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Dry machining of metal using an engraving cutter coated with a droplet-free ta-C film prepared via a T-shape filtered arc deposition

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ABSTRACT

Tetrahedral amorphous carbon (ta-C) films were prepared on cutters which are used for engraving. Engraving tests were performed on metal plates using non-coated and ta-C-coated cutters, under dry machining conditions, without oil. Generally, the metal plate is engraved using a cemented carbide (WC-Co) cutter, which uses oil for the cutting process, to fabricate a nameplate. The oil causes a high environmental load and complicates the machining process. Therefore, from an industrial viewpoint, there is a need for a dry machining process. The ta-C film is a hydrogen-free diamond-like carbon film with a high mechanical hardness. In this study, droplet-free ta-C films were prepared on WC-Co cutters using a T-shape filtered arc deposition method. The work materials used in the engraving tests were aluminum, copper, and brass. The results of the engraving tests demonstrated suppression of metal adhesion to the cutting edge, prevention of chipping of the cutting edge, and a decrease in cutting resistance during engraving when a ta-C film had been coated onto the cutting edge. In addition, burr and residue on engraved grooves were also suppressed by using a ta-C-coated cutter. The ta-C film coating offered a remarkable improvement in the engraving performance of a WC-Co cutter in the dry machining process.

1. Introduction

In metal machining such as in nameplate fabrication, a cemented carbide (WC-Co) cutter is used with oil for engraving. In the fabrication of the nameplate, the remaining oil on the nameplate is washed away after the engraving process is complete. Then, the nameplate is finished by inking into the engraved groove. This machining process which uses oil is known as "wet machining." Wet machining requires processes such as the application and removal of oil. It also creates environmental effects such as pollution and destruction of the natural environment. A machining process without oil is known as "dry machining" [1]. However, it is difficult to engrave and cut metal without oil using traditional cutting tools such as a cutter, drill, and end mill due to high cutting resistance between the cutting edge and the work material.

The materials used in nameplate manufacturing are aluminum, copper, brass, and so on. In particular, aluminum is often used as a work material for cutting tools including drills and end mills. During the dry machining of aluminum, adhesion of the aluminum work material to the cutting edge reduces machining accuracy [2]. Adding a film coating to the cutting tool surface can help prevent aluminum adhesion [3,4].

Diamond-like carbon (DLC) is an amorphous carbon containing diamond (sp^3) and graphite (sp^2) microstructures [5,6]. A sp^3-rich DLC, composed only of carbon atoms, is called tetrahedral amorphous carbon (ta-C). The ta-C films possess excellent mechanical properties such as low friction, high hardness, and high flatness [7–10].

The most common fabrication process for ta-C films is the vacuum arc deposition method. The vacuum arc deposition method can fabricate ta-C films with high hardness and high density. In the vacuum arc deposition method, a cathode spot, which is very active and has a high temperature, is formed when an arc discharge is generated between a cathode and anode [11]. The cathode material evaporates from the cathode spot, and the evaporated cathode material forms an arc plasma. Ions, which originate from the cathode material, are produced in high density between the electrodes when the arc discharge is ignited. The

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