CHAPTER 52

TECHNOLOGY
MANUFACTURING PROCESSES
&
AUTOMATION ENGINEERING

Doctoral Thesis

01. CHINU KUMARI

Micro/Nano Finishing of Freeform Surface with Fluid Based Finishing (MRFF) Process.

Supervisor: Prof. Sanjay Kumar Chak

Th 26198

Abstract

Nano-finishing of the freeform surfaces is the most prominent requirement of present day's industries to enhance their functionality, dimensional control, and endurance strength. Due to extreme hardness and softness of some newly developed components, up to nano-level finishing of these surfaces is still not an easy task. The common or conventional finishing processes for soft and non-magnetic components made up of materials like copper and aluminium are chemo-mechanical polishing, single point diamond turning, CNC machining, and vapour surface polishing etc. These processes lead to subsurface damage as well as there is no other option of choosing the workpiece having geometry except cylindrical and plane. Obtaining a nano-level surface finishing with these processes is difficult and uneconomical. Additionally, final finishing value obtained after completion of above mentioned processes cannot be predicted accurately because the forces acting during these processes cannot be controlled. To get rid of above-mentioned challenges, various advanced finishing processes like, magnetic abrasive machining, ball end magnetorheological finishing, chemo-mechanical magnetorheological finishing, ultrasonic assisted magnetic abrasive finishing, and rotational magnetorheological abrasive flow finishing have been developed. These are the magnetic field assisted processes where magnetic flux density controls the magnetic force that is mainly responsible for cutting action which results in nano-level finishing. The total cutting force acting on the abrasives for removal of micro-chips in advanced finishing processes is extremely less as compared to the forces acting in conventional processes. In these magnetic assisted advanced finishing process, the cutting action relies upon a special fluid called magneto-rheological fluid that is a blend of abrasives with carbonyl iron particles in the base medium of water or oil. In the existence of magnetic field (MF), magneto-rheological fluid (MR) attains dipole moment and forms a chain of abrasives and EIP (electrolytic iron powder) in the direction of MF. To deform this chain, energy is required which is mainly accountable for onset of large yield shear stress that is finally responsible for finishing operation. In this way, this fluid acts as a flexible brush of abrasives which imply finishing action on workpiece surface. Significant attraction of magnetic lines of forces towards ferromagnetic workpiece makes the magnetic assisted processes suitable for magnetic material. The researchers tried to improve the performance of magnetic assisted processes for nonmagnetic material but desired level of finish was not obtained. To eliminate these drawbacks, a new process called Magnetorheological abrasive honing (MRAH) is developed to finish the non-magnetic materials with enhancement in rate of material removal. Magnetorheological honing process is also one of the magnetic field assisted abrasive based finishing process where combined rotational and reciprocating motion is involved during the finishing process similar to conventional honing process. Since MRAH is a newly developed process, the past literature was simply focused on finishing the flat and cylindrical shaped workpieces. The research in the field of nanofinishing of the soft freeform surfaces is not yet reported. In the present study, modifications were done in existing setup of magnetorheological honing processes for finishing of spherical diamagnetic brass workpiece. The finishing of brass specimen with MRAH process considering the effect of MR fluid was not reported in literature. The present approach desires to achieve good surface finishing of freeform spherical copper workpiece with minimum finishing time. The maximum performance of MRAH process can be achieved only when there is strict control over these parameters. To achieve this control, perfect chemistry must be made between machining parameters and MR fluid. Hence, our study is primarily focused on parametric optimization of freeform brass workpiece. Finishing time, rotational speed, magnetizing current, conc. of abrasives are the parameters chosen for study with % reduction in roughness value and material removal as response. These response parameters depend on the operating conditions as well as magnetorheological (MR) fluid, workpiece geometry and type of electromagnet used. Central composite rotatable design (CCRD) was used to plan the experiments. The effects of chosen parameters on % reduction in roughness value were determined using ANOVA. Response optimizer available with Minitab 17 was used to maximize the % reduction in roughness value (%ΔRa). In the present study, aluminium oxide is used as abrasive for finishing the freeform brass surface. During MRAH process, reciprocating motion with rotational motion was assigned to the finishing fluid and the workpiece, respectively. The combination of rotary and reciprocating motion results in helical motion of the abrasives on the workpiece surface. As the rotational speed increases from 132 rpm to 468 rpm the contact length of abrasives is increased and as a result there is an increase in number of roughness peaks coming in contact with the abrasives. %ΔRa was continuously improved with rise in magnetizing current from 2 A to 4.68 A due to formation of stronger chain of CIPs/EIPs. It was also noticed that the %ΔRa was fast during the starting phase of finishing because initially, the sharp edges are appeared on the surface with small shearing area. After finishing time of 7.25 min. the finishing rate was decreased. Apart from these, as the vol.% of abrasives in MR fluid was increased from 5 % to7%, %ΔRa was also increased. At higher abrasive particles concentration, larger numbers of abrasive particles are trapped in between CIP chains which creates large distance between two CIPs and reduce the magnetic force. Rotational speed was found as the most dominating parameter as compared to magnetizing current, finishing time and conc. of abrasives.

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02. V. VIJAYA VANI

Some Investigation in ECDM Process While Machining Electrically Non-Conductive Materials.

Supervisor: Prof. Sanjay Kumar Chak

Th 26199

Abstract

In the modern era micromachining of glass has gained much importance in recent years in the MEMS field. However, their brittleness and hardness pose a problem for machining micro features with good surface quality. Hybridization of machining technique eliminates the limitations of the individual processes. In recent years, Electro Chemical Discharge Machining (ECDM) is one of the unconventional hybrid machining technique, high temperature melting and thermally assisted chemical etching enables the ECDM process capable for micromachining of high strength and high-temperature resistant materials. ECDM has combined characteristics of ECM and EDM, which is effectively been used for machining electrically non-conductive, hard, and brittle materials like glass, quartz, composites, and ceramics. ECDM process has the potential to machine various features such as micro holes, micro slots, micro grooves, and 3D micro surfaces on glass. However, the industrial application of this process is limited due to difficulty in machining micro holes with higher machined depth with high aspect ratio also craters with burr free surfaces. In ECDM process, the machining rate mainly depends on the availability of the electrolyte at the electrode tip. Machining accuracy like taper, entry and exit diameter of the hole at high depths is rigorously affected due to lack of electrolyte at the machining zone resulting in more taperness. To improve the machining performance of the ECDM process, loose abrasive particles were mixed in an electrolyte while machining blind holes on soda-lime glass. Low surface quality (i.e. more over cut and tapered micro holes) are few limitations of the process. To enhance the machining capabilities a novel approach of PMECDM has been conducted. Used Al2O3 and SiC with an average particle size of 14μm and 30 g/l to study the effect of powder mixed electrolyte. Also different tool motions were given to study their effect on the performance of the process. The rotating tool helps in supplying greater quantity of fresh electrolyte in the machining zone, as well as avoid the discharge being focused on the same point. In the current study, a comparative analysis was performed with stationary, rotational electrode and also with and without addition of abrasives into the electrolyte. Among all, abrasive mixed electrolyte with tool rotational motion has shown a tremendous improvement on the surface quality of the machined craters. This study is mainly focused on investigating the effect of process parameters (voltage and electrolyte concentration) on the responses (material removed, machined depth overcut, aspect ratio and HAZ). Thermal erosion is the major material removal mechanism in the ECDM process, resulting craters with micro cracks and severe Heat Affected Zone (HAZ). This paper aims to address the impact of abrasive mixed electrolytes and different tool motions on the material removed, machining depth, outer diameter and aspect ratio and length of HAZ. In HAZ. Abrasive mixed electrolyte with tool rotational motion has shown a tremendous improvement on the surface quality of the machined craters. Also, study led to analyze the effect of thermal properties of abrasives on machining performance of ECDM process. The maximum machined depth achieved with rotary electrode along with Al2O3 abrasive mixed electrolyte was 2.31mm in 5mins. Imparting the rotary motion to the tool electrode, the side of the revolving tool was covered with a gas layer, which preventing the chemical dissolution at the electrode side surface. As a result machining process occurs just at the bottom end of the tool, resulting in more accurate circular shapes. The results shows that imparting rotary motion along with SiC abrasives, results that tremendous reduction in outer diameter from 1237.37μm to 712.8μm. The maximum HAZ was achieved with stationary electrode and conventional electrolyte is 220.80μm. HAZ is reported with rotary electrode along with SiC suspended electrolyte is 45.4μm. Response surface methodology has been used to plan the experiments and ANOVA has been used to analyze the impact of each process parameters on the responses. The significance of process parameters on the responses has been evaluated using ANOVA. A second-order regression equation has developed for predicting the relation between input process parameters and quality characteristics. It is observed that the addition of Al2O3 abrasives has improved the material removed and machined depth. On the other hand, the addition of SiC abrasives into the electrolyte has reduced the diametric overcut due to their specific characteristic. In this article RSM based CCRD experimental technique was used. Gray Relational Analysis (GRA) for multi-objective optimization of input variables and machining environments during micromachining of glass by ECDM process. The complex multiple answer optimization problem can be reduced to an optimization of a single response grey relational grade using grey relational analysis. In this study, at 31V and 25% electrolyte concentration maximum grey relational grade is achieved for this parametric conditions. The main motive behind the process variables optimization is to achieve maximum material removal, maximum machined depth, minimum overcut and minimum heat affected zone. Keywords: ECDM, Abrasives, GRA, Electrolyte concentration, Material Removal, CCRD, Heat Effected Zone, Aspect Ratio.

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