SUPERLASERS FOR THE REAL WORLD

Laser Shock Peening

AN EFFECTIVE TOOL FOR UPGRADING YOUR METAL ADDITIVE MANUFACTURING

WHITE PAPER

INTRODUCTION

For the last two decades, a significant improvement in metal Additive Manufacturing (AM) technology has been achieved. Those improvements and the advantages of this technology such as complex geometry parts manufacturing, reduction of parts weight, material waste reduction during parts production to a minimum, and overcoming other limits of conventional technologies make AM very attractive for manufacturing processes. The ability of manufacturing parts on-demand in a relatively short time can completely change the supply chain management in many industries. Customizing the parts to a patient-matched level brings significant improvements to the final quality of medical and dental implants. While all the constituent technologies of the metal AM have been in the continuous process of improvement, the AM is becoming a more affordable, reliable, and robust state-of-the-art manufacturing method.

PROBLEM

Nowadays parts produced by AM have almost the same mechanical properties as parts produced by conventional means. However, in comparison with conventional parts, AM parts still do not exhibit such mechanical properties essential for so call critical parts, for instance in aerospace or medical industries. The mechanical anisotropy, voids, lack of fusion defects, undesirable and detrimental tensile residual stresses, and resulting distortions are limiting factors to be considered for AM of critical parts where high quality is indispensable for economic and safety reasons. All these effects can significantly reduce the quality of the part, causing crack initiation and resulting in early material failure. Nevertheless, for improving the fatigue behavior of AM parts, the reduction of the surface roughness and inducing the compressive residual stresses are the most influential.

FIGURE 1: ADDITIVELY MANUFACTURED TURBO CHARGER

SOLUTION

AM post-processing techniques can be classified as thermal, where the material is exposed to the heat treatment to improve its properties, by reliving residuals stresses; chemical/electrochemical where improvements are achieved by polishing the surface; and mechanical post-processing, such as plastic media blasting, sandblasting, and shot peening, which is oriented to reduce the surface roughness, reduce the crack initiation and improve the dynamic properties of the material. However, improvements achieved with these processes are related to the surface quality of the AM part or residual stress relief at the near-surface only. Such enhancements, however, are insufficient to meet the most demanding criteria for the critical parts.

Laser Shock Peening (LSP) is a cold-working process that plastically deforms metallic material to induce mechanical strain. By applying LSP it is possible to change the state of the residual stresses and instead of tensile residual stresses have beneficial compressive residual stresses. **FIGURE 2** below illustrates what the typical depth profile of residual stresses looks like before and after application of LSP on AM produced 316L stainless steel. In comparison to other peening processes and other post-processing methods of AM, LSP imparts compressive residual stresses deep into material, up to several mm (other surface enhancement technologies up to a few hundred microns).

Materials processed with LSP demonstrate numerous improvements. Resistance to the crack initiation becomes significantly higher and if the crack has been already initiated, the growth of the crack will be slowed down. Furthermore, the wear resistance and stress corrosion cracking resistance of the LSP processed metal was shown to be significantly improved. All those improvements, in particular deep compressive residual stresses, greatly prolong fatigue lifetime, suppress fatigue failures, and overall increase the quality of metal additive manufacturing. **FIGURE 3** illustrates the fatigue lifetime improvement of AM Ti6Al4V alloy, widely used by many industries, achieved by LSP. The testing has been stopped when 10 million cycles have been reached without failure.

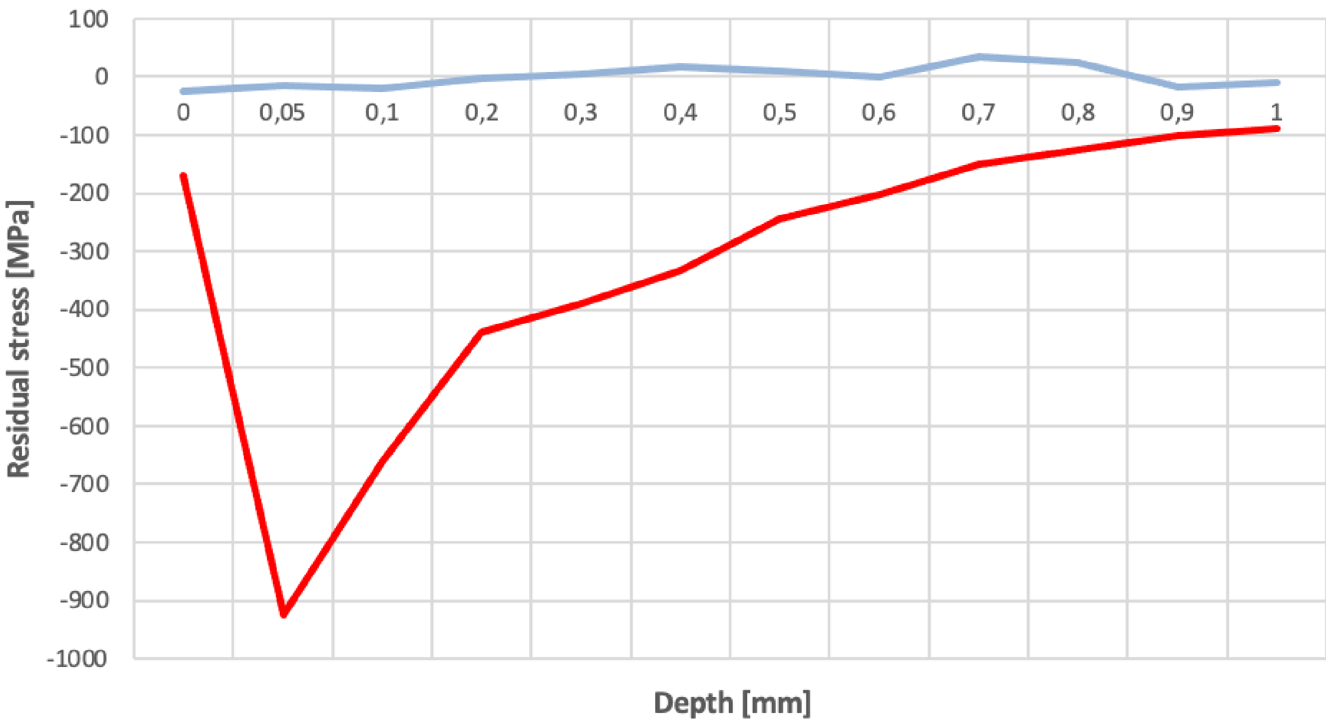

FIGURE 2: RESIDUAL STRESS DEPTH PROFILE FOR AM 316L STAINLESS STEEL BEFORE AND AFTER LSP PROCESSING

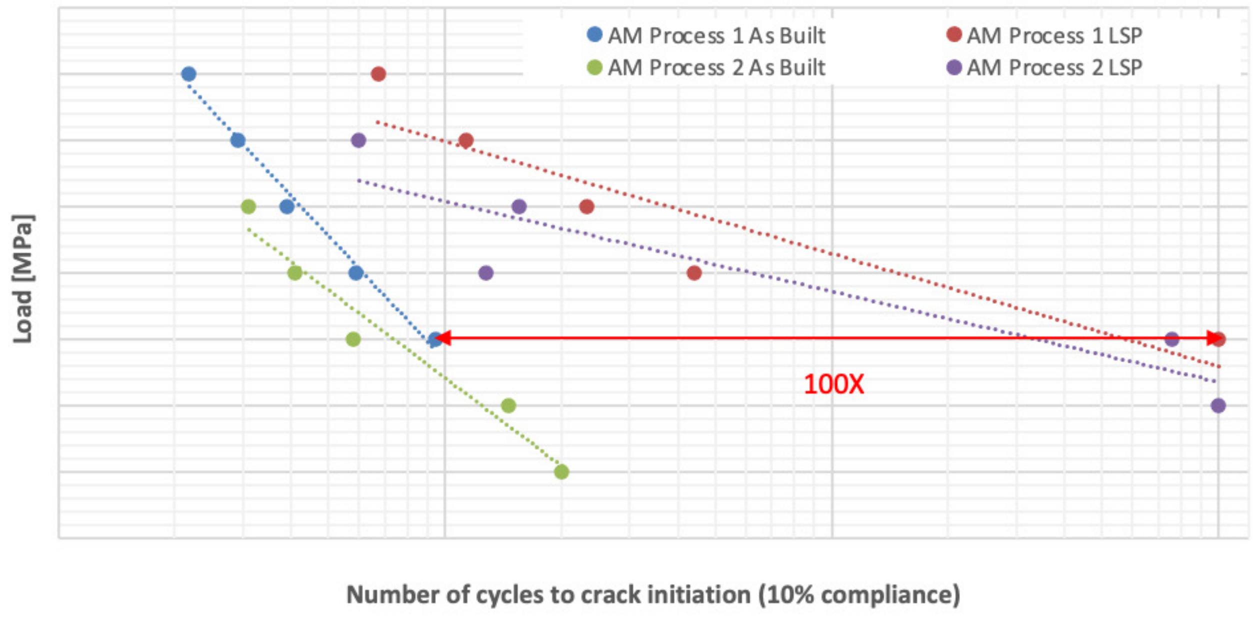

FIGURE 3: FATIGUE LIFETIME OF ADDITIVELY MANUFACTURED TI6AL4V BEFORE AND AFTER LSP PROCESSING

SUMMARY

LSP is a technology that can expand the performance of the Metal Additive Manufacturing technology. It has been proved that the LSP significantly improves the quality of AM parts and enables usage of AM for the critical parts in the most demanding industries. In combination with the LSP, metal AM can find its way to many new unexplored applications. Together, these two technologies are an extremely powerful tool that can be used in many industries with numerous benefits.

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Czech Academy of Sciences

EUROPEAN UNION
European Structural and Investment Funds
Operational Programme Research, Development and Education

MINISTRY OF EDUCATION, YOUTH AND SPORTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 739573 (HiLASE CoE)

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