Manufacturing of Helical Trajectory Hole by Electrical Discharge Machining

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Abstract: Nowadays, helical trajectory holes has many uses such as cooling in injection mould. This work shows how to manufacture helical trajectory hole which cannot be machined by conventional methods of machining processes. It presents a nontraditional method applied for drilling deep hole with helical trajectory using electrical discharge machining process (EDM). A suggested technique has been carried out to perform a helical hole in a work piece. A helical electrode attached to a designed mechanical mechanism is used. Design and production of a helical electrode is explained and presented that helical electrode is attached to special mechanical mechanism design to be connected to an EDM machine. Also, electrode wear has been studied in this work.

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1. Introduction

As known in the injection moulding its necessary to achieve high productivity to improve the thermal control during moulding 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.

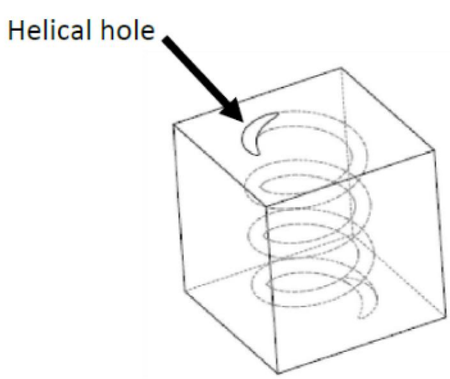


Fig. 1 Long hole with helical trajectory

It cools the tool and washes away eroded particles from workpiece [1,2]. Being a non-contact type of thermo-erosion process, EDM is not constrained by any mechanical property or complex geometry [3,4]. The application of EDM process is best suited for machining of hard materials that would be either difficult or ineffective with conventional machining methods. The most common application of EDM process is generating replica of tool shape on workpiece. However, the phenomenon of material removal of EDM process was utilized for other machining operations [5-7]. These operations are performed by introduction of relative movement between tool electrode and workpiece while maintaining spark distance between electrodes. Relative movements between electrodes could be attained either after some modification or after having attachment on die-sinking EDM. If motion of tool electrode is guided and controlled on a specified trajectory, then its movement is termed as orbital tool movement.

That helical trajectory holes cannot be produced on either traditional machines or traditional electric discharging machine. Some articles and patents, which deal with erosion curved holes, achieve results, but there are few works that treat the issue of constructive elements and the geometry of a tool-electrode to achieve electrical erosion holes helical trajectories.

To achieve electrical erosion machining of the cooling holes in gas turbine blades it needs a curved electrode. The electrode is made of copper pipe. By controlling the rotation of the electrode around its own axis, this can make more cooling curves holes at the same time in the metal piece, but the holes are made on a circular path in a plane at angles less than 180° [8]. In another study, a method is presented using electric erosion of curved cooling channels for gas turbine blades using non-tubular electrode with full helical shape. Being non-tubular section, this presents great difficulties in washing the electrode gap [9].

To make holes for fuel injectors using electro-erosion process it made only a segment of the curve less than a full length of a step. Because of poorly electrode washing and disposal of the erosion products from the working gap, this method is less productive and it has high rate electrode wear [10]. In order to achieve curved holes, an electrode is driven by its own weight. This method is based on the property of a lead wire. For its necessary to use an electro-erosion machine that can control the movement at least four axes. It requires isolating the power supply cable to the electrode – which complicates washing working gap. Another drawback of the method is the difficulty of controlling electrode position as well as developing precision curved geometry and no possibility of achieving long helical trajectories holes [11].

Lee et all, [5] describes the machining by EDM of drilled holes required for cooling injecting molds. They designed a leading mechanism by wires and pulleys. This mechanism mounted on a working electrical erosion machine has the disadvantage of not being able to achieve holes with small diameter curves, due to the large size of the guiding system, and the guide wire of the electrode system must be electrically insulated from the work piece. The method is particularly good for unions like "U" where it has two parallel holes or union-range like "L" of two holes perpendicular, without being able to achieve long helical trajectories holes.

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 100x100x100 mm. The chemical composition of work piece material is shown in Table1.

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.

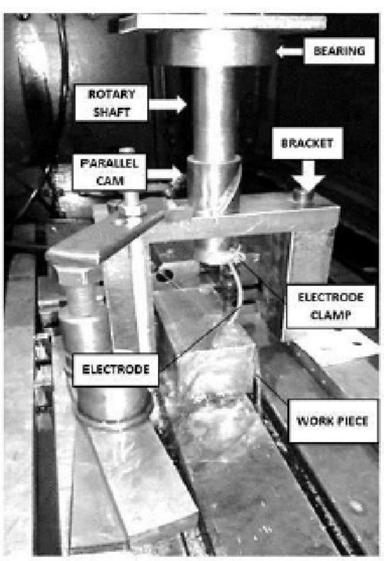


Figure 2. a photograph of constructed mechanism

2.2.1 Helical Electrode

The electrode material is pure copper (usn c80100), of 5.5 mm diameter, 150 mm length as shown in Fig. 3**.** The chemical composition of the electrode material is shown in Table 2.

The helical electrode 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.

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).

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.

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 (Hochen 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.

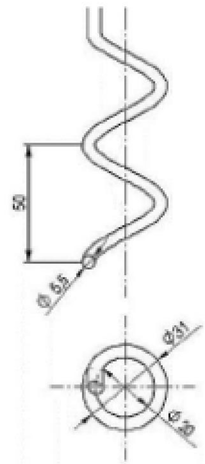


Fig. 3 Designed helical electrode

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%

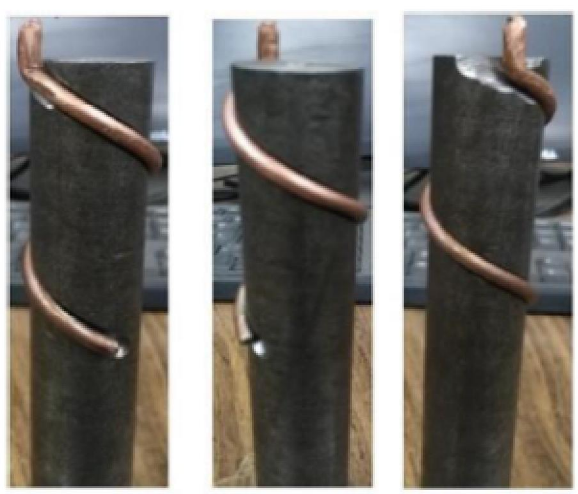


Fig. 4 Electrode bending on the mandrel Fig. 5 Mandrel after engraving process

(a) Engraved cam sleeve (b) Sleeve dimensions

Fig. 6 Parallel cam

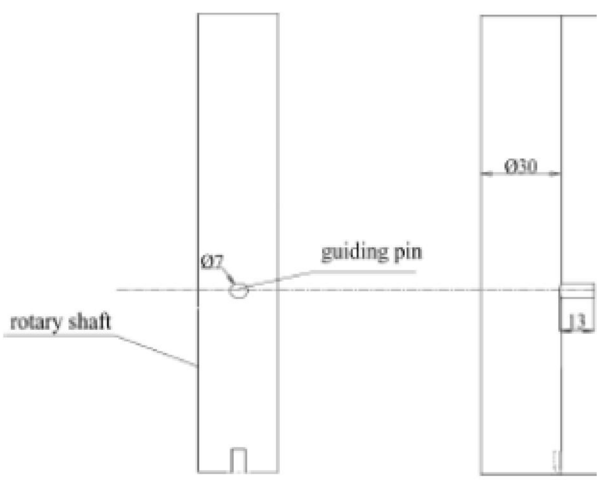


Fig. 7 Rotary Shaft

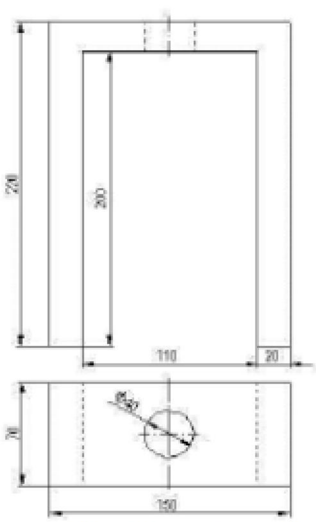


Fig. 8 dimensions of bracket

Table 3 EDM parameters

Electrode	usn c80100 pure copper
Work piece material	6060 pure aluminum
Die electric fluid	Kerosene
Floe rate	$3\ cm^3\ s{-1}$
Polarity	Positive for electrode
Electrode wear ratio	0.01%
Duty factor	79%
Current	10 Amperes
Pulse-on	4 sec
Pulse-off	0 sec
Gap	0.07 mm
Retract position	2 mm
Spark holding time	5 sec

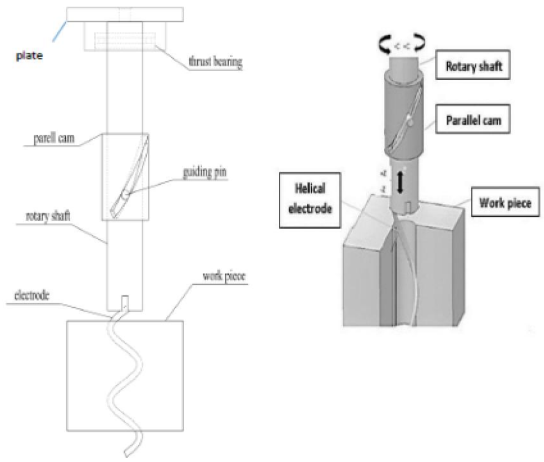


Fig.9 developed mechanism

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.

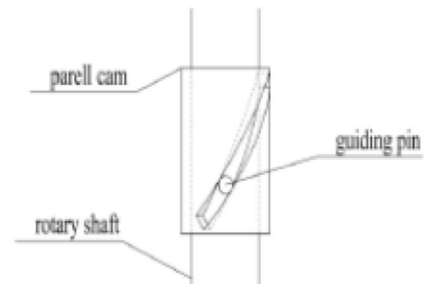


Fig. 10 Assembly of pin an helical groove

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 is measured by the following equation,

$$\text{Electrode wear rate} = \frac{\text{Electrode weight before machining} - \text{Electrode weight after machining}}{\text{time}} = \frac{29.6028 - 26.8938}{7\text{x}60} = 0.00645 \ \ (\text{gm/min.})$$

The inlet and outlet hole diameters in addition to electrode tip diameter has been measured by digital vernier caliper with accuracy 0.05. Also the weight of helical electrode before and after machining has been 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.

3.2 Implemented Hole Diameter

The inlet hole diameter is varying from 8.2 to 9.4 mm 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 4.9 to 5.5 mm as shown in Fig. 12(b), it is smaller than the electrode diameter because of wear occurred at the electrode tip.

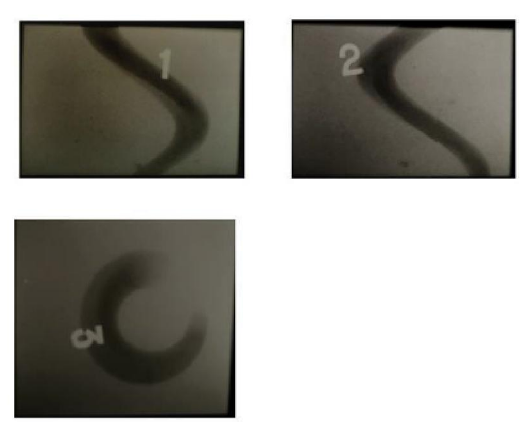
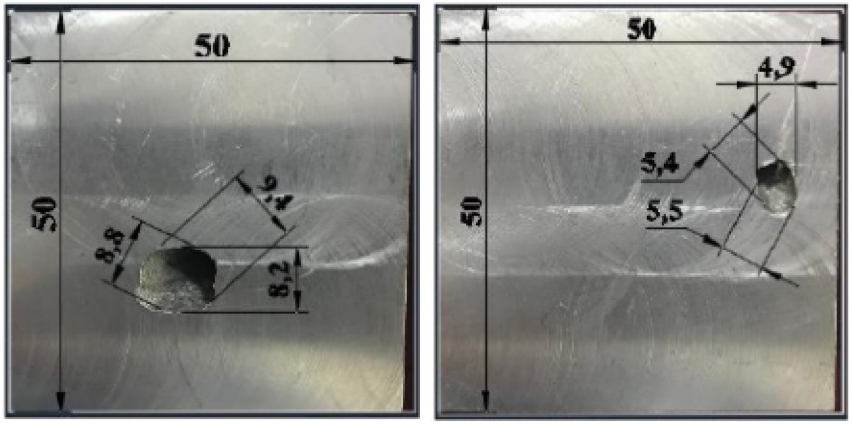


Fig. 11 Different radiography views of the drilled helical hole



(a) Inlet hole (b) Outlet hole

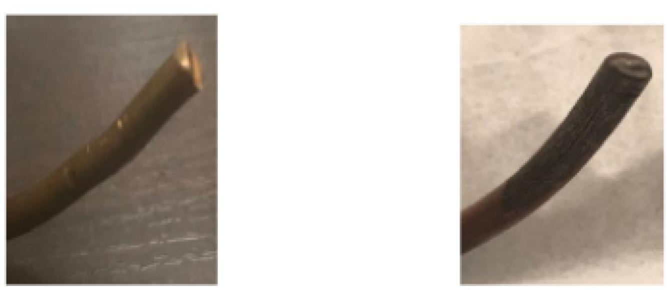
Fig. 12 Inlet and outlet holes of the work piece

Figure 13 showse top radiography of the worke piece to illustrate the main diameter of the implemented helical hole. The internal main diameter of the implemented helical hole is 19.65 mm which decreased by 2% of the internal main hole diamter of the electrode. The external main diameter oe the implemented hole is 31.35 mm which increased by 1% of the external main hlediameter of the electrde.

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 5.5 mm while its diameter after the process is 5.35 mm, 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 0.00645 gram/min.

Fig. 13 Top radiography of the work piece



Before machining After machining

Fig. 14 Shape of the electrode tip before and after the machining process

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 0.00645 gr/min. Finally, it has to be mentioned (as a disadvantage) that the produced helical electrode is used once.

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