Experimental Investigations and Performance Optimization of Electrochemical Honing for Finishing the Bevel Gears

A THESIS

Submitted in partial fulfillment of the requirements for the award of the degree

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by

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **Experimental Investigations and Performance Optimization of Electrochemical Honing for Finishing the Bevel Gears** in the partial fulfillment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY** and submitted in the **DISCIPLINE OF MECHANICAL ENGINEERING, Indian Institute of Technology Indore**, is an authentic record of my own work carried out during the time period from July 2010 to September 2013 under the supervision of **Dr. N. K. Jain**, Associate Professor, Discipline of Mechanical Engineering.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other institute.

2nd sept, 2013
(Shaikh Javed Habib)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

2nd Sept 2013
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ABSTRACT

Gear is the modified form of a wheel having teeth on its periphery meshing with a mating gear. It is the most commonly used mechanical element for efficient and smooth transmission of motion and/or power between two parallel shafts (e.g. spur and helical gears), intersecting shafts (e.g. bevel gears) or non-parallel non-intersecting shafts (e.g. hypoid gears and worm and worm wheel). More than two billion gears of different types and sizes are manufactured annually for various applications (Goch, 2003). It is an indispensable element in most of the machines and equipments e.g. automobiles, aerospace, marine, machine tools, process industry machineries, clocks, toys, mechatronic devices, MEMS/NEMS applications, etc. Operating performance and durability of gears depends on the form accuracy and surface finish of their teeth. Most of the gear manufacturing processes and subsequent heat treatment processes, particularly case hardening, cause distortions necessitating one or more than one gear finishing process in order to achieve the desired surface finish and form accuracy. The enhancement of surface quality and form accuracy can effectively reduce operating noise of the gears and increase their durability. Bevel gears are cut on the frusta of cones and this conical geometry makes their finishing very difficult. Gear lapping and gear grinding are the two conventional processes for finishing the bevel gears. Gear lapping is an old technique and generally not used due to long finishing time which may deteriorate the form accuracy. Gear grinding is the most commonly used process but, it suffers from some inherent limitations such as complex tooling, surface defects such as grinding burn, and high cost of tooling and operation (Karpuschewski *et al*, 2008). This necessitates exploring the possibility of developing an ideal bevel gear finishing process which will overcome the limitations of the conventional gear finishing processes.

Electro-chemical honing (ECH) is an innovative hybrid process of mechanical honing electro-chemical machining (ECM). It combines capabilities of mechanical honing such as reduction of form errors and generation of cross-hatched lay pattern for lubricating oil retention with capabilities of ECM such as higher material removal rate (MRR), generation of stress free surface due to non-contact machining, and process performance being independent of the work material properties, high surface quality and form accuracy, absence of tool wear, no thermal or mechanical damage to the finished surface (Rajurkar *et al*, 1999). At the same time, ECH also overcomes the individual limitations of mechanical honing (such as rapid wear and frequent breakage of honing tool, micro-cracks on the finished surface, residual stresses, marks of the honing tools etc.) and ECM (formation of metal oxide passivating layer on the anode surface which prohibits further ECM action, selective dissolution etc.). All this is realized because in ECH, majority of the material is removed by the ECM whereas; the role honing is just to scrap the passivating metal oxide layer formed on the anodic workpiece surface due to electrolytic dissolution.