Evaluation of optimal parameters for machining brass with wire cut EDM

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Wire-cut electric discharge machine (WEDM) has been applied for dimensional accuracy, surface finish, and geometric features of work pieces (electrodes, dies etc.) in metal cutting industry. This study evaluates optimal parameters (discharge current, voltage at rated wire speed and tension) for brass electrode (sizes, 5-80 mm). Influence of optimal parameters on cutting speed, surface roughness, spark gap (cutting off-set required) and material removal rate (MRR) is studied. Mathematical relations are obtained for cutting speed, spark gap and MRR. Effect of wire material on cutting criterion is also evaluated for work piece (5 mm thick) using 4 wires of different copper percentages. This study is useful in finding cutting time for any size of job and to set parameters for required surface finish with high accuracy of cutting.

Keywords: Cutting Speed, Spark gap, Wire material, WEDM

Introduction

Wire-cut electric discharge machine (WEDM) is used in the field of dies, moulds, precision manufacturing and contour cutting etc. Any complex shape can be easily generated with high grade of accuracy and surface finish using computer numerical control (CNC) WEDM. Customized software development has further strengthened process technology in improving geometrical and technological data of work piece. An analysis of effects of various process parameters for achieving improved machining characteristics is required for successful utilization of process with high productivity. This study analyzes effects of process parameters on machining characteristics of CNC WEDM on different criteria (cutting speed, surface finish, spark gap, specific energy consumption) and evolves optimal parameters.

Experimentation

Optimal parameters that are set on machine before cutting are as follows: machine, ELCUT 234; dielectric, de-ionized water; dielectric conductivity, 38 mhos; wire tension, 80 N; wire velocity, 2.5 m/min; wire diam, 0.25 mm; and gap voltage, 75-80 V. Brass work pieces (thickness, 5, 10, 20, 40, 60 and 80 mm) were cut with rectangular slots (4 mm x 6 mm) and L-slots using CNC part programming. Cuts (4) were performed on each work piece by altering current. Data for maximum cutting speed and minimum wire rupture was recorded. Rectangular slot was tested for surface finish using Taly surf, and L slots for spark gap using Shadow graph and microscope. Experiments were repeated on 5 mm thick job with 4 different wires (A, B, C, and D) having following composition: A, 90% Cu + 10% Zn; B, 85% Cu + 15% Zn; C, 80% Cu + 20% Zn; and D, 66% Cu + 34% Zn. Results were tested for fitness with any size of brass work piece.

Results and Discussion

After setting the job for cutting, wire tension, which is varied to identify optimal stretched condition without rupture, is determined as 80 N. Sample tests were performed under a pre set gap voltage (80 V) to see the effect of wire velocity on maximum achievable cutting current. Hence, to optimize process, by varying discharge current, other criteria are recorded, plotted and analyzed using Origin 8.0 software. R² value, standard deviation, (SD), and error analysis were performed.

Best-fit curve for variation of cutting speed with respect to thickness of work piece shows curve with downward slope (Fig. 1). Cutting speed decreases as thickness of the job increases, may be due to high quantity of material removal at higher thickness with limited power.
Fig. 1—Thickness vs cutting speed ($R^2=0.9851$, SD = 0.247)

Fig. 2—Effect of thickness on spark gap ($R^2 = 0.99061$, SD = 1.40185)

Fig. 3—Effect of current on cutting speed

Fig. 4—Effect of current on spark gap

Fig. 5—Effect of current on MRR

Fig. 6—Effect of thickness on current
source and current carrying capacity of the wire. $R^2$ value (0.9851) and SD (0.247) are obtained. This plot is useful for cutting time estimation, process planning and cost estimation. Plot (Fig. 2) of variation of spark gap with increase in thickness is useful for providing offset during CNC part programming. Best-fit curve, equation is obtained using Origin 8.0 software. $R^2$ value and SD are determined and found to be satisfactory. Plot (Fig. 3) to determine effect of discharge current on cutting speed for different sizes of work pieces tested, gave optimum values of current and cutting speed for stable cutting. For thick jobs (5 mm and 10 mm), variation is drastic, whereas for other thicknesses it is normal. Plot (Fig. 4) on effect of spark gap with current for all sizes of work pieces tested, showed an increasing trend in spark gap with current increment. At higher current, spark will jump longer distance and may cause more over cut.

Discharge current increases as material removal rate (MRR) increases for different sizes of work pieces (Fig. 5). A linear pattern (Fig. 6) of discharge current at optimum value was observed with increase in work piece thickness under same set of machining conditions. From this plot (Fig. 6), optimum current can be considered for any job thickness in working range of machine. By increasing MRR (Fig. 7), work piece thickness increases up to 60 mm and then declines. $R^2$ value (0.89922) and SD (1.6829) obtained are within permissible limit. Roughness values decrease with increase in thickness (Fig. 8). Wire (90% Cu) gave best results (Table 1) and is preferable for higher productivity.

Mathematical Relations
Following mathematical relations were developed using Origin 8.0 software: 1) Cutting speed and work piece thickness, $Cs=1.0356+\left\{\frac{22542.18}{1+\exp\left(T+101.54\right)/13.06}\right\}$; and 2) Spark gap and work piece thickness, $SG = 79.08-\left\{\frac{34854.37}{1+\exp\left(T+114.55\right)/17.73}\right\}$.

Conclusions
Effect of parameters (discharge current, job thickness, material composition) studied on machining criteria (cutting speed, spark gap, MRR) is useful in determining quantification of parameters for quality cuts on brass. Mathematical relations developed are more

![Fig. 7: Effect of thickness on MRR ($R^2 = 0.89922$, SD = 1.6829)](image1)

![Fig. 8: Effect of thickness on surface finish](image2)

<table>
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<th>Cu %</th>
<th>Current</th>
<th>Voltage</th>
<th>Power</th>
<th>Cutting speed, Cs mm/min</th>
<th>Spark gap mm/1000</th>
<th>MRR mm/min</th>
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beneficial to estimate cutting time, cost of machining, process planning and accuracy of cutting for any size of job within machine range. Results are useful in manufacturing wire EDM system for die and tool and electrodes.

References


