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Remanufacturing with ECH - A Concept

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Abstract

A concept of remanufacturing is develops for expensive saving for new components. The cost of spare parts for aerospace and automobile engine are very high, in many cases repair of parts is cost effective. A lot of components are reused, which results in decreasing the amount of materials, energy and waste. This paper aims to find the remanufacturing possibilities with electrochemical honing (ECH) process, for difficult to machined alloy of engine parts. ECH process have their own advantages to remove any hard material with controlled surface generation with excellent surface finish. Furthermore, it provides highest productivity and increasing the service life of critical components. This paper presents a unexplored concept with some direction for future research with an objective to mature the remanufacturing engineering.

Keyword : Remanufacturing; ECH; surface quality; engine parts

1. Introduction

Currently, the aerospace and automobile industries are looking for opportunities that may reduces costs while still complying with safety regulations. Safety regulations for aero-engines industries are very tight. The efforts needed to comply with these regulation have a significant impact on the cost structure of airline companies [1]. Nowadays, for remanufacturing, there is great variety of techniques are used to deposited new material on the worn-out or wear off or small damage components and as a hard coating on the cheaper material, such as laser cladding, high oxy fuel cladding, dabber welding, tungsten inert gas cladding, chemical vapour deposition and physical vapour deposition. But, the final surface characteristic of deposited layer from all the above techniques, unable to

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develops the precision surface finish as required for matching parts.

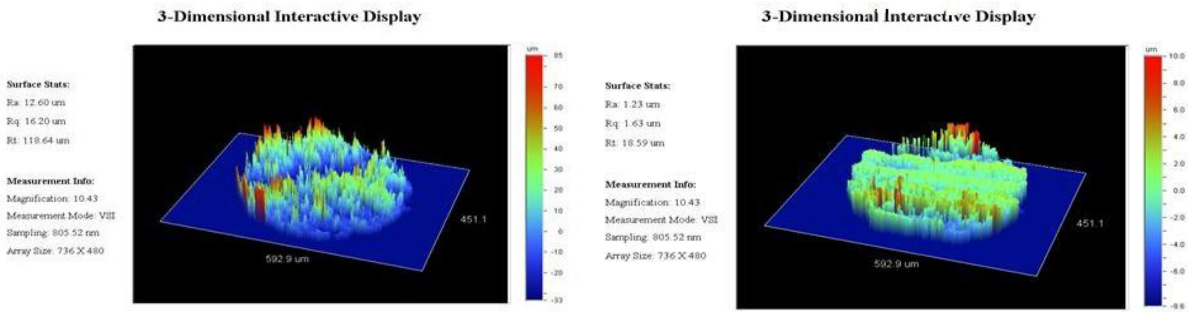
Therefore, the further surface treatment is required to achieve sufficient surface quality by removing small amount of material. Generally, grinding or polishing processes are applied under controlled conditions. Moderately light cuts are recommended, and periodic dressing of grinding wheel are required to keep in proper condition. Excessive wheel loading tends to poor grinding action and causes poor surface finish, high residual tensile stresses, and low grinding ratio [2]. To achieve high finishing, mostly different grades of grinding wheels in sequence or abrasive polishing is applied on the coated part. In this way, remanufacturing of engine parts reused in their original form.

All these further surface treatments to achieve high surface finish of remanufactured part, increases the processing cost and machining time. Nevertheless, there is not extensive literature which clearly explains the contribution of surface treatments and surface properties. Moreover, remanufacture able engine parts e.g. inlet valve and exhaust valve, cylinder linear, shafts, bearings and automatic transmission are made of hard and difficult to machined alloys [3]. The problems related to surface quality are especially revealed in the finishing of poor machinability of hard alloys such as titanium, nickel, chromium, cobalt, satellite, nitride, vanadium etc. realized by grinding process. In this respect conventional processes, grinding and polishing have some operational limitation to deal with these hard alloys. For eliminate such crucial issues, non-conventional processes such as ECH will be one alternate to fill the requirements to commercialize remanufacturing engineering in the aerospace industries, automobile industries, biomedical devices, marine and chemical industries.

ECH has capabilities and potential to be developed as an alternative to conventional finishing processes and can play an important role as high-precision finishing method. It has potential to overcome most of the limitations of conventional finishing methods and at the same time offers high productivity [4]. ECH is well known for offering excellent work surface quality on a material of any hardness as long as it is electrically conductive. ECH process has the flexi-features with regard to control of machined surface characteristics. It can produce surfaces with distinct cross-hatch lay pattern required for oil retention, surfaces with compressive residual stresses required for the components subjected to cyclic loading, and completely stress-free surfaces [5]. ECH can also correct the geometrical shape inaccuracies associated with the cylindrical workpiece (such as out-of-roundness or circularity, axis-distortion, tapered hole, bellmouth holes, barrel-shaped holes). From the past work on ECH of cylinder linear and gears has concluded the process is capable of serving as a substitute of conventional processes. This paper attempts to define some direction for future research with an objective to revive the interest of the global research community to mature the ECH process.

2. Historical background

Development of electrochemical-reaction-based processes stemmed from the principle of anodic material removal first discovered by Michael Faraday (1791–1867). In 1929 the Russian W. Gusseff, and later C. F. Burgess in 1941, suggested the application of anodic material removal as a machining technique [6]. It was not until 1959, however, that the phenomenon of controlled anodic material removal was put forward in the form of commercial apparatus for regular industrial application by Anocut Engineering Company of Chicago [7]. Nowadays, ECM is invariably used in machining of difficult-to-machine but electrically conducting materials, which are extensively used in automobiles, aerospace, space, defence, cutting tools, dies and moulds and biomedical applications. Moreover, ECM combining with conventional and unconventional machining process to develop a hybrid machining process. Some typical examples of combining ECM with conventional machining process are electrochemical grinding (ECG), electrochemical honing (ECH), electrochemical abrading (ECA), and electrochemical sharpening (ECS). The concept of taking help of electrolyte dissolution to improve the performance and productivity of mechanical honing evolved during 1963-1965 [8-11]. Randlett and Ellis compared the mechanical honing and ECH processes and suggested the successfully tested electrolyte for different materials and machining time variation between two processes for different materials [12-13]. In the ISEM-7 research article, Budzynski presented the results of optimization of ECH of cylindrical holes that were considerably deformed by heat treatment using ammonium nitrate as electrolyte. This work was a first attempt at the optimization of ECH process. Several input variables; current density, machining rate, honing pressure of abrasive sticks etc. and output parameters; shape deviations, average and maximum surface roughness etc. were studied. This study revealed that current density, honing unit pressure, and machining time are significant parameters in material removal, but these parameters do not influence the shape deviations and surface finish. Budzynski presented his pioneering work on ECH of cylindrical holes in subsequent papers [14-16]. The application of ECH for gear teeth finishing was first reported by Chen in 1981. Since material removal in ECH is governed by Faraday's law of electrolysis, the amount of the material removed and consequently the accuracy of the gear profile can be controlled either by controlling the amount of the current passed or by varying the duration of time [17]. Jianjun [18] reported the use of pulse power supply in ECH to improve the result than ECH under continuous current by providing relaxation period to the machining process during pulse-off time. Dubey reported that current, electrolyte concentration, electrolyte inlet temperature, abrasive stick pressure, abrasive stick grit size, and two interactions of current intensity with electrolyte concentration and with speed ratio have significant influence on percentage improvement in maximum surface roughness (R_t) values. It was also reported that individual effects of electrolytic parameters become less influential while the mechanical honing related parameters and interactions assume greater importance for macro-geometrical error correction in ECH of internal cylinders because three honing related process parameters and two interactions of electrolyte concentration with current intensity and with speed ratio have a significant influence on percentage improvement in out-of-roundness. The same authors reported that current, electrolyte concentration, abrasive stick pressure, and abrasive stick grit size are the factors influencing the percentage improvement in average surface roughness (R_a) value significantly. With distinct co-ordination of electrolytic dissolution and mechanical scrubbing, ECH can be developed as a precision micro-finishing process for critical components of tribological importance [19, 20].



(a) (b)

Fig. 1. Three dimensional surface plot of gear tooth surface (a) before PECH (b) after PECH [21].

Singh [21, 22] recently experimentally investigated the input process parameter for precision finishing of external gears with pulse-assisted ECH (PECH) process to improve the results than ECH under continuous current by providing relaxation period to the machining process during pulse-off time. It was reported that 85% in maximum percentage improvement of roughness value and 79 % in average surface roughness value after PECH process. Three dimensional surface plot of the work surface before and after PECH process as shown in Fig. 1 to visualize the process performance.

3. Process principle of ECH

ECH is a hybrid machining process (HMP) in which workpiece is made as an anode and the tool is made as a cathode by applying a small DC electric potential across them. The inter-electrode gap (IEG) is maintained between workpiece and the tool to avoid short circuiting, and filled with the electrolyte. During this, non-conductive spring controlled honing tool is applied with equal pressure on the workpiece. The honing tool is given simultaneous rotary and reciprocatory motions, as in conventional honing, to finish the workpicece surface [7]. The mechanism of material removal in ECH is based on the interaction between electrolytic actions with mechanical abrasion. It is reported in the literature that more than 90 per cent of the material removal occurs through electrolytic action, and remaining material and oxide layer removal occurs through mechanical honing action [19]. The schematic diagram of working principle of ECH of coated part will be designed as shown in Fig. 2.

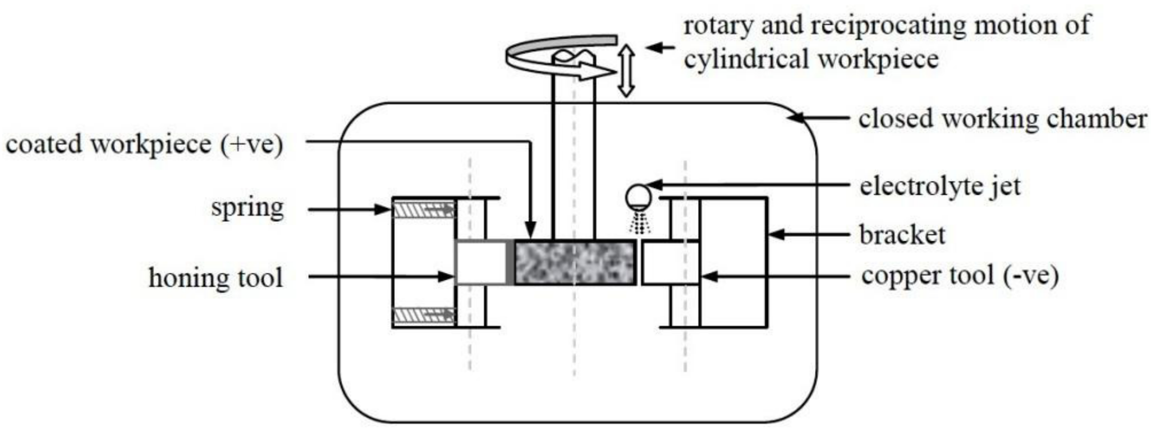


Fig. 2. Schematic diagram of working principle of ECH of coated part.

4. Applications

As with conventional finishing processes, ECH can be employed not only to produce high finish and surface integrity, but also to correct shape deviations of coated cylindrical workpieces, such as taper bell mouth hole, barrel-shaped hole, axial distortion, and boring tool marks. Material of any hardness can be machined by ECH as long as it is electrically conductive. Materials processed by ECH include cast tool steels, carbide, titanium alloys, 17-7PH stainless steel, Inconel, and gun steels [19,20]. ECH is an ideal choice for super finishing, improving the surface integrity, and increasing the service life of the critical components such as internal cylinders, transmission gears, carbide bushings and sleeves, rollers, petrochemical reactors, moulds and dies, gun barrels, pressure vessels, coated parts etc. which are made of very hard and/or tough, wear-resistant materials, most of which are susceptible to heat distortions. Consequently, ECH finds prevalent use in the aerospace, automobile, avionics, marine, power generation, and fluid power industries [21]. It is evident from the process principle and literature survey of ECH of internal cylinder and gears that ECH has many advantages with regard to quality and productivity of finishing over the most commonly used conventional finishing methods like grinding, polishing, honing, lapping and shaving [22,23].

5. Conclusion and future scope

Remanufacturing of engine parts is in the development phase and therefore a sustained global research is required to meet the surface quality as good as for new components. Present aspect, which unexplored is the use of ECH process for remanufactured components which can improve dimensional accuracy and surface characteristics of deposited layer in a single action. From the literature survey presented in this paper, it is very clear that ECH have great capability to remove small amount of any hard material to achieve high surface quality as long as it is electrically conductive. ECH is a HMP of controlled electrolytic dissolution and selective conventional honing. The efficiency of correcting micro- and macro-geometrical errors depends highly on the proper co-ordination of these two actions. ECH has been acknowledged as an ideal choice for improving the surface integrity and consequently, the service life of critical components.

References

[1] O. Yilmaz, N. Gindy, J.Gao, A repair and overhaul methodology for aeroengine components, J. Robotics and Computer-Integrated Manufacturing 26 (2010) 190–201.
[2] Z. Bogdanowicz, K. Grzelak, Laser rebuilding of engine exhaust valves, J. of KONES Power train and Transport, (2011) Vol. 18, No. 1.
[3] L. Sexton, Laser cladding of aerospace materials, J. of Materials Processing Technology 122 (2012) 63-68.
[4] H. S. Shan, Advanced manufacturing processes, Tata McGraw Hill, New Delhi, India, 2006.
[5] G. F. Benedict, Nontraditional manufacturing processes, Marcel Dekker, New York, 1987.
[6] W .Gusseff, British Patent 335003.
[7] J. F. Wilson, Practice and theory of electrochemical machining, John-Wiley & Sons, New York, 1971.
[8] Eshelman, R. H. Electrochemical honing reports ready for production jobs, Iron Age (1963) 124.
[9] Ann. Honing gets electrolytic help, Iron Age (1965) 106.
[10]Ann. Tooling for electrochemical honing, Tool Manufacturing Engineers (1965) 68.
[11]N.Given, Electrochemical honing: four times faster, Machinery (1965) 72 119.
[12]E. Randlett, A. Jr, M. P. Ellis, Electrochemical honing, American Society of Tools and Manufacturing Engineers, Technical Paper MR67-648 (1967) 1-13.
[13]E.Randlett, A. Jr, M. P. Ellis, Electrochemical honing – ECH, American Society of Tools and Manufacturing Engineers, Technical Paper MR68-815 (1968) 1-11.
[14]A. F.Budzynski, Theoretical principles and technical factors of electrochemical honing, International Symposium on Electro Machining 6 (1980) Krakow.
[15]A. F.Budzynski, , Research on optimization of the process of electrochemical honing (ECH), International Symposium on Electro Machining 7 (1983) 355-371.
[16]A. F. Budzynski, Electrochemical honing - studies on shape precision of holes being processed, International Symposium on Electro Machining 8 (1987) 155-161.
[17]C. P.Chen, J. Liu, G. C.Wei, C. B.Wan, J. Wan, Electrochemical honing of gears: a new method of gear finishing, Annals of CIRP 30(1) (1981) 103-106.
[18]Y. Jianjun, D. Yujie, Z. Shaohua, J. Baiyang, Z. Jingjing, A novel technique of polishing gear working surface using PECMP, J. of Precision Engineering and Manufacturing 10 (4) (2009) 57-62.
[19]A. K. Dubey, Experimental investigations on electrochemical honing. Proc. IMechE, Part B: J. Engineering Manufacture 222 (B3) (2008) 413–426.
[20]A. K. Dubey, H. S. Shan, N. K. Jain, Analysis of surface roughness and out-of-roundness in electrochemical honing of internal cylinders. J. of Advanced Manufacturing Technology 38(5-6) (2008) 491–500.
[21] H. Singh, P.K. Jain, Experimental investigation of precision finishing of spur gears by pulse electrochemical honing (PECH), M. Tech Dissertation, Mechanical and Industrial Engineering Department, I.I.T. Roorkee, 2010.
[22]J.P. Misra, P.K. Jain, D.K. Dwivedi, Precision finishing of gears by electrochemical honing process: a state of art review, J. of advanced manufacturing system (2011) Vol.10, Issue 02, 309.
[23]J.P. Miisra, H. Singh, P.K. Jain, N.K. Jain, Effects of electrolyte composition and temperature on precision finishing of spur gears by pulse electrochemical honing , J. of Precision Technology (2012) Vol.3, No.1, 37-50.