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The wear rates and performance of three mold insert materials

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ABSTRACT

In this study, a rapidly solidified aluminum alloy was compared with beryllium copper and 6061 aluminum alloys in terms of their wear rates, hardness and performance as mold insert materials. A Vickers hardness measuring machine and a tribometer were used to determine the hardness values and wear rates of the materials. Three sets of mold inserts were made of these materials, and the insert surfaces and the molded plastic lens surfaces were characterized using a scanning electron microscope and a surface profilometer, respectively. The investigation results indicate that the BeCu alloy has the lowest wear rate, while aluminum 6061-T6 has the highest wear rate. Although the rapidly solidified aluminum alloy is not as hard as the BeCu alloy, the differences between their wear rates and hardness values are not as great as the differences between aluminum 6061-T6 and the BeCu alloy. The results also indicate that the rapidly solidified aluminum alloy performs much better than aluminum 6061-T6 in molding of plastic lenses and is comparable to the BeCu alloy. It is able to attain finer surfaces of the molded plastic lenses. This is an important finding, and this means that the rapidly solidified aluminum alloy can replace the BeCu alloy as a good mold insert material, because beryllium (Be) is a toxic element. The finding gives the industry a better choice for selection of mold insert materials.

1. Introduction

High technologies continue to be developed for the design and manufacturing of advanced products made of advanced materials [1–3]. Advanced technologies have also been developed for various applications on micro-scales such as micro-lenses, micro-sensors [4,5], micro-machining [6], micro-actuators [7], micro-systems [8], and micro-assemblies [9]. Molding plays an important role in the manufacturing industries, and many products including micro components such as micro-lenses are manufactured by molding, which is widely adopted in the plastic and glass lens production, automobile, aerospace, and other manufacturing industries, as it has many advantages over the processes for manufacturing of products one by one [10–13]. The materials widely used for making lens mold inserts are mainly 6061 aluminum alloys, beryllium copper alloys and nickel coated steel alloys [14].

One preferred metal for making industrial mold inserts is aluminum, although the advantages of aluminum have decreased due to its strength and wear-resistance limitations [10,13,14]. Aluminum 6061-T6 is a good choice for fast prototyping of mold inserts [14]. It is highly machineable, which enables fast cutting [13,14] and diamond turning [15]. Its low specific density allows ease during mold making, assembling, and setting up of the molding machine [13], and therefore lowers the manufacturing cost. However, it has lower strength than beryllium copper and nickel coated steels [13,14]. In the molding process, the high temperature of the polymer melts degrades the insert surface and the entire mold [14].

Beryllium copper is another preferred mold insert alloy [6]. Its mechanical and thermal properties such as wear-resistance behavior are based on its chemical compositions [13]. This metal has high temperature conductivity, enabling high production speeds [16]. It is suitable for molding on a large production scale because of its relatively high strength [13,14], which on the other hand requires relatively costly tools for machining.

Steel alloys are often used in making of molds, because they can have improved strength, reliable mold functioning, and long service lives, while their high strength hinders the machinability and increases the production cost [13]. Very often, polishing of steel molds has to be conducted [17,18]. Furthermore, steel alloys cannot be simply turned using a single-point diamond tool because of the rapid tool wear, which requires the use of a special vibration-assisted cutting system to reduce the cutting force and tool wear [19]. Coating a layer of nickel on steels can enhance the machinability, but this also increases the production cost [13] and time.

The quality of molded lenses very much depends on the surface topographic condition of the mold insert, and with the advancement in material sciences, materials with better strength and

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