LASER SHOCK PEENING FOR IMPROVEMENT OF STAINLESS STEEL FOR NUCLEAR POWER GENERATION

Stainless steel in the nuclear industry

Stainless steel alloys are widely used in nuclear power plant (NPP) industry where they play a critical role in the plant safety and effective operation. Typical parts manufactured from stainless steel are reactors pressure vessels, pipes, tanks, containment canisters, and many others which means that an improvement in the stainless steel area is very attractive and potentially highly beneficial for the nuclear power industry. Laser Shock Peening represents one such direction where the surface of stainless steel components is bombarded by targeted laser pulses in order to boost the component performance in the NPP environment, leading to less service downtime and overall increased safety.

HiLASE profile

HiLASE Centre is a scientific research centre of the Institute of Physics of the Czech Academy of Sciences. The main goal of the research centre is to develop new frontier laser technologies - diode (diode pumped solid state laser systems, DPSSLs) with high energy per pulse and high repetition frequency at the same time. HiLASE Centre also tests the durability of optical materials (LIDT – Laser Induced Damage Threshold) and conducts research in precision cutting, drilling, welding, micromachining, surface cleaning and strengthening material through laser shock peening. For more information visit **www.hilase.cz**

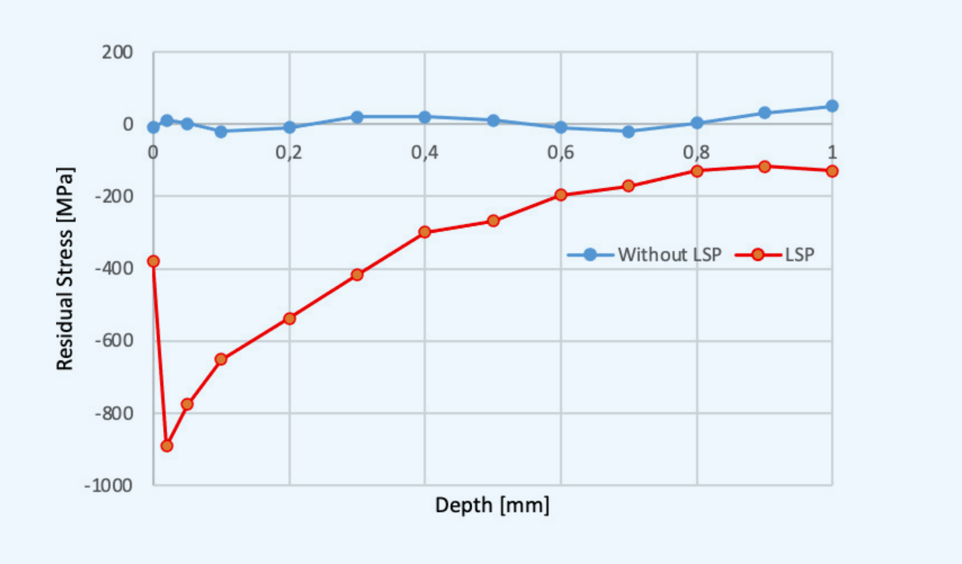

FIGURE 1 RESIDUAL STRESS DEPTH PROFILE OF STAINLESS STEEL 304L BEFORE AND AFTER THE LSP PROCESSING

Laser Shock Peening

Laser Shock Peening (LSP) is a surface enhancement method that improves the mechanical properties of metals by imparting beneficial compressive residual stress up to several millimetres deep. This is done by creating laser generated micro-explosions on the top of the material, creating plastic deformation which leads to compressive stresses. Changing the state of residual stresses from tensile to compressive in weakened places such as welds leads to increased fatigue strength and fatigue life, slows down crack growth and increases resistance to stress corrosion cracking and wear. LSP has already been successfully used in this manner to treat reactor vessels in Japan and further research is carried out by HiLASE team. FIGURE 1 shows a typical LSP result where compressive residual stresses are generated either from relaxed state as in this case or from tensile state. The material is 304L stainless steel, which is widely used in NPPs; for example

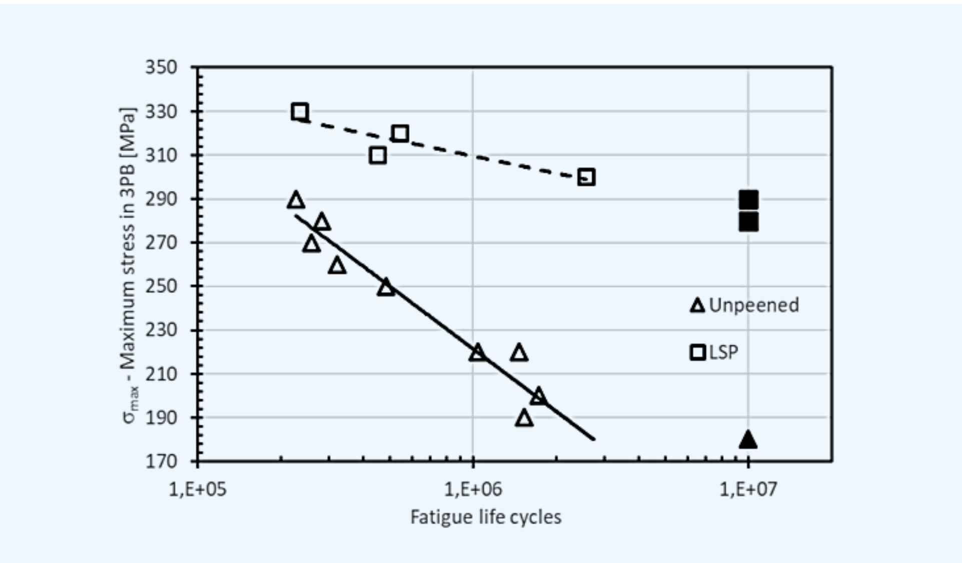

FIGURE 2 FATIGUE LIFE IMPROVEMENT OF 08CH18N10T STAINLESS STEEL USED FOR NUCLEAR REACTORS

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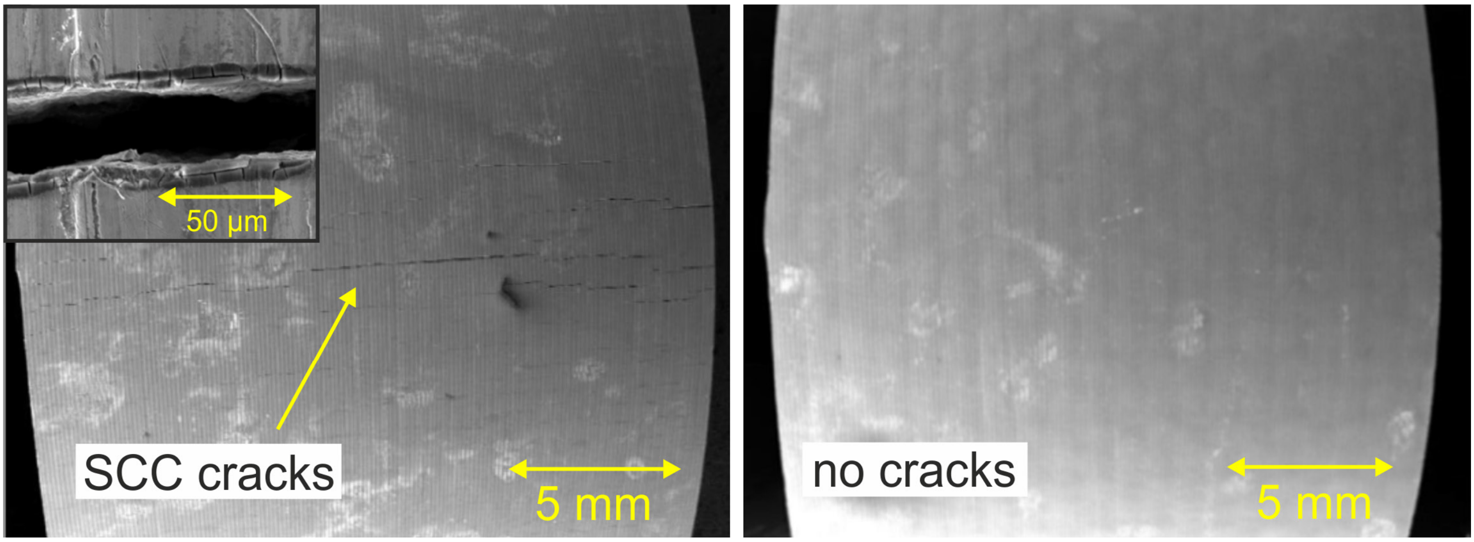

FIGURE 3 THE EFFECT OF STRESS CORROSION ON 08CH18N10T STAINLESS STEEL AFTER 20 HOURS IN CORROSIVE ENVIRONMENT; LEFT - BEFORE LSP, RIGHT - AFTER LSP

in operation related applications. Such change in residual stresses usually results in improved fatigue life which, depending on the material and the component, can be more than order of magnitude.

Fatigue life improvement of 08CH18N10T

FIGURE 2 shows the fatigue life curve for stainless steel 08CH18N10T that is used for nuclear reactors. The samples were processed by parameters developed by HiLASE LSP team. After the processing, the samples were subjected to 3-point bend fatigue test. Due to the newly imparted compressive residual stresses, the high-cycle fatigue life performance was improved over the whole range of loading stresses by more than a factor of 10.

Stress Corrosion CrackWing resistance improvement

Due to the sensitization of material in the aggressive NPP environment (radiation), certain components may become susceptible to Stress Corrosion Cracking (SCC). In order for SCC to manifest, three conditions must be met simultaneously: corrosive environment, weakened material and tensile stresses. Eliminating one of these three conditions would then lead to SCC arrest. In this case, the solution is provided by removal of the tensile stresses via LSP. In fact, LSP has been recognized as one of the most promising technologies for preventing SCC in nuclear components. FIGURE 3 shows a tube segment after 20h constant load test in corrosive environment. The photo on the left shows the tube with clearly developed SCC cracks of various sizes while the LSP treated surface on the right shows no such signs.
Similar principle can be used for preventing SCC on canisters for keeping nuclear fuel waste. LSP can be used both on parent material as well as on welds, which are always the most critical part of any pressure vessel, pipe system or a tank.

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