Experimental Investigation of Process Parameters f AISI 4140 Steel Using EDM

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***Abstract*—Electric Discharge Machining (EDM) is an alternative machining process to the traditional machining process for the precise machining complex-shaped electrically conductive machine parts. In EDM, machining is not affected by the mechanical properties of the work piece. The spark erosion process removes the material. It is commonly used in advanced industries in which precise parts of high quality are required, such as the aerospace, automobile, die manufacturing, and molds industries, to machine hard metals and their alloy. The economics of machining depends on the proper selection of EDM machining parameters, tool material, and dielectric. Dielectric fluid has a significant impact on EDM processes. The AISI 4140 steel is a chromium-manganese molybdenum grade used to make the dies for plastic injection molds and extrusion dies for thermoplastics and compression moulds. The primary purpose of this project work is to study the impact of EDM conditions (Pulse on time, peak current) on MRR and SR during machining of AISI 4140 steel. The pulse on-time peak current is a significant EDM condition that affects the SR and MRR. The SR and MRR are directly proportional to pulse on time & peak wind for Spark erosion oil (EDM oil) as dielectric fluid. Also, the prediction ability of the developed models is significant.**

***Index Terms*—Electric Discharge Machining (EDM), Dielectric fluid, sparkerosion, peak current, thermoplastics.**

I. INTRODUCTION

Electric Discharge Machining (EDM) is an alternative machining process to traditional machining process for the precise machining of complex shaped electrically conductive machine parts. In the EDM machining, material is removed because of the sparking between the work piece and tool. Due to the spark, the material from the work piece melted and vaporized. The EDM machining is possible if both work piece and tool are eclectically conductive. The EDM machining not depends on the mechanical properties of the work pieces. Now days, due to global competitiveness, manufacturing industries are more concerned about the quality of their products with high metal removal rate. These focus on manufacturing better quality components at minimum cost. During EDM machining, the machining conditions play important role. The responses i.e. MRR, surface finish of machined part, tool wear, dimensions of the machined work piece etc. depends on the proper selection of the EDM conditions i.e. pulse on time, pulse off time, peak current, gap voltage, types of tools, types of dielectric fluids etc. Therefore, for the desired EDM output, judicious selection of the machining condition requires. The selected EDM machining conditions should yield required shape and size of the machined surface with desire surface finish at minimum cost of production. Therefore, the proper selection of EDM conditions according to desire outputs (responses) can be obtained using design of experiments.

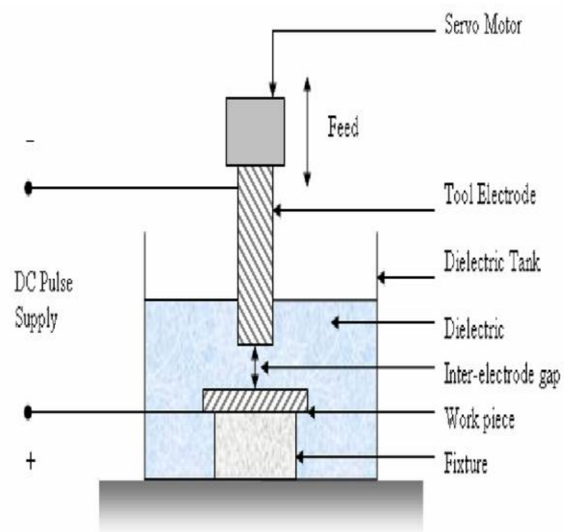

Figure.1.Electric discharge machining

In this technological era, manufacturing industries are facing challenges from such advanced difficult- to-machine materials, viz. super alloys, ceramics and composites and stringent design requirements (high surface quality, high precision, high strength, complex shapes, high bending stiffness, good damping capacity, low thermal expansion and better fatigue characteristics) and machining costs. There is a growing trend to use light weight and compact mechanical component in the recent years; therefore there has been an increased interest in the advance materials in modern day industries. The new concept of manufacturing uses non-conventional energy sources like sound, light, mechanical, chemical, electrical, electrons and ions. The machining processes are non-conventional in the sense that they do not employ traditional tools for metal removal and instead they directly use other forms of energy. For the last few years, EDM has been used to machine advanced materials with desired shape, size and required accuracy. EDM is a non- conventional machining process, where electrically conductive materials is machined by using precisely controlled sparks that occur between an electrode and a work-piece in the presence of a dielectric fluid. It uses thermoelectric energy sources for machining extremely low machinability materials; complicated intrinsic- extrinsic shaped jobs regardless of hardness have been its distinguishing characteristics.

II.EXPERIMENTAL PROCEDURE

Experiments were conducted on a die sinking EDM machine, model Electronica Smart CNC. In this study, AISI 4140 steel is selected as the work material. Chemical composition of the work piece material . A cylindrical electrode of copper was used as the tool. Spark erosion oil (EDM oil) was used as a dielectric. The process parameters and their levels for the main experiments were decided on the basis of the pilot experiments conducted using one-factor-at-a-time approach. The Box-Behnken design (BBD) was used for planning and executing the subsequent main experimentation, In this study, an effort has been made to model the empirical relationship between machining parameters by using response surface methodology. The work piece was connected to the positive polarity while the tool electrode was maintained at negative polarity. Side flushing method was employed for the dielectric fluid. The process parameters and depth of cut were programmed in the NC controlled unit. Once the experimentation was completed, the work pieces were cleaned thoroughly using acetone and the final individual weight of electrode was measured.

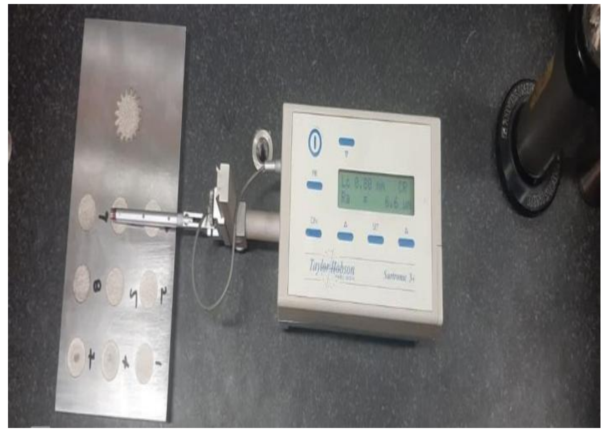

Figure.2.Pictorial view of portable surface tester

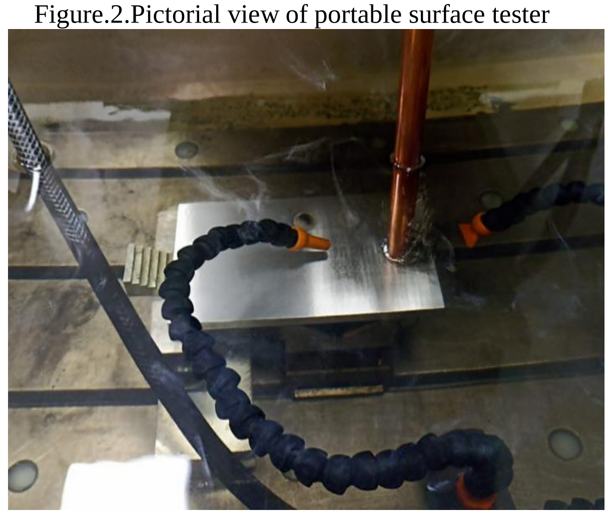

Figure.3.Spark erosion

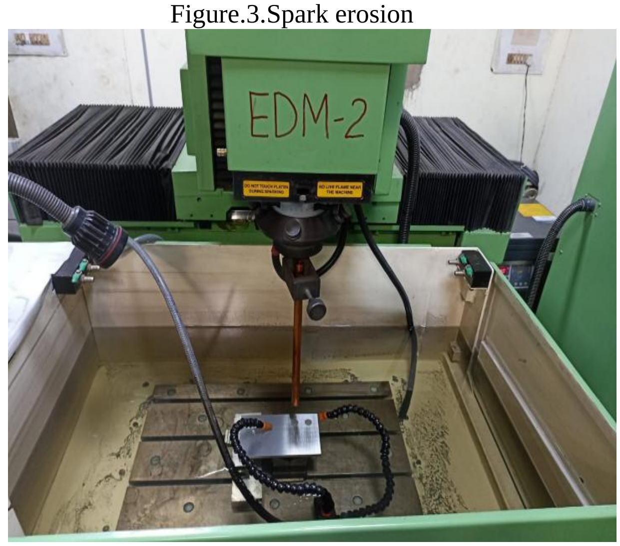

Figure.4.EDM Machine

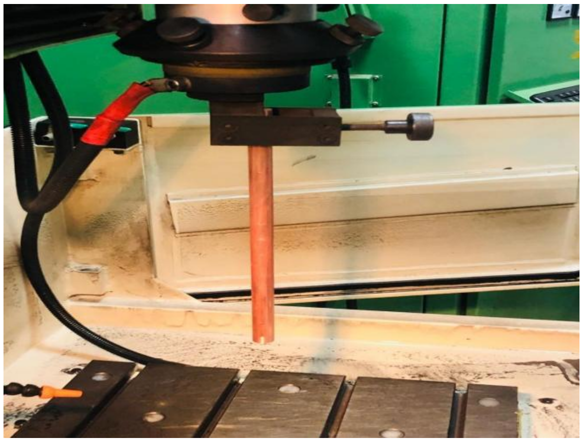

Figure.5.Machine holding electrode

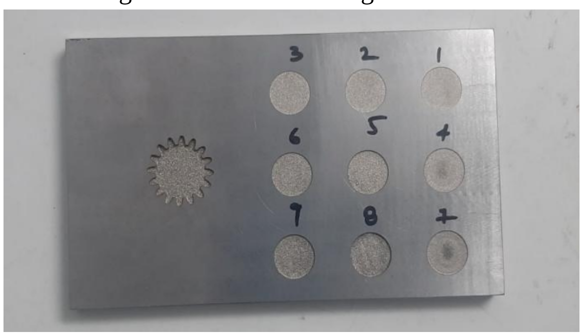

Figure.6.Work piece after EDM machining

III.PROCESS PARAMETERS AND PERFORMANCE MEASURES

The process parameters and performance measures are shown. The process parameters can be divided into two categories i.e. electrical and non-electrical parameters. Major electrical parameters peak current, pulse duration and pulse interval, electrode gap, polarity and pulse wave form. The EDM process is of stochastic thermal nature having complicated discharge mechanism . Therefore, it is difficult to explain all the effect of these parameters on performance measures.However, researchers now rely on process analysis for optimization of parameters to identify the effect of operating variables on achieving the desired machining characteristics. Lin et al. applied grey relational analysis for solving the complicated interrelationships between process parameters and the multiple performance measures. Taguchi approach has also been used by many other researchers to analyze and design the ideal EDM process. Main non-electrical parameters are flushing of dielectric, work piece rotation and electrode rotation. These non electrical parameters play a critical role in optimizing performance measures. Researches on flushing pressure reveal that it affects the surface roughness, tool wear rate, acts as coolant and also plays a vital role in flushing away the debris from the machining gap .Work piece rotary motion improves the circulation of the dielectric fluid in the spark gap and temperature distribution of the piecework yielding better MRR and SR. Similarly, electrode rotation results in better flushing action and sparking efficiency.

Table 1: Specification of portable surface tester

Parameter	value
Range	(200 -0.001) µm
Power supply	5V,1A,110-240V AC,50 Hz
Roughness standard	±3% of measured value

3.1 EDM electrode wear

As consequence of the development of electrical discharge machining process, the electrode is affected by wear; knowing the evolution of the electrode wear, a better estimation of its service life is possible. It is expected that the electrode wear depends on the energy of the electrical discharges and the mass of the electrode. It is known also that the nature of the work piece material exerts influence on the evolution of the electrode wearing process. In the project, some theoretical considerations are used to highlight the above mentioned aspects. A set of experimental tests was designed and developed in order to highlight the influence exerted by the nature of the work piece material and by the size of the cross section of the electrode, respectively, on the electrode wear. Empirical mathematical models corresponding to the evolution of the electrode wear were established.

Features	Specification
Tank dimension	800X500X350 mm
Work table dimension	550 X 350 mm
Traverse (X,Y,Z)	300, 200, 500 mm
Maximum job weight	300 kg
Maximum job height above the table	250 mm
Pulse generator	S 50 CNC
Pulse generator type	MOSFET
Maximum working current	50A
Power supply	3 phase,415 V AC, 50Hz

Table 2 : EDM Machine specifications

Table 3: Chemical composition (wt %) of AISI 4140

C %	S %	P %	Si %	Mn %	Cr %	Mo %	Fe %
0.380 - 0.430	0.040	0.035	0.15 - 0.30	0.75 -1.0	0.80 - 1.10	0.15 - 0.25	Remaining steel

IV. RESULTS

S.no	Current (A)	T_{on}	Toff	MRR (mm^3/min)	SR (microns)
1	5	20	12	0.086	4.2
2	5	50	24	0.100	4.5
3	5	75	32	0.120	5.0
4	10	20	12	0.196	5.2
5	10	50	24	0.348	5.6
6	10	75	32	0.357	6.2
7	15	20	12	0.348	4.4
8	15	50	24	0.724	6.7
9	15	75	32	0.784	9.2

Table 4:MRR & SR Values

V.GRAPHS

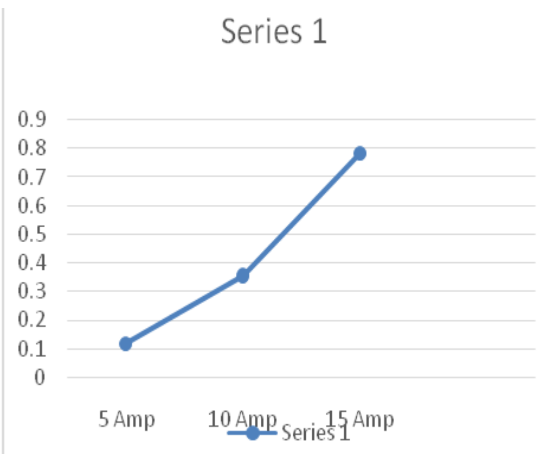

Figure.7Current vs Material Removal rate

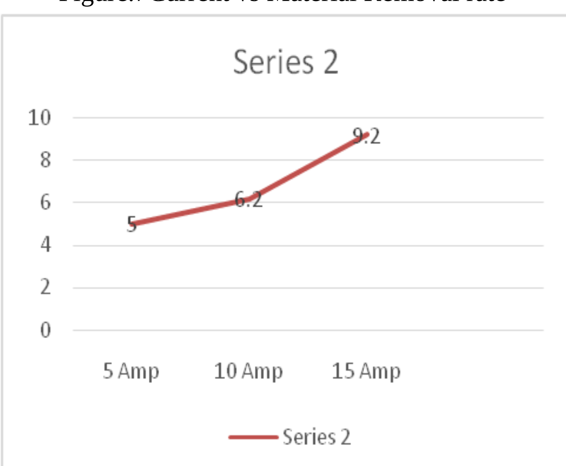

Figure 8:Current vs Surface Roughness

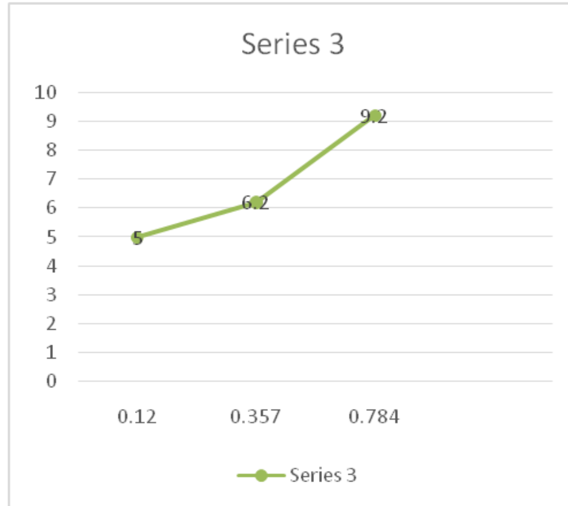

Figure 9:Material Removal Rate vs surface roughness

VI. CONCLUSION

The Project work was focused on assessing the Electro Discharge Machining (EDM) behaviour of AISI 4140 tool steel as work-piece and copper as electrodes. The experiment were analyzed against the variation of some of the most important EDM parameters namely, current (I_p), pulse on-time (T_{on}), pulse off-time (T_{off}) that influence the process performance. The measured technological outputs were Material Removal Rate (MRR), Surface Roughness (SR)

FUTURE SCOPE

The objective of the review article has been aimed to report the work of various researchers for improving material removal rate during EDM and bridging the gap between the untouched areas in the future . After elaborate scrutiny of the published work, the following remarks emerge from the existing published work. Various theoretical models describing material removal mechanisms have been proposed by researchers from time to time. A major limitation of these models is that the models are based on several assumptions. Therefore, these models cannot be universalized applicable to all conditions. Case to case empirical models is better suitable for quantifying material removal rate. So there is a scope to develop more of such models in future research works and also to find solutions to the assumptions made by researchers. Most of the research work in EDM relates to the use of 3D form tools. Alternate types of tools like frame type and plate type are yet to be tried for more work-tool interfaces. Even in 3D form tools, not much-published work is available corresponding to the use of different tools cross-sectional geometries like rectangular, triangular, etc., on performance measures like MRR, SR, etc. Therefore, the effect of different tool geometries on MRR, SR, etc., has to be explored for more work materials. Hollow tube and eccentric drilled holes type electrodes are reported to have a positive impact on MRR due to improved flushing conditions. Such designs need investigations for more work materials to evaluate their case-to-case effects.

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