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Role of the Power Supply and Inter-Electrode Gap in Electrochemical Honing Process

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Abstract

The process performance of electrochemical honing (ECH) is often increased by the use of the appropriate and optimal input process parameters. This study focuses on the types of power supply and inter-electrode gap in ECH of spur gears, with the aim to determine which parameters are most significant for the required output. Based on the experimental findings, pulse assisted ECH gives marginal improvement in surface finish at the cost of three times higher processing time as compared with direct current ECH and higher value of IEG up to 1 mm helps to give controlled anodic dissolution in ECH of spur gears.

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Keywords: ECH; power supply; IEG; spur gear; precision finishing

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1. Introduction

Gears are essential to the global economy and are used in nearly all applications where power transfer is required, such as automobiles, aerospace, marine and industrial equipments. The problem of high quality gear manufacturing to assurance smooth running at high speed and at high load become more and more acute as the speed of gear as well as the demand on noiseless transmission are increasing [1]. This forces gear manufacturers to respond with improved gear systems that are high finished and manufactured faster than before.

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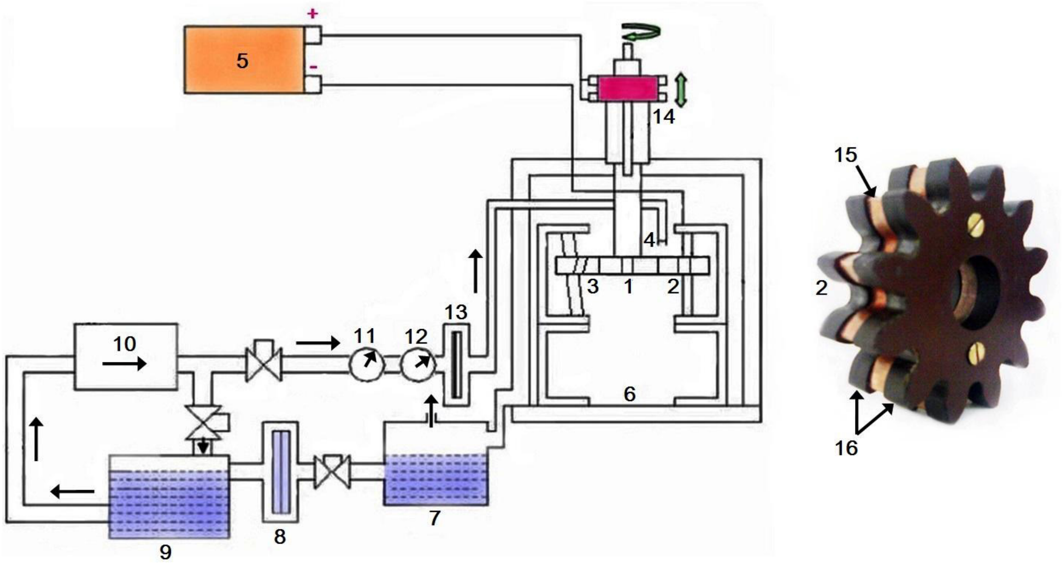
In general, conventional finishing processes i.e. gear grinding, gear shaving, gear honing, gear lapping are used to reduce form errors and surface roughness of gears. These processes have some limitations such as surface burn, change in microstructure, residual stresses formation, generation of micro-cracks, correct only minor profile errors, high tool wear, long processing time and high processing cost [2]. Over the past few decades, electrochemical honing (ECH) was developed as a hybrid precision finishing process for gears. ECH is a high accuracy and high productive gear finishing method as compared to conventional finishing processes. In ECH process, modern electrochemical machining (ECM) process is combined with conventional honing to take the advantages such as faster material removal capability of ECM and the correcting capacity for form errors of honing in a single process while overcome their individual limitations at the same time. Nearly 90 percent of the workpiece material is removed by electrolytic action and rest by mechanical honing [3, 4]. Mechanical honing is mainly used to scrub the passivating electrolytic metal oxide microfilm from a higher work profile of the gear to correct the surface geometrical inaccuracies. Generation of cross-hatch lay pattern by simultaneous rotation and reciprocation of the honing gear is essential for lubrication between mating surfaces of gear tooth.

In 1981, Chen et al. pulled out research work on ECH of spur gears by designed a sandwich type cathode gear and discussed the development of productive, high-accuracy, long tool life, a gear finishing method based on ECH principle [5]. Later than some research's have carried out in this field to explore various aspects of the ECH of gears technique as reported in the references [6-10]. In general, there are very few references available on ECH of gears. It is reported that the material removal rate of ECH is two to eight times higher than conventional finishing processes and can provide better surface finish up to 0.05μm [11].

In this paper follow-up work is presented as follows: Firstly, ECH system is designed and fabricated for spur gear, different input power supply such as direct current and pulse current is used for anodic dissolution and both power supplies are compared in the surface roughness and processing time. Secondly, a set of parametric experiments are conducted to find the effects of inter-electrode gap (IEG) on the process output. Finally, the experimental results are presented and conclusions are made.

2. Experimental Setup



1. Workpiece gear, 2. Cathode gear, 3. Honing gear, 4. Electrolyte inlet, 5. Power supply, 6. Finishing chamber 7. Settling tank, 8. 1st stage filter, 9. Storage tank, 10. Pump, 11. Pressure gauge, 12. Flow gauge, 13. 2nd stage filter, 14. Carbon-brush assembly, 15. conducting gear, 16. Insulating gear

Fig. 1. A Schematically view of designed experimental setup of ECH of spur gear.

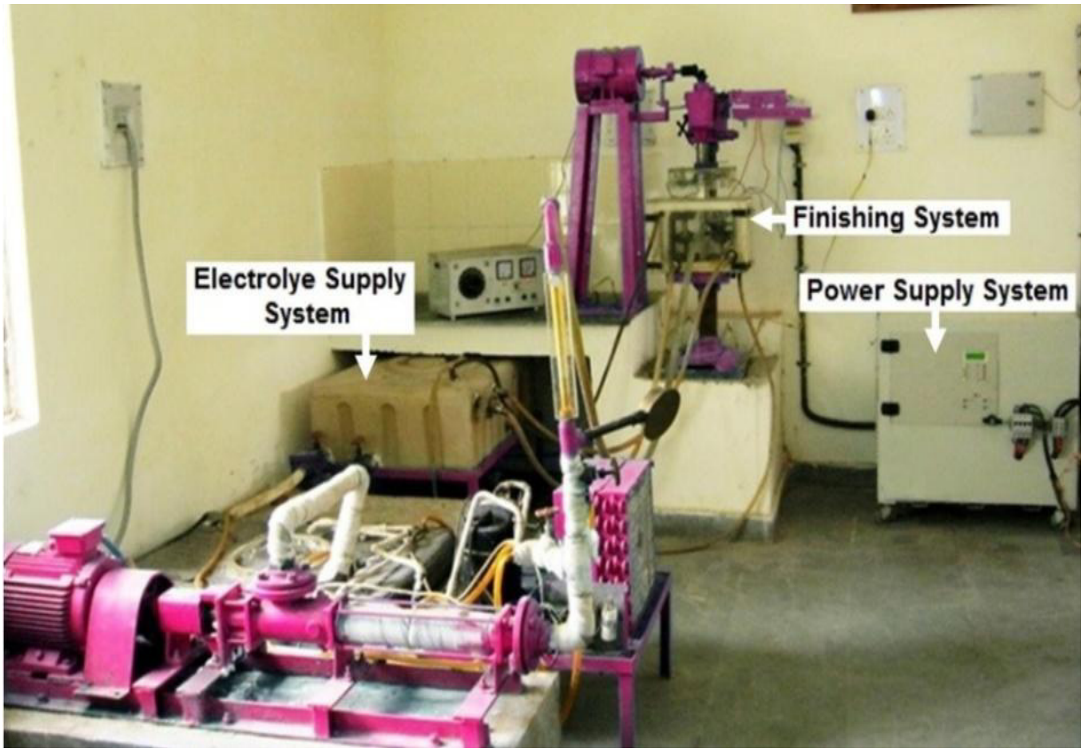


Fig. 2. A photograph view of developed experimental setup of ECH of spur gear.

The schematic diagram and the photograph of designed experimental setup of ECH of spur gear is illustrated in Fig. 1 and Fig. 2 respectively. It consists of an electrolyte system, a finishing system and a power supply system. The electrolyte system consists of an electric pump used to supply a full stream of electrolyte in an ECM zone from

the storage tank, the electrolyte flow rate is controlled by control valves and electrolyte gauge. The finishing system consists of an electric motor used to drive the workpiece gear, the workpiece gear drive the specially designed cathode gear and honing gear, of which driver speed is controlled by a speed regulator. For honing process, helical gear is used to ensure the dual flank contact by cross-axis arrangement with the workpiece spur gear. The power supply system consists of an input power device, used to supply power for anodic dissolution between anode and cathode through carbon brushes and brass rings.

3. Comparison of ECH with pulse-assisted ECH

There are result of two studies compared in graphical form which one is based on the ECH of spur gears using direct current and other is based on the ECH of spur gears using pulse current. The experimental conditions are listed in Table 1.

Table 1. Experimental comparison of the ECH and PECH.

	Current (A)	Duty cycle (%)	Voltage (V)	Rotating Speed (rpm)	Electrolyte concentration (%)	Processing time (min)	PIR_a (%)	PIR_t (%)	MRR (mg/min)
ECH	20	Nil	30	65	10	8	73.06	76.13	164.68
PECH	20	22.2	30	65	10	24	80.65	81.07	139.26

In this study, electrolyte composition of 75% NaCl + 25% $NaNO_3$ at a temperature of 30^o C and flow rate of 20 l/min has been used for the workpiece material of EN8. For conventional honing, EN24 tempered alloy steel is used with a honing tool, which scrub away the oxide layer that generate on the workpiece surface during ECM. The optimum processing time of these experimental conditions is selected on the basis of the average percentage improvement in the roughness (PIR_a) and maximum percentage improvement in the roughness (PIR_t) values using equation (1) as follow:

$$PIR_a / PIR_t = \frac{Initial\ R_a / R_t value\ \text{-}\ Final\ R_a / R_t\ value}{Initial\ R_a / R_t\ value} 100\% \quad (1)$$

The photographic view of the finishing system and a comparison graph of processing time is shown in Fig. 3(a) and 3(b) respectively. The graph shows that significant processing time is 8 minutes for ECH and 24 minutes for PECH and pulse current assistance gives 7.59 % higher PIR_a, and 8.94 % higher PIR_t as compared with direct current.

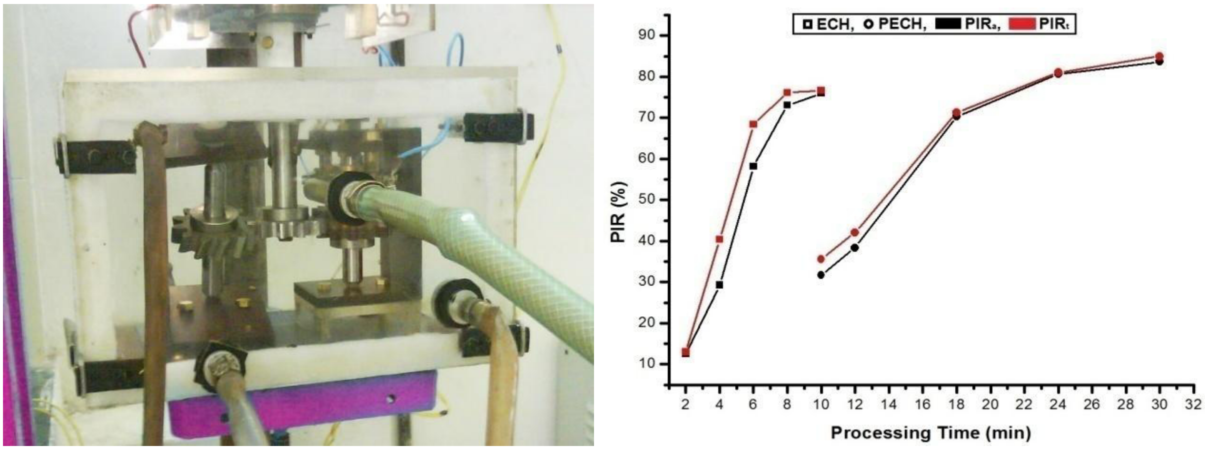


Fig. 3. (a) photographic view of finishing system; (b) a comparison graph of processing time.

4. Effects of IEG on ECH performance

ECH posses exhibits self regulating characteristic by virtue of the fact that surface roughness depends on the controlled amount of anodic dissolution and mechanical scrubbing. The amount of anodic dissolution has been controlled by using a small amount of current or by providing higher IEG [12]. The effects of IEG on ECH process performance has been studied by fixing the input parameters at optimum level as described in table 1. Table 2 presents the result for PIR_a and PIR_t values corresponding to five different IEG respectively.

Table 2. Effect of IEG on PIR_a and PIR_t values for different experiments

Exp. No.	IEG (mm)	Before		After		PIR_a (%)	PIR_t (%)
		R_a (μm)	R_t (μm)	R_a (μm)	R_t (μm)		
1	0.4	3.18	19.74	0.88	6.57	72.32	66.72
2	0.6	2.77	24.43	0.76	6.13	72. 57	74.91
3	0.8	3.07	27.92	0.82	6.75	73.26	75.83
4	1	3.05	27.99	0.79	6.89	74.05	75.39
5	1.2	3.26	27.36	1.02	8.23	68.59	69.92

It shows that more significant range of IEG is from 0.4 mm to 1 mm. The increase of the IEG beyond 1mm causes the decrease of anodic dissolution at the constant level of input process parameters and therefore surface roughness decrease. Conversely, the smallest value of IEG below 0.4 mm, increases the dissolved metal and surface roughness ascent.

5. Conclusion

ECH has a the potential to become a preferable alternate to the conventional gear finishing processes due to its distinct features such as independent from the gear material hardness, almost negligible tool wear, low cycle time and ability to correcting geometrical errors and surface finish which enhance the functional performance and durability of the spur gears. The presented work on precision finishing of spur gears by using ECH and PECH processes indicates that pulse assistant in ECH leads a marginally higher surface quality of $PIR_a = 7.59$ and $PIR_t = 0.42$ than the ordinary ECH process. The processing time of PECH process is nearly three times higher than the ECH. Therefore, processing time is one of the insignificant responses in PECH, which determines lower productivity from the practical point of view of the process. The use of the appropriate value of IEG enhanced the process performance characteristics. The lower value of IEG provides higher anodic dissolution, which decreases the surface quality and large IEG also root to decrease of surface quality at the selected processing conditions. The IEG from 0.4 to 1 mm has been predicted more significant for ECH of the spur gear.

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