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COMPARATIVE STUDY ON EDM OF PURE COPPER ELECTRODE AND FLAME HARDENED ELECTRODE WHILE MACHINING D2 STEEL

Pawan Kumar[1], Amit Pancharya[2], Amit Mishra[3], Arun Kumar[4], Prabhat Kumar[5]
[1,3,4,5]M.Tech, [2]Associate Professor
[1,2,3,4,5]Malaviya National Institute of Technology, Jaipur
[1]NAI BAZAR WARD NO.5, BUXAR PIN-802101, BIHAR
[2]9, Motidungri Road, Jaipur, Rajasthan
[3]Santnagar, Sidhauli District- Sitapur, U.P., 261303
[4]Hostel No- 08, 5Hostel No- 04

ABSTRACT: In this research work D2 steel was machined on EDM by flame burned then quenched tool. The quenching medium was water and Mobil oil. As D2 steel is a very hard material and its machining by conventional processes is difficult, a very hard tool like CBN is used to machine it. But by using EDM technique it can be easily machined, the only problem associated with it is high tool wear which we have tried to reduce. TWR and MRR was measured for the prepared tools and the process variables were input current and lift and all the variables were kept constant. It is found that TWR has reduced for the water quenched copper electrode and oil quenched copper electrode as compared to pure copper electrode.
Key words: MRR, TWR, EDM, D2 steel, copper

Abbreviations:
MRR- material removal rate
TWR- tool wear rate
EDM- electrode discharge machining

I. INTRODUCTION

EDM is the process mostly used for making dies and normally dies are made of hard materials which are difficult to machine. EDM is the most versatile process amongst the non-traditional machining processes and also it is economically justified. But then the problem associated with EDM is its tool wear rate (TWR) which is higher in the case of copper, which is most commonly used tool for the EDM process. There are several methods by which TWR can be reduced like coating with some insulated material, electroplating electrically resistive material. These methods are costlier in nature. So we have tried a very economical way of reducing TWR, which is by making copper oxide layer on the outer periphery of electrode by burning it with oxidizing flame and subsequently quenching in different media like water and oil. For this the set up used was of oxy-acetylene welding which is also very easily available. An oxidising flame was made by allowing more oxygen to the flame which results in adequacy of oxygen to react with copper and form oxides of copper which are electrically and thermally insulators. As only the outer periphery of the tool is burnt which means only outer periphery will give insulation. As copper gives flame test which confirms the formation of oxide layer, while burning copper gives bluish green colour. This on copper after cooling converts to yellowish colour.

II. METHODOLOGY

Hao-Long Chen [6] et al. studied the effect of the oxide film formed on the electrical properties of Cu-Zn alloy electric contact material. They found that the oxide film formed from heating oxidation of 70 wt% Cu-30wt% Zn alloy contact material in atmosphere at high-temperature and different heating times. The above research paper motivates our methodology and research work.

Preparation of tools:

Copper was selected for the tool material because of its high electrical conductivity. Firstly the surface of copper was made scale free with the help of emery paper and then for making copper oxide layer on the outer periphery of copper tool, set up of oxy acetylene welding was used. Oxidizing flame was used so that there will be adequate amount of oxygen to react with copper and form the oxide of copper. The quenching oil used was Mobil oil, because flash point of Mobil oil is very high. For water quenched tool, normal tap water was used. And air cooled tool was cooled in still air condition. Initially the surface of copper was made scale free and smooth with the help of emery paper then flame burning of copper was done.

Fig.1 flame burning of copper

Prepared tools:

Fig.2 prepared tools

From extreme left, oil quenched, air cooled, oil quenched, cold rolled and oil quenched . Quenching was done to make fine grain structure of copper tool, because of which inter molecular distances between the copper atoms will be less. This results in proper holding of atom thus less erosion of tool. For comparison purpose only air cooled tool was prepared.

Experimentation:

All the experiments were performed on EZNC (EMS5535-R50 ZNC), SERIES 2000, keeping all factors constant except input current and lift. For higher depth of cut lift is a important parameter as it allows the debris to escape from the machining area which improves the MRR. But too high lift can reduce the MRR as it takes unnecessary time. Utmost precaution was taken while performing machining. Sponge was used to soak the dielectric after machining so that the reading taken is genuine.

III. RESULTS AND DISCUSSION

Observation tables:

1. For pure copper tools

Sl.No	Ip	Ton	SEN	TOU	IB	SPK	LFT	GAP	Sample Weight Before	Sample Weight After	Tool Weight Before	Tool Weight After	Machining Time (min)	MRR (mm3/sec)	TWR (mm3/sec)	%Wear
1	3	17	50	4	3	10	0.2	40	214.904	214.446	75.361	75.353	6.3167	9.41639139	0.14230158	1.511213422
2	6	17	50	4	3	10	0.2	40	214.446	213.928	75.353	75.301	2.9	23.1574922	2.01472298	8.665089584
3	9	17	50	4	3	10	0.2	40	213.928	213.436	75.301	75.243	2.2833	27.9841037	2.85413828	10.19914132
4	12	17	50	4	3	10	0.2	40	213.531	212.479	75.275	75.099	2.08333	65.5793257	9.49215002	14.47430256
5	15	17	50	4	3	10	0.2	40	212.479	212.094	75.099	75.02	1.63333	30.6123074	5.43454445	17.75280896
6	3	17	50	4	3	10	0.5	40	212.094	211.619	75.02	75.015	5.9333	10.3989649	0.09468555	0.910703726
7	6	17	50	4	3	10	0.5	40	211.619	211.146	75.015	74.994	3.35	18.336887	0.70434345	3.841128822
8	9	17	50	4	3	10	0.5	40	211.146	210.726	74.994	74.965	2.1833	22.8865248	1.36719128	5.973782772
9	12	17	50	4	3	10	0.5	40	210.726	210.2	74.941	74.846	2.33333	29.2764797	4.57464538	15.62566754
10	15	17	50	4	3	10	0.5	40	119.518	119.214	88.443	88.413	1.1667	33.8394784	2.88916304	8.537847428
11	3	17	50	4	3	10	1	40	122.397	122.064	88.634	88.625	4.6667	9.26709522	0.21669187	2.33829335
12	6	17	50	4	3	10	1	40	122.064	121.682	88.625	88.617	2.7333	18.1503639	0.32886123	1.813871287
13	9	17	50	4	3	10	1	40	121.682	121.358	88.617	88.587	1.5	22.1462748	1.77409817	8.010819809
14	12	17	50	4	3	10	1	40	121.358	120.998	88.587	88.54	1.6	29.2207792	3.3005618	11.29525599
15	15	17	50	4	3	10	1	40	119.214	118.905	88.413	88.364	1.2667	31.6806427	4.34642613	13.71958111
16	3	17	50	4	3	10	1.2	40	120.998	120.617	88.54	88.534	5.1167	9.67039683	0.13175627	1.362470141
17	6	17	50	4	3	10	1.2	40	120.617	120.248	88.534	88.524	2.91667	16.4304079	0.3852323	2.344630188
18	9	17	50	4	3	10	1.2	40	120.248	119.864	88.524	88.496	2.15	23.1954092	1.46328717	6.308520599
19	12	17	50	4	3	10	1.2	40	119.864	119.518	88.496	88.443	1.5333	29.3061142	3.88381672	13.25258167
20	15	17	50	4	3	10	1.2	40	118.905	118.614	88.364	88.326	1.13333	33.3461638	3.76736072	11.2977335

Table.1. observation table for pure copper tool

For this tool TWR is more and MRR is less.

2. For oil quenched copper electrode

Sl.No	Ip	Ton	SEN	TOU	IB	SPK	LFT	GAP	Sample Weight Before	Sample Weight After	Tool Weight Before	Tool Weight After	Machining Time (min)	MRR (mm3/sec)	TWR (mm3/sec)	%Wear
1	3	17	50	4	3	10	0.2	40	254.76	254.315	103.614	103.52	6.35	9.10113509	1.73405291	19.05314985
2	6	17	50	4	3	10	0.2	40	254.315	253.928	103.516	103.52	2.58333	19.4554084	0.04349408	0.223557762
3	9	17	50	4	3	10	0.2	40	253.928	253.432	103.515	103.48	2.416667	26.6547209	1.81325043	6.802736499
4	12	17	50	4	3	10	0.2	40	253.432	252.956	103.476	103.43	1.95	31.7016317	2.76577355	8.724388632
5	15	17	50	4	3	10	0.2	40	252.956	252.479	103.428	103.36	1.3333	46.4622005	5.98329565	12.8777071
6	3	17	50	4	3	10	0.5	40	252.479	252.006	103.357	103.32	6.4833	9.47489264	0.64123261	6.767703162
7	6	17	50	4	3	10	0.5	40	252.006	251.546	103.32	103.31	3.08333	19.3752403	0.40085072	2.06888129
8	9	17	50	4	3	10	0.5	40	251.546	251.031	103.309	103.28	2.71667	24.619522	1.1580602	4.703828952
9	12	17	50	4	3	10	0.5	40	251.031	250.611	103.281	103.22	1.71667	31.7739895	3.79621822	11.94756554
10	15	17	50	4	3	10	0.5	40	250.611	250.205	103.223	103.15	1.56667	33.6556344	5.09202837	15.12979465
11	3	17	50	4	3	10	1	40	250.205	249.709	103.152	103.13	6.68333	9.63824686	0.4539216	4.709586807
12	6	17	50	4	3	10	1	40	249.709	249.279	103.125	103.12	3.23333	17.2714062	0.17375206	1.006009929
13	9	17	50	4	3	10	1	40	249.279	248.801	103.12	103.1	2.61667	23.7240164	1.07349752	4.524940059
14	12	17	50	4	3	10	1	40	248.801	248.456	103.095	103.05	1.9	23.5816815	2.66114725	11.28480703
15	15	17	50	4	3	10	1	40	239.783	239.356	103.05	103.01	2.15	25.7928118	2.29945127	8.915085651
16	3	17	50	4	3	10	1.2	40	239.356	238.925	103.006	103	7.31667	7.65020508	0.06142661	0.80294064
17	6	17	50	4	3	10	1.2	40	238.925	238.533	103.002	103	3.766667	13.5156867	0.05965993	0.44141252
18	9	17	50	4	3	10	1.2	40	238.53	238.006	103	102.99	3.35	20.3140143	0.43602214	2.146410498
19	12	17	50	4	3	10	1.2	40	238.006	237.738	102.987	102.97	1.916667	18.1592289	1.17244728	6.456481637
20	15	17	50	4	3	10	1.2	40	237.738	237.28	102.967	102.93	2.85	20.8703577	1.34042973	6.422648545

Table.2. observation table for oil quenched tool

3. For air cooled copper tool

Sl.No	Ip	Ton	SEN	TOU	IB	SPK	LFT	GAP	Sample Weight Before	Sample Weight After	Tool Weight Before	Tool Weight After	Machining Time (min)	MRR (mm3/sec)	TWR (mm3/sec)	%Wear
1	3	17	50	4	3	10	0.2	40	240.893	240.353	91.895	91.891	7.1	9.8774465	0.06330116	0.640865585
2	6	17	50	4	3	10	0.2	40	240.353	239.811	91.891	91.868	3.61667	19.4625471	0.71454395	3.67137941
3	9	17	50	4	3	10	0.2	40	273.889	273.37	91.87	91.811	2.7	24.963925	2.45526425	9.835249291
4	12	17	50	4	3	10	0.2	40	273.37	272.944	91.811	91.735	1.83333	30.1771505	4.65782256	15.43493169
5	15	17	50	4	3	10	0.2	40	272.944	272.465	91.735	91.641	1.61667	38.4789674	6.5330573	16.97825526
6	3	17	50	4	3	10	0.5	40	272.465	271.967	91.641	91.62	6.9	9.37323546	0.34196385	3.648301069
7	6	17	50	4	3	10	0.5	40	271.967	271.496	91.62	91.607	3.45	17.730096	0.42338381	2.387938644
8	9	17	50	4	3	10	0.5	40	271.496	271.002	91.607	91.553	2.583333	24.8345235	2.34867736	9.45730792
9	12	17	50	4	3	10	0.5	40	271.002	270.561	91.553	91.472	1.96667	29.1216764	4.62768212	15.89085072
10	15	17	50	4	3	10	0.5	40	270.561	270.178	91.472	91.385	1.41667	35.110689	6.90018205	19.6526535
11	3	17	50	4	3	10	1	40	270.178	269.699	91.385	91.377	6.816667	9.12583704	0.1318645	1.444957894
12	6	17	50	4	3	10	1	40	269.699	269.267	91.377	91.364	3.41667	16.4206365	0.42751397	2.603516438
13	9	17	50	4	3	10	1	40	269.267	268.804	91.364	91.303	2.68333	22.4086751	2.55426376	11.39854879
14	12	17	50	4	3	10	1	40	268.804	268.415	91.303	91.229	1.9	26.5892003	4.37610881	16.458219
15	15	17	50	4	3	10	1	40	268.415	268.016	91.229	91.145	1.6	32.3863636	5.8988764	18.21407451
16	3	17	50	4	3	10	1.2	40	267.927	267.466	91.112	91.103	7.56667	7.91234848	0.13364346	1.689049209
17	6	17	50	4	3	10	1.2	40	267.466	267.09	91.103	91.074	4.41667	11.0561054	0.73775649	6.672842458
18	9	17	50	4	3	10	1.2	40	210.176	209.906	91.074	91.058	1.83333	19.126363	0.98059422	5.126924677
19	12	17	50	4	3	10	1.2	40	209.906	209.593	91.058	90.975	1.68333	24.1481769	5.54011554	22.94216893
20	15	17	50	4	3	10	1.2	40	209.593	209.303	90.975	90.907	1.2333333	30.5370314	6.19495917	20.28671058

Table.3. observation table for air cooled copper tool

4. For water quenched copper tool

									Sample Weight		Tool Weight		Machining Time	MRR	TWR	
Sl.No	Ip	Ton	SEN	TOU	IB	SPK	LFT	GAP	Before	After	Before	After	(min)	(mm3/sec)	(mm3/sec)	%Wear
1	3	17	50	4	3	10	0.2	40	261.268	260.863	103.489	103.49	5.25	10.0185529	0.02140182	0.213621862
2	6	17	50	4	3	10	0.2	40	260.863	260.348	103.488	103.46	3.08333	21.6918451	1.16611119	5.375804516
3	9	17	50	4	3	10	0.2	40	260.348	259.854	103.456	103.43	2.416667	26.5472422	1.39480802	5.254059955
4	12	17	50	4	3	10	0.2	40	259.815	259.465	103.41	103.38	1.66667	27.2726727	2.15729906	7.91011236
5	15	17	50	4	3	10	0.2	40	259.456	258.974	103.378	103.33	1.7	36.8220015	3.04031725	8.256795189
6	3	17	50	4	3	10	0.5	40	258.574	258.518	103.332	103.33	6.41667	9.22920755	0.07004228	0.758915771
7	6	17	50	4	3	10	0.5	40	258.518	258.091	103.328	103.32	3.31667	16.7199466	0.27101774	1.620924664
8	9	17	50	4	3	10	0.5	40	258.091	257.621	103.32	103.31	2.6	23.4765235	0.56179775	2.399019364
9	12	17	50	4	3	10	0.5	40	257.621	257.168	103.307	103.28	2.13333	27.5771535	1.52739003	5.538606543
10	15	17	50	4	3	10	0.5	40	257.146	256.703	103.272	103.23	1.81667	31.6691901	2.47396722	7.811905547
11	3	17	50	4	3	10	1	40	256.703	256.218	103.232	103.23	8.43333	7.46881872	0.06661636	0.891926329
12	6	17	50	4	3	10	1	40	256.218	255.749	103.227	103.22	4.18333	14.5599537	0.29544766	2.029179943
13	9	17	50	4	3	10	1	40	255.749	255.276	103.216	103.2	3.1333	19.6050718	0.46617756	2.377841651
14	12	17	50	4	3	10	1	40	255.276	254.795	103.203	103.17	2.65	23.5726538	1.56879372	6.65514261
15	15	17	50	4	3	10	1	40	254.795	254.377	103.166	103.12	1.96667	27.6028588	2.79946202	10.14192785
16	3	17	50	4	3	10	1.2	40	254.377	253.951	103.117	103.11	7.75	7.13866778	0.08898804	1.218547238
17	6	17	50	4	3	10	1.2	40	253.951	253.483	103.111	103.1	4.5	13.5064935	0.17478152	1.294055508
18	9	17	50	4	3	10	1.2	40	253.483	253.055	103.104	103.09	3.06667	18.1253332	0.51294522	2.829990549
19	12	17	50	4	3	10	1.2	40	253.055	252.584	103.09	103.05	2.7833	21.9770888	1.57439819	7.163815931
20	15	17	50	4	3	10	1.2	40	252.584	252.203	103.051	103	1.833	26.9942823	3.00361046	11.12683948

Table.4. observation table for water quenched copper tool

5. For cold rolled and oil quenched copper tool

									Sample Weight		Tool Weight		Machining Time	MRR	TWR	
Sl.No	Ip	Ton	SEN	TOU	IB	SPK	LFT	GAP	Before	After	Before	After	(min)	(mm3/sec)	(mm3/sec)	%Wear
1	3	17	50	4	3	10	0.2	40	237.265	236.976	79.927	79.926	3.6667	10.2360345	0.03064324	0.299366277
2	6	17	50	4	3	10	0.2	40	236.976	236.653	79.926	79.925	4.16667	10.0675244	0.02896627	0.267854037
3	9	17	50	4	3	10	0.2	40	236.653	236.342	79.925	79.901	1.61667	24.9832126	1.66801463	6.676541783
4	12	17	50	4	3	10	0.2	40	236.342	236.088	79.901	79.868	1.2	27.4891775	3.08988764	11.24037866
5	15	17	50	4	3	10	0.2	40	236.088	235.684	79.868	79.797	1.4	37.4768089	5.69823435	15.20469463
6	3	17	50	4	3	10	0.5	40	235.684	235.347	79.797	79.792	4.8	9.11796537	0.1170412	1.283632948
7	6	17	50	4	3	10	0.5	40	235.347	234.991	79.793	79.78	2.71667	17.0185434	0.53767081	3.159923318
8	9	17	50	4	3	10	0.5	40	234.991	234.542	79.78	79.75	2.65	22.0044107	1.27199491	5.78063612
9	12	17	50	4	3	10	0.5	40	234.542	234.125	79.75	79.691	2.01667	26.8540932	3.28720786	12.24099372
10	15	17	50	4	3	10	0.5	40	234.125	233.77	79.691	79.641	1.78333	25.8527003	3.15827366	12.18547238
11	3	17	50	4	3	10	1	40	197.885	197.488	79.641	79.635	6.8667	7.50847446	0.09817777	1.307559505
12	6	17	50	4	3	10	1	40	244.303	243.9	79.635	79.622	3.9333	13.3062981	0.37136098	2.790866256
13	9	17	50	4	3	10	1	40	197.488	197.121	79.622	79.605	2.61667	18.2148829	0.72997832	4.007592689
14	12	17	50	4	3	10	1	40	243.9	243.651	79.605	79.56	1.5333	21.0902383	3.29758024	15.63557601
15	15	17	50	4	3	10	1	40	197.121	196.746	79.56	79.493	1.81667	26.8080051	4.14389506	15.4576779
16	3	17	50	4	3	10	1.2	40	243.651	243.29	79.493	79.488	6.6	7.10350256	0.08512087	1.198294376
17	6	17	50	4	3	10	1.2	40	196.746	196.367	79.488	79.479	3.86667	12.7295009	0.26152631	2.054489935
18	9	17	50	4	3	10	1.2	40	243.29	243.009	79.479	79.457	2.1	17.3778602	1.17710005	6.773561518
19	12	17	50	4	3	10	1.2	40	196.367	195.962	79.457	79.394	2.55	20.6264324	2.77594184	13.45817728
20	15	17	50	4	3	10	1.2	40	243.009	242.583	79.394	79.313	2.15	25.7324071	4.23308074	16.45038772

Table.5. observation table for cold rolled and oil quenched copper tool

From the observation tables we can conclude that TWR has reduced for the prepared tools as compared to the pure copper tool. Also MRR is improved for certain combinations.

IV. CONCLUSIONS

1. Flame burned copper gives less TWR and more MRR as compared to pure copper tool.
2. Flame burned and oil quenched tool gives the best result.

Research gap:

1. Non-Uniformity of oxide layer which affects the result.
2. Inert condition can be applied for better result.

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