Effect of peening angle and coverage on surface orientation of laser powder bed fusion Ti64 parts

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Abstract:

Poor surface integrity is a key concern in laser powder bed fusion (LPBF), directly deteriorating the quality, durability, and performance of the printed components. The key driving forces for the poor surface integrity are partial powder adhesion and high thermal gradients associated with rapid cooling, leading to unstable melt-pool behavior. Consequently, high surface roughness introduces stress concentration points that significantly affect the product's life and reliability. While process parameter optimization offers some improvements, its potential for achieving industry-required surface quality remains limited. Thus, the goal of this research is to equip a surface post-processing technique to enhance surface characteristics matching with the industry standards. Specifically, the research objective is to understand the surface strengthening effect from strain-induced material flow generated by elastic-plastic deformation through dynamic impact in LPBF parts.

1. Introduction

Shot peening is a cold working process used for improving service life and surface strength by retaining the core ductility. Three main components of shot peening are the media, intensity, and coverage [1], [2], [3]. The media size and material are a critical parameter usually kept constant during post-processing due to the complexity it involves for in-process variation. Ghanbari et al. [4] showed that increasing the media size increases the roughness at high intensities. Comparing with peening using a distribution of media sizes or commonly known as mixed shot process shows lower roughness compared to larger media [5]. This helps to identify the media size depending on the intensity. On the other hand, the peening intensity is typically controlled by adjusting the speed of the shots, air-pressure, or the wheel speed in centrifugal wheel peening systems [6]. It is measured using Almen strips with standard thicknesses according to SAE J442 [7].

The peening angle indirectly affects the intensity and coverage. At a non-perpendicular peening angle generates a shear stress along with a normal impingement of media. This results in shear generated material flow. One of the major advantages of this phenomenon is that the peening angle influences the depth and distribution of compressive residual stresses. A steeper angle (closer to 90°) generally creates deeper and more concentrated compressive stresses. In contrast, a shallower angle leads to a wider distribution of these stresses but at a shallower depth, along with more pronounced lateral material flow [8], [9].

The elastic and plastic deformation generated during the dynamic impact of the shot peening process generates specific zones on the surface of the part. The elastic zone works as a recoverable deformation around the plastic zone and acts as a support matrix. This elastic zone helps in confinement of the plastic zone by localizing it, thus concentrating the compressive residual stress within the plastic zone. The boundaries of the plastic zone have direct applicability to the depth