# Using Laser Shock Peening to Enhance Metallic Additive Manufacturing

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Abstract: In the present work, the effects of laser shock peening on mechanical properties of metal additive manufacturing parts made of SS 304L, SS 316L, AlMg10Si, and Ti6Al4V were discussed. The samples were evaluated for residual stress, microstructure, computed tomography scanning, and/or fatigue life testing. All the measurements/testings were carried out on the As-Built and LSP treated samples and the results were compared.

## 1. Introduction

Additive Manufacturing (AM) technology has brought numerous benefits to mankind and considering the benefits of the technology such as manufacturing of complex shapes and lightweight parts, easy customization, design freedom, etc.[1]. It is expected that this technology will be a more vital part of the manufacturing processes in the coming years. Even though this technology has found its place in many industries, and it's regularly used nowadays, there are still areas where additive manufacturing cannot be applied because of certain limitations [4]. These limitations are not allowing additive manufacturing to be used for critical parts, either because of technical or safety reasons. By employing Laser Shock Peening (LSP), many of these limitations can be overcome, mitigated, or even completely eliminated. Laser Shock Peening can significantly improve the mechanical properties of the AM parts and bring AM technology into the most demanding applications and industries. In the present work laser shock peening on SS 304L, SS 316L, AlMg10Si, Ti6Al4V. The residual stress measurements were presented for SS 304L and SS316L samples, while the porosity in AlMg10Si was discussed and for Ti6Al4V fatigue life is presented in this paper.

## 2. Laser Shock Peening process

For the results presented in this paper, LSP experimental work has been carried out at HiLASE' premises in the laboratory that is dedicated to the LSP research. Figure 1 presents the scheme of the LSP arrangement. For all the experiments a BIVOJ laser system was used with all the characteristics important for the LSP processing. The laser beam was specially fixed, and the samples were moved by the robotic arm with a predefined path.

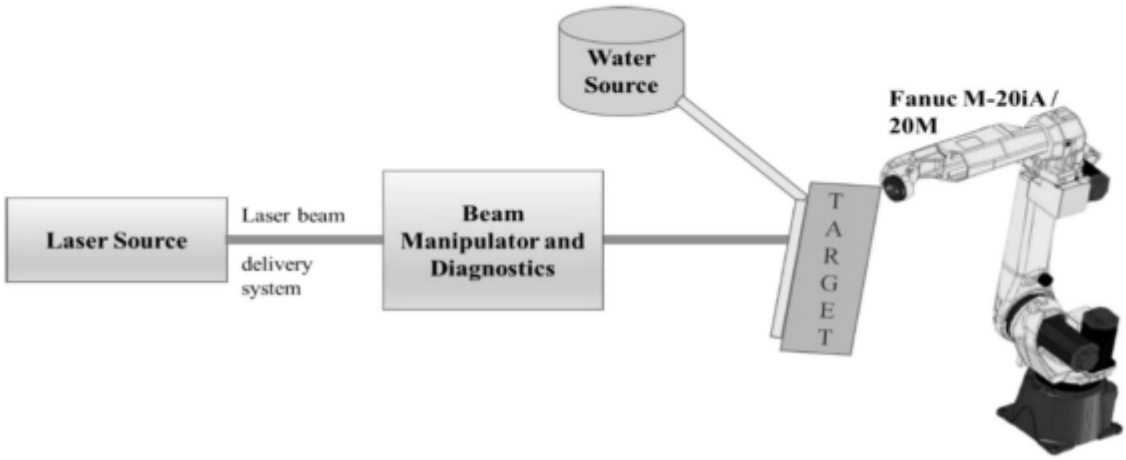


**Figure 1: Scheme of the laboratory for LSP at HiLASE Center [3]**

## 3. Experimental results

### 3.1 Residual stress change

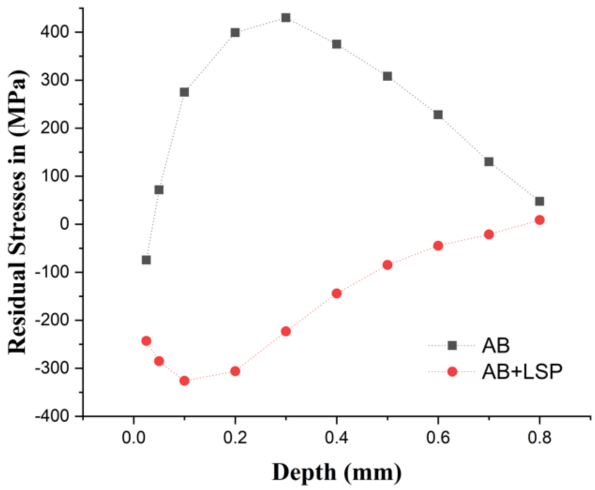


**Figure 2: Change of the residual stress state from tensile to compressive for 304L additively manufactured part**

Figure 2 presents how the LSP is changing the state of residual stresses from the tensile regime to the compressive regime for additively manufactured samples made of stainless steel 304L. In this particular case, samples have not been heat-treated for stress relaxation and this is the reason for high tensile stresses. The laser energy per pulse for this processing was 5J and we have used the sport size 2 mm X 2 mm. The pulse width was 14 ns, and the corresponding power density was 4.9 GW/cm$^2$. Figure 3 presents what the residual stress profile looks like when the samples are heat-treated for the stress release purpose. In both cases, a significant amount of compressive residual stresses has been achieved deep into the material. In the end, this typically brings improvement in fatigue properties of the part. The corresponding power density, in this case, was 2.5 GW/cm$^2$, achieved with similar laser parameters as in the first case.

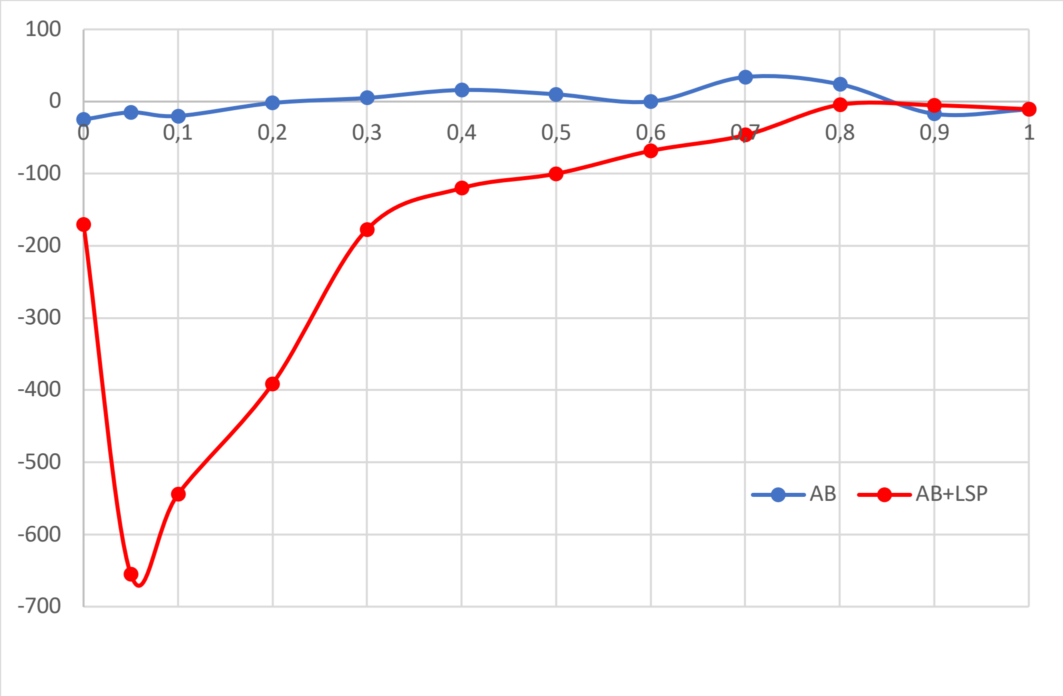


**Figure 3 Residual stress distribution for additively manufactured 316L parts before LSP (AB) and after LSP Microstructure evaluation**

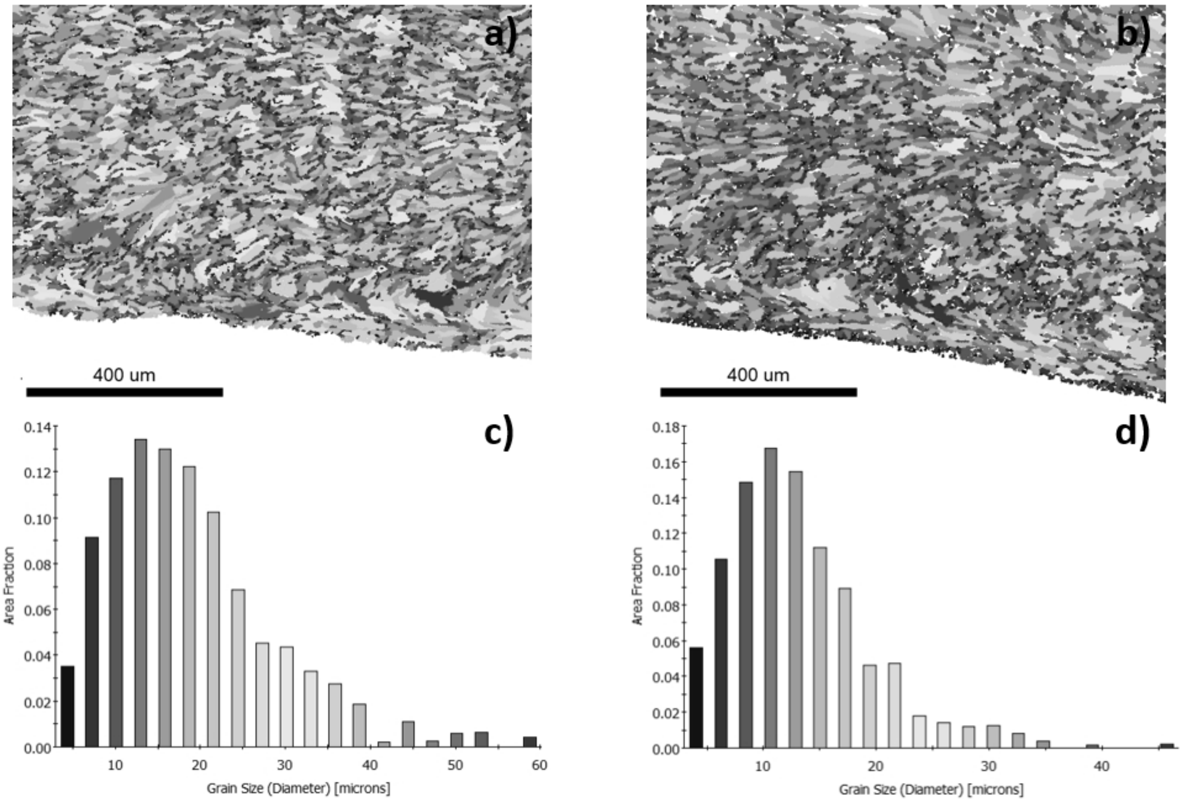


**Figure 4 SEM of additively manufactured stainless steel 304L parts before (a) and after LSP (b) and grain size distribution before (c) and after (d) LSP**

Figure 4 presents the scanning electron microscopy (SEM) of the cross-sectional cut unpeened sample (Fig. 4a) and LSPeened sample (Fig. 4b). Whereas Fig. 4c and 4d depict the grain size distribution over the area fraction within the unpeened and LSPeened samples respectively. It can be seen by comparing Fig. 4b with Fig. 4a that the grain sizes have been reduced due to the transfer of shock waves causing plastic deformation within the material. The observation can be further verified with the grain size distribution as presented in Fig. 4c and 4d. It is visible from Fig. 4d that grains of more than 40 microns were totally diminished from the measured range and smaller grains of 2 μm to 20 μm have gathered the larger area. Such improvement in grain structures has resulted in higher values of compressive residual stresses as presented in Fig. 3 also.

## 3.2 Porosity mitigation

During printing, the strategies for the outer skin and inner infill differ. Where these two strategies meet, we are observing a systematical drawback which is the formation of porosity. This porosity was successfully mitigated using laser shock peening up to a certain depth as can be seen from the Computed Tomography scan results shown in figure 5. The power density used during LSP processing was 3.6 GW/cm$^2$.

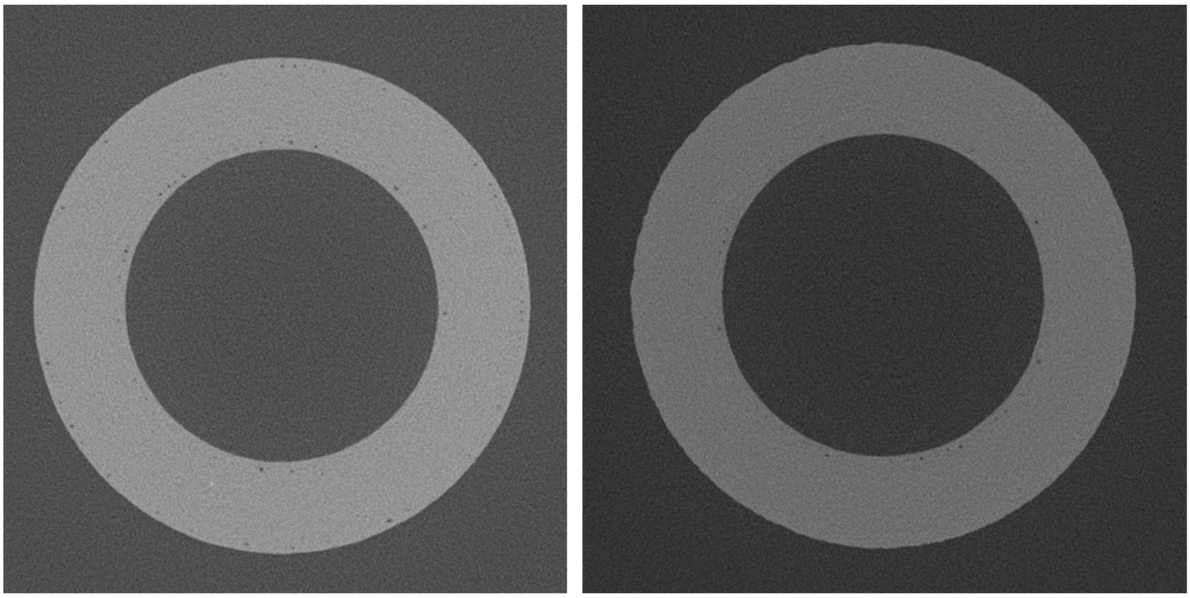

**Figure 5 Porosity mitigation for AlSi10Mg; left before LSP, right after LSP**

## 3.3 Fatigue life improvement

Fatigue life improvement is the major benefit of LSP. In the case of additive manufacturing, fatigue life improvement can be longer than for the parts that are traditionally produced. The fatigue life of the AM parts can be prolonged several dozen times. The reason for this is that AM parts are quite often of the r quality after the production, compering to the parts traditionally produced. At HiLASE Centre, we have achieved an improvement in fatigue life of Ti6Al4V 100 times. In the case of the stainless steel 316L samples with a stress riser, the improvement was significantly less, but still, it was a valuable improvement (up to 4 times) [3].

## 4. Conclusions

Laser Shock peening is a promising method for the post-processing treatments of metal additively manufactured parts. It can completely change the state of residual stresses in the additively manufactured part from tensile to a compressive state of residual stresses. By imparting high compressive residual stresses, deep into the part. LSP significantly can prolong the lifetime of the component that is additively produced and make it available for the applications that require the highest quality. The refinement of the microstructure is another benefit that LSP brings to additive manufacturing. Also, the mitigation, or complete elimination of the porosity, which is often a problem for additive manufactured parts, is possible with LSP. Certainly, LSP is a superior technology for certain improvements in additive manufacturing.

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