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Machining introduced microstructure modification in aluminium alloys

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Abstract: In the present study, the impact of machining on the microstructure of AA7150-T651 aluminium alloy is investigated. It is found that a near-surface deformed layer is formed on the alloy due to severe shear strain during machining operation. The near-surface deformed layer of approximately 500 nm thickness distributes uniformly across the machined alloy surface. Ultrafine equiaxed grains with the dimensions of 50-100 nm are formed within the near-surface deformed layer. Further, the strengthening precipitates ($MgZn_2$) that are initially present in the alloy in T651 temper are dissolved into the alloy matrix within the near-surface region. Subsequently, the dissolved alloying elements segregate at the grain boundaries of the newly formed fine grains in the near-surface deformed layer.

Key words: aluminium alloy, machining, grain refinement.

1 Introduction

AA7xxx series aluminium alloys, with the highest strength among all the aluminium alloys, have been widely used in the aerospace industry. Such alloys is mainly used for structural components, including wing skin, stringer of the main wing, fuselage strengthening pieces and so on [1]. The T651 is a commonly used temper for AA7150 alloy to achieve desired strength by precipitation strengthening [2]. Often, thick alloy plates are machined to the specific geometry of the components. The machining operation involves significant frictional force between the toll and the work piece and, consequently, introduces significant shear strain to the alloy region immediately beneath the tool.

Previous studies have found that high shear deformation processes, such as rolling, mechanical polishing and grinding etc., introduce severe plastic deformation within the near-surface region of aluminium alloys, resulting in the formation of near-surface deformed layers on the alloys [3-12]. The near-surface deformed layer is generally characterised by ultrafine equiaxed grains [5, 7, 13-16]. Extensive research have been carried out on the formation and evolution of the near-surface deformed layers within alloys subjected to high shear deformation processes as the near-surface microstructure has significant influence on the surface properties of the alloys [3-8, 17-19]. It is found that the severe plastic deformation results in the generation of dislocation network, which subsequently leads to grain refinement through dynamic recrystallization [20]. However, very limited research on the impact of machining on the microstructure within the near-surface region of the work piece have been reported although machining is widely used in manufactring aluminium alloy products. Recent work of the authors has simulated orthogonal machining of AA7150-T651 aluminium alloy by cutting using ultramicrotomy [21]. The simulation successfully introduced the interaction between the tool and the workpiece, and the associated shear deformation in the workpiece. As a result, near-surface deformed layers, characterized by ultrafine grains with diameters less than 100 nm, were generated on the workpiece. It is found that the thickness of