Effect of direct current and pulse current on processing time, electrolyte composition and electrolyte concentration of electrochemical honing

H. Singh*, P.K. Jain

Department of Mechanical and Industrial Engineering, Indian Institute of Technology Roorkee, Roorkee-247667, Uttarakhand, *E-Mail: hps_me@yahoo.com

Abstract

The effects of processing time, electrolyte composition and electrolyte concentration on the electrochemical honing (ECH) performance under direct current and pulse current condition were studied. ECH is a hybrid machining processes used for finishing internal cylinders, gun barrels and gears, based on the combination of electrochemical machining (ECM) process having high material removal capability and controlled functional surface generating capability of conventional honing process in a single operation. It is reported that the material removal rate of ECH is two to eight times higher than the conventional gear finishing processes and can provide better surface finish value to $R_a \leq 0.05 \mu m$ and hence its benefits can be widely used for aerospace, automobile, gear manufacturing, nuclear reactor applications etc. Moreover, the pulse assistance in ordinary ECH provides the relaxation period to the ECM zone of the system during pulse-off time to discharge the dregs out of the inter electrode gap and thus improves the process capability for maximizing the service life and overall performance of gears. Based on the experimental findings at the optimum setting of input process parameters, pulse current shows an improvement of 22.73 percent in average surface roughness and 13.48 percent in maximum surface roughness value of EN8 spur gear as compared to direct current. SEM images have revealed that finished surface having uniform structure and free of scratches and micro-cracks.

Key words: electrochemical honing (ECH), pulse and direct current, spur gear

1 Introduction

In the recent years, various aspects of electrochemical honing (ECH) have investigated at International level with the objective to enhance the process performance for high precision finishing of gears. Gears are critical components in modern precision machinery for power transmission mechanisms. Gear teeth must smooth and error free, for positive transmission of power and/or motion and to improve the load carrying capacity. Modern industrial gears found in automobiles, machining tool transmissions, airplanes, etc., are required to have low contacting noise with high torque transmission (Jianjun, 2007). The service performance and lifespan of gears can be improved by employing gear finishing processes. Conventional gear finishing processes such as gear grinding, gear shaving, gear honing, gear lapping, etc. are time consuming, costly and having material hardness limitation. These drawbacks of conventional gear finishing processes can be eliminated by employing advanced gear finishing processes namely electrochemical honing (ECH) of gears, electro-mechanical polishing (ECMP) of gears, ultrasonic-assisted lapping of gears, etc.

ECH is a hybrid micro-finishing process combining the faster material removal capability of electrochemical machining (ECM) and functional surface generating capability of mechanical honing. Hence, it increases the beneficial outcome of the machined surfaces like excellent work surface quality, completely stress-free surfaces, produce surfaces with distinct cross-hatch lay pattern required for oil retention and surfaces with compressive residual stresses required for the components subjected to cyclic loading (Jain, 2009). From last decade, ECH is evolved as a promising gear finishing technique for its micro removal characteristics. The application of ECH for gear teeth finishing was first reported by Capello and Bertoglio in 1970 and they described the ECH micro finishing the hardened cylindrical gear tooth face. It was found that the helix and involute profile obtained from the end result of the process were not yet acceptable. Chen in 1981, described the development of a productive, high accuracy, zero tool wear, gear finishing method. The total works were done in the field of checking the ability of correcting geometrical errors in ECH of gears, its principle and methods of improving. Naik in 2008, investigated the precision finishing of spur gears by ECH and concluded that a nano-finished uniform honed work surface having much better characteristics parameters coupled with a cross hatch lay pattern can be performed by ECH.

Now-a-day, to further enhance the capabilities of ECH process, pulse power supply is executing in ordinary ECH with intention to provide relation time in machining zone and reducing the inter-electrode
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gap (IEG) for better result (Singh, 2010). This paper highlights the comparison of experimental results of pulse assisted ECH and direct current ECH of spur gears to analysed the effect of direct current and pulse current on processing time and electrolyte based parameters of ECH.

2 Working Principle

The basic principle of ECH of spur gears described by Chen in which the anodic workpiece gear, rotating and reciprocating axially as indicated by the arrow head, meshes with the honing gear and specially shaped cathode gear simultaneously as shown in Fig.1. The specially designed cathode gear is fabricated by sandwiching a conducting gear between two non-conducting gears and undercutting the profile of the conducting gear as compared to that of non-conducting gears to provide IEG to avoid short circuit. The IEG is flooded with a suitable electrolyte for workpiece material to complete the electrical circuit. In ECH, majority of material removal occurs due to electrolytic dissolution governed by Faraday’s laws of electrolysis and role of honing is very limited. But, as the electrolyte is passivative, therefore when the power supply is switched on, there will be a formation of metal oxide micro-film on the teeth profiles of workpiece gears due to evolution of oxygen at anode. This film is very thin, compact, insulating and protecting the workpiece surface from further EC dissolution. As the honing gear rotates in mesh with the workpiece surface, it scrubs this film selectively on the high spots thus exposing fresh material layer for further EC dissolution. As a result of this ECH not only smoothens the surface, but also corrects the shape related geometric errors.

3 Experimentation

EN8 alloy steel spur gear having hardness of 260 BHN was used to study. The pitch diameter of the gear 76.2 mm, tooth thickness 10 mm, module 6.3 mm and 12 teethes were selected. The chemical composition of EN8 steel is listed in Table 1.

<table>
<thead>
<tr>
<th>Alloy Steel</th>
<th>C</th>
<th>Cu</th>
<th>Fe</th>
<th>S</th>
<th>Si</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN8</td>
<td>0.38</td>
<td>0.48</td>
<td>98.34</td>
<td>0.34</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Photograph of workpiece spur gears is shown in Fig. 2. The properties and surface characteristics were studied before experimentation by hardness tester, scanning electronic microscopy and energy dispersive x-ray analysis.

4 Result and Comparison

The experimental results of PECH sectioned into processing time, electrolyte composition, and electrolyte concentration, to study their effects on the surface finish of spur gear and compared with the ordinary ECH performance studied by Naik. Average surface roughness ($R_a$) values of the gear tooth profile (at middle of the tooth) are collected before and after
the process and percentage improvement is calculated from the formula given below (Dubey, 2006):

\[
\frac{P_{IR}}{P_{IR_{\text{in}}} = \frac{\text{Initial } R / R_{\text{in}} - \text{Final } R / R_{\text{m}}}{\text{Initial } R / R_{\text{m}}}} \times 100%
\]

4.1 Processing time

In PECH, processing time considerably higher due to pulse-on and pulse-off time combination. A comparison graph in Fig.3 shows that most appropriate processing time 24 min for pulse current have five times higher than most suitable time 5 min for direct current.

4.2 Electrolyte composition

The experiments were carried out to study the effect of three different compositions on PIR, with PECH and compared with ECH as shown in Fig.4. Results show that 3:1 ratio of NaCl and NaNO₃ gives much better PIR value with pulse current. The rate of electrolysis depends on the number of ions present in the solution as it determines the conductivity of the electrolyte. The PIR values increase with increasing percentage of NaCl in an electrolyte solution up to certain level and then start decreasing, but the material removal rate continuously increasing.

4.3 Electrolyte concentration

The electrolyte concentration of 3:1 ratio of NaCl and NaNO₃ varies 5 to 10 percent by volume. At the stage, when other parameters were fixed at optimum levels, pulse current gives higher PIR values with almost same variation trend as compared to direct current.

5 Discussion

Both types of power supply studied shows precision improvements in the surface quality. After fixing the finishing time and electrolyte based parameters at optimal level, the main experimental results through design methodology (BBD) shows finally an improvement of 22.73 percent in average surface roughness (PIR) and 13.48 percent in maximum surface roughness (PIR) value of EN8 spur gear using pulse current as compared with direct current. The SEM micrographs have revealed that finished surface having uniform structure, free of scratches and micro-cracks are shown in Fig. 6 (a) for...
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PECH and Fig.6 (b) for ECH. The surface roughness micrographs of the work surface taken before and after PECH by the optical profiler interfaced with Vision® 32 software to analyzed the effect of PECH as shown in Fig. 8.

Micro-hardness distribution of a gear surface were varied in the same range from 255 to 310 BHN, before and after processing of direct and pulse current ECH. It indicates that ECH process with any type of power supply has no effect on mechanical properties of the workpiece.

6 Conclusion

On the basis of the comparison study of the precision finishing of spur gear using direct current and pulse current ECH, the PECH ensures higher finishing of machined surface. Because of better electrolyte flow in the IEG and added opportunity to minimize the IEG, and control of electrolyte conductivity. But the improved amount of surface finish on the spur gear tooth surface was marginally small as a respect to the increased amount of processing time. Thus, higher processing time of PECH, declining the production rate and increasing the operating cost. In addition, due to absence of large amount of input current and heat generation in ECM zone, the use of pulse assisted ECH was not highly beneficial.

References


