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The stamping behavior of an early-aged 6061 aluminum alloy

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ABSTRACT

The stamping behavior of 6061 aluminum alloy with various conditions of early-aging is investigated in the present study. The relationship between the stamping performance, microstructure and mechanical property for this alloy is also discussed. Experimental results show that the 6061 aluminum alloy with a 10–30 min early-aging at 160 °C will exhibit excellent stamping performance. The burnished surface of these treated alloys can reach a quite high value of 47%. Meanwhile, the mechanical strength and impact toughness have important effects on the stamping behavior of 6061 aluminum alloy. The moderate values of mechanical strength and toughness will exhibit an optimal stamping performance.

1. Introduction

6061 Aluminum alloy is a popular commercial material due to its light weight, high specific strength, high thermal conductivity and excellent corrosion resistance [1]. This alloy has been widely applied in various engineering fields, for example, the cell phone frame and covers, bike drivetrain parts, hand tools and automobile parts. Cole and Sherman [2] reported that aluminum alloys had the potential to be used extensively in vehicle structures and closures due to the requirements for improved fuel economy and emissions. Burger et al. [3] also studied the alloy sheet of 6xxx aluminum alloy and demonstrated the microstructure and mechanical properties required for automotive applications. The mechanical properties of 6061 aluminum alloy have been improved by a variety of thermal–mechanical treatments, such as precipitation hardening and equal-channel angular pressing (ECAP). The T6 treatment involving solution treatment and subsequent artificial aging is a common method to increase the strength of 6061 aluminum alloy [4]. Ozturk et al. [5] have discussed the variation of the yield stress, ultimate tensile strength, ductility and strain hardening rate with aging time in relation to the microstructural changes induced by the heat treatment for 6061 aluminum alloy. They found that slightly different Mg/Si atomic ratio would lead to a different time to peak aging and the presence of β'' precipitates led to significant changes in the mechanical behavior of the material. The yield stress increased significantly, the hardness varied linearly with the yield stress and the strain hardening capability was reduced. Buha et al. [6] also studied the effects of interrupted aging procedure on the microstructural development and mechanical properties of alloy 6061 and found that the interrupted aging treatment could increase simultaneously the alloy's tensile properties, hardness, and toughness. Dorward and Bouvier [7] rationalized the factors affecting strength, ductility and toughness of 6061 alloys and indicated that the best combination of strength and ductility could be achieved in materials with high soluble Mg_2Si and excess silicon concentrations. Kim et al. [8–11] studied the post-ECAP aging effect on strength and microstructure of the ECAP processed 6061 Al alloy. They found that the post-ECAP aging could produce a very impressive strengthening effects due to the aging precipitates, high dislocation density and ultrafine grain structure.

The traditional forging and lathing techniques have been currently used to manufacture the big parts of 6061 aluminum alloy, such as the parts for automobile and motorcycle. However, these techniques have high cost but low-speed production, and hence are not suitable to manufacture the small components for bicycle derailleur and electronic products. Meanwhile, these small components have complicated and exquisite structures and need higher precision of machining. Therefore, more efficient and stable manufacturing processes have to be developed for the high-speed mass production of these small industrial components. It is known that the 6061 aluminum alloy generally has lower formability than Al–Mg alloys (5XXX series). Some studies have also studied the machinability of 6061 aluminum alloy recently. Demir and Gunduz [12] investigated the effect of artificial aging on the machinability of AA6061 in as-received, solution-treated, and T6-treated states. Their results indicate that aging treatment will significantly affect the surface roughness of the workpiece. Ozturk et al. [13] investigated the effects of aging parameters on formability of 6061-O alloy. They found that the formability decreases with increasing aging time. In fact, 6061 aluminum alloy has often been previously aged to increase its mechanical strength and then stamped for

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