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Laser shock peening of AA6061-T6: Influence of pulse energy on texture evolution and mechanical properties

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Abstract. In this study, laser shock peening (LSP) was applied to aluminium 6061 alloy, and the resulting texture evolution and mechanical properties were investigated. LSP resulted in a recrystallised microstructure with a reduced texture index and an increased volume of shear components. Grain size decreased significantly to 4.12 μm with increased volume of dislocations. The application of LSP significantly affected the mechanical properties. Surface LSPed at 2.22 J exhibited better mechanical properties, with a hardness and tensile strength of 92.5 HV and 376 MPa, respectively, while LSP applied at higher pulse energy exhibited a reducing trend.

Keywords. Laser shock peening; aluminium; texture; EBSD; hardness; tensile strength.

1. Introduction

Aluminium 6061 alloy demonstrates low density, superior formability and castability, and good weldability and is hence considered a potential material in the aircraft, automobile, and shipbuilding industries [1,2]. This alloy possesses peak properties under the T6 condition and can be varied further by suitable heat treatment and thermo-mechanical processing routes [2,3]. However, some deformation techniques induce excess heat into the surface, thus changing their microstructure and crystallographic texture, subsequently influencing their mechanical properties. A similar phenomenon was reported on different aluminium alloys, including 7075 [4], Al–Li [5], which were subjected to deformation. Since grain structures and crystallographic textures are highly influential in deciding the mechanical behaviour, a suitable low-temperature processing route has to be utilised to bring out a microstructure with favourable properties.

Laser shock peening (LSP), in recent times, is widely utilised by researchers to enhance the surface properties of various metallic materials. Flexible processing conditions and low processing temperature have made LSP a potential technique to bring out a material with tailor-made surface properties. In LSP, a continuous laser beam with a fixed pulse energy is applied to the surface of the target, which produces a high-pressure plasma zone. As the plasma expands, shock waves are generated, which cause plastic deformation, thus forming compressive residual stress (CPRS) on the surface with modified properties [6]. LSP can cause significant changes in crystallographic texture, which has been studied previously. Karthik *et al* [7], in their investigation, noted a drastic change in texture and dislocation features in LSPed AISI-321 grade steel. Zabeen *et al* [8] also detailed the changes incurred in the crystallographic texture of the Al–Li alloy after LSP. Similarly, under the influence of CPRS with a modified grain structure, considerable enhancements in mechanical properties have been reported previously for various aluminium alloys [9,10]. It is thus evident that besides grain refinement, LSP can alter texture characteristics and mechanical properties. Therefore, in this preliminary study, LSP was applied on the surface of the AA6061-T6 substrate at different pulse energies, and the resulting changes in bulk texture, microstructure, and mechanical properties were investigated. It is to be noted that residual stress analysis was not conducted in this study, since the investigation was limited only to the surface of the treated specimens.

2. Experimental

AA6061 sheets were selected as the substrate material (BMA) for LSP. Samples were prepared to a mirror finish and covered with black tape as shown in figure 1a. According to the pattern given in figure 1b, with a beam diameter set to 2.5 mm, LSP was applied on the target material using an Nd:YAG laser source at pulse energies of 2.22, 3.15, and 3.57 J, respectively. Figure 1c and d show the schematic and the experimental setup of LSP, and

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The tensile test results (stress–strain curves) of the samples are plotted in figure 4b. Compared to BMA, which had a tensile strength of 249 MPa, LSPed samples exhibited improved values. The sample LSPed at 2.22 J had the highest value of 376 MPa, while samples LSPed at 3.15 and 3.57 J exhibited a tensile strength of 339 and 335 MPa, respectively. It can be noted that, unlike hardness, improvement in tensile strength was significantly better for all the LSPed samples due to the presence of recrystallised fine-grained structure, where an increase in grain boundary area arrested plasticity by pinning dislocations. The dense dislocations (work hardening), on the other hand, trapped each other from moving (tangling) through various planes, thereby affecting deformation.

4. Conclusions

The surface of AA6061-T6 was treated by LSP at three different power densities, and the key findings from the study are presented below:

1. LSPed surfaces exhibited a reduced texture index, with copper, S, and brass as dominant components.
2. LSP resulted in a modified grain structure due to recrystallisation with enhanced density of dislocations.
3. Hardness and tensile strength rose to a maximum of 92.5 HV and 376 MPa at 2.22 J. Improvement in properties was mainly due to grain boundary strengthening and work hardening phenomena.

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