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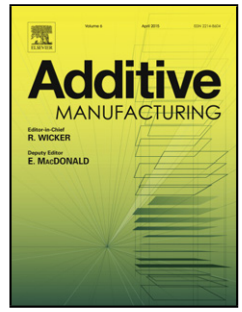

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Tailoring residual stress profile of Selective Laser Melted parts by Laser Shock Peening

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Abstract

The paper describes a new approach in controlling and tailoring residual stress profile of parts made by Selective Laser Melting (SLM). SLM parts are well known for the high tensile stresses in the as – built state in the surface or subsurface region. These stresses have a detrimental effect on the mechanical properties and especially on the fatigue life. Laser Shock Peening (LSP) as a surface treatment method was applied on SLM parts and residual stress measurements with the hole - drilling method were performed. Two different grades of stainless steel were used: a martensitic 15-5 precipitation hardenable PH1 and an austenitic 316L. Different LSP parameters were used, varying laser energy, shot overlap, laser spot size and treatments with and without an ablative medium. For both materials the as-built (AB) residual stress state was changed to a more beneficial compressive state. The value and the depth of the compressive stress was analyzed and showed a clear dependence on the LSP processing parameters. Application of LSP on SLM parts showed promising results, and a novel method that would combine these two processes is proposed. The use of LSP during the building phase of SLM as a "3D LSP" method would possibly give the advantage of further increasing the depth and volume of compressive residual stresses, and selectively treating key areas of the part, thereby further increasing fatigue life.

Keywords: Selective laser melting; Laser shock peening; 3D Laser shock peening; Residual stress profile; 15-5 PH stainless steel; 316L stainless steel

1. Introduction

Selective laser melting (SLM) is a part of a large family of Additive Manufacturing (AM) processes. Over the last decades more than thirty different types of Additive Manufacturing processes have been developed [1], [2], with SLM being one of the most researched over the past years.

However, although the mechanical properties have become close to those of bulk materials [3]–[14], SLM has some inherent drawbacks such as warping, cracking and detrimental tensile residual stresses (TRS). A large degree of shrinkage occurs during liquid - solid transformation, thus accumulating considerable tensile residual stresses on the surface of the SLM produced components. The complex residual stresses (RS) that arise during cooling are regarded as key factors responsible for the distortion and even delamination of the final parts [9], [10], [15]–[17]. These residual stresses may even cause process failure during the building phase [18].

The last melted layer shrinks during cooling while the layer underneath, already solidified constrains it and prevents further shrinking [15], [16]. Since this mechanism occurs for each layer at each step of the SLM process, large tensile residual stresses accumulate inside the manufactured component which cause significant and detrimental anisotropy of the mechanical properties of produced parts [5], [17], [19]–[21], thus limiting their application.

Different methods have arisen to reduce residual stresses. In situ heating (e.g. build plate heating; reheating of the melt pool) is commonly used [15], [22]. Adapting scanning strategies can also have a strong impact on residual stresses [15], [23]. As a post treatment, annealing is widely used and has