Study of machining parameters of micro ECM on SS304 steel with nickel coated copper tool

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Abstract. The aim of present study is to determine the optimum parameters on machining the material SS304 and nickel-coated copper tool by micro electrochemical machining. The coating process is done by an electroplating method. The parameters involved in the process are feed rate (0.5, 0.6, 0.7) duty ratio (0.6, 0.7, 0.8) voltage (16, 17, 18). Taguchi approach is used to find out the optimum machining parameter and the Minitab 17 software is used to achieve better results. Copper coated tool life is improved when compared to the normal tool. The material removal rates (MRR), tapered angle, circularity, overcut are calculated by measuring the values on the video measuring machine.

1. Introduction
Micro Electrochemical machining is one of the most recent and useful machining processes. In this process, the electrolysis method is used to remove the metal from a workpiece. The raising of demand for producing micro slices and structures in most of the industries, and also with quick improvement in micro-electro-mechanical systems (MEMS), F.KLOCKE et al.[1] perform research on titanium - nickel-based alloys which are mainly used for aero-engine parts. Results show about the performance of material properties was analyzed by using a scanning electron microscope (SEM). Abhishek Tiwari et.al[2] researched on to minimize the MRR error by using the fuzzy logic system. the minimized error for MRR by using the input parameters is voltage, feed rate mm/sec, and gap mm. Minghuan Wang et.al [3] studied the application of drilling a micro-hole on electrochemical machining. the results show that multiple holes can be done by using a single electrode using a matrix array based on machining the hole quality is studied. Vladimir M. Volgin et al [4] perform research on modeling and analyzing the process on machining. the results help us to study the changes of characteristics in the worked surface and also it helps to find the morphological of the machined surface. J.M. Park et.al [5] study of electrochemical machining and its application on micro machined parts and to study about machining properties. The results show that the chemical reaction between the tool and the workpiece were verified based on the machining parameters and the properties were tested and burr formed during machining is minimized.
2. Materials and Experimentation.
The workpiece used in this project is SS304, because it is easily available and also it has a wide range of applications in industry. Figure 1 shows the SS304 material and figure 2 shows the microstructure of SS304. SS304 Material is widely applicable for gears, Pinions, Shaft, Spindle, Cranes, Rolling mill.

![SS304 Steel](image1)

![Micro structure of SS304](image2)

**Table 1.** Chemical composition of SS304

| Element      | Carbon | Manganese | Silicon | Sulphur | Nickel | Chromium | Phosphorous |
|--------------|--------|-----------|---------|---------|--------|----------|-------------|
| Percentage   | 0.07   | 1.86      | 0.35    | 0.008   | 8.33   | 18.02    | 0.039       |

2.1 Selection of tool electrode
Copper is selected as a base tool for machining. Although, copper is widely used as electrode material in ECM due to its high wear rate. The measurement of the electrode is 90 mm length and its inner diameter is 0.15 mm and the outer diameter is 0.5 mm. The hole section is generally made to provide the dielectric medium in the machining area for removal of burr also reduce the heat generation.

2.2 Selection of coating materials
The coating material increases the MRR and may reduce the tool wear rate. Here but we some improvement in the MRR and tool wear rate when compared with the normal tool, and also coating will help to increase the tool life. With the help of the above image, we can calculate the coating thickness, here base material was copper and coated material was a nickel. With the help of an electro less plating method nickel-coated above the copper. After coating the sample send through for SEM image, with help of SEM analysis calculate the thickness of the coating.

![Nickel Coated tool image](image3)

![SEM image of Nickel Coated tool](image4)
2.3 Electrolyte

![Sodium Nitrate](image)

**Figure 5. Sodium Nitrate**

- **Symbol**: NaNO₃
- **Molar mass**: 84.9947 g/mol
- **Melting point**: 308°C
- **Density**: 2.26 g/cm³
- **Boiling point**: 380°C

| Machining parameters | Units | Level 1 | Level 2 | Level 3 |
|----------------------|-------|---------|---------|---------|
| Voltage              | V     | 16      | 17      | 18      |
| Feed                 | mm/min| 0.5     | 0.6     | 0.7     |
| Duty ratio           | -     | 0.6     | 0.7     | 0.8     |

**Table 2. Parameters and its levels**

![ECM Machine](image)

**Figure 6. ECM Machine**

3. Results & Discussion

3.1 Determination of optimal parameters

The results of the drilling process were tabulated in Table 3. “Smaller-the-better” quality characteristic was used to find the tapered angle, circularity& over cut and larger-the-best was used to find maximum MRR.
Table 3. Results for coated tool

| S.No | Feed rate (mm/min) | Volt (V) | Duty ratio | MRR (mm$^3$/min) | Over cut of coating tool (mm) | Taper angle of coated tool | Cirularity (mm$^3$/min) |
|------|-------------------|----------|------------|------------------|-----------------------------|---------------------------|------------------------|
| 1    | 0.5               | 16       | 0.6        | 0.0245           | 0.0904                      | 4.460                     | 1.060                  |
| 2    | 0.6               | 16       | 0.7        | 0.1078           | 0.0739                      | 4.118                     | 1.025                  |
| 3    | 0.7               | 16       | 0.8        | 0.1278           | 0.0659                      | 5.710                     | 1.039                  |
| 4    | 0.5               | 17       | 0.6        | 0.1599           | 0.0639                      | 5.767                     | 1.015                  |
| 5    | 0.6               | 17       | 0.7        | 0.1487           | 0.0654                      | 6.107                     | 1.021                  |
| 6    | 0.7               | 17       | 0.8        | 2.6560           | 0.1119                      | 5.483                     | 1.034                  |
| 7    | 0.5               | 18       | 0.6        | 0.1350           | 0.1059                      | 6.760                     | 1.152                  |
| 8    | 0.6               | 18       | 0.7        | 0.1383           | 0.0719                      | 7.857                     | 1.041                  |
| 9    | 0.7               | 18       | 0.8        | 0.1459           | 0.1154                      | 6.503                     | 1.040                  |

3.2 Signals to noise ratio

![Plot for SN ratios](image)

**Figure 7. MRR**

From figure 7. The results shows that greater the better quality characteristic The S/N ratio is help to obtain the rank influencing parameters on MRR, overcut, tapered angle & circularity “larger-the-better” quality characteristic is help to find the optimum process parameters that affect the MRR.
Followed by feed rate is highly influenced by the voltage & duty ratio. The optimal parameter for MRR is duty ratio is 0.7, voltage is 16, feed rate is 0.7.

![Plot for SN ratios](image1)

**Figure 8. Over Cut**

From figure 8. The results shows that lower the better quality characteristic. The S/N ratio is help to find the rank of influencing parameters on the, overcut “lower-the-better” quality characteristic is used to find the optimal process parameters that affect the overcut. Followed by duty ratio is highly influenced by the voltage & feed rate. The optimal parameter for overcut is duty ratio is 0.8, voltage is 16, feed rate is 0.6.

![Plot for SN ratios](image2)

**Figure 9. Circularity**

From figure 9. The results shows that lower the better quality characteristic. The S/N ratio is help to find the rank of influencing parameters on circularity “lower -the-better” quality characteristic is used to find optimal process parameters that affect the circularity. Followed by duty ratio is highly
influenced by the voltage & feed rate. the optimal parameter for circularity is duty ratio is 0.8, voltage is 17, feed rate is 0.5.

![Plot for SN ratios](image)

**Figure 10.** Tapered Angle

From figure 10. The results show that lower the better quality characteristic The S/N ratio is help to find the rank of influencing parameters on the, overcut “lower-the-better” quality characteristic is used to find optimal process parameters that affect the overcut. Followed by duty ratio is highly influenced by the voltage & feed rate the optimal parameter for overcutting is duty ratio is 0.8, voltage is 16, the feed rate is 0.6.

### 3.3 Confirmation test

The confirmation experiment is done with optimum process parameters. The predicted MRR was calculated by using a linear regression model. The linear regression equation obtained using MINITAB 17 is given below.

\[
\text{MRR} = 0.166 - 0.0054 \text{ Feed Rate} - 0.00631 \text{ Voltage} + 0.0047 \text{ Duty Ratio}
\]  

The confirmation experiment is done with optimum process parameters. The predicted TAPERED ANGLE was calculated by using a linear regression model. The linear regression equation obtained using MINITAB 17 is given below.

\[
\text{TA} = -2.67 + 2.70 \text{ Feed Rate} + 0.525 \text{ Voltage} - 4.30 \text{ Duty Ratio}
\]

The confirmation experiment is done with optimum process parameters. The predicted CIRCULARITY was calculated by using a linear regression model. The linear regression equation obtained using MINITAB 17 is given below.

\[
\text{CIRCULARITY} = 1.58 - 0.005 \text{ Feed Rate} - 0.0500 \text{ Voltage} + 0.237 \text{ Duty Ratio}
\]

The confirmation experiment is done with optimum process parameters. The predicted OVERCUT was calculated by using a linear regression model. The linear regression equation obtained using MINITAB 17 is given below.

\[
\text{OVERCUT} = 0.0222 - 0.0267 \text{ Feed Rate} + 0.0102 \text{ Voltage} - 0.0717 \text{ Duty Ratio}
\]
4. Conclusion

The Micro-ECM experimental work was conducted on SS304 steel workpiece using a Nickel coated Copper tool. The material removal rate, tapered angle, overcut, along with circularity is compared based on coated tool. In Micro-ECM the current is directly equivalent to the material removal rate.

- MRR is improved by the nickel coated electrode compare to the uncoated electrode. The nickel coated electrode produces high Material removal rate due to its low electrical conductivity.
- Life span of the tool is improved by the coated tool compare to the uncoated tool.

The optimal process parameter for the nickel coated copper tool MRR the feed rate is 0.7, voltage is 17, duty ratio is 0.8, followed by for tapered angle feed rate is 0.6, voltage is 18, duty ratio is 0.7, for circularity feed rate is 0.5, voltage is 18, duty ratio is 0.6 and for overcut feed rate is 0.7, voltage is 18, duty ratio 0.8.

5. References

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