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ANALYSIS OF MACHINING AND SURFACE FINISHING OF VARIOUS MATERIALS IN EDM

C. Krishnaraj, G. Sundaram, C. Karthickkumar and K. Kathirvel
Karpgam College of Engineering, Coimbatore, Tamilnadu, India
E-Mail: desper_sundar@yahoo.co.in

ABSTRACT

The proper selection of manufacturing conditions is one of the most important aspects to take into consideration in the majority of non-traditional machining processes and particularly, in processes related to Electrical Discharge Machining (EDM). EDM process is based on thermoelectric energy between the work piece and an electrode. Material Removal Rate (MRR), Tool Wear Rate (TWR) and surface finish are important performance measures in EDM process. Despite a range of different approaches, all the research work in this area shares the same objectives of achieving more efficient material removal rate and improved surface quality. The paper researches on EDM relating to MRR and TWR along with surface finish in various work materials like Hot Die Steel (11 / 13) and Aluminium (1100 / 2024) with different tool electrodes (Copper and Brass) and analysis will be carried out for the optimal solution as well as the result.

Keywords: electrical discharge machining (EDM), hot die steel (HDS), aluminium (AL), metal removal rate (MRR), tool wear rate (TWR).

1. INTRODUCTION

Electrical discharge machining is a non-contacting technique in which work material and tool does not contact with each other during machining. In die sink EDM, both the tool and the work material are immersed in the dielectric fluid (EDM oil). Work material is connected with positive polarity (anode) where as tool electrode with negative polarity (cathode). The unwanted portion of metal is removed by the action of electrical discharge of high current density in short duration between tool and work material.

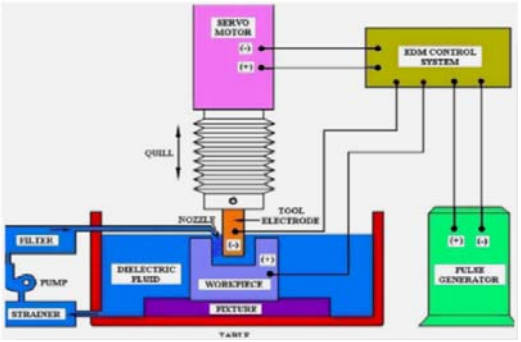

Figure-1. Experimental setup of EDM.

Micromachining and ultra precision machining can be done easily for complex shape and hard materials. EDM is widely used in die mould making industries, aerospace, nuclear, sports, automotive, medical and surgical instruments.

Rajesh Choudhary [1] investigated on EN- 31 with different electrode materials like copper, brass and graphite. Kerosene is used as dielectric fluid. The result indicated that copper offered high MRR, brass producing low SR and graphite showing high SR.

Lee [2] carried out experimental work with tungsten carbide as work material, EDM 22 oil as dielectric fluid and electrode materials with graphite, copper and copper tungsten. He exhibited the results that copper gives lowest MRR, highest relative wear and best SR.

Tebni [3] analysed the residual stress and geometrical character of EDM and wire cut EDM on 50CrV4 and X200Cr15 as work material and electrode as copper and graphite and showed results that copper gives better surface quality than graphite. Also this work determines the input parameter characteristic that increase in discharge energy increases surface roughness. Low electric energy input gives finer surface texture, less metal removal rate, increase in machining time and high surface residual stress.

Ghewade [4] experimented with Inconel-718 while copper as electrode, and concluded that MRR is affected by peak current (Ip) and gap voltage (Vg). The electrode wear rate is less influence by pulse on time (Ton) and duty cycle (t). High peak current increases MRR and with high pulse on time (Ton) Electrode Wear Rate (EWR) increases. Krishnaraj[5] researched the failure models and finds the corrective action to reduce the potential of occurrence.

From the literatures, one can see that negative polarity of tool electrode is the best for MRR and surface finish. High values of Peak current (Ip) and Pulse On time (T_{on}), low values of Pulse Off time (T_{off}) gives high MRR, TWR and it is inversely proportional to surface finish.

Copper and Brass electrodes exhibit different results with different work materials in order to MRR and SR.

The main aim of this work is to identify the best electrode for each grade of the materials and to find the difference in the grades of each material.

2. EXPERIMENTAL SETUP

This study consists of the experiments on ELECTRONICA M2S - EMS 5030 die sink EDM machine to examine the work materials Aluminium 1100 / 2024 and Hot Die Steel H 11 / 13 with copper and brass as electrodes. ELECTRONICA EDM oil is used as dielectric fluid.

The surface roughness value was examined by MITUTOYO SURFACE ROUGHNESS TESTER 3100. SPER SCIENTIFIC DECIMAL DISPLAY STOP WATCH - 810048 was used for observing readings in timing calculation.

Figure-2. Electrical discharge machine.

A. Work material

Aluminium 1100 / 2024 and Hot Die Steel 11 / 13 were used as work materials. Aluminium 1100 commonly used in spun hollowware, fin stock, heat exchanger fins, cooking utensils, decorative parts, giftware, rivets and reflector.

Aluminium 2024 is widely used in aircraft structures, especially in wings and fuselage structures under tension, fuse parts, hydraulic valve bodies, rectifier parts, fastening device, veterinary and orthopedic equipments.

Table-1. Properties of Aluminium 1100/2024.

Properties	AL 1100	AL 2024
Density, 10^3 kg/ m^3	2.71	2.78
Thermal conductivity, w/m-k	218	121
Youngs modulus, Gpa	75	73
Tensile strength, Mpa	110	213

Hot die steel 11 has a high hot tensile strength with toughness. It has good thermal conductivity and insusceptibility to hot cracking.

Hot die steel 13 has an air hardening tool steel which combines a good hardness with toughness. It gives high temperature strength and wear resistance. The major application of both HDS is in pressure casting dies, metal extrusion for processing light metals, forging dies, moulds, screws and barrels for plastic processing.

Hot Die Steel 11/13 properties

Density – 7.8 g /cm^3
Ultimate tensile strength – 1990 Mpa
Yield tensile strength – 1650 Mpa
Modulus of elasticity – 210 Gpa

Table-2. Composition of work materials.

Elements / work material	AL 1100	AL 2024	HDS 11	HDS 13
Aluminium, Al	99.3	93.3	0.0086	0.0081
Iron, Fe	0.477	0.126	91.2	90.5
Chromium, Cr	0.0032	0.0055	5.23	5.20
Manganese, Mn	0.0005	0.55	0.459	0.363
Magnesium, Mg	0.022	1.67	0.011	0.011
Vanadium, V	0.0047	0.007	0.3	0.8
Silicon, Si	0.14	0.058	0.869	0.94
Titanium, Ti	0.013	0.052	0.032	0.0036
Copper, Cu	0.0097	4.21	0.092	0.084

B. Dielectric fluid

ELECTRONICA EDM oil consists of purified non hazardous chemicals which offer greater resistance to electrode wear, high dielectric strength(60Kv), low viscosity for easy flushing and virtually odorless.

C. Tool material (Electrodes)

Copper and brass are used as electrodes. Copper is a ductile metal and has tensile strength with very high thermal and electrical conductivity. It has major usage on power applications as wires, integrated circuits, printed circuit boards, heat sinks, heat exchangers, vacuum tubes, cathode ray tubes, roofing plumbing, domes, wall cladding, and radio frequency shielding. It is also used for anti-bio-fouling and anti-microbial applications.

Brass is an alloy of copper and zinc. It has major application on locks, gears, bearings, casings, valves, plumbing, fittings, and tools around explosive glass.

Table-3. Properties of electrodes.

Properties	Copper	Brass
Density, g/cm^3	8.96	8.4
Melting point, °c	1083	990
Specific heat capacity, J/g°c	0.385	0.38
Thermal conductivity, w/mk	401	159
Electrical resistivity, Ω cm	1.69	4.7

D. Experimental procedure

Experiments on work material of each grade were carried out for best surface finishing and high metal removal rate, Electrode Wear Rate with both electrodes. By comparing the results, suitable electrode was selected. Different input values are used to obtain high MRR and low SR.

Table-4. Constant input parameters.

Parameters	Values
Gap control	3 µm
Lift timing	4 µs
Spark timing	1 µs
Sensitivity	7
Ignition	4
Flushing pressure	5 kg / cm^2
Tool polarity	Negative
Work material polarity	Positive
finishing	Normal
Impulse flushing	Off
Pump	On

Table-5. Varying input parameters.

Parameters	High MRR	Low SR
Peak current (Ip), amps	7	0.5
Pulse On time (T_{on}), µs	7	3
Pulse Off time (T_{off}), µs	6	9

3. RESULTS AND DISCUSSIONS

A. Metal Removal Rate (MRR)

For high metal removal test, the machining (rough) is done on each grade of each material with rough machining input values for 2mm depth of cut; the time is calculated for each step. The electrode which has low machining time is considered as best for metal removal rate.

Table-6. MRR time (min) for 2mm depth of cut.

	AL 1100	AL 2024	HDS 11	HDS 13
Copper	2.00.61	1.42.36	5.34.17	3.53.18
Brass	1.39.80	2.49.65	7.36.55	8.39.87

Determination of MRR with respect to Time, t (min)

Rough machining is done on each grade of each material for 2mm depth of cut. Low machining time is considered as the best for metal removal rate. For Aluminium 1100, Brass electrode is suitable for high MRR in low machining time. For Aluminium 2024 and HDS H 11/13, Copper electrode is suitable for high MRR in low machining time.

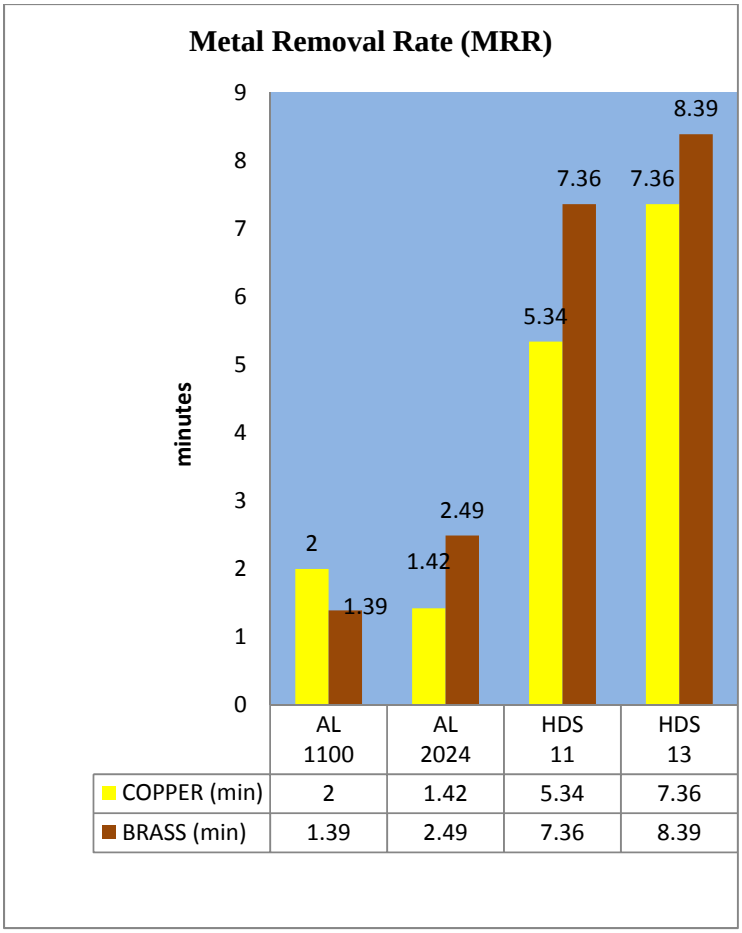

Figure-3. MRR Time (min) for 2mm depth of cut.

B. Surface finish

For the best surface finishing test, the machining is done on each grade of each material. The electrode which has low surface roughness value is considered as the best for surface finish. The surface finish is experimented with the help of surface roughness tester.

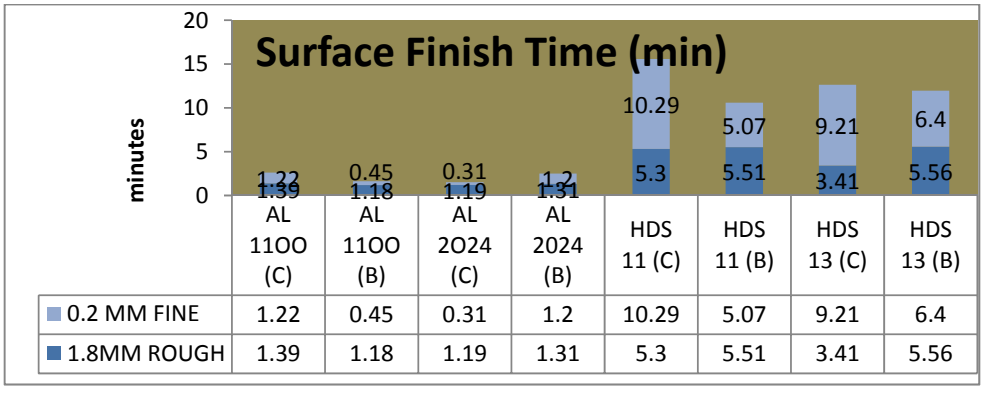

Figure-4. Surfaces finish machining time (min).

B.i. Determination of surface finish with respect to Time, t (min)

For surface finishing test, the metal removal rate was too low, as the input parameters Peak Current (Ip) and Pulse on Time (T_{on}) was provided with less value and then, machining time was increased so high. To eliminate these problems, with rough machining input values are given up to 1.8 mm depth of cut and then the remaining 0.2mm depth of cut with surface finish machining input values were given. The pulse on time (T_{on}) was reduced from 7 - 3 µs and Peak Current (Ip) was reduced from 7 - 0.5 amps. The Pulse off Time (T_{off}) was increased from 6 - 9µs. The electrode which has low surface roughness value is considered as best for surface finishing.

Table-7. Surface finishes machining time (min).

	Depth of cut (mm)	**AL 1100**	**AL 2024**	**HDS 11**	**HDS 13**
Copper	1.8 rough	1.39.51	1.19.36	5.30.61	3.41.37
	0.2 finish	1.22.97	0.31.76	10.29.74	9.21.71
Brass	1.8 rough	1.18.37	1.31.41	5.51.80	5.56.08
	0.2 finish	0.45.10	1.20.40	5.07.57	6.40.60

Comparison of Surface finishes machining time (min)

For surface finish machining, low surface roughness value (Ra) is considered as the best for surface finishing. While in the mean time, the machining time is considered for fine metal removal rate.

For Aluminium 2024, Copper electrode is suitable for high MRR in low machining time. For Aluminium 1100 and HDS 11/13, Brass electrode is suitable for high MRR in low machining time. Aluminium takes very low machining time than HDS for same input values.

For HDS materials, high surface finishing is obtained in less time with Brass, although in rough machining, Copper gives high MRR in less time.

B. ii. Determination of surface finish with respect to roughness value, Ra (µm)

For surface finishing test, the electrode which has low surface roughness value is considered as the best for surface finishing.

Table-8. Surface roughness value Ra, (µm).

	AL 1100	**AL 2024**	**HDS 11**	**HDS 13**
Copper	2.64- 2.79	2.85- 3.02	3.36- 3.40	2.92- 3.05
Brass	2.26- 2.38	2.71- 2.79	3.52- 3.59	3.57- 3.70

Comparison of surface finish with respect to roughness value, Ra (µm)

For Al 1100/ 2024, Brass is the best electrode with low surface roughness value. For HDS 11/13, Copper is the best electrode with low surface roughness value.

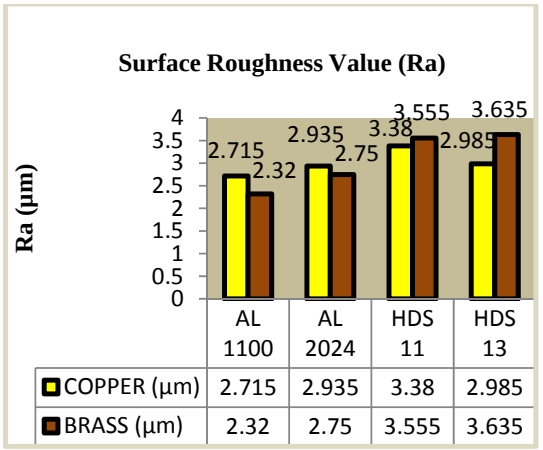

Figure-5. Surface roughness value Ra, (µm).

B. iii. Effect of roughness value on machining time

The surface roughness did not give much more difference between the electrodes. The time taken for surface finishing gave the result that aluminium is machined very quickly than that of HDS materials. Brass wears more with HDS. Surface machining with copper electrode takes more time for HDS materials.

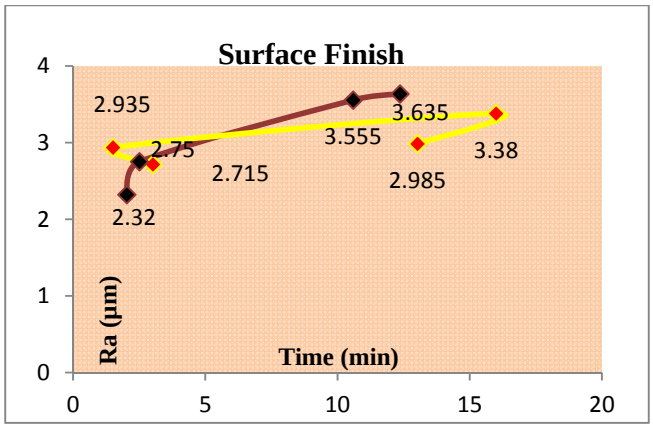

Figure-6. Effect of roughness value on machining time.

C. Comparison of tool wear rate

For Aluminium 1100 / 2024 and Hot Die Steel 11 / 13; Copper has high tool wear rate (TWR) which also eroded more while on machining. Tool wear rate is nothing but Electrode Wear Rate (EWR). Since comparing with copper, Brass has very low wear rate for both rough machining and fine machining in all the materials as well as its grades.

Figure-7. Copper/ Brass electrodes after machining.

D. Comparison of grades

D. i. Comparing Al 1100 and 2024

Al 1100 has less time machining for both MRR and SR with Brass electrode. Al 2024 has less machining time for both MRR and SR with Copper electrode. Al 1100/2024 has the best SR value the Brass electrode.

Figure-8. Machining of Al 1100 / 2024.

D. ii. Comparing HDS 11 and 13

HDS 11/13 has less machining time for MRR with copper electrode. HDS11/ 13 have less time machining SR with brass electrode. HDS 11/13 has the best SR value with copper electrode.

Figure-9. Machining of HDS 11 / 13.

E. Comparing the results

Tabulate the results of rough machining time, fine machining time, roughness results and low tool wear rate for conclusion.

Table-9. Over all comparison of results.

Experiment	Rough machining time	Fine machining time	Roughness result	Low tool wear rate
AL 1100	Brass	Brass	Brass	Brass
AL 2024	Copper	Copper	Brass	Brass
HDS 11	Copper	Brass	Copper	Brass
HDS 13	Copper	Brass	Copper	Brass

4. CONCLUSIONS

The experimental investigation is conducted to identify the best electrode between copper and brass for work material Aluminium 1100 / 2024 and Hot Die Steel 11 /13. Tentatively, the following conclusions may be drawn from the results.

A. For Aluminum 1100, Brass is the suitable electrode for less machining time and surface roughness.

B. For Aluminum 2024, Copper is the suitable electrode for machining in less timing and Brass is suitable for surface finishing.

C. For both Hot Die Steel 11/13, Copper is the suitable electrode for best MRR and SR. For fine machining, Brass takes less timing.

D. For Aluminium 1100 / 2024 and Hot Die Steel 11 / 13; when compared with Brass, Copper has high tool wear rate (TWR).

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