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Assessment of Electrical Discharge Machine Die Sink Parameters on Material Removal Rate of Heat-Treated Medium Carbon Steel

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Abstract: **Electrical Discharge Machine Die Sink is used to do subtractive machining especially on hardened materials like molds and such. The machine has plenty of process parameters that can be adjusted and balanced to achieve desired machining result. The study focuses on how these parameters can affect the material removal rate. The process parameters namely, machining current in low and high voltages, arc, machining gap and duration. The combination of the process parameters mentioned can affect the material removal rate by increasing it or decreasing its outcome. The machine used to collect data was a CHMER CM240 50MP. The collection of method is by removal of process parameter setting which yielded the least desired result, this is to improve data collection and cost management. The materials used in the study is an AISI 4340 for the workpiece and copper electrode for the tool. The top result of the experimentation was then cross examined to produce a more conclusive outcome. The applicability of the study to existing electrical discharge machine die sink can be seen from the statistical analysis and its ease of usage to actual working conditions.**

Keywords: **EDM die sink, AISI 4340, material removal rate, heat-treatment.**

I. INTRODUCTION

Manufacturing is one of the many industries in the Philippines that is growing steadily and multiple investors consider establishing businesses in the country. Every plant or factory has machinery and equipment with specialized parts, some of which are not readily available in the market due to discontinued production or low demand. This is where machine shops come in, which may be already inside the plant or outsourced, to fabricate job with ranging complexity. As a country competing globally, presence of multiple related research supporting the rising industry will attract more investors and may affect the economy positively. In manufacturing improving material removal rates (MRR) of machines correlates to increase in production and therefore additional income. Improvement of production includes variation of multiple process parameters available to the machine. In this research, process parameters present such as machining gap and duration, machining current in low and high voltage, and arc was experimented on CHMER CM240 50MP EDM. Test on the workpiece such as hardness test and metal composition were conducted for ease of study reproduction in the future. Testing of the workpiece and tool was conducted at Metals Industry Research and Development Center – Department of Science and Technology located in Taguig. A previous study has used the process parameter such as peak current, servo voltage, main supply voltage, servo speed and jump speed [1]. It is said that there are multiple ways to improve MRR by electrode design, controlling process parameters, EDM variations, powder mixed dielectric, dry EDM and EDM with water, and some other more techniques [2]. Improvement of MRR without sacrificing quality machine surface and the integrity of the electrode dimensions is the intention of the research.

II. MACHINE AND MATERIALS

A. Electrical Discharge Machine Die Sink

Electrical discharge machine is thermal erosion process where controlled electric spark discharge takes place between tool and work-piece to have the eroding effect on work-piece to form a replica of tool on work-piece. As there is no mechanical contact between both electrodes during whole process and erosion is produced by electrical discharge. Electrical conductivity of electrode and work-piece is the basic requirement of this process [3]. The researchers used the CHMER CM240 50MP electrical discharge machine die sink made in Taiwan. The model EDM used have three parts, the main machine, control panel and power supply. From Fig. 2 the control panel of CHMER EDM die sink, which includes the legends that will be used in data collection of the experiment. The format of the legends used are letter followed by a number, letter corresponds to a process parameter and number is the intensity of setting. The legends are as follows: A: machining low voltage current, B: machining high voltage current, C: machining gap, D: machining duration and E: arc setting. Machining low voltage has five settings and machining high voltage has four settings, both process parameters initially experimented. After the collection of the leading material removal rate, it is then experimented with the combination of the process parameters: machining gap, machining duration and arc settings which have 10 notches each.

Fig. 1 EDM die sink: CHMER CM240 50MP

Fig. 2 Control Panel: CHMER EDM

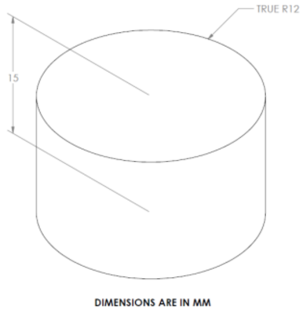
The validation of the study was done through the experimentation process, systematic process machine setting and organized collection of data present. The five varying process parameters extensive experimentation of electrical discharge machine die sink set in the study was conducted inside the local business the SKAN Machine Shop, located in Dasmariñas, Cavite. After thorough experimentation and collection of top five material removal rate the data then is compared to another model of electrical discharge machine die sink, a BEST EDM die sink from Amvel Metal Fabrication Services located at Silang, Cavite. Both EDM die sink machines have different terminology used for process parameters that can be found on the control panel. The researchers carefully read both corresponding manual to each machine and carefully translated its equivalent or near equivalent to one another. Though there is no direct conversion of terminology, the researchers based the conversion from the description written on the manual.

Fig. 3 Control Panel: BEST EDM

B. Material: AISI 4340 and Copper

AISI 4340 steel is an alloy steel of nickel, molybdenum, and chromium with medium carbon content. It is known for its high toughness and the ability of further enhancement in strength by applying heat treatment condition [4]. One of the objectives of the study was to relate to the local businesses and machine shops. Selection of readily available local materials for workpiece and tool to be experimented was essential. The researchers selected a widely known and used steel with medium percentage carbon present which is AISI 4340.

The tool that was used is Copper, because it is a common base material because it is highly conductive and strong. It is useful in the EDM machining of tungsten carbide, or in applications requiring a fine finish [5]. The design and dimension of workpiece and tool was selected to simplify the experimentation and to lessen unnecessary machining for the materials used. The inspection of workpiece after EDM process was also considered in design. This is to allow the measuring device, digital micrometer, to fit in the machined part.



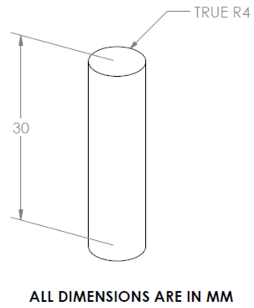


Fig. 4 Design of AISI 4340 Workpiece **Fig. 5 Design of Copper Tool**

III. EXPERIMENTATION METHOD AND PROCESS PARAMETERS

The procedure done in the experiment was elimination of low yield of material removal rate process parameter via testing of the first parameter considered which is machining low voltage current; followed by the next process parameter considered which was machining high voltage current. The next tests done was the combination of the rest of the process parameters which was machining gap, machining duration and arc. The experimentation in its totality yielded multiple combination of setting and ranges of material removal rates. The study contains five process parameters. Initial experimentation requires to identify which setting with respect to machining low voltage and high voltage produces high material removal rate. The identification of the setting to be used in proceeding experiment with respect to the machining gap, machining duration and arc or anti-arc settings. From numbers 1 to 5, entries were tested once with 0 value of machining high voltage current and varying machining low voltage current. It yielded the reference for which to be used when added values of machining high voltage current is further used. Some setting was removed due to impracticality to the goal of experiment. A1 setting was removed due to low material removal rate yield and A5 was removed due to severe deterioration of the surface machined. Further experimentation paired with varying high voltage current and the researchers determined that the setting with high MRR and low effect to the surface roughness, via visual inspection, was A3B4. After experimentation it is apparent that low voltage current with a value of ¼ and high voltage current with a value of 1/16 produced high MRR with little to no visible craters.

TABLE I: Legend for process parameters code

Code	Process Parameter
A	Low Voltage Current
B	High Voltage Current
C	Machining Gap
D	Machining Duration
E	Arc

IV. RESULTS AND DISCUSSION

The importance of the experimental research was to acknowledge that some process parameter relation to each other is not proportional, therefore multiple settings may have different result or may stray from improved operation. This relationship established is believed to benefit operators and instructors in being an effective user of electrical discharge machine. The effective use of the machine promotes sustainable machining in terms of profitability and productivity.

In Table II contains the mean material removal rate experimented initially on the CHMER EDM die sink. After thorough experimentation with singular trial, the researchers experimented the top 5 additional of two trials more to have enough data to obtain the mean MRR. The experiment is then repeated on BEST EDM die sink with nearly identical setting of process parameter. From the corresponding code the top 5 setting for CHMER occurred at machining gap set to 1 and machining duration set to 2 paired with varying arc settings.

TABLE II: Top 5 settings with high MRR for CHMER EDM

No.	Code	MRR Trial 1	MRR Trial 2	MRR Trial 3	Mean MRR
1	C1D2E6	9.7419	9.6066	10.0229	9.790
2	C1D2E7	10.2415	9.5962	9.2631	9.700
3	C1D2E5	9.8044	9.6066	9.6482	9.686
4	C1D2E4	9.6170	9.5442	9.5650	9.575
5	C1D2E2	9.8668	9.2111	9.5858	9.555

TABLE II: Top 5 settings with high MRR for BEST EDM

No.	Code	MRR Trial 1	MRR Trial 2	MRR Trial 3	Mean MRR
1	C1D2E6	8.5242	8.0975	8.0766	8.233
2	C1D2E7	7.3377	7.3481	7.1920	7.293
3	C1D2E5	9.3776	9.4609	9.3256	9.388
4	C1D2E4	9.3985	9.8564	9.1174	9.457
5	C1D2E2	9.7315	9.8356	9.8564	9.808

The trend in figure 4.1 for CHMER is a steady declining slope, this serves as the reference for the succeeding experiment on BEST EDM die sink. The CHMER slope has value close to each other due it is a product of primary experimentation and selected from the top five highest material removal rate. From table 4.11 it can be seen that the top five material removal rate skipped some of the arc setting and only arc settings 6,7,5,4 and 2 were used. This is due to the nature of anti-arc setting from CHMER from 1 to 10 has fluctuating trend. The fluctuation also occurs to BEST setting that can be seen on Fig. 6. The relation of gathered mean material removal rate of both machines is inversed. The inverse relation can be interpreted due to CHMER has “anti-arc” and BEST has “arc” setting. The deviance of top 1 and top 2 setting to its corresponding match can be interpreted that arc or anti-arc setting from different machine have different intensity. The arc and anti-arc setting definitions from both of the EDMs have no quantitative value written on corresponding manuals.

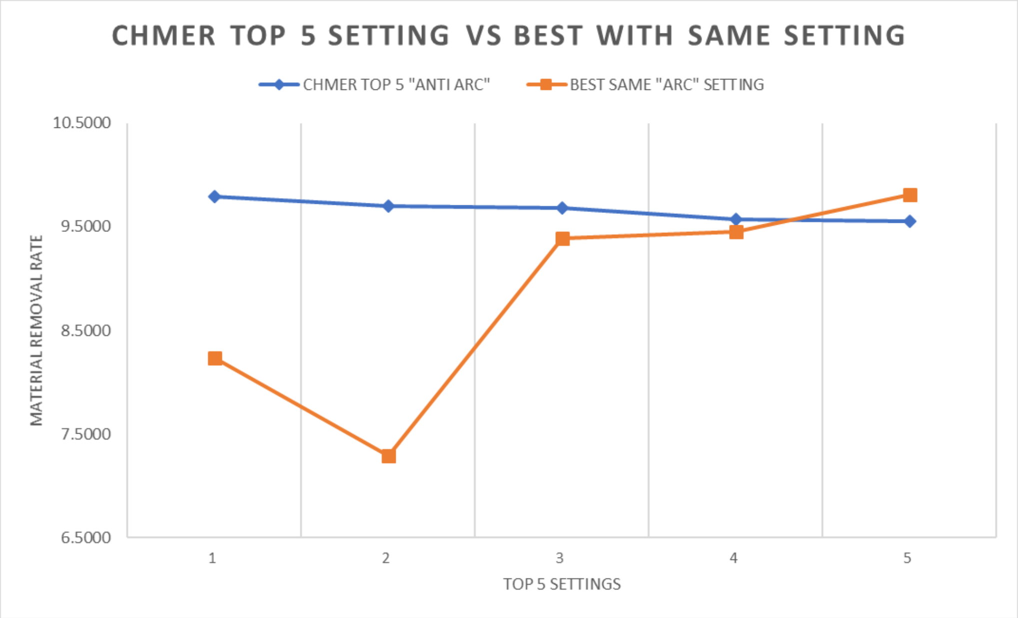


Fig. 6 CHMER vs BEST EDM die sink: Top 5 settings

V. CONCLUSION

Replication of actual working conditions in collecting data was accomplished in the study. Information such as material type and hardness can be obtained and used in order to improve the development of data. The study gathered data of the experiment and assessed the setting where an electrical discharge machine die sink can be used with its most productive capability. The best setting considered by the researchers for machining low voltage current is 1/4 and 1/16 for machining high voltage current. Good material removal rate and low surface deterioration was observed in the setting mentioned. The MRR lowers when machining gap was raised. However, for the machining duration and arc, it displayed a varying relationship in different levels of both process parameter where it is considered unpredictable. The graphical presentation present of the top five settings for both CHMER and BEST EDM die sink manifested the reliability of the settings used. The process parameter where the improved operation occurred is determined to be at machining low voltage current 1/4, machining high voltage current 1/16, machining gap 1, machining duration to 2, and arc or anti-arc to 5,4 or 2 settings. Methods of statistical analysis was used to determine quantitatively the effect of data gathered, it resulted to no significant difference. Having no significant difference proves that the setting used in one EDM die sink can be applicable to another model of EDM die sink. After the verification of results of the experiment, the outcome is then recommended to a local machine shop named, Amvel Metal Fabrication Services located at Silang. This concludes the study having its results shared for further use and development in electrical discharge machining die sink. The gap in the knowledge pertaining to the relation of process parameters such as machining duration and arc or anti-arc, may be still dismal, but other objectives such as improved production was attained.

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