Improving the surface quality in wire electrical discharge machined specimens by removing the recast layer using magnetic abrasive finishing method

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Abstract This study explores the feasibility of removing the recast layer formed on aluminum alloy cylindrical specimens machined by wire electrical discharge machining (WEDM) by using magnetic abrasive finishing (MAF). The WEDM is a thermal machining process capable of accurately machining parts with high hardness or complex shapes. The sparks produced during the WEDM process melt the metal’s surface. The molten material undergoes ultra-rapid quenching and forms a layer on the surface defined as recast layer. The recast layer may be full of craters and microcracks which reduce service life of materials tremendously, especially under fatigue loads in corrosive environments. This investigation demonstrates that MAF process, can improve the quality of WEDM machined surfaces effectively by removing the recast layer. The present work studies the effect of some parameters, i.e., linear speed, working gap, abrasive particle size, and finishing time on surface roughness and recast layer thickness using full factorial analysis. Three-level full factorial technique is used as design of experiments for studying the selected factors. In order to indicate the significant factors, the analysis of variance has been used. In addition, an equation based on regression analysis is presented to indicate the relationship between surface roughness and recast layer thickness of cylindrical specimens and finishing parameters. Experimental results show the influence of MAF process on recast layer removal and surface roughness improvement.

Keywords MAF · WEDM · Recast layer · DOE · ANOVA

1 Introduction

Wire electrical discharge machining is a widely accepted nontraditional material removal process used to manufacture components with intricate shapes and profiles. During the wire electrical discharge machining (WEDM) process, the material is eroded ahead of the wire and there is no direct contact between the workpiece and the wire, eliminating the mechanical stresses during machining [1]. WEDM process makes use of electrical energy generating a channel of plasma between the cathode and anode [2], and turns it into thermal energy [3] at a temperature in the range of 8,000–12,000 °C [4] or as high as 20,000 °C [5] initializing a substantial amount of heating and melting of material on the surface of each pole. A portion of this molten material is then ejected and flushed away. The remaining material resolidifies rapidly on the surface of the work piece. The accumulated new structure on the surface is called the “recast layer” due to its nonrevelation by etching [6, 7]. The recast layer formed by WEDM process increases surface roughness, makes the surface hard and brittle, and decreases the fatigue strength due to the presence of microcracks and microvoids [8].

Removing the damaged surface in a postmachining process greatly increases fabricating time and cost. Therefore, this study presents magnetic abrasive finishing (MAF) process to remove the recast structure for removing microcrack and discharge craters. In MAF, the material is removed from the surface of workpiece, by the circulation of the abrasive particles in the magnetic field [9–11]. These particles form a
flexible magnetic abrasive brush which does not require dressing. The MAF apparatus neither needs a very precise worktable nor a very stiff structure since its cutting tool is a unique flexible magnetic brush. Nevertheless, a mirror like refined surface of high quality can be obtained easily. Finished surface neither showed a deteriorated layer nor micro-cracks. MAF yielded better surfaces, especially of complex shapes [12–14].

Until now, several researches have been done in order to clarify the effective parameters in MAF process and its results such as surface roughness and amount of material removal rate. Shinmura et al. have studied basic principle of the MAF process and concluded that the stock removal and surface finish value (Ra) increase as the magnetic abrasive particle diameter “D” increases [15].

By using the ball-shaped magnetic abrasive pole with special grooves, Lin indicated an adjunction in finishing efficiency during the magnetic abrasive finishing of free-form surfaces. The researcher found that working gap had the largest impact on the finishing quality [16]. It was confirmed that automation of three-dimensional die and mold surface polishing is possible using magnetic polishing tool by Kim et al. in 2007. They concluded that the polishing pressure can be estimated by equivalent magnetic circuit and, thus, can be changed to the desirable value by changing the working gap [17]. On the other hand, Wang and his colleagues [18] revealed that the recast layer formed on Inconel 718 alloy can be effectively softened by phosphoric acid coupled with hydrochloric acid and the softened recast layer can be easily removed by a steel brush. Schumacher suspended special powders in the dielectric fluid as a mean of improving surface properties. The powder particles facilitate ignition process by creating a higher discharge probability and lowering breakdown strength of the insulating dielectric fluid [19].

Most of the researchers have been using the MAF process to improve the surface roughness and material removal rate. But hardly any information is available about removing the recast layer in WEDM machined surfaces. This study indicates that the recast layer can be removed by MAF process using steel grits as an abrasive and permanent magnets as a magnetic flux supply. Figure 1a shows the workpiece with its recast layer before finishing and Fig. 1b shows it after finishing for a period of time. In addition, other approaches did not adequately pay attention to surveying the aluminum alloys workpieces while they have growing range application in modern industries. Furthermore, in comparison with the other conventional methods and with regard to the built-up edge produced during polishing of ductile material, MAF is suitable for inner surface polishing of aluminum alloy tubes. The present work uses full factorial experimental design to statistically investigate the effect of working gap, rotational speed, finishing time, and abrasive particle size on