

# **THEORETICAL FOUNDATIONS, BENEFITS, AND LIMITATIONS OF LASER SHOCK PEENING IN RUSSIA**

Oleg Plekhov

Perm federal research center of the Ural Branch of the Russian Academy of Science  
(PFRC UB RAS), 13a, Lenin Str., 614018, Perm, Russia  
\*corresponding author: poa@icmm.ru

## **Abstract**

Despite decades of research, metal fatigue remains an unpredictable phenomenon, responsible for major technological failures and substantial economic losses. Consequently, controlling fatigue crack initiation and propagation is of paramount practical importance. One highly effective approach is the generation of deep Compressive Residual Stresses (CRS). Laser Shock Peening (LSP) is an advanced surface treatment technique capable of inducing significant CRS to depths exceeding 1 mm. The process involves subjecting a metal surface to high-energy, nanosecond-duration laser pulses. This generates high-pressure plasma, leading to the propagation of elastic-plastic waves through the material. The resulting plastic deformation in the surface layer creates CRS with amplitudes as high as -1 GPa.

This study presents integrated theoretical and experimental investigations into CRS formation via LSP. The theoretical component addresses a set of coupled physico-mechanical phenomena, including laser-induced ablation, the propagation of nanosecond-scale elastic-plastic waves, and the subsequent computation of self-equilibrated residual stress fields. Particular emphasis is placed on analyzing the thermal conditions during LSP. It is demonstrated that, unlike other laser-based techniques, LSP does not cause material overheating or recrystallization.

An original experimental setup was developed to measure pressure pulse profiles in real-time and reconstruct the resulting through-thickness CRS distributions. This setup enables precise determination of the actual duration and amplitude of the pressure impulses generated during treatment. The established correlation between laser parameters and pressure pulses was utilized for process optimization and validation of the developed mathematical model.

Experimental results confirm that optimally calibrated LSP parameters can increase the fatigue life of notched specimens by several times. Conversely, improperly induced residual stresses can catastrophically reduce fatigue performance. This is illustrated by a case study on gigacycle fatigue regime, where the presence of significant tensile residual stresses in the specimen volume reduced the fatigue limit by three orders of magnitude.

Beyond fatigue life extension, LSP technology holds promise for other mechanical engineering applications. The report concludes with an analysis of its potential for improving the tribological properties under dry and boundary frictions.

## **Keywords**

Laser shock peening; fatigue; gigacyclic fatigue regime; tribology.