SecondAssignment

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1 Course of Multiagent Systems for smart machining: Second Assignment

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1.1 Assignment:

- Open data from last week:
  - Each student will analyze one operation
  - Compare power of operations:
  - Average per revolution:
  - Min/Max per revolution:
  - Profile of the power curve per revolution(during cutting)
  - Energy in one revolution:
    - Energy is the integral of the power.

1.2 Brief Summary of Data Processing Steps

My task is to analyze the pocket formation step so this notebook is focused on it.

1.3 Importing Data

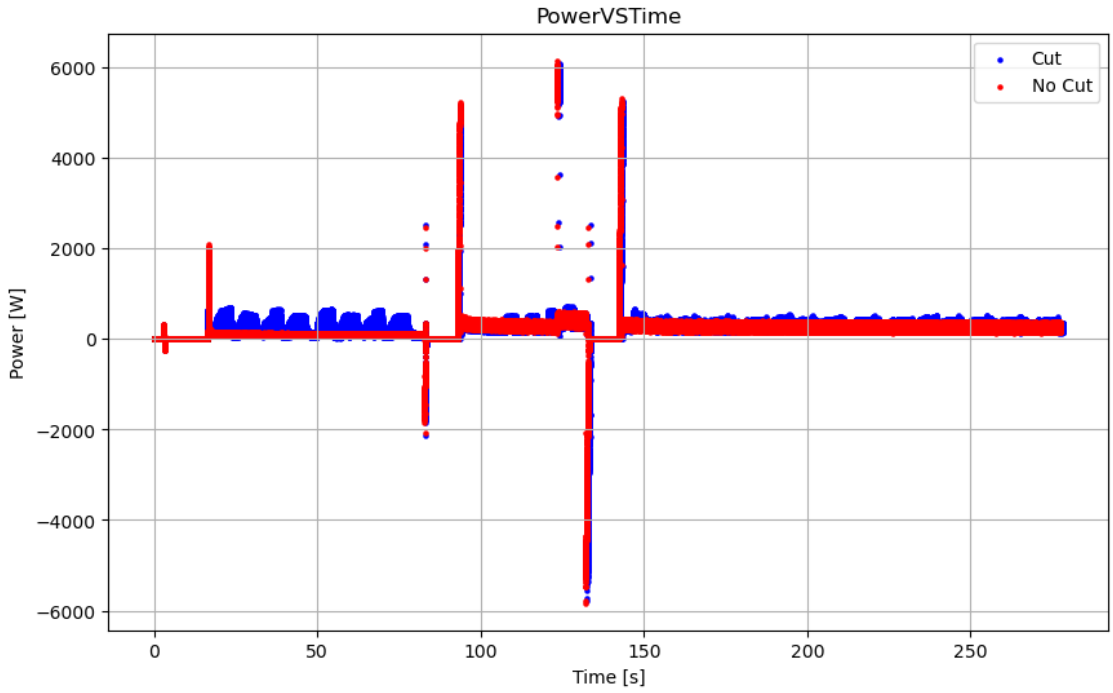
[34]:
```
import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
import matplotlib.ticker as ticker

# File data CSV
filedataC = 'Dati/Session5A1B.csv'                    #cut
filedataNC= 'Dati/Session5A1A.csv'                    #nocut

# Reading csv
dfC = pd.read_csv(filedataC, skiprows=10)
#dfC = dfC.iloc[:, :-1]
dfC = dfC.apply(pd.to_numeric, errors='coerce')
```

```
dfC = dfC.dropna()
dfNC = pd.read_csv(filedataNC, skiprows=10)
#dfNC = dfNC.iloc[:, :-1]
dfNC = dfNC.apply(pd.to_numeric, errors='coerce')
dfNC = dfNC.dropna()
```

[35]:
```
dfC.columns = ['time',
               'prog_pos_x',
               'meas_pos_x',
               'power',
               'prog_pos_y',
               'meas_pos_y',
               'prog_pos_z',
               'meas_pos_z']

dfNC.columns = ['time',
               'prog_pos_x',
               'meas_pos_x',
               'power',
               'prog_pos_y',
               'meas_pos_y',
               'prog_pos_z',
               'meas_pos_z']
```

1.4 Power visualization

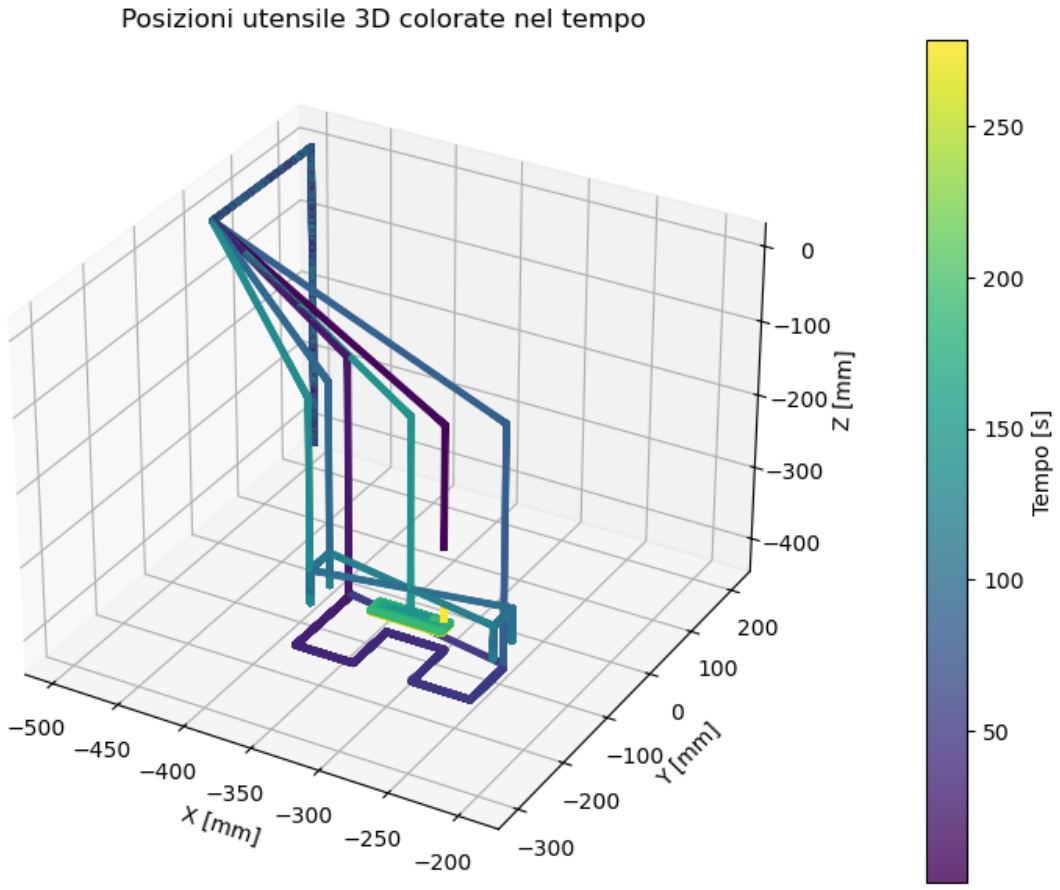
[36]:
```
plt.figure(figsize=(10,6))

# dfC
plt.scatter(dfC['time'], dfC['power'], label='Cut', color='blue', s=5) # s=20␣
 ↪dimensione punti

# dfNC
plt.scatter(dfNC['time'], dfNC['power'], label='No Cut', color='red', s=5)

# Labels
plt.xlabel('Time [s]')
plt.ylabel('Power [W]')
plt.title('PowerVSTime')
plt.legend()
plt.grid(True)

plt.show()
```



1.5 Position Visualization of the full process:

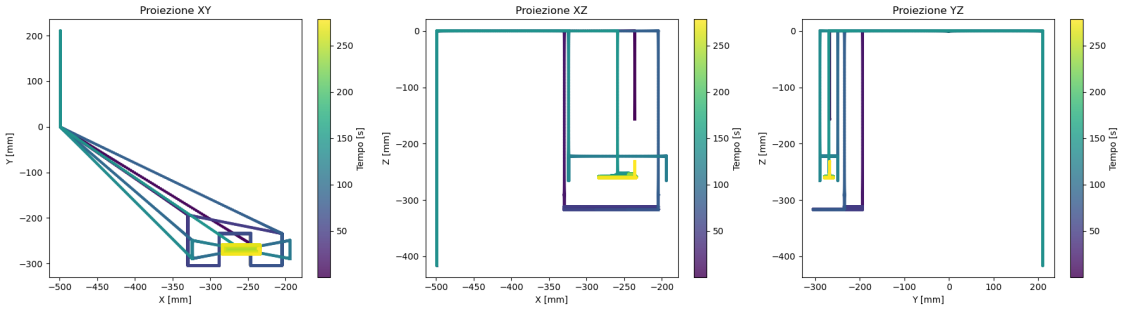
[37]:
```
import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import Axes3D

# Scegli il DataFrame
df = dfC  # oppure dfNC

# Crea figura e asse 3D
fig = plt.figure(figsize=(10,7))
ax = fig.add_subplot(111, projection='3d')

# Scatter 3D con colore direttamente dal tempo
sc = ax.scatter(df['meas_pos_x'], df['meas_pos_y'], df['meas_pos_z'],
                c=df['time'], cmap='viridis', s=5, alpha=0.8)

# Etichette assi
ax.set_xlabel('X [mm]')
ax.set_ylabel('Y [mm]')
ax.set_zlabel('Z [mm]')
ax.set_title('Posizioni utensile 3D colorate nel tempo')

# Barra colore per il tempo
cbar = plt.colorbar(sc, ax=ax, pad=0.1)
```

```
cbar.set_label('Tempo [s]')

plt.show()
```



[38]:
```
# choose DataFrame
df = dfC  # oppure dfNC

# Imposta figure e dimensioni
fig, axes = plt.subplots(1, 3, figsize=(18, 5))

# 1 Proiezione XY
sc1 = axes[0].scatter(df['meas_pos_x'], df['meas_pos_y'], c=df['time'],␣
 ↪cmap='viridis', s=5, alpha=0.8)
axes[0].set_xlabel('X [mm]')
axes[0].set_ylabel('Y [mm]')
axes[0].set_title('Proiezione XY')
cbar1 = plt.colorbar(sc1, ax=axes[0])
cbar1.set_label('Tempo [s]')
```

```
# 2 Proiezione XZ
sc2 = axes[1].scatter(df['meas_pos_x'], df['meas_pos_z'], c=df['time'],␣
 ↪cmap='viridis', s=5, alpha=0.8)
axes[1].set_xlabel('X [mm]')
axes[1].set_ylabel('Z [mm]')
axes[1].set_title('Proiezione XZ')
cbar2 = plt.colorbar(sc2, ax=axes[1])
cbar2.set_label('Tempo [s]')

# 3 Proiezione YZ
sc3 = axes[2].scatter(df['meas_pos_y'], df['meas_pos_z'], c=df['time'],␣
 ↪cmap='viridis', s=5, alpha=0.8)
axes[2].set_xlabel('Y [mm]')
axes[2].set_ylabel('Z [mm]')
axes[2].set_title('Proiezione YZ')
cbar3 = plt.colorbar(sc3, ax=axes[2])
cbar3.set_label('Tempo [s]')

plt.tight_layout()
plt.show()
```

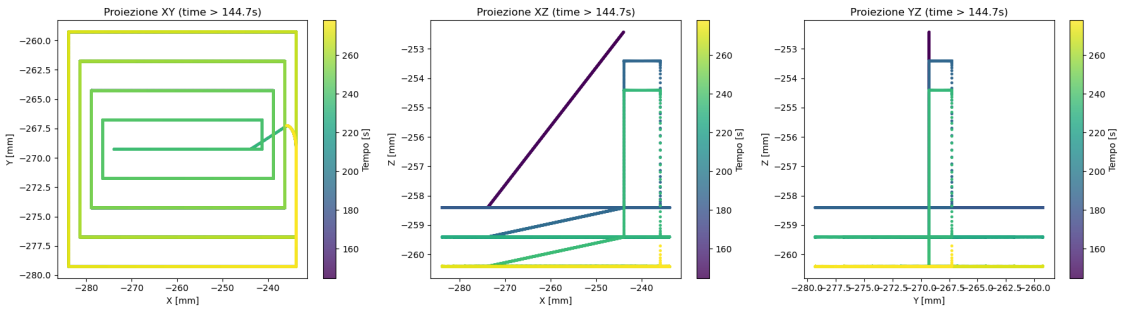


From this plot it is clear that the pocket formation is the last operation

1.6 Position Visualization of the Pocket formation

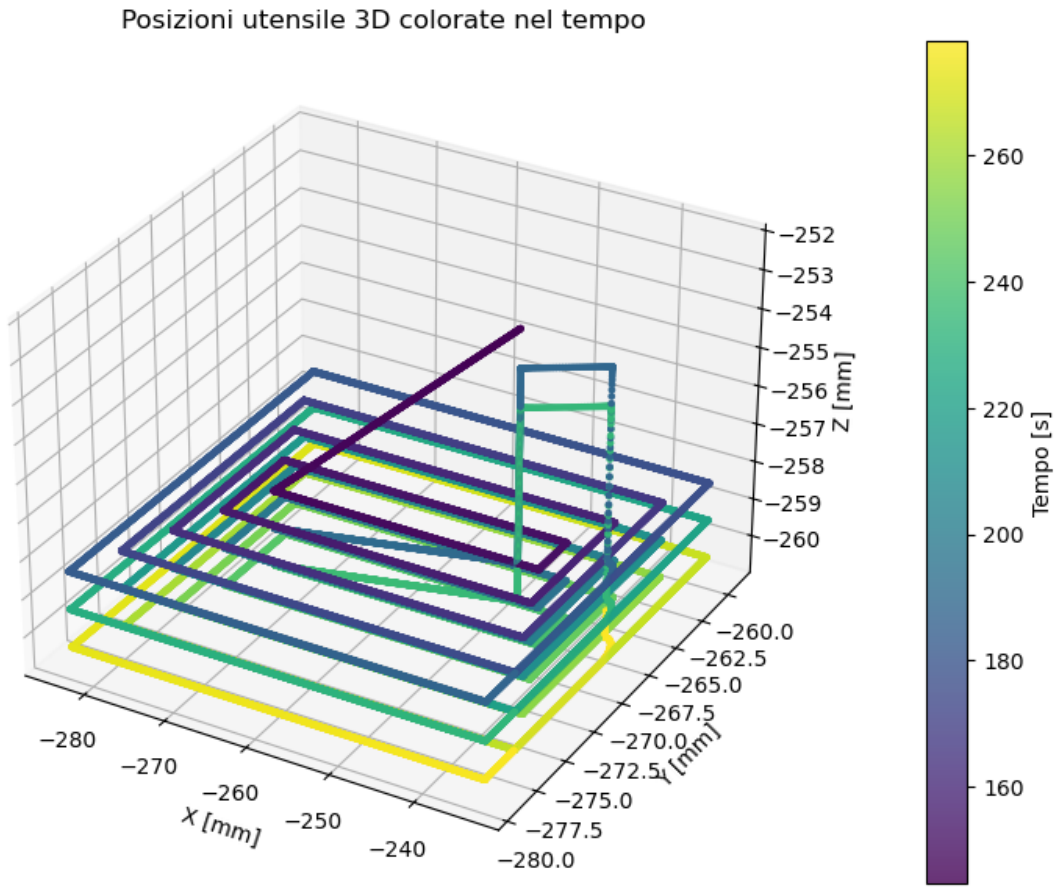
[39]:
```
# Scegli DataFrame
df = dfC  # oppure dfNC

# Soglia temporale
t_soglia = 144.7 # ad esempio 50 secondi
t_soglia2 = 278.1
df_filtered = df[(df['time'] > t_soglia) & (df['time'] < t_soglia2) ]

# Imposta figure e dimensioni
```

```
fig, axes = plt.subplots(1, 3, figsize=(18, 5))

# 1 Proiezione XY
sc1 = axes[0].scatter(df_filtered['meas_pos_x'], df_filtered['meas_pos_y'],
                      c=df_filtered['time'], cmap='viridis', s=5, alpha=0.8)
axes[0].set_xlabel('X [mm]')
axes[0].set_ylabel('Y [mm]')
axes[0].set_title(f'Proiezione XY (time > {t_soglia}s)')
cbar1 = plt.colorbar(sc1, ax=axes[0])
cbar1.set_label('Tempo [s]')

# 2 Proiezione XZ
sc2 = axes[1].scatter(df_filtered['meas_pos_x'], df_filtered['meas_pos_z'],
                      c=df_filtered['time'], cmap='viridis', s=5, alpha=0.8)
axes[1].set_xlabel('X [mm]')
axes[1].set_ylabel('Z [mm]')
axes[1].set_title(f'Proiezione XZ (time > {t_soglia}s)')
cbar2 = plt.colorbar(sc2, ax=axes[1])
cbar2.set_label('Tempo [s]')

# 3 Proiezione YZ
sc3 = axes[2].scatter(df_filtered['meas_pos_y'], df_filtered['meas_pos_z'],
                      c=df_filtered['time'], cmap='viridis', s=5, alpha=0.8)
axes[2].set_xlabel('Y [mm]')
axes[2].set_ylabel('Z [mm]')
axes[2].set_title(f'Proiezione YZ (time > {t_soglia}s)')
cbar3 = plt.colorbar(sc3, ax=axes[2])
cbar3.set_label('Tempo [s]')

plt.tight_layout()
plt.show()
```



[40]:
```
# Scegli DataFrame
df = dfC  # oppure dfNC
```

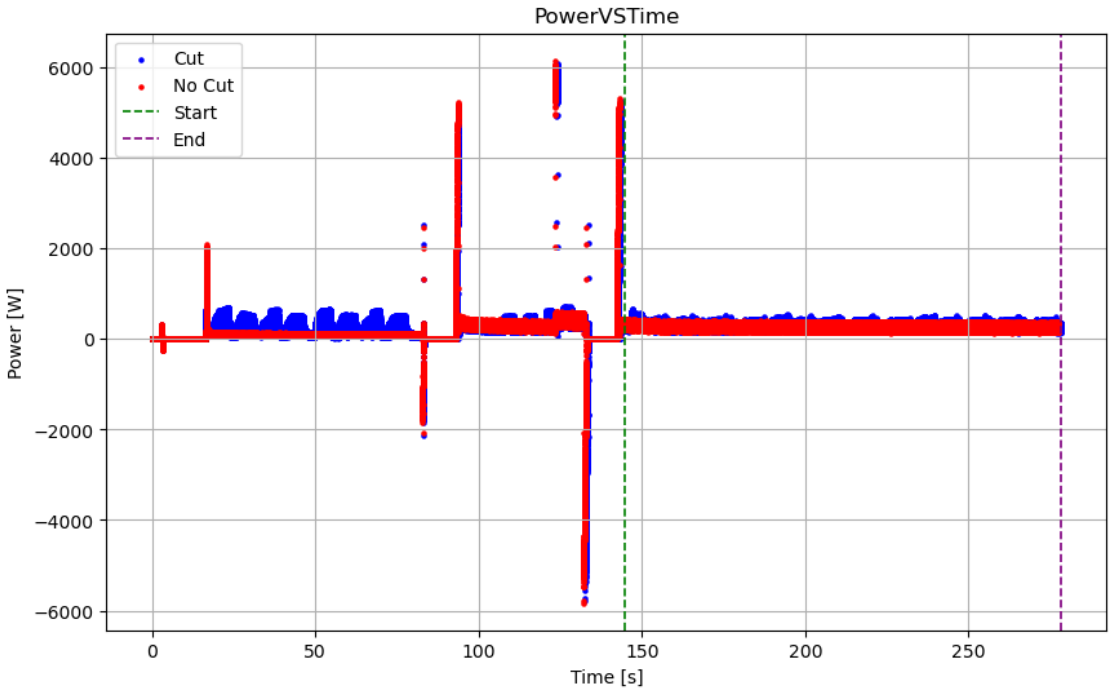
```
# Soglia temporale
t_soglia = 144.7 # ad esempio 50 secondi
t_soglia2 = 278.1
df = df[(df['time'] > t_soglia) & (df['time'] < t_soglia2) ]

# Crea figura e asse 3D
fig = plt.figure(figsize=(10,7))
ax = fig.add_subplot(111, projection='3d')

# Scatter 3D con colore direttamente dal tempo
sc = ax.scatter(df['meas_pos_x'], df['meas_pos_y'], df['meas_pos_z'],
                c=df['time'], cmap='viridis', s=5, alpha=0.8)

# Etichette assi
ax.set_xlabel('X [mm]')
ax.set_ylabel('Y [mm]')
ax.set_zlabel('Z [mm]')
ax.set_title('Posizioni utensile 3D colorate nel tempo')

# Barra colore per il tempo
cbar = plt.colorbar(sc, ax=ax, pad=0.1)
cbar.set_label('Tempo [s]')

plt.show()
```



1.7 Power of the pocket formation task:

[41]:
```
plt.figure(figsize=(10,6))

# dfC
plt.scatter(dfC['time'], dfC['power'], label='Cut', color='blue', s=5)

# dfNC
plt.scatter(dfNC['time'], dfNC['power'], label='No Cut', color='red', s=5)

# Linee verticali
plt.axvline(x=144.7, color='green', linestyle='--', linewidth=1.2,␣
 ↪label='Start')
plt.axvline(x=278.1, color='purple', linestyle='--', linewidth=1.2, label='End')

# Labels
plt.xlabel('Time [s]')
plt.ylabel('Power [W]')
plt.title('PowerVSTime')
```

```
plt.legend()
plt.grid(True)

plt.show()
```

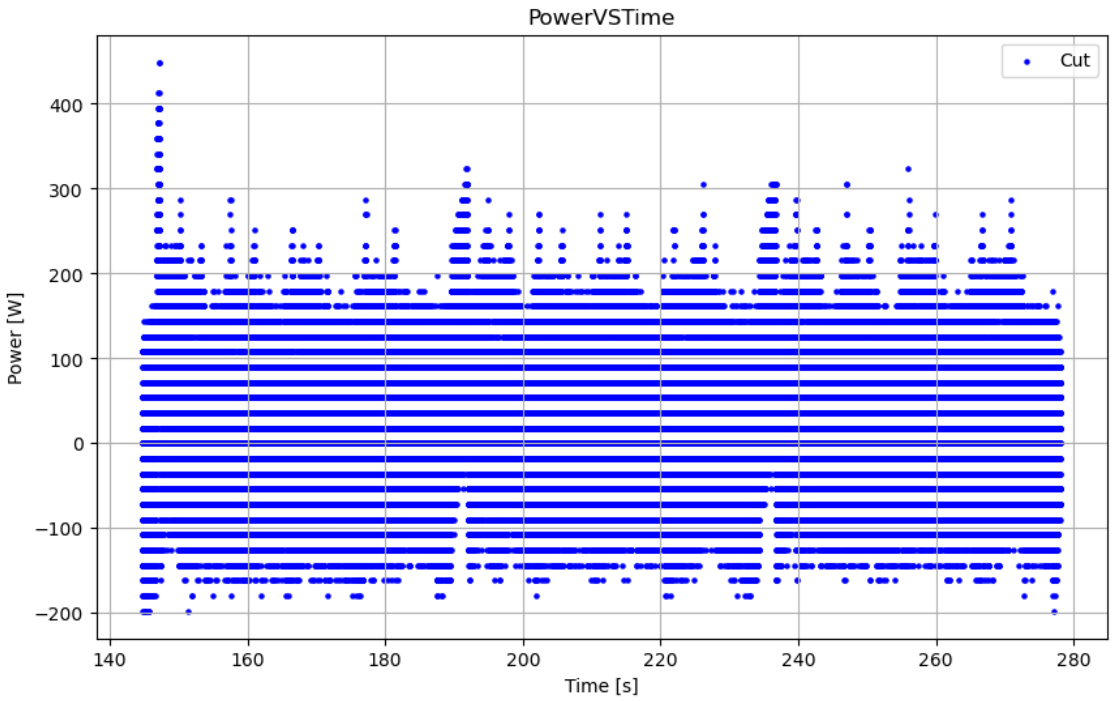


[42]:
```
t_min = 144.7
t_max = 278.1

# Filtra dfC
dfC = dfC[(dfC['time'] >= t_min) & (dfC['time'] <= t_max)].copy()

# Filtra dfNC
dfNC = dfNC[(dfNC['time'] >= t_min) & (dfNC['time'] <= t_max)].copy()
```

1.8 Power difference:

[43]:
```
# Unisci tramite merge_asof (accoppiamento per tempo più vicino)
df_merged = pd.merge_asof(
    dfC.sort_values('time'),
    dfNC.sort_values('time'),
    on='time',
    suffixes=('_C', '_NC')
)
```

```python
# Calcola differenza
df_diff = pd.DataFrame({
    'time': df_merged['time'],
    'power_diff': df_merged['power_C'] - df_merged['power_NC']
})

plt.figure(figsize=(10,6))

plt.scatter(df_diff['time'], df_diff['power_diff'], label='Cut', color='blue',␣
 ↪s=5)

plt.xlabel('Time [s]')
plt.ylabel('Power [W]')
plt.title('PowerVSTime')
plt.legend()
plt.grid(True)

plt.show()
```



From the previous plot we notice that often the cutting power is negative. This is not possible and probably comes out from a data inconsistency. So from now on we consider only total power not cutting power

1.9 Machining Parameters:

Here I report the full programming code:

NOTE: I have never learned about CNC programming and in any video of this course isn't explained CNC programming su I interpreted commands through an IA.

```
E_HEAD(272113663,0,0,0,170,-70,-15,71,17,5,25,0,1,20,,4,7,6,100,1,0,33279);*RO*
$AN_SLTRACE=1 E_MI_PL("FR_SURF_D63_ALU","FORET5.5_CARB_FSI",1,0.1,2,400,2,13,0,90,-1,90,0.5,0,
E_DR_PEC(1,0,0,"FORET5.5_CARB_FSI","FR2T D10 ALU FSI",1,0.08,3,80,2,40,-1.5,90,1.5,90,0,0.6,1,
_E_P001: E_PS_SEQ(1,0,0,0,90,20,90,-15,90,20,90,-55,90,150,90,-15,90,150,90,-55,90,,0,,0,,0,,0
E_DR_PEC(1,0,0,"FORET5.5_CARB_FSI","",1,0.08,3,80,2,40,-18,90,14,90,4,0.6,1,1.4,1.6,90);*RO*
_E_P002: E_PS_SEQ(1,0,0,0,90,,0,,0,,0,,0,150,90,-15,90,150,90,-55,90,,0,,0,,0,,0,,0,,0,,0,,0,,0
E_DR_PEC(1,0,0,"FORET5.5_CARB_FSI","",1,0.16,3,80,2,40,-18,90,14,90,4,0.6,1,1.4,1.6,90);*RO*
_E_P003: E_PS_SEQ(1,0,0,0,90,20,90,-15,90,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,0);*
E_DR_PEC(1,0,0,"FORET5.5_CARB_FSI","",1,0.08,3,100,2,40,-18,90,14,90,4,0.6,1,1.4,1.6,90);*RO*
_E_P004: E_PS_SEQ(1,0,0,0,90,,0,,0,20,90,-55,90,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,,0,0);*
‘
```

From now on it should be pocket formation: - two cutting edges - diam = 10

```
E_PO_REC(4,0,0,"FR2T D10 ALU FSI","",1,0.05,2,150,2,1,15,3,0,-1,90,3,91,1,0,85,90,-35,90,60,30
$AN_SLTRACE=0 E_END(0,1,0);*RO* M30 ;#SM;*RO*
```

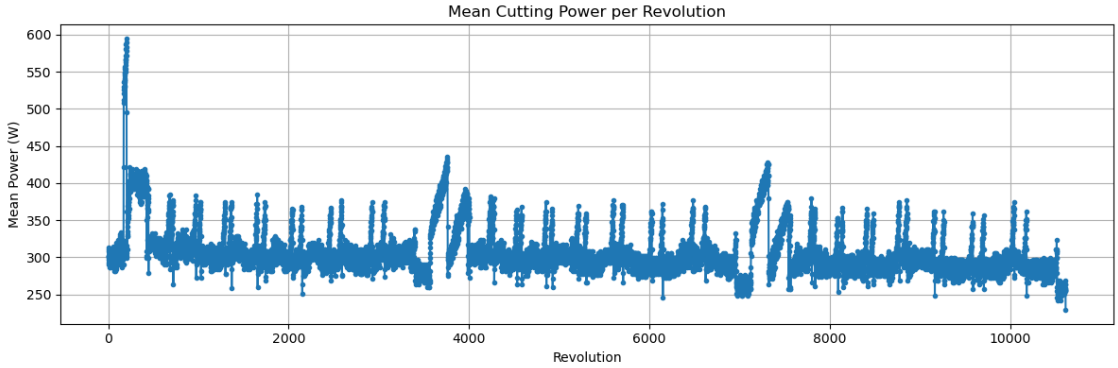
Then the guy how send me data from INSA said that :

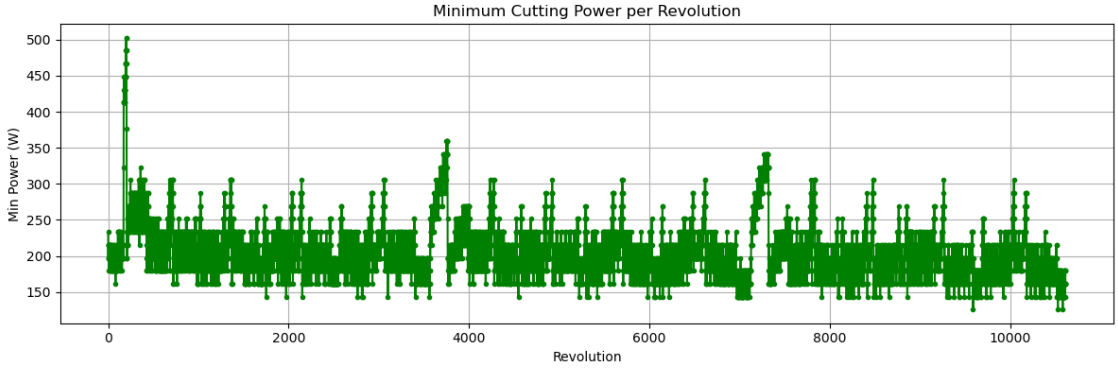
- depth of pass = 1 mm
- cutting speed = 150 m/min
- feed per tooth = 0.05 mm/tour

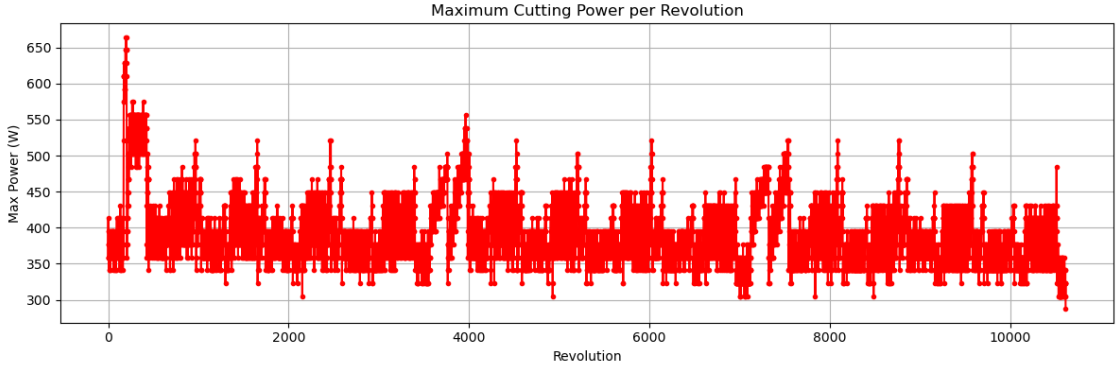
[44]:
```
D=10
depth=1
Vc=150
feed=0.05
N = Vc/(np.pi * D) * 1000

# Revolution counter (just in the surfacing interval!)
Trev = 60/N # (s) revolution period

dfC['rev'] = ((dfC['time'] - dfC['time'].iloc[0])/Trev).astype(int)
dfC.insert(0, 'rev', dfC.pop('rev'))

stats = dfC.groupby('rev')['power'].agg(
    mean_power='mean',
    min_power='min',
    max_power='max'
).reset_index()

pd.set_option('display.precision', 2)

stats.head(12).style.format("{:.2f}").set_caption("First 12 revolutions")
```

[44]: <pandas.io.formats.style.Styler at 0x272d0247a10>

[45]:
```
fig, axes = plt.subplots(3, 1, figsize=(12, 12))
fig.subplots_adjust(hspace=0.4)

axes[0].plot(stats['rev'], stats['mean_power'], marker='.')
axes[0].set_xlabel('Revolution')
axes[0].set_ylabel('Mean Power (W)')
axes[0].set_title('Mean Cutting Power per Revolution')
axes[0].grid(True)

axes[1].plot(stats['rev'], stats['min_power'], marker='.', color='green')
axes[1].set_xlabel('Revolution')
axes[1].set_ylabel('Min Power (W)')
axes[1].set_title('Minimum Cutting Power per Revolution')
axes[1].grid(True)

axes[2].plot(stats['rev'], stats['max_power'], marker='.', color='red')
axes[2].set_xlabel('Revolution')
axes[2].set_ylabel('Max Power (W)')
axes[2].set_title('Maximum Cutting Power per Revolution')
axes[2].grid(True)

plt.tight_layout()
plt.show()
```







[46]:
```
energy_per_rev = []

for rev_id, group in dfC.groupby('rev'):
    t = group['time'].values
    p = group['power'].values

    dt = t[1:] - t[:-1]                  # Δt_j
    p_avg = (p[1:] + p[:-1]) / 2         # (P_j + P_{j+1})/2b

    E = (p_avg * dt).sum()

    energy_per_rev.append([rev_id, E])
```

```
energy_per_rev = pd.DataFrame(energy_per_rev, columns=['rev', 'energy'])
plt.plot(energy_per_rev['rev'], energy_per_rev['energy'], marker='.',␣
 ↪linestyle='-')
plt.xlabel('Revolutions')
plt.ylabel('Energy (J)')
plt.title('Energy per Revolution - Cutting Process')
plt.grid(True)
plt.tight_layout()
plt.show()
```