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Abrasive jet polishing on SKD61 mold steel using SiC coated with Wax

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ABSTRACT

This study investigates the abrasive jet polishing (AJP) of electro-discharge-machined and ground SKD61 mold steel specimens using #2000, #3000 or #8000SiC particles and compound additives comprising either pure water, pure water and water-solvent machining oil, or pure water and water wax. The results show that when the polishing process is performed using #2000SiC particles with a pure water and water wax additive, the surface roughness of the electro-discharge-machined SKD61 surface is reduced from Ra: 1.0 μm to 0.08 μm within 90 min. Polishing the ground SKD61 surface using #3000SiC particles with pure water and water wax, the surface roughness is found to reduce from an initial value of Ra = 0.36 μm to a final value of Ra = 0.054 μm within 60 min. To improve the polishing performance, a gas atomization technique is employed to fabricate wax-coated #3000SiC particles. The results show that when polishing is performed using these wax-coated particles and a compound additive of pure water and water wax, the roughness of the ground surface is from Ra: 0.36 μm to 0.049 μm within 45 min. Overall, the results show that the use of wax-coated abrasive particles reduces the polishing time and achieves an improved surface finish.

1. Introduction

High-precision molds are invariably fabricated using electrical discharge machining (EDM) and/or grinding techniques. However, the EDM's surfaces are characterized by a brittle recast layer, while the ground surface usually exhibits burr defects. The recast layer contains many small craters and microcracks, which not only damage the molded component during the mold-off operation, but also reduce the life expectancy of the mold itself (Takino et al., 2005; Curodeau et al., 2004). Researchers have proposed a variety of techniques for stripping the recast layer, including chemical polishing (CP), electrical polishing (EP), abrasive polishing, magnetic polishing, and so forth (Andrade et al., 2005; Lee, 2000; Yin and Shinmura, 2004; Yamaguchi and Shinmura, 2004). However, while these methods improve the surface finish considerably, it is invariably necessary to carry out a cleaning operation following the dressing process, which inevitably extends the machining time and increases the machining cost. Furthermore, in the case of abrasive polishing, recycling the abrasive particles and polishing liquid following the machining operation is a time-consuming and expensive process.

Compared to traditional abrasive polishing techniques, the wet abrasive jet polishing (AJP) technique (Balasubrama et al., 2002) has a lower abrasive consumption and enables the abrasive particles and polishing fluid to be more easily recycled. Previous researchers have investigated a variety of topics in the AJP field, including suitable sacrificial layer materials, high-resolution AJP techniques, the use of AJP to fabricate matrix orifices in micro-components, and so on (Wensink et

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al., 2000a,b; Park et al., 2004). However, a review of the literature reveals that very few researchers have attempted to explore the correlation between the AJP processing conditions and the quality of the polished surface. In a recent study, the current authors conducted a series of experimental investigations to establish the optimal processing conditions for the abrasive jet polishing of SKD61 mold steel surfaces using SiC or Al_2O_3 particles with a composite additive of pure water and water-solvent machining oil (Tsai et al., 2007). The results indicated that a 1:1 ratio of pure water and machining oil yielded an effective improvement in the surface roughness of the specimen. However, it was found that the polished surface contained embedded fragments of the abrasive particles, which were not easily removed using a post-processing operation. Accordingly, the current study explores the feasibility of using wax as an additive in the AJP process to obtain a mirror-like surface finish with minimal particle contamination. In the study, the AJP process is used to polish electro-discharge-machined or ground SKD61 mold steel specimens using SiC particles with grit sizes ranging from #2000 to #8000 and three different compound additives, namely pure water, pure water and water-solvent machining oil, and pure water and water wax. The effects of the various AJP processing conditions on the surface quality of the polished surface are systematically examined and a Taguchi analysis is performed to determine the optimal processing parameters. A gas atomization technique is then used to fabricate wax-coated #30000SiC abrasive particles. A series of experiments are performed to compare the polishing results obtained using these wax-coated particles with those obtained using uncoated particles of an equivalent size.

2. Experimental details

2.1. AJP system

Fig. 1 presents a schematic illustration of the AJP system used in the present study. As shown, the major hardware items include an X-Y table actuated by a stepping motor operating under the control of a PC, a rotating platform driven by a 3-axis motion controller (NextMove ES; USA), a nozzle to supply the air stream and the abrasive particles/additives, a collection reservoir to enable the recycling of the fluid and the particles, and an abrasive mixing system.

Table 1 – Fixed factors in Taguchi design experiment

Fixed factors	Levels
Aperture of nozzle (material: WC)	4 mm
ANSI mesh of abrasive particles	#2000SiC
Additives	Water
Blasting time	3 min
Workpiece	SKD61
Blasting path	Two axis path
Mix the velocity	200 rpm
Table moving gap	20 mm

2.2. Experiment material and equipment

The polishing tests were performed using non-heat-treated SKD61 mold steel specimens (SKD61 (JIS) = H11 (AISI)) with a hardness of HRC 20–23. The specimens were machined using either an EDM system or a surface grinder and were then cut into experimental test pieces with dimensions of 10 mm × 10 mm × 5 mm using a wire-EDM technique. The polishing trials were performed using SiC particles with grit sizes of #2000, #3000 or #8000 (see Fig. 2) mixed with an additive of pure water, pure water and water-solvent machining oil, or pure water and water wax, respectively.

2.3. Experimental method

2.3.1. Taguchi design

The optimal AJP processing conditions were established using the robust Taguchi design method. The fixed AJP parameters and the Taguchi control factors are summarized in Tables 1 and 2, respectively. As shown in Table 2, the six control factors were each assigned three different level settings. Accordingly, the experimental trials were configured in an L_{18} orthogonal array. The quality of each design solution was evaluated by measuring the surface roughness (in μm) of the polished specimens. To account for variations in the initial surface roughness of the different specimens, the surface roughness improvement was normalized in accordance with

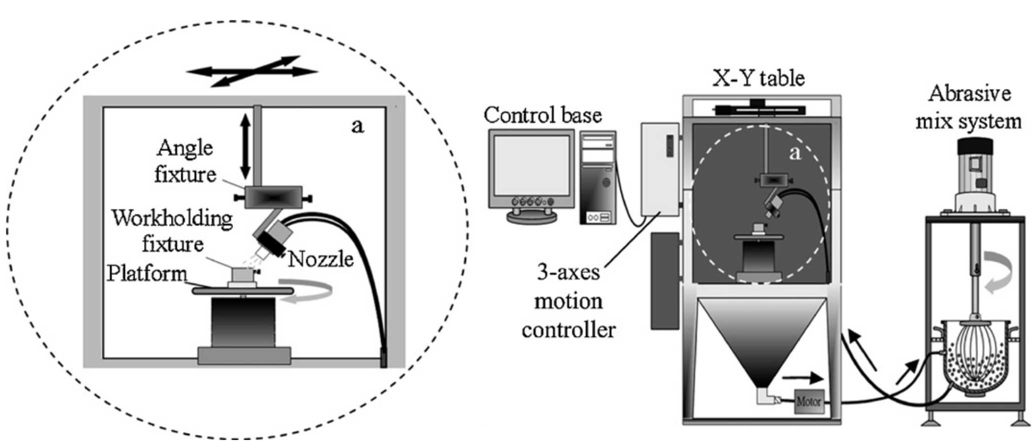

Fig. 1 – Schematic illustration of AJP system.