Experimental Investigation of the Machining Characteristics of Micro EDM using Tungsten Carbide (WC) as an electrode and its Improvement by Electrode Coating

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Abstract: Micro electric discharge machining (micro EDM) is a Non-conventional machining process. Micro tool is used in micro EDM as compared to EDM process. Micro electrical discharge machining is one of the most Precise Technique for the fabrication of microstructures. Micro electric discharge machining is used for making very small parts 50 to 100 Micrometers. Precisely controlled spark is occurs in between electrode and workpiece. Dielectric fluid is used in between wire and workpiece for providing insulation and ionization effect at specific voltage. In this study Tungsten carbide is used as one of tool electrode. Tool coatings are used to increase life of the tool. Coating help to improve performance and life of the tool. The development of the coated carbide tool technology has vastly included the advancement in manufacturing technology. This paper describes comparative study of the performance of WC, WC coated TiAlN, WC Coated AlCrN.

***Index Terms*– Micro EDM, Non-Conventional, Tool Coating.**

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1. Introduction

In recent years, there has been an increasing demand for micromachining, due to the need for miniaturization and lighter weight in products [1]. Micromachining techniques use precision machining to manufacture micro-components within very close tolerances. Micro electrical discharge machining (micro EDM) can be used to machine almost every conductive material, regardless of its hardness. It has been widely used in processes to fabricate micro scale structures and components such as micro injection, for micro die/molds, fuel nozzles, micro probes, photo-masks, and micro tools [2]. Since EDM is a non-contact machining process, there are no physical cutting forces between the work-piece and the electrode, which makes the method very effective for micromachining with a thin electrode. This makes it easy to produce micro-parts without distortion due to physical force [3]. Micro EDM is becoming increasingly important for the manufacture of micro- and miniature parts and structures and in the development of micro-electro mechanical systems [4]. Over the next four years, the Microsystems market, including Micro- Structure Technologies (MST) and Micro-Electro-Mechanical Systems (MEMS), is predicted to grow at a rate of 16% per year from $12 billion in 2004 to $25 billion in 2009 across a spectrum of 26 MEMS/MST products [5]. Conventional processes are increasingly being improved for use in micro- machining. The most common processes are micro milling, laser machining and more specifically micro EDM, which is being applied in many micro applications [6]. Tool electrode materials that are used for micro EDM are tungsten carbide (WC), brass, cemented carbide, copper (Cu), and tungsten copper (CuW), because they give goodperformance and can be machined [7]. WC is an important tool electrode material, because it has a high melting point, high mechanical hardness, and high thermal and superior corrosion resistance, which allows higher currents to be supplied from the pulse generator during EDM machining, without electrode breakage [8].

2. METHODOLOGY

Design and Analysis:

Our aim is to investigate performance characteristics of coated electrode using Hyper-15 micro-EDM machine. After machining, MRR and TWR are to be calculated. Surface topography of the machined channel will be analyzed using SEM and XRD analysis i. e. Scanning electron microscope (SEM) analysis of the machined Micro channel and tool. X-Ray Diffraction Analysis (XRD) of the machined Micro channel and tool to find composition of individual elements. The complete analysis will be studied and reported.

Performance Testing:

After electrode coating from the outsourcing, it will be experimented on HYPER-15 micro-EDM machine. Machining parameters like MRR and TWR will be calculated by weighing the work piece and tool before and after machining using precision balance. The accuracy of balance is 10 mg. The SR of the machined channel and the tool will be analyzed using SEM. XRD analysis also will be carried out for finding the composition of individual elements.

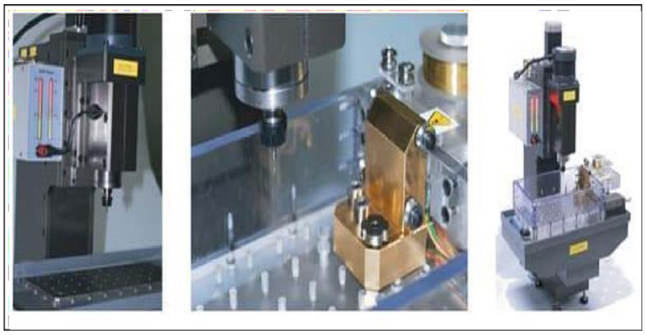


Figure 1 Hyper-15 hybrid EDM machine

Coating process:

In the current study CVD Coated tools are used for machining process.

CVD coatings can be found in an assortment of customer things. They are famous for having a long-lasting and environmentally inviting lean film surface. CVD items are utilized in an assortment of applications such as machine instruments, explanatory stream way components, wear components, instrumented, and numerous other regions that require a tall execution lean film. There are numerous lean movies accessible, but what makes the chemical statement strategy distant better; a much better a higher a stronger an improved an improved coating for tall execution exactness applications Chemical vapor statement may be a response that happens when a unstable antecedent is conveyed into a chamber, regularly beneath vacuum.

This chamber is warmed to a response temperature, causing the antecedent gas to respond, or break down, and tie to the fabric surface. Coating fabric gathers on the surface over time, coming about in a coating that covers the complete uncovered part's surface. A trichlorosilane forerunner, for illustration, can be utilized to join silicon to a surface. When trichlorosilane is warmed within the coating chamber, the taking after breakdown and coating response may happen

$SiHCl_3$ à $Si + Cl_2 + HCl$

The chlorine and hydrochloric corrosive gas will be vented from the chamber and scoured agreeing to fitting administrative necessities while the silicon will bond to any uncovered surfaces (both inner and outside). The CVD coating framework may see comparable to the chart underneath.

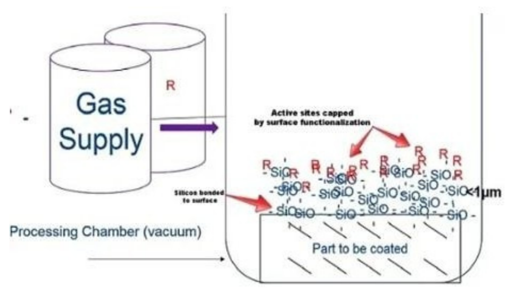


Figure 2 CVD Coating process

3. EXPERIMENTATION

The micro-EDM machine was used for the experiments on coated micro tools. Because the machining is on a micro scale, the tool chosen has a diameter of 500 microns, making coating a challenging process. The machining performance of coated tools is determined using (TiAlN) and AlCrN coating on tungsten carbide (WC) tools. For these tools, brass was chosen as the work piece material. Copper tools were used to make a trail on a spring steel work piece. Copper tools produced S are used alongside conventional tools to compare machining performance.

3.1 Work piece for coated micro-Tools

The work piece material selected is Brass. It is alloy of copper 60% with 40% Zinc. Since the scope of the experimentation is limited to comparative performance analysis of coated tools and uncoated tools. Hence for ease of operation brass is material selected. The reason for selecting Brass is its extensive properties like its conductive nature. It returns to its original shape withoutdistorting

Figure 3 Work piece for coated micro-Tools Brass

3.2 Experimental Design

A variety of input factors were used to design the experimentation and the experimentation was carried out. Coating material, Ton time and Toff time, gap voltage, gap current, etc. are three input parameters.
The time in microseconds that the peak current is prepared to flow throughout each cycle is known as the spark on-time (also known as pulse time or Ton). The metallic specks on the work item are removed at this period by energy. This energy is controlled by the peak current and the on-time duration.
The interval in microseconds between the two pulse on times is known as the spark off-time (pause time or Toff). This gives the melted particle time to congeal on the work piece and be washed away using the arc gap's flushing process. Gap Current and Gap Voltage are the current and voltage between the gap of the electrode and work piece expressed in Volt and Ampere respectively. With reference to literature, operator's manual provided by manufacturer the Voltage, Gap Voltage, Gap Current are taken as listed in tables 4.4 and 4.5.Metal removal rate and tool wear rate are determined for performance evaluation of coated electrodes and uncoated electrodes. For this Ton and Toff time as well as weight before machining and after machining are recorded for tooland work piece. Total machining time is recorded for calculations. MRR is the rate at which metal gets removed from work piece per unit time. Similarly, TWR is rate at which electrode (tool) wear occurs per unit time. This is summarized in table 1

Table No.1 Design of experiments

Sr.No.	Material	Ton	Voltage	Current
1	1	50	60	2
2	1	60	70	4
3	1	70	80	6
4	2	50	70	6
5	2	60	80	2
6	2	70	60	4
7	3	50	80	4
8	3	60	60	6
9	3	70	70	2

4. Results and Discussion

From the figure 4 and 5, it is observed that coating improves MRR slightly than uncoated tools simultaneously tool wear rate of coated tool is relatively decreased when compared with uncoated tool the factors like uniformity of coating, conductivity of coating material also affects the tool wear rate and material removal rate. For micro tools uniform coating becomes difficult task but for macro machining tool coating of uniform thickness will be easier task. If coating material is having average conductivity, then it also affects MRR and TWR, as for material having average conductivity MRR will not affect so much but tool wear willbe minimum. This is implementable in precise machining.

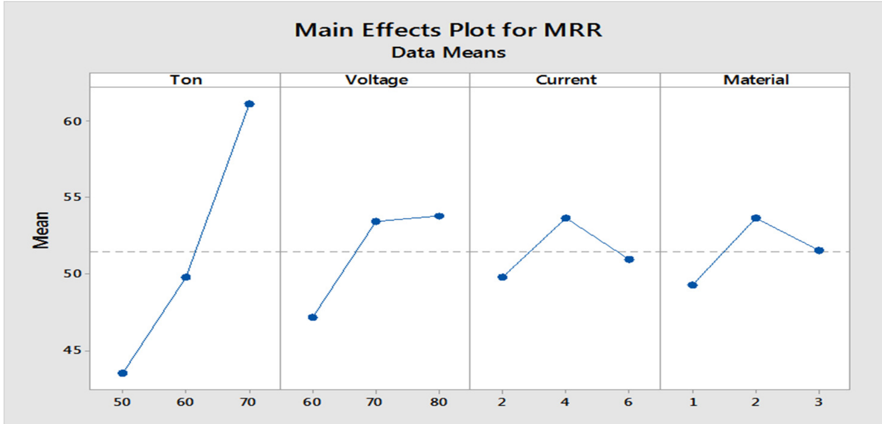


Figure 4 Main Effect Plot of MRR

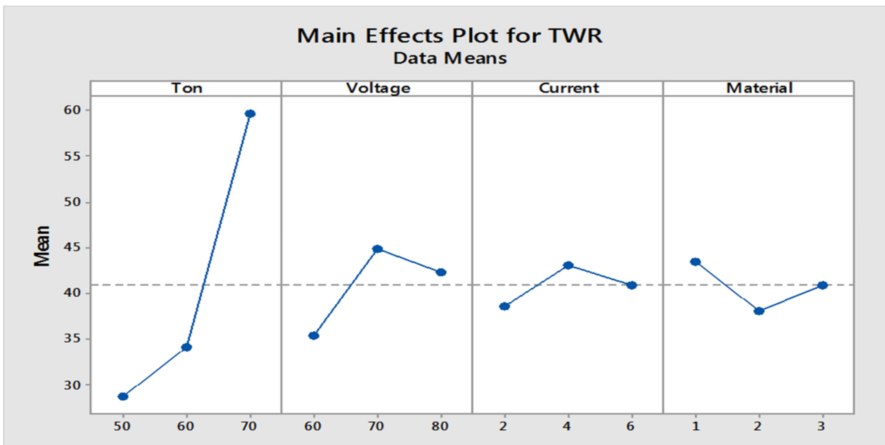


Figure 5 Main Effect Plot of TWR

4.1 Grey Relational Analysis

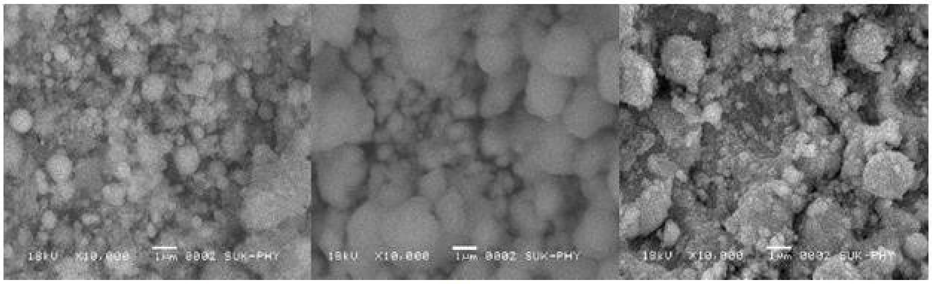
The optimal best and worst readings obtained from GRA method are summarized in Table 2 the readings are ranked from 1 to 9. The process shows that 2A, 60 µs, 80V, TiAlN coating gives best reading with higher MRR and lower TWR. Whereas 4 A, 60 µs, 70V and uncoated parameter levels shows worst reading in terms of lower MRR and higher TWR. The overall readings show that coating process is better than uncoated.

Table No. 2 GRA Analysis

Sr. No.	Material	Ton	V	I	MRR	TWR	MRR (GRR)	TWR (GRR)	MRR (GRC)	TWR (GRC)	GRG	Rank
1	Uncoated	50	60	2	**35.38**	**23.81**	0.000	1.000	0.5	1	0.750	5
2	Uncoated	60	70	4	51.76	43.01	0.628	0.519	0.72864	0.6754	0.702	9
3	Uncoated	70	80	6	60.71	**63.76**	0.970	0.000	0.97134	0.5	0.736	8
4	TiAlN	50	70	6	47.13	29.99	0.450	0.845	0.64524	0.86603	0.756	4
5	TiAlN	60	80	2	52.63	30.7	0.661	0.828	0.74678	0.8529	0.800	1
6	TiAlN	70	60	4	61.2	53.76	0.989	0.250	0.98939	0.57153	0.780	2
7	AlCrN	50	80	4	48.08	32.39	0.487	0.785	0.66076	0.8232	0.742	7
8	AlCrN	60	60	6	45	28.89	0.369	0.873	0.61296	0.88719	0.750	6
9	AlCrN	70	70	2	**61.48**	61.48	1.000	0.057	1	0.51469	0.757	3

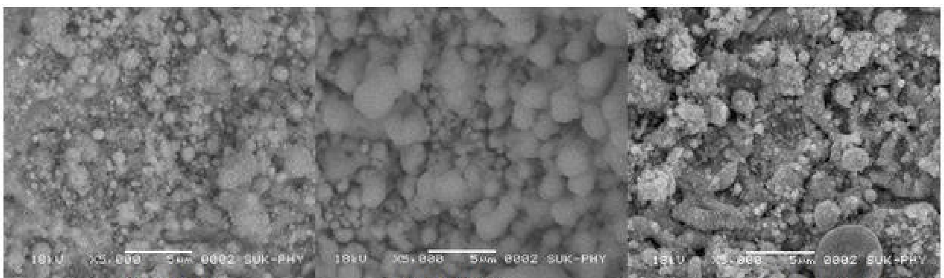
4.2 Scanning Electron Microscope Images

The reason for taking scanning Electron microscope images is to analyze and compare the surface texture and roughness of machined surfaces. For that, steps from 10000X to 100X with intermediate stages of 5000X, 1000X, 400X are taken for examination at different levels. Since the size limitations for work samples, targeted work piece sample were taken away from work piece plate by cutting it with help of hack saw. After placing the sample in microscope setup microscopic images were takenfor further investigation



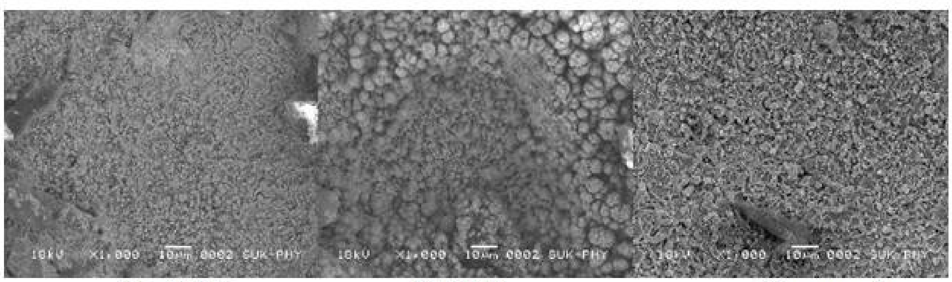
(a) AlCrN (b) TiAlN (c) uncoated

Figure 6 Scanning electron microscope images



(a) AlCrN (b) TiAlN (c) uncoated

Figure 7 Scanning electron microscope images



(a) AlCrN (b) TiAlN (c) uncoated

Figure 8 Scanning Electron Microscope tool surface images

4.3 XRD results

The XRD pattern drawn over 2θ vs. intensity (in arbitrary units) for the Copper tools made by both AlCrN i.e. conventional method indicates that the Cu (111) plane have a dominant orientation at 43.274° (2θ), as shown in Figure. At and b drawn over 2theta vs. intensity in arbitrary units.

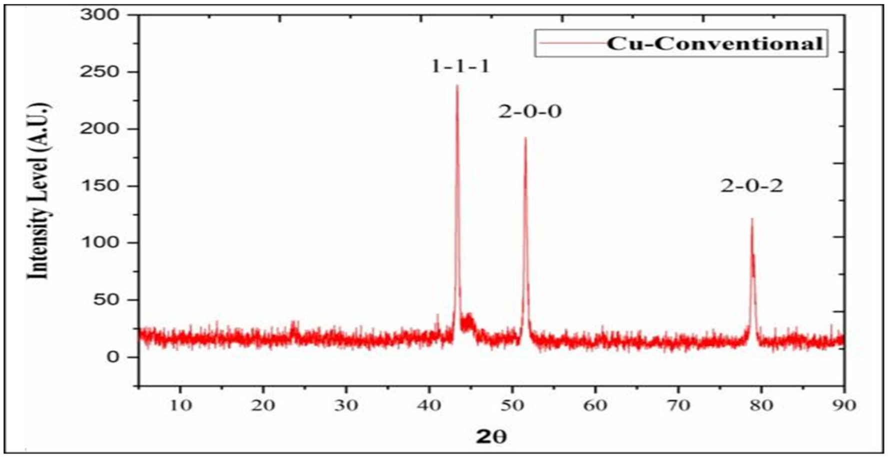


Figure 9 XRD plot for TiAlN Coated sample.

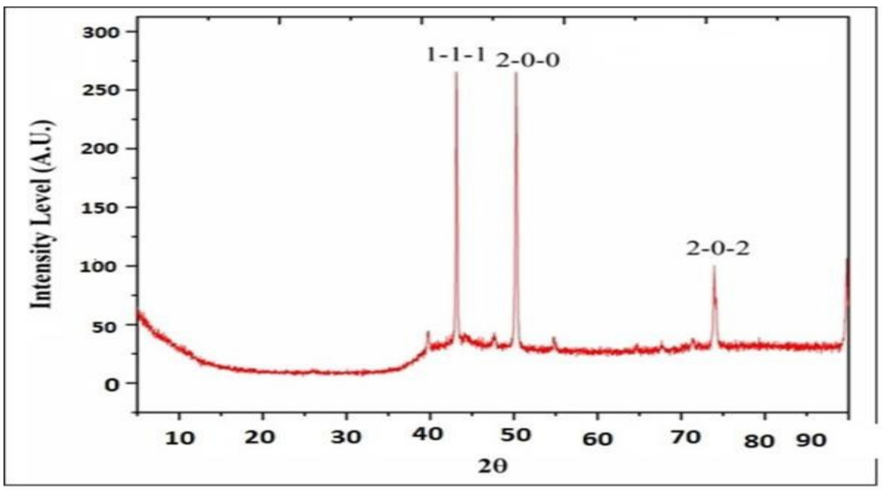


Figure 10 XRD plot for AlCrN Coated sample

5. CONCLUSION

Coating is an advanced manufacturing method which used for manufacturing of electrodes in this project. Also, two types of coatings are done on tungsten carbide electrode. These tools are taken for experimentation to compare them with non-coated regular electrodes. Experimentation on hyper 15 machine and determining machining parameters like MRR, TWR, and XRD and SEM analysis will be carried out to study microstructure of electrodes.

Metal removal rate – TiAlN and AlCrN coated tools shows improvements in metal removal rate than uncoated tools.

Tool wear rate – TiAlN coated tools shows better results regarding tool wear i.e. tool wear rate is lesser than uncoated and AlCrN tools. This is because higher hardness of coating. AlCrN coated tools also have better results in tool wear rate.

REFERENCES

[1] Jahan MP, Wong YS, Rahman M (2010) a comparative experimental investigation of deep-hole micro-EDM drilling capability for cemented carbide (WC-Co) against austenitic stainless steel (SUS 304). Int J Adv. Manuf Technol 46:1145– 1160.
[2] Uhlmann E, Rosiwal S, Bayerlein K, Röhner M (2010) Influence of grain size on the wear behavior of CVD diamond coatings in microEDM. Int J Adv Manuf Technol 47:919–922.
[3] Qin Y, Brockett A, Ma Y, Razali A, Zhao J, Harrison C, Pan W, Dai X, Loziak D (2010) Micro-manufacturing: research, technology outcomes and development issues. Int J Adv Manuf Technol 47:821– 837.
[4] Huang SH, Huang FY, Yan BH (2005) Fracture strength analysis of micro WC-shaft manufactured by micro-electro-discharge machining. Int J Adv Manuf Technol 26:68–77.
[5] NEXUS Market Analysis for MEMS and Microsystems III, 2005-2009, NEXUS Newsletter 01/2006.
[6] E. Uhlmann, S. Piltz, U. Doll, Machining of micro/miniature dies and moulds by electrical discharge machining—Recent development, J. of Materials Processing Technology, 167 (2005) 488- 493.
[7] Jahan MP, Rahman M, Wong YS (2011) a review on the conventional and micro-electro discharge machining of tungsten carbide. Int J Adv Manuf Technol 51:837–858.

[8] Shen Y, Liu YH, Zhang YZ, Dong H, Wang XL, Zheng C, Wang GX, Ji RJ (2016) High-throughput electrical discharge milling of WC-8% Co. Int J Adv Manuf Technol 82:1071–1078.

[9] Hiremath, Somashekhar S., and Leera Raju. "Investigation on machining copper plates with NiP coated tools using tailor- made micro-electro discharge machine." Advances in Materials and Processing Technologies 3, no. 4 (2017): 522-538.

[10] Jin, Zhu Ji, Min Zhang, Dong Ming Guo, and Ren Ke Kang. "Electroforming of copper/ZrB2 composites coatings and its performance as electro-discharge machining electrodes." In Key Engineering Materials, vol. 291, pp. 537-542. Trans Tech Publications Ltd, 2005.

[11] Perveen, Asma, and M. P. Jahan. "Comparative micro-EDM studies on Ni based X-alloy using coated and uncoated tools." In Materials Science Forum, vol. 911, pp. 13-19. Trans Tech Publications Ltd, 2018.

[12] Shirguppikar, S. S., M. S. Patil, V. S. Ganachari, T. V. Kolekar, P. S. Jadhav, and A. B. Chougule. "Experimental investigation of CNT coated tools for EDM processes." Materials Today: Proceedings 5, no. 2 (2018): 7131-7140.

[13] Zhao, Wan Sheng, Yu Fang, Zhen Long Wang, and L. H. Li. "A surface modification method by EDM and its application to cutting tools." In Materials Science Forum, vol. 471, pp. 750-754. Trans Tech Publications Ltd, 2004.

[14] Yuangang, Wang, Zhao Fuling, and Wang Jin. "Wear-resist electrodes for micro-EDM." Chinese Journal of Aeronautics 22, no. 3 (2009): 339-342.

[15] Jothimurug, R., K. S. Amirthagad, and Joel Daniel. "Performance of silver coated copper tool with kerosene-servotherm dielectric in edm of monel 400TM." Journal of Applied Sciences 12, no. 10 (2012): 999-1005.

[16] Uhlmann, Eckart, and Markus Roehner. "Investigations on reduction of tool electrode wear in micro-EDM using novel electrode materials." CIRP Journal of Manufacturing Science and Technology 1, no. 2 (2008): 92-96.

[17] Chiou, Ai-Huei, Chung-Chen Tsao, and Chun-Yao Hsu. "A study of the machining characteristics of micro EDM milling and its improvement by electrode coating." The International Journal of Advanced Manufacturing Technology 78, no. 9-12 (2015): 1857-1864.