Development and Manufacturing of helical trajectory hole by electrical discharge machining using tiped electrode

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Abstract: The technical problem which this paper proposes to solve is the manufacturing of long helical trajectory hole using electric discharge machine E.D.M. recently, helical trajectory holes are used in wide range of applications. It is possible to be drilled by conventional methods or conventional machines. This present investigation, shows how to manufacture helical trajectory hole. Also solves the problem of full electrode wear and un uniformity of hole diameter due to the electrode wear. This investigation discusses a new non-traditional method applied for drilling deep hole with helical trajectory by electrical discharge machining process (EDM) using a tipped electrode. A new suggested mechanism was carried out to perform a helical deep hole in a work piece. A helical electrode attached to designed mechanism is used in this work. Both the pitch of the helical electrode and the helical groove are equal. A guide pin is fixed to the rotary shaft of the EDM machine which will guide the helical electrode to produce a helical hole. Also, electrode wear was studied in this work.
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1. Introduction

The history of electro discharge machining (EDM) dates back to the days of World Wars I and II when B. R. and N. I. Lazarenko invented the relaxation circuit (RC) [1.2]. Using a simple servo controller, they maintained the gap width between the tool and the work piece, reduced arcing, and made EDM more profitable. Since 1940, die sinking by EDM has been refined using pulse generators, planetary and orbital motion techniques, computer numerical control (CNC), and the adaptive control systems. During the 1960s the extensive research led the progress of EDM when numerous problems related to mathematical modelling were tackled. The evolution of wire EDM in the 1970s was due to the powerful generators, new wire tool electrodes, improved machine intelligence, and better flushing. Recently, the machining speed has gone up by 20 times, which has decreased machining costs by at least 30 percent and improved the surface finish by a factor of 15[1,2].

In the manufacturing process “drilling” generally means “boring of straight hole” the most mechanical engineering have taken the concept that the machining of curved or helical trajectory hole has not been put into practical use. but in some products the shape may contain some holes with curved or helical shape. in this case the designer must be change the shape to be able to machined by traditional methods. to solve this problem required to establishment of anew method of fabrication for helical trajectory hole as shown in fig.1.

Some papers describe how to make curved hole by using E.D.M [3,4,5]. in addition l-shape curved hole could be created [6]. but there is an a few works that treads the issue of constructive element and the geometry of a tool electrode to achieve the electrical erosion for making helical trajectory hole.

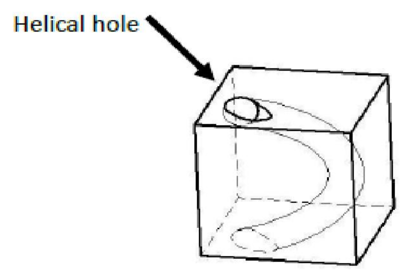


Fig 1. Long hole with helical trajectory

As known in the injection molding its necessary to achieve high productivity to improve the thermal control during molding operation this thermal controlling achieved by using water channels built in the mould, also in gas turbines blade the thermal control is play an important rules of its performance and its life time, so the design of its water channels play an important rules, in recent years and by development of computer programs there are some programs can simulate the optimum trajectory for cooling and enable to appropriate shape and arrangement of this water channel, almost this shape of water channel consists of curved shape and sometimes consists of helical trajectory as shown in Fig.1. This water channels are generally machined by drilling operation if it straight hole but in case of long hole with helical trajectory, it's impossible to make it by traditional method of machining. Most of these suggested methods did not achieve a deep helical trajectory hole, on the other hand a newly suggested mechanical method is presented in this paper to drill a deep hole with a helical trajectory using electrical discharging process.

2. Experimental Work

2.1 Material of Work Piece

The Work piece selected for this work is an aluminum alloy 6060 with dimension 50x50x60 mm. The chemical composition of work piece material is shown in Table1.

2.2 Machining Mechanism

Table1. Chemical composition of aluminum alloy 6060

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Others	Al
6060	0.345	0.130	0.12	0.10	0.425	0.05	0.15	0.10	0.20	Rest

2.2 Machining Mechanism

In this work a mechanism has been designed as shown in Fig. 2. That mechanism consists of helical electrode, parallel cam, rotary shaft, and bracket.

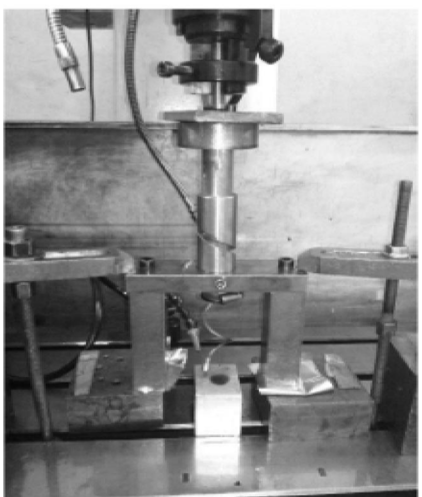


Figure 2. a photograph of constructed mechanism

2.2.1 Helical Electrode

In this work, the electrode was formed by rod of steel (st37), diameter 3mm with length 150mm and electrode tip from pure copper (USN c80100), of 11.5 mm diameter, shown in Fig.3. The chemical composition of the electrode material is shown in Table 2.

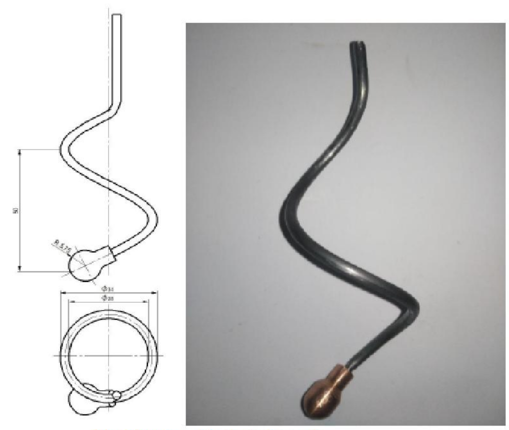


Fig.3 Designed helical electrode

Table. 2 Chemicals composition of (usn c80100)

	Al	Sb	be	C	Cr	Co	Cu	Fe	Pb	Mn	Ni	Nb	P	Si	Ag	S	Sn	Ti
c80100	11.5%	8%	2.85%	358%	1.5%	2.7%	00.0%	1 5.5%	40%	40%	33%	1 1.5%	5%	5.5%	5.5%	08%	19%	02%

To create the helical trajectory wire rod of 3mm diameter has been manufactured by bending process using a mandrel as shown in Fig. 4. The used mandrel which used in this work is made of steel material (St. 37) and its dimension 150 mm length and 20 mm diameter. Mandrel was manufactured for the purpose of bending electrode. That mandrel has been engraved by CNC machine 4-axis by pitch of 50mm and depth of groove of 2.5 mm as shown in Fig.5. and connecting electrode tip by thread in the rod as showne in above **fig 3.**

2.2.2 Parallel cam and rotating shaft

To control the movement of electrode in helical path, a cam has been designed with a helical groove. A steel slave of inner diameter 28 mm. and outer diameter 40 mm. and length 100 mm. has been chosen for this purpose. A helical groove is engraved to coincide with the helical shape of the Electrode with the same pitch of the helical groove to be manufactured as shown in (Fig. 6 a, b).

Fig.4 electrode bending on the mandrel

Fig. 5 mandrel after engraving process

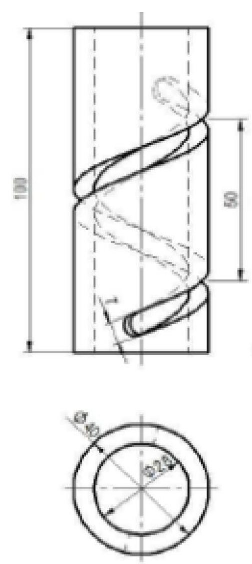


Figure 6 (a): Engraved cam sleeve (from different directions) **Figure 6 (b)** Sleeve dimensions
Fig. 6 Parallel cam

Rotary shaft has been designed to control the helical movement of the electrode and it is made of steel with dimensions as shown in Fig. 7.

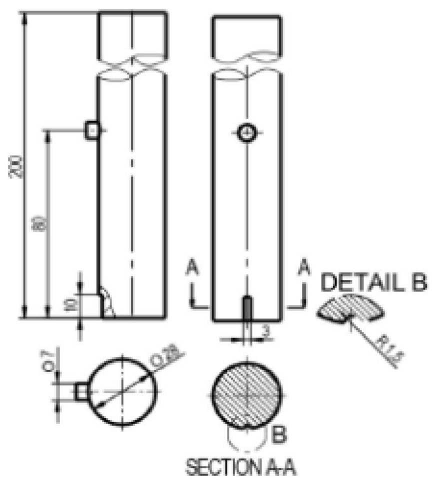


Fig. 7: Rotary Shaft

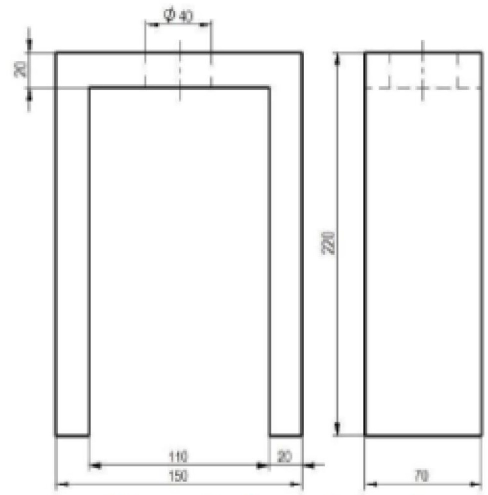


Figure 8: dimensions of bracket

Table 3 EDM parameters

Electrode	usn c80100 pure copper
Work piece material	6060 pure aluminum
Die electric fluid	Kerosene
Floe rate	2.5 cm^3 s−1
Polarity	Positive for electrode
Electrode wear ratio	0.01%
Duty factor	79%
Current	12 Amperes
Pulse-on	30 micro sec
Pulse-off	1 micro sec
Gap	0.075 mm
Retract position	2 mm
Spark holding time	5 sec

2.2.3 The bracket

The bracket designed to hold the parallel cam and it is made of steel and its dimensions are shown in Fig. 8. The function of the bracket is to hold the grooved slotted cam sleeve and fix it to allow the machine shaft to rotate along the cam sleeve.

2.3 EDM Parameters

This work has been performed on EDM sinking machine (JS PNC75A). The machine parameters used for this method is listed in Table 3.

In this work, a CNC electrical discharging machine with (z) and (c) controlled axis is used for making helical hole. The developed mechanism for making a deep hole with helical trajectory is shown in Fig. 9.

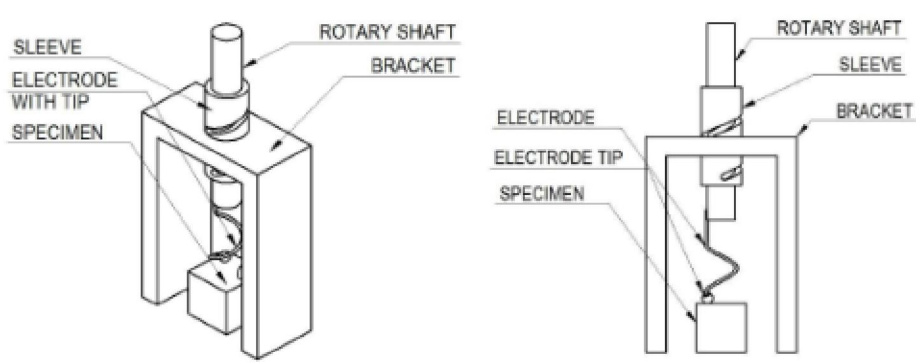


Fig.9 developed mechanism

By using a rotary shaft rotate about an axial bearing which is fixed in plat, as shown in fig. 9. The plate is fixed with EDM machine by a threaded shank in 3R system of the machine, this shaft rotates when the machine move axial in (Z) direction, this motion forces a pin fixed in the shaft as shown in Fig. 10 to move in the helical groove in the parallel cam with the same helical trajectory of the hole, so the electrode with helical shape is moved by the same motion causing erosion in the work piece to perform the helical hole.

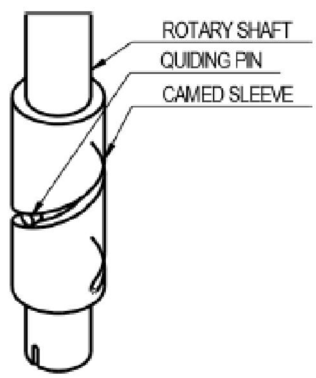


Fig . 10 assembly of pin an helical groove

2.4 Radio Graphic Images

A radiographic picture of the work piece was taken using radiographic test Andrex 300kw (owned to central metallurgical r & d institute) with the following parameters shown in Table. 4.

Table 4 Radiographic parameters

Source	x- ray – Andrex 300kw
Tube voltage	75 KV
Film type	Kodak AA400
sfd	700mm
Tube current	0.5mA
Exposure time	2.0 Min
Processing	Manual

2.5 Electrode Wear Rate

The Electrode wear was measured by the following equation:

$$\text{Electrode Water Rate} = \frac{\text{Electrode weight before machining} - \text{Electrode weight after machining}}{\text{time}} \text{ (gm/min.)}$$

$$= \frac{590{,}457 - 587{,}563}{6X60} = 0.008038 \text{ (gm / min.)}$$

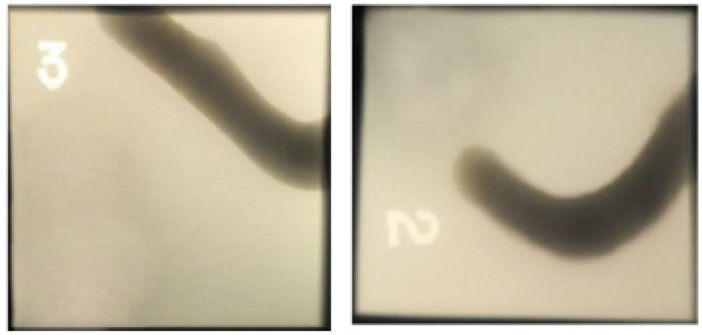
The inlet and outlet hole diameter in addition with electrode tip diameter were measured by digital venire caliper with accuracy 0.05. Also the weight of helical electrode after and before machining wear measured by digital sensitive balance.

3. The Implemented Helical Hole

3.1 Implemented Hole Shape

After radiography by X-Ray, images in Fig. 11 illustrate the helical hole in the work piece. Figure 11.1 is taken from left, Fig. 11.2 is taken from right, and Fig.

11.3 is taken frm top of work piece.



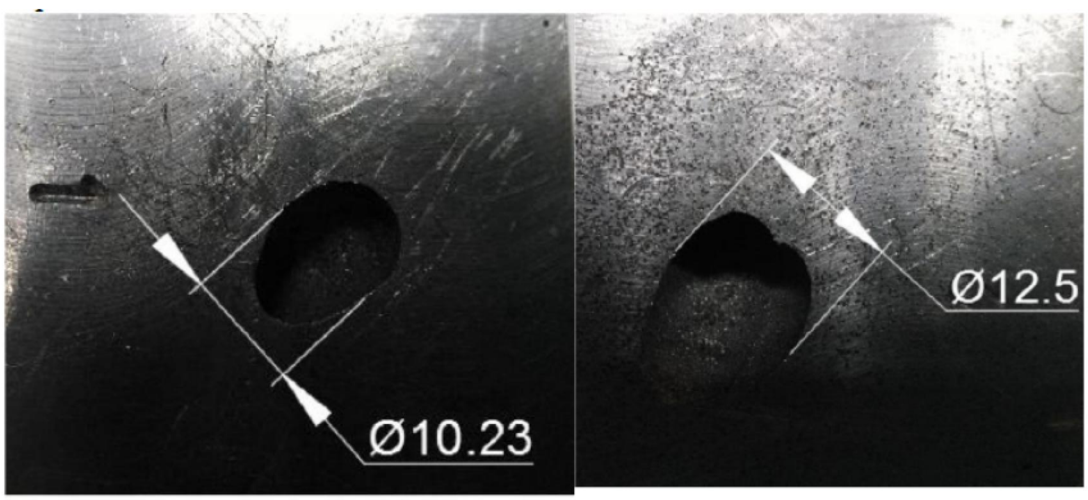
(a)side view of helical hole (b)top view of helical hole

Fig. 11 Different radiography views of the drilled helical hole

3.2 Implemented Hole Diameter

The inlet hole diameter is varying from 12.5 to 17.234mm as shown in Fig. 12(a), it is larger than the electrode diameter because of wear of the electrode body during its entering. That is beside to the error of the electrode dimensions because of the spring back action during bending.

The outlet hole diameter is varying from 10.23 to 13.5 mm as shown in Fig. 12(b), it is smaller than the electrode diameter because of wear occurred at the electrode tip.

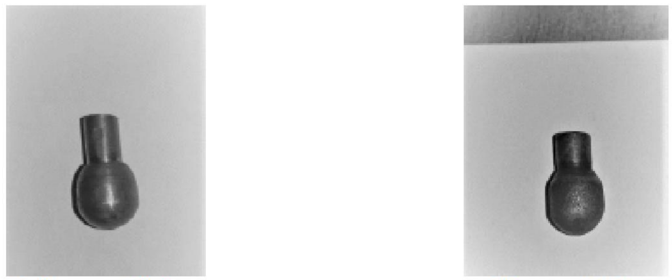


(a) Inlet hole (b) Outlet hole

Fig. 12 Inlet and outlet holes of the work piece

3.3 Electrode Wear

Generally, during EDM machining process the electrode should be worn due to the sparking between the electrode and work piece. The electrode diameter before the EDM process is 11.5 mm while its diameter after the process is 10.15mm, where the wear is represented by 3%. Shape of electrode tip before and after machining can be shown in Fig. 14. It is found that the electrode wear rate is 0.008038 gram/min.



Before machining After machining

Figure.13.shape of the electrode tip after and before the machining.

4. Conclusion

Implementation of a helical hole in a solid block can be done by using the developed mechanical mechanism with a helical electrode on an EDM machine. The implemented helical hole has occurring of 2%. For the internal main diameter and 1% for the external main diameter of helix. The inlet hole is lager than the electrode diameter because of wear between electrode body and work piece during electrode entering. The outlet hole is smaller than the electrode diameter because of wear of electrode tip. The electrode wear rate is calculated as 0.008038 gr/min. Finally, it has to be mentioned (as a disadvantage) that the produced helical electrode is used once.

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