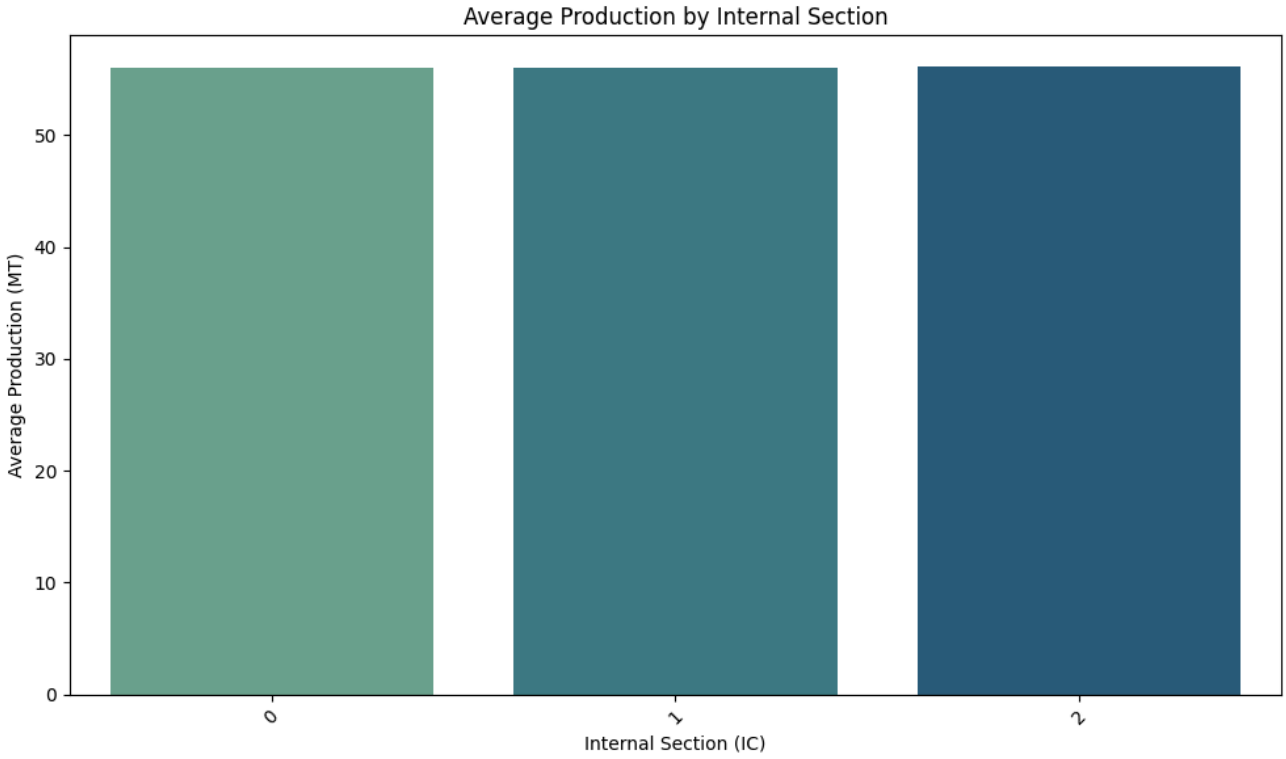
```
/tmp/ipython-input-3578697660.py:5: FutureWarning:


#SECTION_IC vs Production (MT)

plt.figure(figsize=(10,6))
sns.boxplot(data=merged_df, x='SECTION_IC', y='Production (MT)', palette='crest')
plt.title("Production Distribution by Internal Section")
plt.xlabel("Internal Section (IC)")
plt.ylabel("Production (MT)")
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()

plt.figure(figsize=(10,6))
avg_prod = merged_df.groupby('SECTION_IC')['Production (MT)'].mean().reset_index()

sns.barplot(data=avg_prod, x='SECTION_IC', y='Production (MT)', palette='crest')
plt.title("Average Production by Internal Section")
plt.xlabel("Internal Section (IC)")
plt.ylabel("Average Production (MT)")
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```



```
/tmp/ipython-input-3155063354.py:5: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and se

  sns.boxplot(data=merged_df, x='SECTION_IC', y='Production (MT)', palette='crest')
```



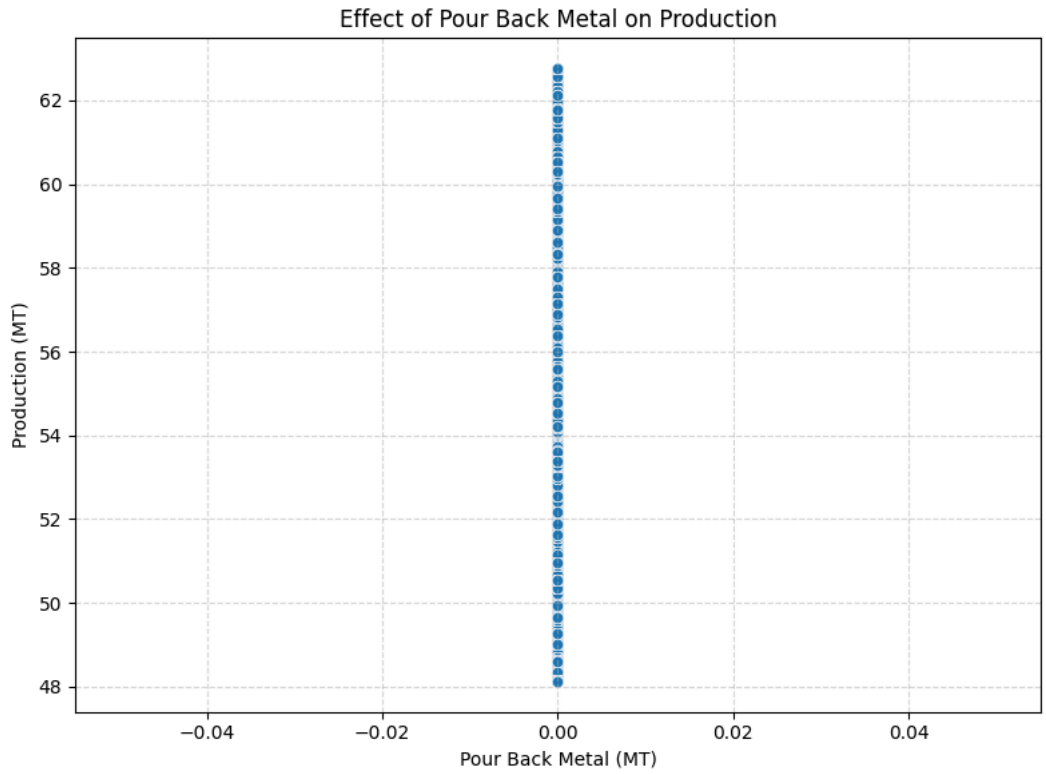

```
/tmp/ipython-input-3155063354.py:16: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and se

  sns.barplot(data=avg_prod, x='SECTION_IC', y='Production (MT)', palette='crest')
```



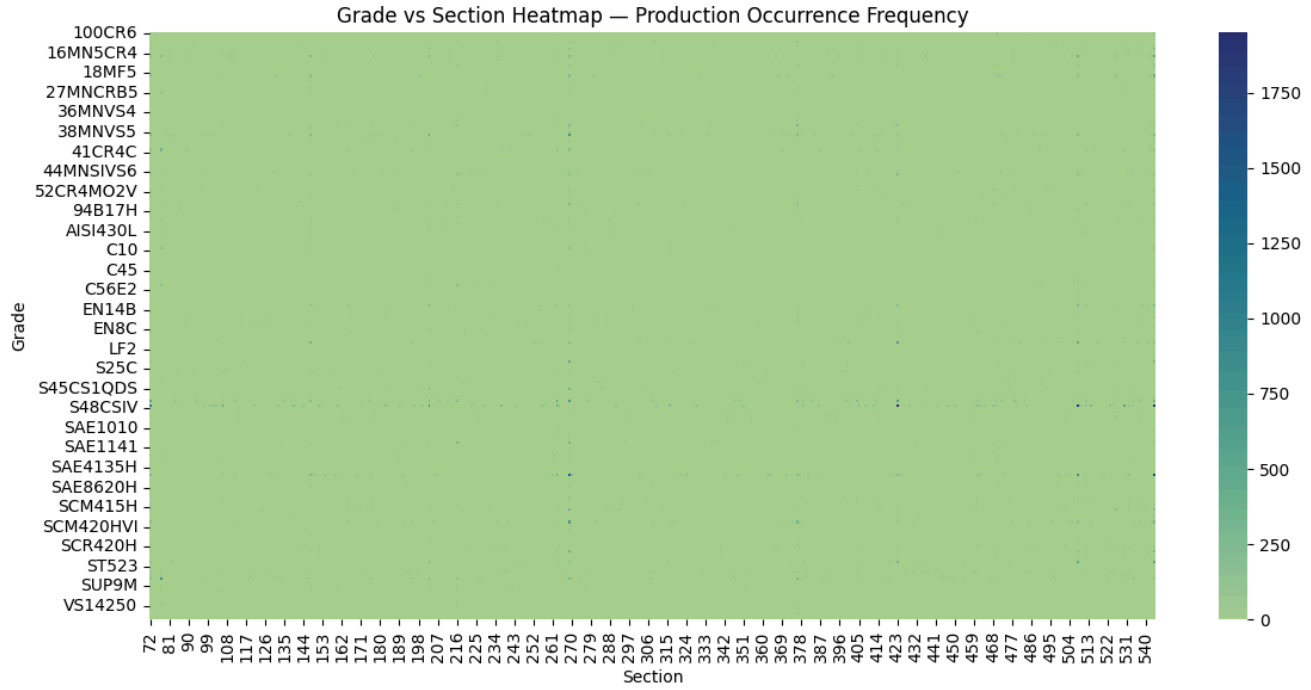

```
# Pour_Back_Metal vs Production (MT)


plt.figure(figsize=(8,6))
sns.scatterplot(
    data=merged_df,
    x='Pour_Back_Metal',
    y='Production (MT)',
```

```
    palette='magma',
    alpha=0.7
)

plt.title("Effect of Pour Back Metal on Production")
plt.xlabel("Pour Back Metal (MT)")
plt.ylabel("Production (MT)")
plt.grid(True, linestyle='--', alpha=0.5)
plt.tight_layout()
plt.show()
```

```
/tmp/ipython-input-3286894681.py:9: UserWarning: Ignoring `palette` because no `hue` variable has been assigned.
  sns.scatterplot(
```



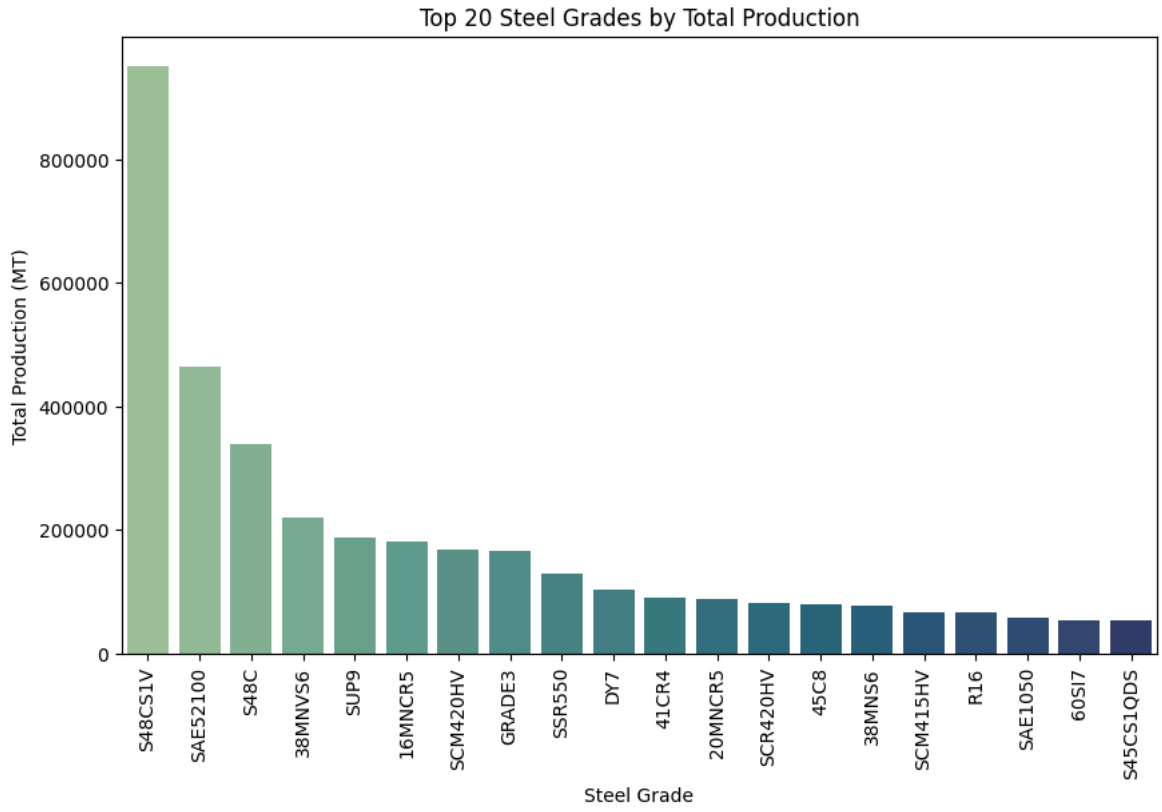

```
# GRADE vs SECTION (Heatmap)
grade_section = pd.crosstab(merged_df['GRADE'], merged_df['SECTION'])
plt.figure(figsize=(12,6))
sns.heatmap(grade_section, cmap='crest', cbar=True)
plt.title("Grade vs Section Heatmap — Production Occurrence Frequency")
plt.xlabel("Section")
plt.ylabel("Grade")
plt.tight_layout()
plt.show()
```



Double-click (or enter) to edit

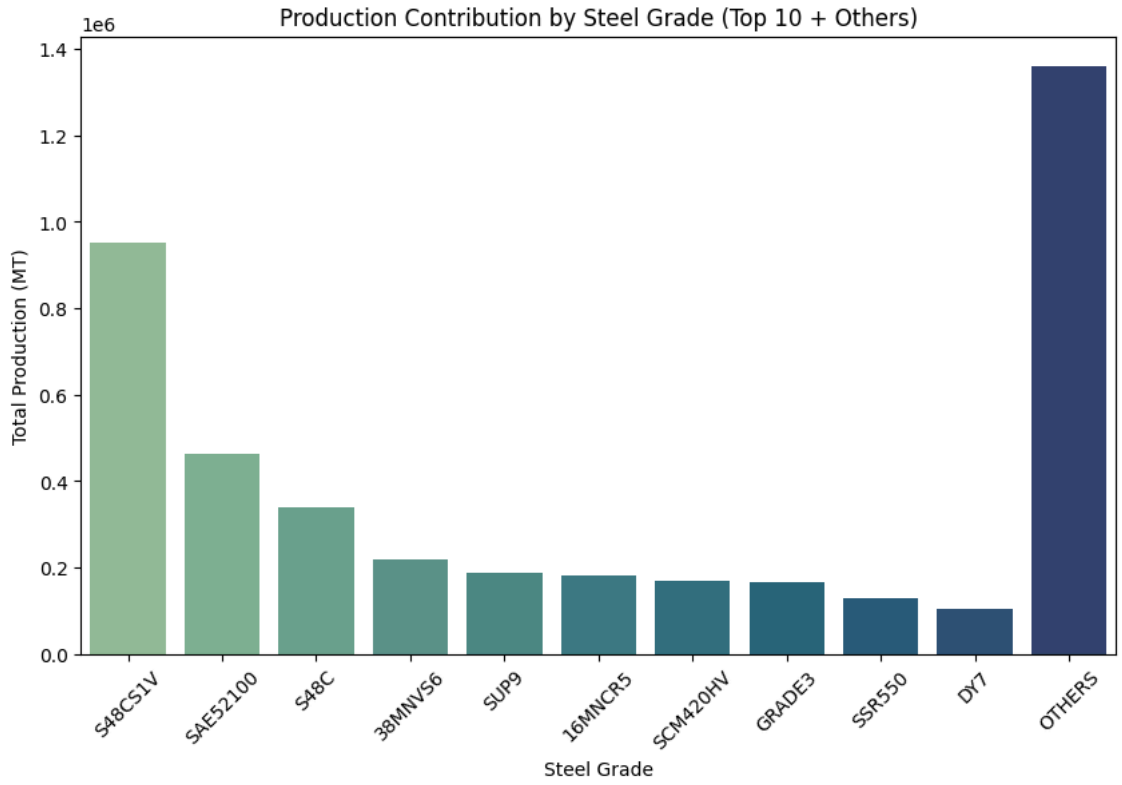
```
# Grade-wise Production Analysis
top_grades = merged_df.groupby('GRADE')['Production (MT)'].sum().nlargest(20).reset_index()

plt.figure(figsize=(10,6))
sns.barplot(data=top_grades, x='GRADE', y='Production (MT)', palette='crest')
plt.title("Top 20 Steel Grades by Total Production")
plt.xlabel("Steel Grade")
plt.ylabel("Total Production (MT)")
plt.xticks(rotation=90)
plt.show()
```

```
/tmp/ipython-input-881170174.py:4: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set

  sns.barplot(data=top_grades, x='GRADE', y='Production (MT)', palette='crest')
```

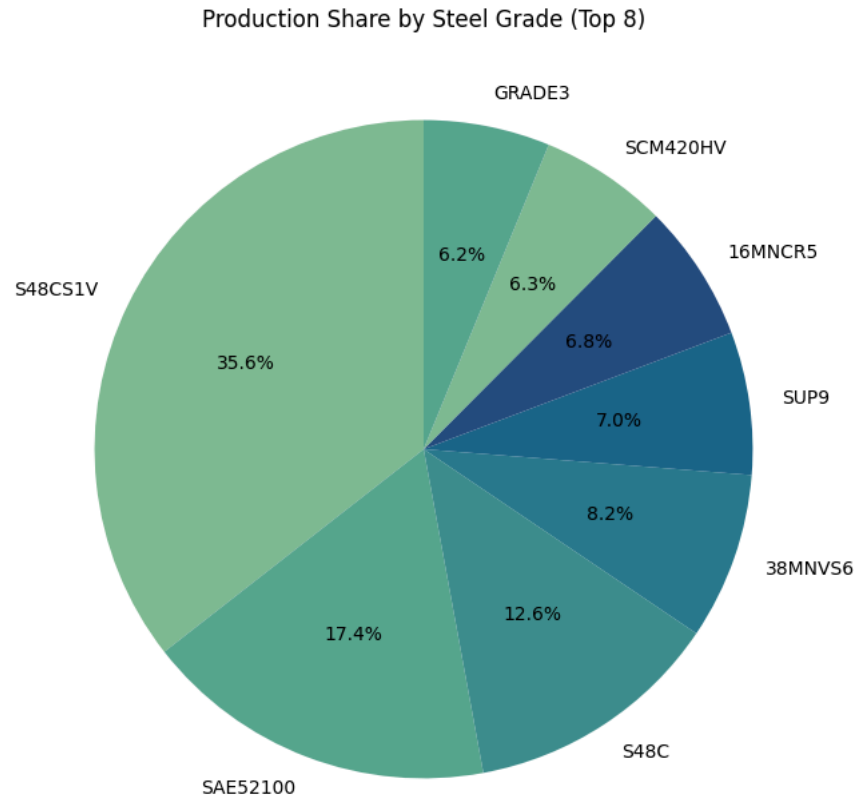



```
import matplotlib.pyplot as plt

# Replace column name if necessary
grade_totals = merged_df.groupby('GRADE')['Production (MT)'].sum().sort_values(ascending=False)

# Top 10 grades
top10 = grade_totals.head(10)

# Combine the rest as "OTHERS"
others = grade_totals[10:].sum()

# Use concat instead of append
grade_summary = pd.concat([top10, pd.Series({'OTHERS': others})]).reset_index()

# Rename columns for plotting clarity
grade_summary.columns = ['GRADE', 'Production (MT)']

# Plot
plt.figure(figsize=(10,6))
sns.barplot(data=grade_summary, x='GRADE', y='Production (MT)', palette='crest')
plt.title("Production Contribution by Steel Grade (Top 10 + Others)")
plt.xlabel("Steel Grade")
plt.ylabel("Total Production (MT)")
plt.xticks(rotation=45)
plt.show()
```

```
/tmp/ipython-input-292851819.py:20: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set

  sns.barplot(data=grade_summary, x='GRADE', y='Production (MT)', palette='crest')
```

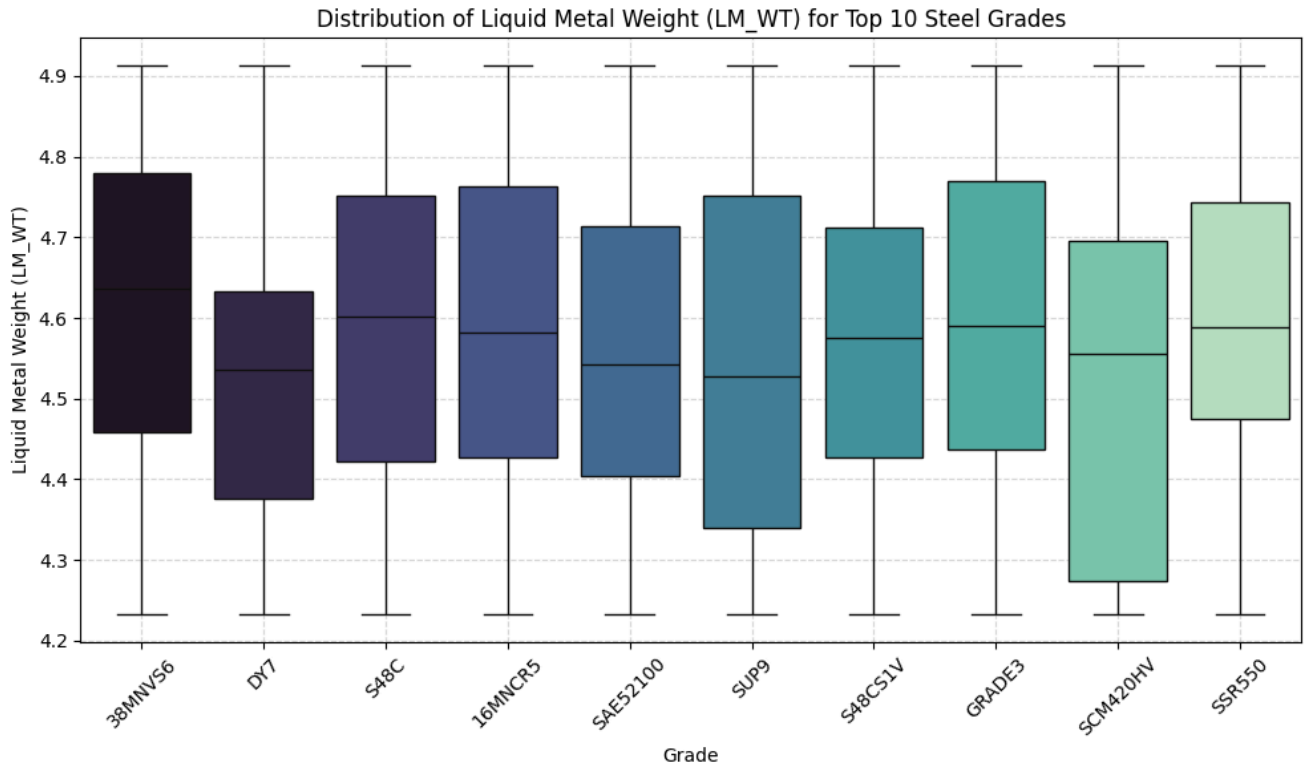



```
# Product Mix Contribution
grade_share = merged_df.groupby('GRADE')['Production (MT)'].sum().nlargest(8)

plt.figure(figsize=(8,8))
plt.pie(grade_share, labels=grade_share.index, autopct='%1.1f%%', startangle=90, colors=sns.color_palette('crest'))
plt.title("Production Share by Steel Grade (Top 8)")
plt.show()
```



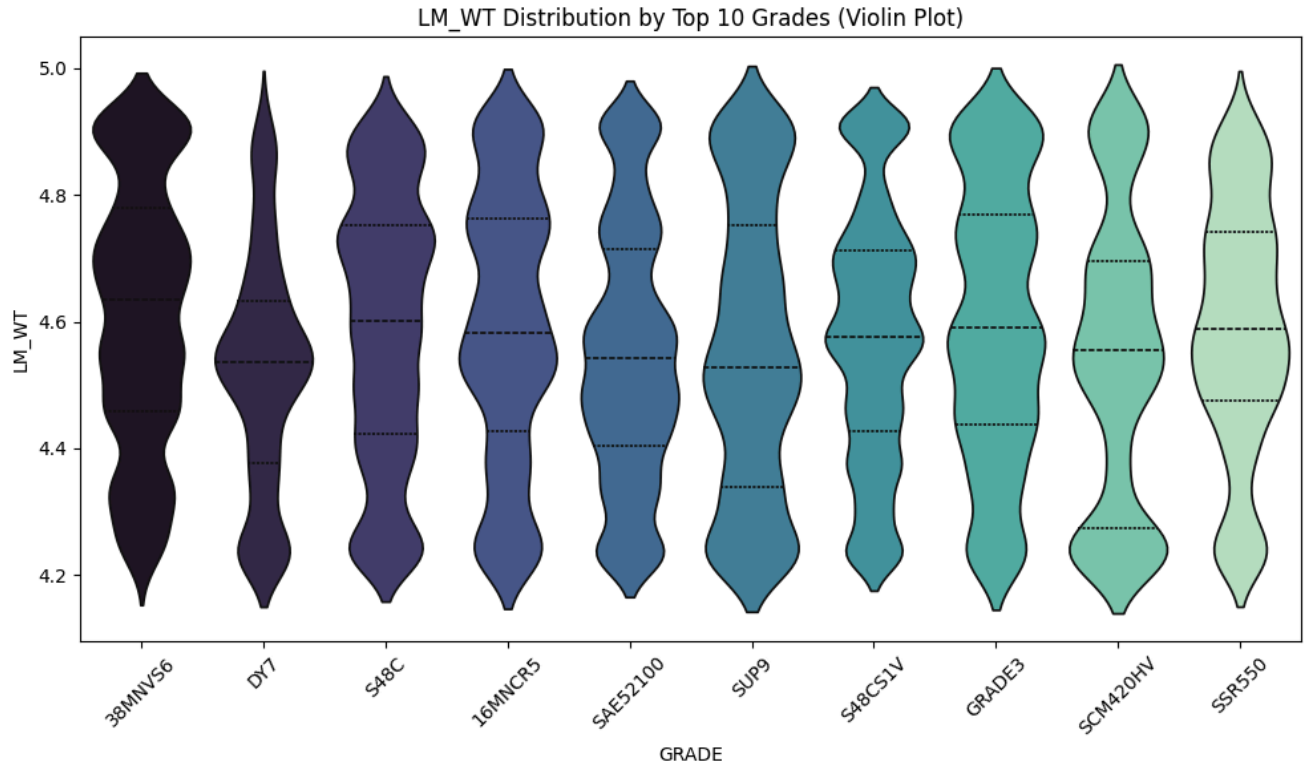
```
# Grade vs LM_WT (Liquid Metal Weight)
# Step 1: Find top 10 grades by total production
top_grades = (
    merged_df.groupby('GRADE')['Production (MT)']
    .sum()
    .sort_values(ascending=False)
    .head(10)
    .index
)

# Step 2: Filter dataset
filtered_df = merged_df[merged_df['GRADE'].isin(top_grades)]

# Step 3: Plot boxplot for only top 10 grades
plt.figure(figsize=(10,6))
sns.boxplot(data=filtered_df, x='GRADE', y='LM_WT', palette='mako')
plt.title("Distribution of Liquid Metal Weight (LM_WT) for Top 10 Steel Grades")
plt.xlabel("Grade")
plt.ylabel("Liquid Metal Weight (LM_WT)")
plt.xticks(rotation=45)
plt.grid(True, linestyle='--', alpha=0.5)
plt.tight_layout()
plt.show()
```

```
/tmp/ipython-input-3146541654.py:15: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set

  sns.boxplot(data=filtered_df, x='GRADE', y='LM_WT', palette='mako')
```

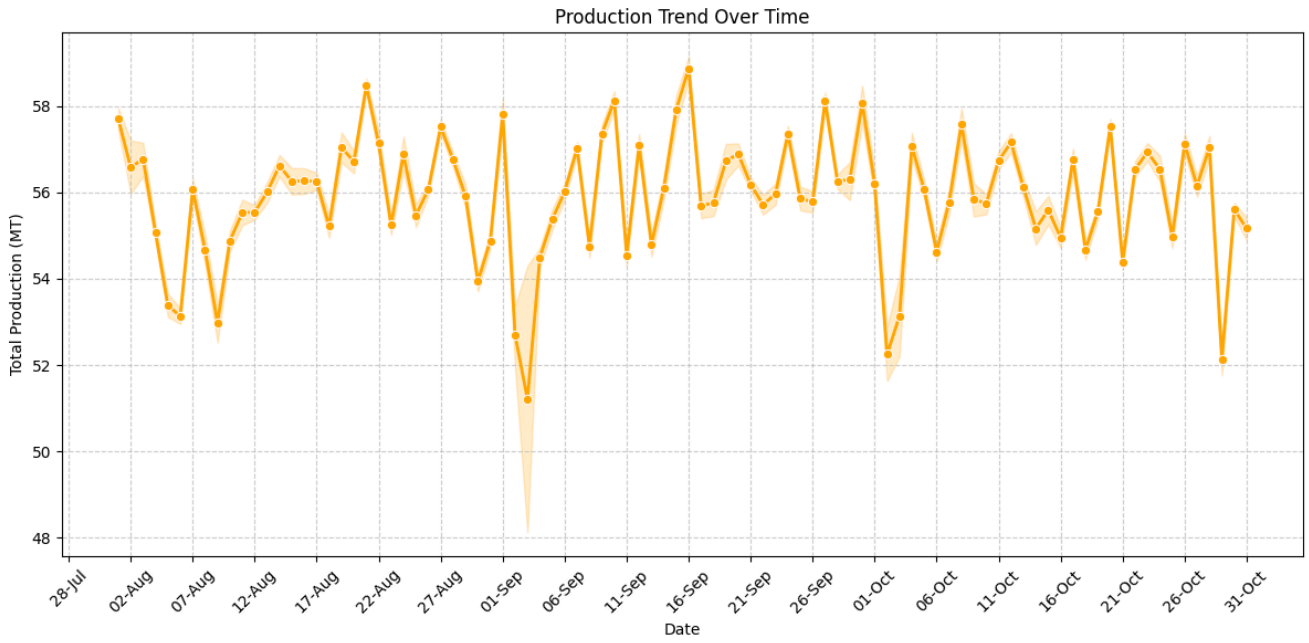



```
plt.figure(figsize=(10,6))
sns.violinplot(data=filtered_df, x='GRADE', y='LM_WT', palette='mako', inner='quartile')
plt.title("LM_WT Distribution by Top 10 Grades (Violin Plot)")
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```

```
/tmp/ipython-input-3317950946.py:2: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set

  sns.violinplot(data=filtered_df, x='GRADE', y='LM_WT', palette='mako', inner='quartile')
```

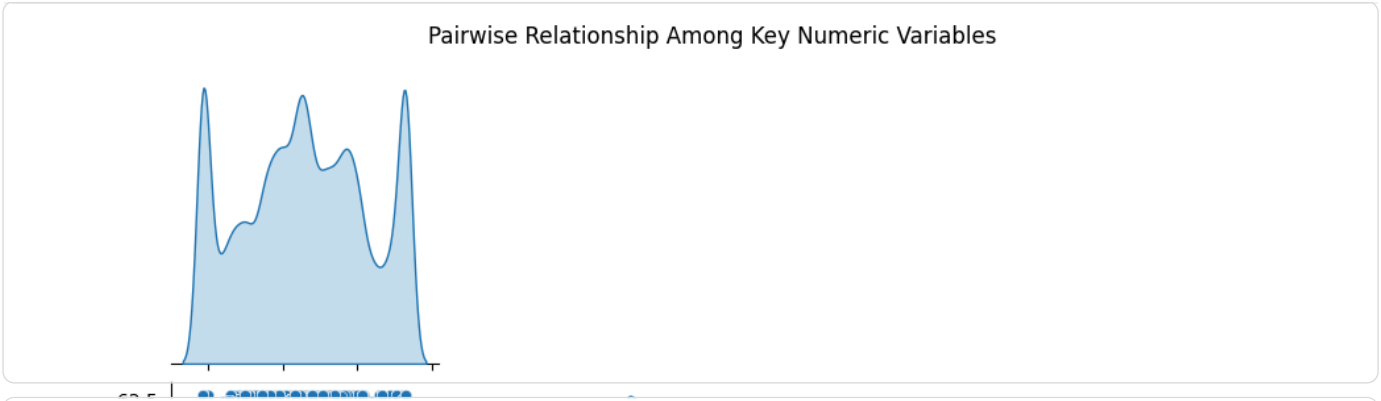



```
# Production Trend Over Time
import matplotlib.dates as mdates

plt.figure(figsize=(12,6))
sns.lineplot(data=merged_df, x='DATETIME', y='Production (MT)', marker='o', linewidth=2, color='orange')

plt.title("Production Trend Over Time")
plt.xlabel("Date")
plt.ylabel("Total Production (MT)")

# ✅ Force date ticks every 5 days
plt.gca().xaxis.set_major_locator(mdates.DayLocator(interval=5))
plt.gca().xaxis.set_major_formatter(mdates.DateFormatter('%d-%b'))

plt.grid(True, linestyle='--', alpha=0.6)
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```

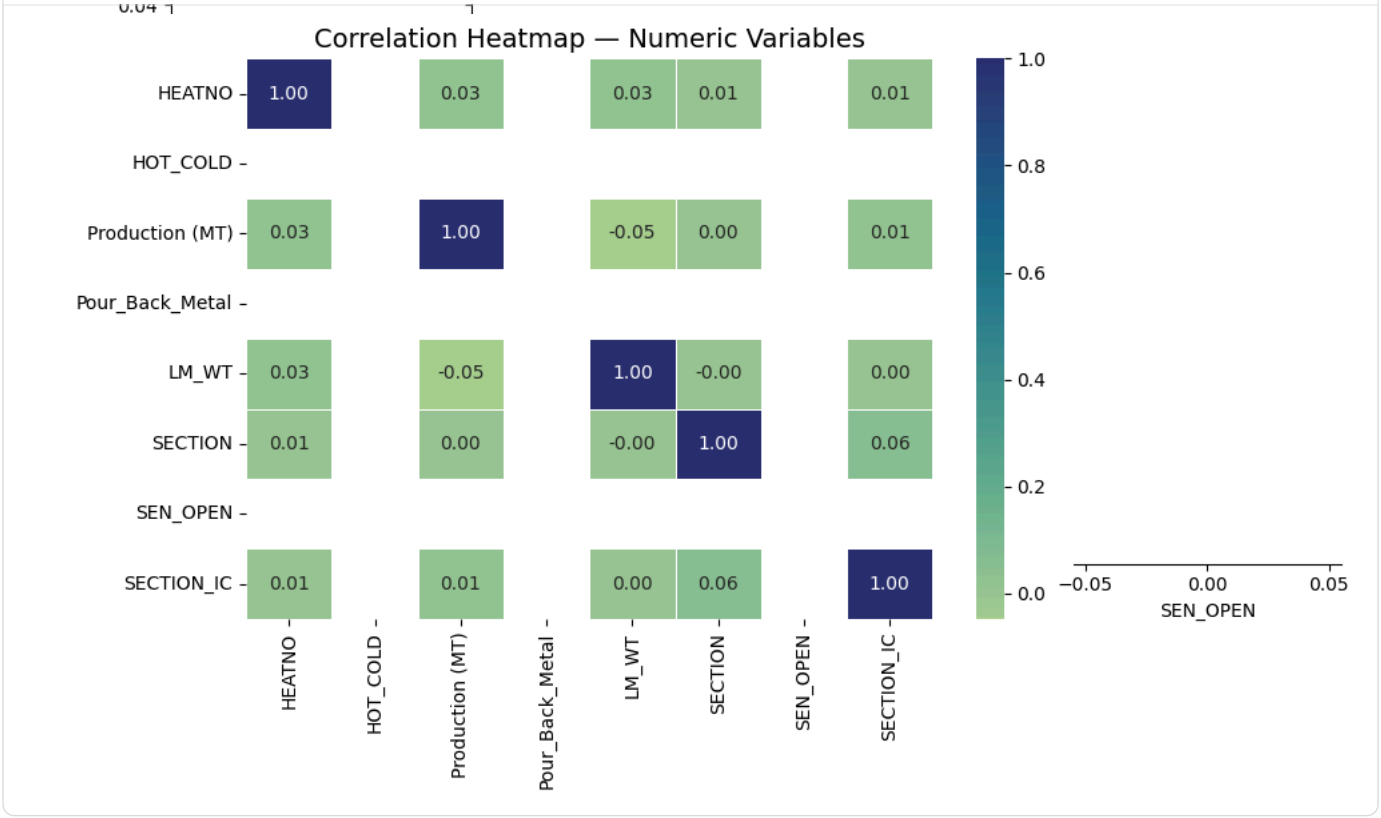


Multi variant analysis

```
num_cols = ['LM_WT', 'Production (MT)', 'Pour_Back_Metal', 'SEN_OPEN']
sns.pairplot(merged_df[num_cols], diag_kind='kde', corner=True, plot_kws={'alpha':0.6})
plt.suptitle("Pairwise Relationship Among Key Numeric Variables", y=1.02)
plt.show()
```



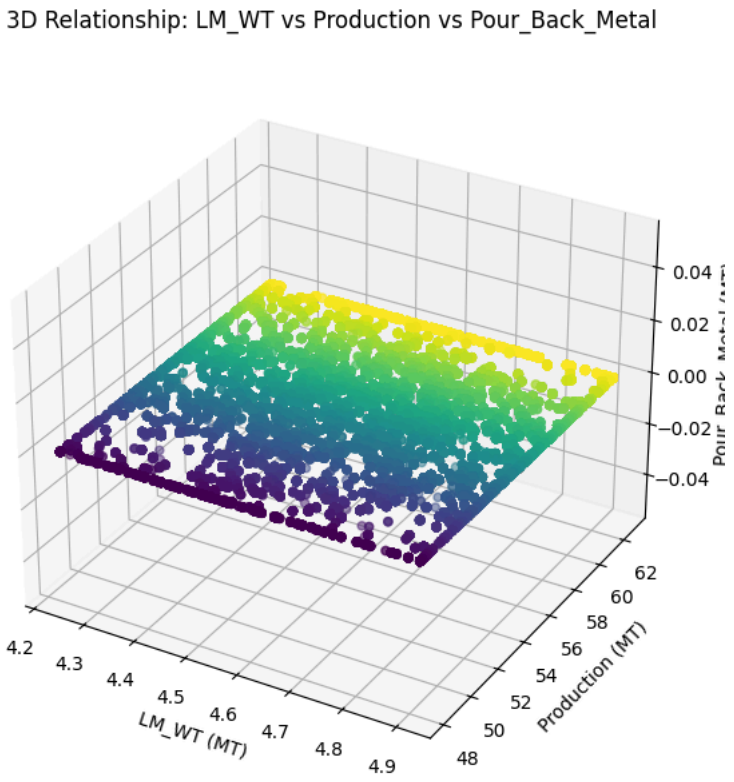

```
plt.figure(figsize=(8,6))
sns.heatmap(
merged_df.corr(numeric_only=True),
annot=True,
cmap='crest',
fmt='.2f',
cbar=True,
linewidths=0.5
)
plt.title("Correlation Heatmap — Numeric Variables", fontsize=14)
plt.tight_layout()
plt.show()
```



Double-click (or enter) to edit

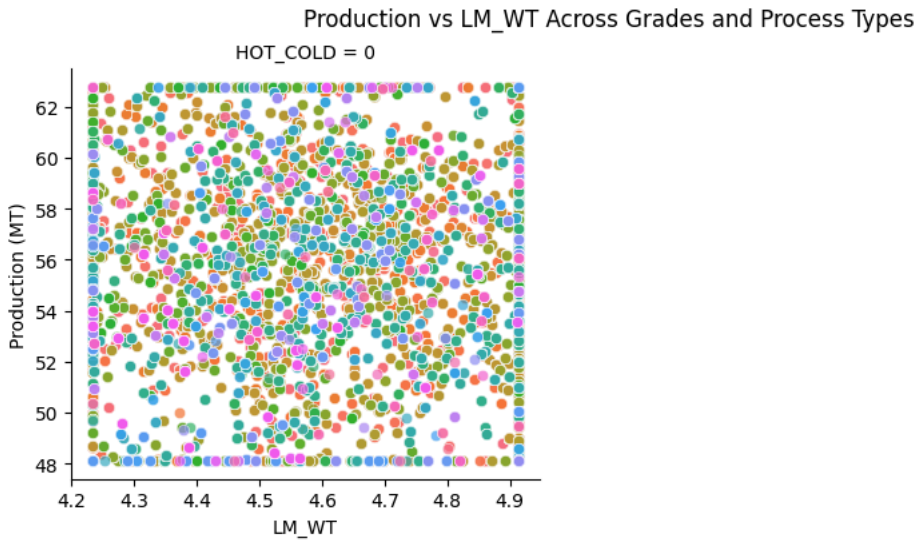
```
from mpl_toolkits.mplot3d import Axes3D

fig = plt.figure(figsize=(10,7))
ax = fig.add_subplot(111, projection='3d')

# Filter to remove zeros for visibility
filtered = merged_df[(merged_df['LM_WT'] > 0) & (merged_df['Production (MT)'] > 0)]

ax.scatter(
    filtered['LM_WT'],
    filtered['Production (MT)'],
    filtered['Pour_Back_Metal'],
    c=filtered['Production (MT)'],
    cmap='viridis',
    alpha=0.5,
    s=20
)
```

```
ax.set_xlabel("LM_WT (MT)")
ax.set_ylabel("Production (MT)")
ax.set_zlabel("Pour_Back_Metal (MT)")
ax.set_title("3D Relationship: LM_WT vs Production vs Pour_Back_Metal", pad=20)
plt.show()
```




```
g = sns.FacetGrid(merged_df, col='HOT_COLD', hue='GRADE', col_wrap=2, height=4)
g.map(sns.scatterplot, 'LM_WT', 'Production (MT)', alpha=0.7)
g.add_legend()
g.fig.suptitle("Production vs LM_WT Across Grades and Process Types", y=1.03)
plt.show()
```

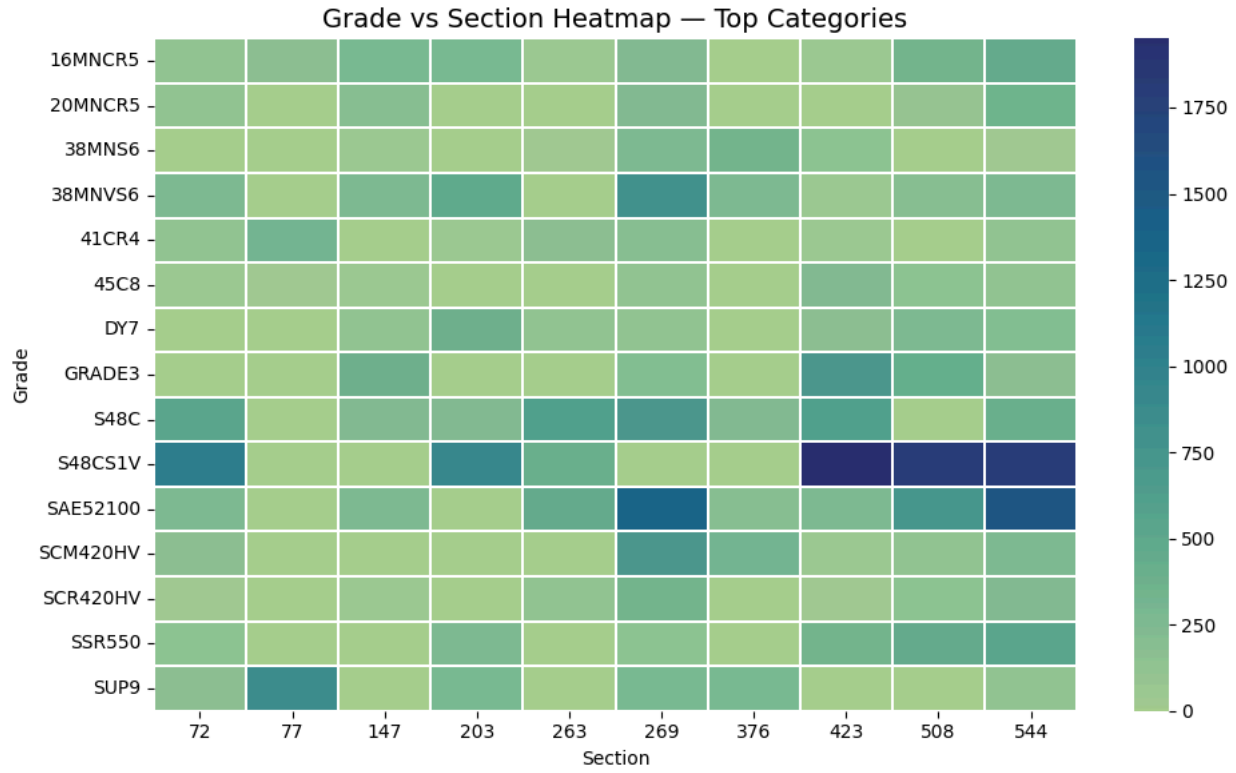

GRADE
38MNSIVS6
AISI430L
38MNSIVS5
C45
38MNVS6
SCM435
AISI420
DY7
52CRMOV4
EN353
20MNCR5
S45CS1V
42CRMOS4
S48C
16MNCR5
34CRNIMO6
SCR420HV
SAE52100
SAE1015
SCM420HVI
C60
S55
SAE1030
38B3
45CP3
SAE8617H
36MNVS6
SUP9A
S45CP3
10601C60
SCM415H
41CR4
S35C
100CR6
EN8D
SAE15B41
SCM420H2V2
SUP9
S48CS1V
S45C
EN19
SAE8650
16MNCR5H
GRADE3
SCM420H
12L14
AISI410
SAE9254
GTD450
S48CSS1V
34CRMO4
15B25
EN9
94B17H
SCM435H
EN18D
35MN6MO3
VS13113
SCR420H
SS400
60SICR8
SCM415HV
SCM420HV
C45GPB
SAE1541M
S45CS1QDS
38MNS6
AISI434MNH
S53CG
AISI435MOH
385MNVS6
EN19C
25MOCR4



20MOCR4
52CRMO2V
16MNCR5LSI
60SI7
SAE8720M
56SICR7
EN1A
266GRADE2
SCR420
38MNVS5
SUP11A
WSS340A2
WSSMIA340A
SCM420
WSSMIA340
SCM415
SCM420HVC
46S20N
VS13111
60SICR7
SAE1050
SAE8620H
C43
C15PBK
SAE8720
15B41M
R10S10U
2NI2CRMO
EN8C
SAE4140
SSR550
SAE15B41H
ICSS1218
51CRV4
S45CSQDS1
GRADE2
44MNSIVS6
C45MOD2
44MNSIV56
LF2
40CAD612PB
R16
SAE8620
ST52
C56E2
C70S6
C45R
16MNCRH
SA350LF2
16MN5CR4
42CRMO4
S40C
SA266
5150N
45C8
C60K
C10
C38N
C10C
C38M
SAE1141
25CRMO4
SAE1548
C40MOD2
40CR4B
40CR4C
CF53
SAE9310
SUP11AM
430L
EN52
AISI434MO
SUP6
AISI434MO1
N52


SUP9M
S25C
41CR4C
VS14250
53CG
S45CQDS
SCM420IYM
16MNCR5D
AISI1117
ST523
SAE4135H
S35CP3
SAE1018
SAE1144
22MN6
V252550
C45RPB
SCM420V
Unknown
C45RPBHH
VS1311354
AISI416
AISI420VS
AISI420VL
15B41
S45CS1VQD
E3250
NITRAALLO
16MNCR5HH
S53C
SAE8319
C15M
SAE59254
C70S6K
X22
C45MO
S48CSIV
S115C
36MNVS4
SCM420H3V2
SCR420HN
S15CP3
SAE4135
SAE5150
42CR4MO2
1541M
UC1
SAE94B17H
S70CVS1
38MN2CR
SCR415HM
SCR415HN
S43C
SAE1541
40MNSIVS6
B14
AI434MO1
AISI434MOI
AISI434MOL
18MF5
350LF6
25MO2V
SUP9AM
SUP11
C45MO2
S48CS
44MN1VS6
27MNCRB5
VS13113SU
40MNVS6
SAE1117
SAE1026
SAE1040
52CR4MO2V
500N

```
# Grade vs Section — Heatmap (Categorical Relationship)

# Use only top 15 grades & top 10 sections for clarity
top_grades = merged_df['GRADE'].value_counts().nlargest(15).index
top_sections = merged_df['SECTION'].value_counts().nlargest(10).index

subset_df = merged_df[
    (merged_df['GRADE'].isin(top_grades)) &
    (merged_df['SECTION'].isin(top_sections))
]

grade_section = pd.crosstab(subset_df['GRADE'], subset_df['SECTION'])

plt.figure(figsize=(10,6))
sns.heatmap(grade_section, cmap='crest', cbar=True, linewidths=0.3)
plt.title("Grade vs Section Heatmap — Top Categories", fontsize=14)
plt.xlabel("Section")
plt.ylabel("Grade")
plt.tight_layout()
plt.show()
```




```
# Grade vs Section — Heatmap (Categorical Relationship)

# Use only top 15 grades & top 10 sections for clarity
top_grades = merged_df['GRADE'].value_counts().nlargest(15).index
top_sections = merged_df['SECTION'].value_counts().nlargest(10).index

subset_df = merged_df[
    (merged_df['GRADE'].isin(top_grades)) &
    (merged_df['SECTION'].isin(top_sections))
]

grade_section = pd.crosstab(subset_df['GRADE'], subset_df['SECTION'])

plt.figure(figsize=(10,6))
sns.heatmap(grade_section, cmap='crest', cbar=True, linewidths=0.3)
plt.title("Grade vs Section Heatmap — Top Categories", fontsize=14)
plt.xlabel("Section")
plt.ylabel("Grade")
plt.tight_layout()
plt.show()
```