Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird
Annals of DAAAM International

EXPERIMENTAL INVESTIGATION ON PRECISION FINISHING OF SPUR GEARS BY PULSE ELECTROCHEMICAL HONING (PECH) PROCESS

MISRA, J[oy] P[rakash] & JAIN, P[ramod] K[umar]

Abstract*: This paper presents the findings of the experimental investigations on precision finishing of spur gears by pulse electrochemical honing (PECH) process. Electrochemical honing (ECH) is one of the most potential hybrid machining processes used for finishing internal cylinders and gears by combining faster material removal capability of ECM and capability of correcting shape-related errors of honing in a single process and overcoming their individual limitations at the same time. Moreover, the pulse assistance in ECH provides the relaxation period to the system during off time to discharge the dregs out of the electrodes' gap and improves the process capability. The present study focuses on the effect of finishing time on precision finishing of gear tooth profile.*
Key words*: ECH, PECH, Spur Gear, Surface Roughness*

1. INTRODUCTION

Gears running at high speed and transmitting large forces are subjected to additional dynamic forces due to poor surface quality of gear tooth profile. Therefore, the gear teeth must be error-free for smooth noiseless motion transmission. The surface quality of gear tooth profile can be improved significantly by the gear finishing processes. Commonly used conventional gear finishing processes such as gear grinding, gear shaving, gear honing, gear lapping are costly, have low productivity, and gear material hardness limitation. This necessitates exploration of electrochemical honing (ECH) process which has capabilities and potential to be developed as an alternative to conventional gear finishing processes. It is reported that ECH is faster than conventional gear finishing processes and can provide surface finish up to 300 nm to the gear tooth profile (Misra et al., 2009). Moreover, the pulse assistance in ECH provides the relaxation period to the system during off time to discharge the dregs out of the electrodes' gap and thus improves the process capability.

There are very few references available on ECH of gears. Jain *et al*. (2009) have done a state-of art review of past work on ECH of internal cylinder and gears. According to the best knowledge of the authors, the application of ECH for gear teeth finishing was first reported by Chen *et al*. (1981). Wei *et al.* (1987) used a current-control method by varying the intensity of the electric field to control the intensity of electrolytic dissolution steplessly along the full profile of the gear using a newly developed gear-shaped cathode in the field-controlled ECH (FC-ECH) of gears. While, He *et al.* (2000) used the time-control method to correct the gear tooth profile errors very efficiently in a process that they called as slow-scanning field controlled ECH (SSFC-ECH) of gears. Ramlal *et al.* (2008) have investigated on ECH of spur gears using different combinations of $NaNO_3$ and NaCl as electrolyte. In recent work, Misra *et al.* (2009) explained the effects of voltage, rotating speed of workpiece and electrolyte concentration on precision finishing of helical gears by ECH. The study of precision finishing of gears by ECH under pulse current condition has not been explored significantly.

2. EXPERIMENTATION

The present study emphases the effect of finishing time on precision finishing of spur gears by PECH process and thus it helps to realize the different aspects of the process. For the present study, PECH experimental setup incorporating several unique features to exercise a precise control over the operational kinematics and process input parameters with a good parameter range was designed and developed indigenously as shown in Fig. 1. It consists of five major subsystems namely pulse power supply system, electrolyte supply system, tooling system, tool motion system, and machining chamber. Pulse power supply system consists of a constant voltage (0-110 V) and pulse-setting DC (up to 100 A) supplying units. Electrolyte supply system consists of electrolyte storage and settling tanks, pump, heat exchanger, flow meter, flow valves. The tooling system contains three types of gears: cathode gear, workpiece gear and honing gear. For the purpose, a special type of cathode gear has been designed having the capability of varying the rate of electrolytic dissolution steplessly along the full profile of the workpiece gear. All gears are mounted on special type of axles made of stainless steel. Brackets are used for holding the gear axles of cathode and honing gears. The tool-motion system comprises of a DC induction motor to provide rotary motion to the workpiece gear and a programmable stepper motor to provide reciprocating motion. The entire tooling system with axles and brackets are enclosed in a machining chamber made of perspex for better visibility and corrosion-resistance. In the present work, finishing time is used as input process parameter to investigate its effect on finishing of gear tooth profile by analysing the surface roughness values before and after the process. The surface roughness values before and after ECH, is measured by a Wyko NT 1100 optical profilometer interfaced with Vision®32 software. Ten separate measurements each at tip, middle and root of one particular gear tooth are taken along the face-width of the gear and the average value is used. Percentage improvement in average/maximum surface roughness value (PIRa / PIRtm) is defined as follows:

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

3. RESULTS AND DISCUSSIONS

Table 1 and 2 presents the percentage improvement of average and maximum surface roughness values for different finishing times respectively. Table 3 and Table 4 shows the change in PIR_a and PIR_{tm} value for different finishing time durations. Fig. 2(a) and 2(b) show variation of PIR_a and PIR_{tm} with finishing time. From these graphs, it is evident that PIR_a and PIR_{tm} increase with the finishing time but at a decreasing rate because intensity of EC dissolution deceases as the surface gets smoothened. Therefore, increments in PIR_a and PIR_{tm} for first two time periods are most

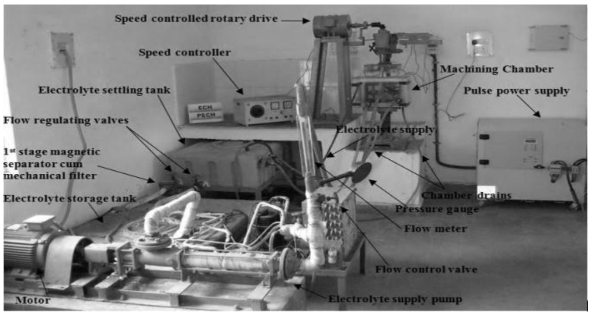


Fig. 1. Photographic view of experimental setup for PECH of spur gears

significant but for the time period from 24 min to 32 min it is insignificant. Therefore, in present study, finishing time of 24 min is found the most appropriate for PECH of spur gears.

4. CONCLUSION AND FUTURE SCOPE

The present study established the feasibility of using PECH for precision finishing of spur gears. An experimental setup for the same has been designed and developed. Based on the results, 24 min is found optimum for precision finishing of spur gears. PECH is capable of greatly reducing the irregularities of the gear tooth profile. However, like most of the hybrid machining processes (HMPs), PECH is also in the development phase and therefore a sustained global research is required to transform it into a matured manufacturing technology and for its successful industrial applications and commercialization. It is very evident that very few attempts have been made to analyse and mature the process and hence, the process has plenty of scope for future work. In the present study, only the effect of finishing time has been investigated. The effects of other parameters on precision finishing of spur gears by PECH yet to be explored.

Finishing Time (in Min)	At Tip of gear profile	At Middle of gear profile	At Root of gear profile
8 min	26.95	31.79	35.93
16 min	44.45	34.41	49.91
24 min	63.09	58.67	71.64
32 min	64.19	58.62	72.77

Tab. 1. PIR_a values for different finishing times

Finishing Time (in Min)	At Tip of gear profile	At Middle of gear profile	At Root of gear profile
8 min	35.97	62.35	49.68
16 min	46.39	68.70	57.12
24 min	58.61	76.87	70.28
32 min	58.86	72.35	71.31

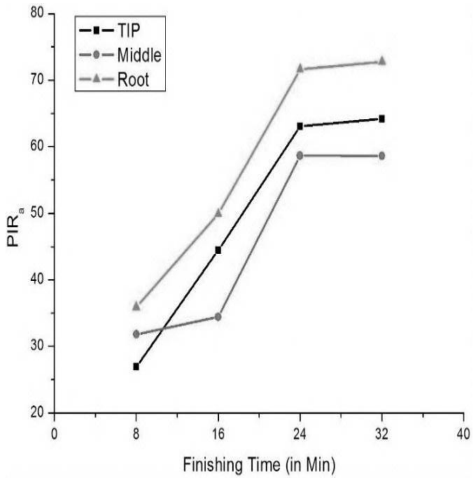
Tab. 2. PIR_{tm} values for different finishing times

Finishing Time Duration (in Min)	At Tip of gear profile	At Middle of gear profile	At Root of gear profile
8 - 16	35.97	62.35	49.68
16 - 24	46.39	68.70	57.12
24 -32	58.61	76.87	70.28

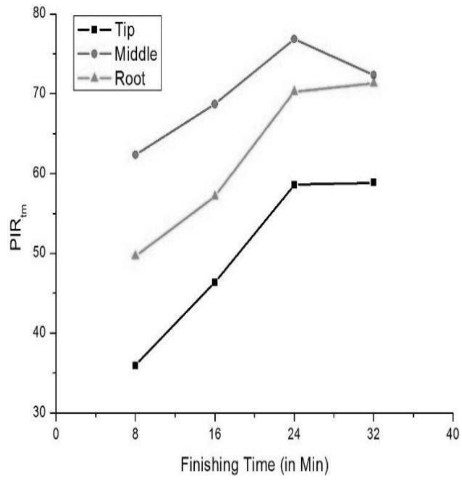
Tab. 3. Increment of PIR_a for different finishing time duration

Finishing Time Duration (in Min)	At Tip of gear profile	At Middle of gear profile	At Root of gear profile
8 - 16	35.97	62.35	49.68
16 - 24	46.39	68.70	57.12
24 -32	58.61	76.87	70.28

Tab. 4. Increment of PIR_{tm} for different finishing time duration



(a)



(b)

Fig. 2. Effect of finishing time on (a) PIR_a and (b) PIR_{tm}

5. REFERENCES

Chen. C. P.; Liu. J., Wei. G. C., Wan. C. B. & Wan. J. (1981). Electrochemical honing of gears: a new method of gear finishing. *Annls CIRP*, 30(1), pp. 103–106.

He, F.; Zhang, W. & Nezu, K. A. (2000). Precision machining of gears: slow scanning field controlled electrochemical honing. *JSME Int. J. Ser. C*, 43(2), pp. 486–491.

Jain. N. K.; Naik. L. R., Dubey. A. K., & Shan. H. S. (2009). State-of-art-review of electrochemical honing of internal cylinders and gears. *Proc. IMechE, Part B: J. Engineering Manufacture*, 223(6), pp. 665-681, 09544054.

Naik. L. R.; Jain. N. K., & Sharma. A. K. (2008). Investigation on Precision Finishing of Spur Gears by Electrochemical Honing. *Proc. of 2nd International and 23rd AIMTDR Conference*, Shunmugam, M. S. & Ramesh Babu, N. (Eds.), pp. 509-514, I.I.T. Madras, India.

Misra, J. P.; Jain, N. K., & Jain, P. K. (2010). Investigations on Precision Finishing of Helical Gears by Electrochemical Honing (ECH) Process. *Proc. IMechE, Part B: J. Engineering Manufacture* (in press).

Wei. G. Q.; Wang. Z. B., & Chen. C. P. (1987). Field controlled electrochemical honing of gears. *Precision Engg*. 9(4), pp. 218–221, 0141-6359.