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Study Of Parametric Influence In Machining Inconel With WEDM

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Abstract: *This paper presents an experimental investigation of machining accuracy on wire cut electrical discharge machining of Inconel 75 material of thickness 5mm to 90mm in different sizes. An extensive research has been carried out with an aim to select an appropriate machining current, cutting speed and spark gap that can be achieved during the machining at the optimum cutting condition, for cutting Inconel75 work piece of any thickness. Mathematical correlations are developed to determine the machining current, cutting speed and spark gap. Statistical analysis is performed to prove its validity. Finally the correlation are useful for evaluating the machine settings for the required finish, cutting speed, machining time and tool offset for different machining situations arising out of customer requirements.*

Keywords: ***WEDM, Cutting speed, Spark Gap, Current, Thickness, MRR.***

1. Introduction

In the WEDM process the electrode is a metallic wire that may be bare or coated depending upon the application. The wire runs between two guides (Fig. 1), which impose on it the requirements of verticality. Discharges occur in a dielectric fluid, commonly de-ionised water, due to the voltage drop across the gap, and as a consequence of the discharges, work material is removed. Wire path is programmed by the user and controlled by the Numerical Control of the machine. In recent years, WEDM has become very popular for the machining of complex shapes in very hard materials, especially hardened steels, but also alloys for aeronautical equipment and even ceramics or PCD and became a key technology for the manufacture of stamping, pressing and extrusions tools. However, it suffers from the contour inaccuracy and drum-shape of a work piece, which are thought to be mainly caused by wire bending and vibration. One of the main research fields in the WEDM process is the improvement of geometrical accuracy and corner radius. For a better understanding of the causes of lack of accuracy, the mechanics of the process must be analyzed. With the wire subjected to the deformation induced on it during the process depends on factors such as the cutting conditions (mainly, open-circuit voltage, current, dielectric flow, pulse time and off-time), the cutting regime (roughing or finishing cut), if it is a taper or a vertical cut and of course, the geometry being machined. Although estimation of some of these components is difficult, some values can be found in the literature. The maximum deviation, measured between the position of the guides and the deformed wire (actual) is commonly known as wire-lag. As far as part accuracy is concerned, both wall flatness and part profile, especially at those points where there is a change in the direction of movement of the guides (following the NC program), are affected. Wire-lag is responsible for the so-called "back-wheel" effect in corner cutting, as shown in Fig. 2. Prediction of the accuracy of corner cutting requires a sound knowledge of wire deformation [1]. Since wire is excited by discharges that occur at intervals of time equal to off-time it should be possible to analyze the dynamic behavior of the mechanical system. In the work [2] the natural frequencies of the system are calculated using a basic free vibration model of the wire hold by the ends. Experimental modal analysis has also been used [3] for the characterization of the dynamic behavior of the wire. In a later work [4], modeling and analysis of wire vibration is also addressed. Still, the practical feasibility of such models is quite limited, mainly due to the difficulties in modeling damping effects introduced in the system by both friction between wire and guides, and dielectric flushing. However the least possible corner radius that can be achieved during machining sharp internal corners is also depends on current and work piece thickness [5-10. The effects of these two parameters are discussed in the present work.

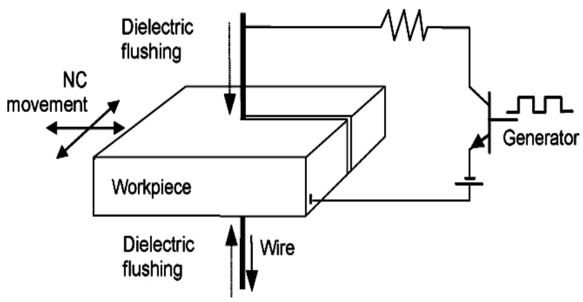

Figure 1: Wire guiding system

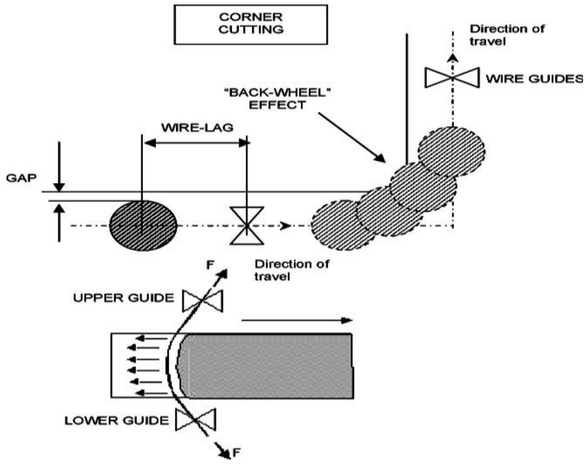

Figure 2: Back wheel effect in corner cutting

2. APPROACHES TO WEDM CORNER CUTTING ACCURACY OPTIMIZATION

It has been shown in fig.2 how wire-lag affects part precision. Since there is always some (even, if very little) wire deformation, an "exact" solution to the problem cannot be formulated. However, the error introduced in part geometry can be minimized so that the part can be acceptable for the user. Different approaches can be found in the literature, aiming at reducing wire deformation by reducing the forces exerted on it and by increasing the tensile force applied by the machine. In the first case wire-lag is measured and using the obtained value, machine parameters are modified in order to reduce the forces acting on the wire. Since this action is accompanied by an increase in the tensile force imposed by the machine, off-time is simultaneously increased in order to avoid wire breakage. The consequence is a reduction of cutting speed, and therefore, productivity decreases. Different methods for measuring wire deformation can be found in the literature [5, 6], commonly based on optical or electrical contact techniques. Wire path modification tries to reduce the consequences of "back-wheel" effect. In this case, since machine parameters (especially, off-time) are not modified, cutting speed is maintained at its maximum. Different proposals for wire path modification can be found in the literature. Although most of the papers have tried to minimize or solve the problem by different means, a clear description of the influence of current and thickness of work piece is still to be done. The influence of these two factors is analyzed in the following section.

3. EXPERIMENT SETUP

In order to study the influence of the current and work piece thickness on the geometry of the corner and spark gap, tests were carried out on ULTRACUT 334 WEDM machine. Work material was Inconel 75 of thickness from 5mm to 90mm. Brass (CuZn36) wire as given by DIN 160, strength 900 N/mm^2 and 0.25mmdiameterwas used. Electrical parameters for each case were selected by machine table and literature [9] in order to use industrial cutting conditions.

Machine	: ULTRACUT 334,
Dielectric	: De- ionized water
Dielectric conductivity	: 38 mhos
Wire tension	: 70 N
Wire velocity	: 3.4 m/min
Wire diameter	: 0.25 mm
Wire material	: (CuZn36) Brass
Gap voltage	: 80 volts

The work piece of 5mm thickness is programmed to machine a slot of 30mm long for measuring the slot width and a "L" cut for measuring the corner radius at a particular current value (Fig.3). The experiments are repeated by varying current till consistent cutting is achieved with least wire breakage and high cutting speed. Similarly experiments are performed on work pieces of thickness 14, 25,35,50,70 and 90mm.

Figure 3: Slots Machined

Measurements are carried out using a Nikon OPTOMECH-Rapid-1 optical microscope (100X). Corner geometry was measured at the cutting slot on test-part.

The spark gap is computed from the slot width as

W = d + 2 x Sg

Where W= Slot width, d = wire diameter and Sg = Spark gap

The variation of spark gap with current for a particular thick work piece and work piece thickness is evaluated and discussed in the following article.

The spark gap variation with work piece thickness is shown in the fig.7 and best fit curve is arrived at using Origin 8.0 software. The mathematical correlation is derived and its statistical analysis ANOVA is performed to calculate the co efficient of variance, R^2 and standard deviation.

4. RESULTS and DISCUSSIONS

The variation in the discharge current with the increase in work piece thickness is obtained and shown in Fig. 4. For a specified set of machining conditions it is observed that with increase in thickness, the required machining current also increases. This is attributed to the high amount of energy required for high thickness job in which machining is possible only by increasing the current. However the rate of current rise is found decreasing with increasing thickness. This may be due to the wire electrode current carrying limitation. This plot is useful to extract suitable minimum discharge current required for machining of any thickness INCONEL 75 work piece with in the machine working range. By regression/ interpolation of the obtained data the equation for the best fit curve is obtained as

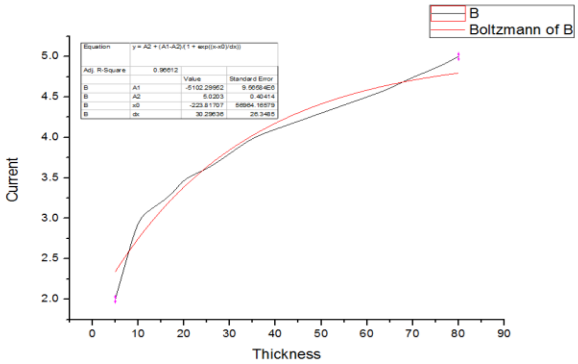

Figure 4: Effect of Thickness on current

The mathematical correlation obtained is

I=5.02-[5107.31/(1+exp{(T+223.8)/26.3})] (1)

Where I is machining current, amp

The statistical analysis shows the values of R^2 = 0.9717 and standard deviation as 0.0235.

Fig.5 shows the effect of thickness on cutting speed for various sizes of the work pieces. The plot indicates that as thickness of the work piece increases the cutting speed decreases rapidly. For thickness beyond 70mm the cutting speed almost remains constant. If the thickness increases, the volume of metal to be removed increases which demands more energy and it may become a machine constraint. At the same time the spark is jumping to the sides of the wire causing more width of cut, reducing the cutting speed. The data thus obtained is subjected to regression/ interpolation and the best fit curve correlation is obtained in the form

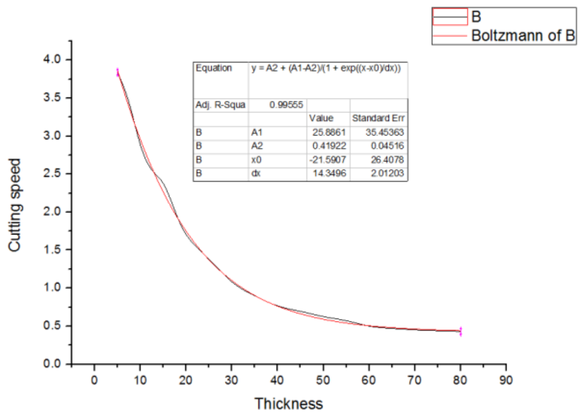

Figure 5: Effect of thickness on cutting speed

C_s =0.42+[26.3/[1+exp{(T+21.6)/14.3}]] (2)

Where C_s= cutting speed, mm/min

T=work piece thickness, mm

The variation of spark gap with the increase in thickness of work piece is depicted in the Fig.6. The curve shows an increasing trend in spark gap with increase in thickness of work piece. This may be due to the property of spark, which jumps longer at higher current values an essential requirement at higher thickness. However the rate of variation is proportionate to the thickness. The best suitable curve is drawn and statistical analysis (ANOVA) is carried out.

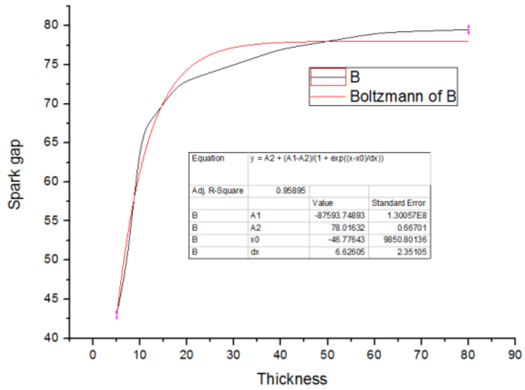

Figure 6: Influence of Thickness on Spark gap

The mathematical correlation obtained is

S_g =78.016-[87671.75/{1+exp{(T+46.77)/6.63}}] (3)

Where Sg is the spark gap in micro meters.

The statistical analysis shows the values of R^2 = 0.9657 and standard deviation as 0.2557. The correlation is useful in finding the spark gap in turn cutting width, to compute the MRR and program the wire off set during CNC part programming, and hence higher accuracy can be achieved.

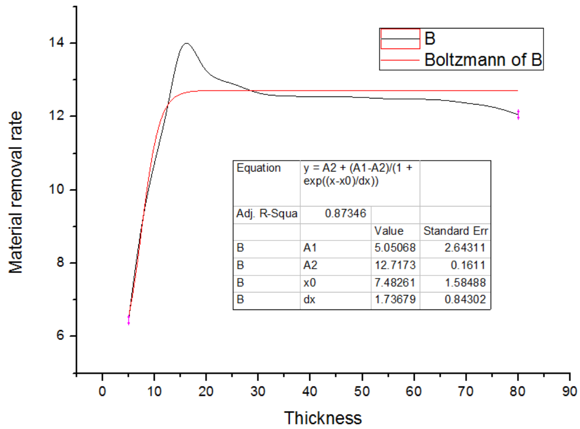

Figure 7: Effect of work piece Thickness on MRR

The variation of corner radius with the increase in thickness of work piece is depicted in the Fig.7. The curve shows an increasing trend in corner radius with increase in thickness of work piece. This may be due to the property of spark, which jumps longer at higher current values an essential requirement at higher thickness, causing deeper cutting. However the rate of variation is proportionate to the thickness. From this plot the corner radius that can be achieved can be predicted while machining a particular thick work piece at optimum cutting parameters.

5. CONCLUSIONS

The influence of parameters, like current and job thickness, on the machining accuracy criteria such as cutting speed, spark gap and MRR are determined. A better control on machining accuracy achieved in comparison with earlier researchers by controlling current. The results are useful in setting the parameters required for quality cuts on inconel 75 work pieces of any size ranging from 5mm to 90mm. Suitable parameters can be selected for machining with the wire available. The mathematical relation developed is much more beneficial to estimate the spark gap, accuracy of cutting for any size of the job within machine range. The maximum error obtained in the calculated values and experimental values is less than 2%. These results will be useful to make the Wire EDM system to be efficiently utilized in the modern industrial applications like die and tool-manufacturing units. The experimental data obtained is useful in developing the data base, expert system and in evaluating Machinability index value.

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