L.7: Improvement in ratcheting fatigue life of HSLA steel by laser shock peening

High strength low alloy steel (HSLA) is one of the most popular structural materials widely used in naval, automotive, and many other industries due to its high strength to weight ratio, corrosion resistance, and excellent mechanical properties than other regular carbon steels. The fatigue performance of HSLA steel is one of the most critical requirements for the application in the automotive industries, which is often under severe cyclic loading conditions during their services. Positive mean stress-based asymmetric cyclic loading is responsible for the failure of significantly large number of the automotive structural components; popularly known as ratcheting fatigue failure. During the ratcheting fatigue, a considerable accumulation of the plastic strain takes place that is attributed to the failure of the components when plastic strain reaches to a critical value. Different surface treatment techniques are adopted to improve the fatigue life of engineering components used under cyclic loading condition. To prolong the fatigue life of HSLA steel under ratcheting loading condition, laser shock peening (LSP) based surface treatment is adopted in the present study.

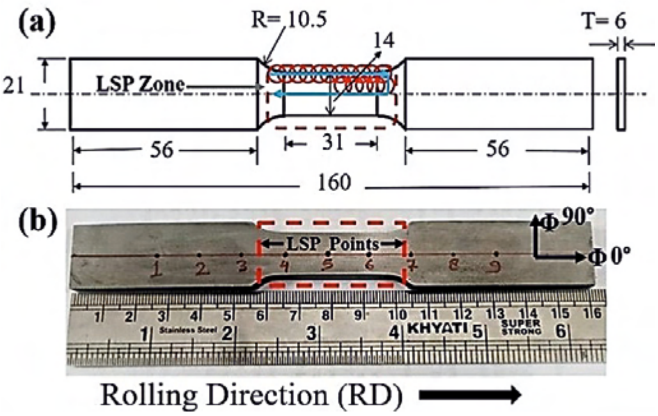

Fig. L.7.1: (a) Schematic and (b) photograph of LSP treated HSLA steel fatigue samples.

The fatigue specimens of HSLA steel shown in Figure L.7.1 ((a) & (b)) are laser peened using an in-housed developed Q-switched Nd:YAG laser at laser power density of ~3.5 GW/cm^2 with double LSP impacts, while fixing other peening parameters such as laser spot size of 3 mm, repetition rate of 2 Hz, overlap percentages of 70% and 58% along and perpendicular to rolling directions, respectively. It is evident from Figure L.7.2 that post LSP treatment generates significant amount of compressive residual stress along the depth as compared to the un-peened sample. Further, to study the effect of LSP on fatigue behaviour, three typical cyclic loading conditions with different mean stress (σ_m) and stress amplitude (σ_a) values i.e., σ_m=5 & σ_a=415 Mpa, σ_m=15 & σ_a=415 Mpa, σ_m=25 & σ_a=455 MPa were selected followed by ratcheting fatigue tests of un-peened and laser peened specimens at each loading conditions. Figure L.7.3 represents histograms comparing the fatigue lives of un-peened and laser peened specimens at different loading conditions.

It is evident that the ratcheting fatigue life gets enhanced after the LSP for all the three loading conditions. At mean stress of 15 MPa and stress amplitude of 415 MPa, the fatigue life of the treated specimens reached ~1970 cycles, which is almost double of that of untreated specimens with a fatigue life of ~ 950 cycles. In a similar way, the other two loading conditions also show ~1.8 times life enhancement.

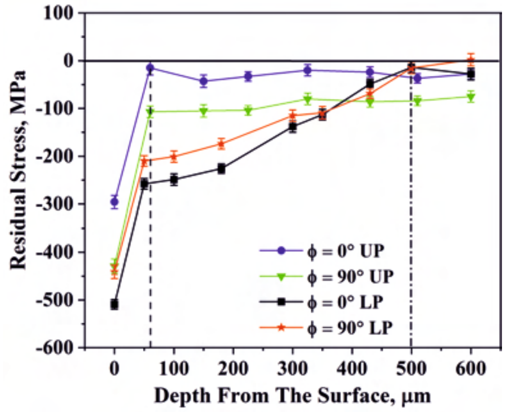

Fig. L.7.2: Residual stress measured along the depth of laser peened (LP) and un-peened (UP) samples.

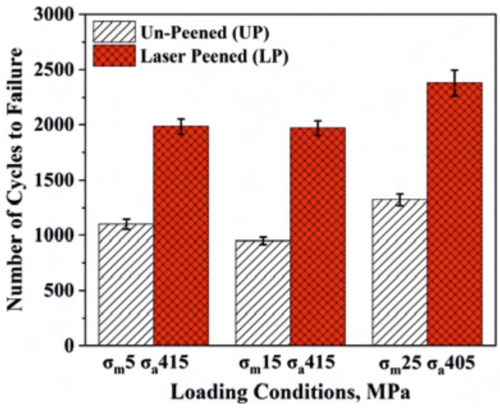

Fig. L.7.3: Ratcheting lives of un-peened and laser peened specimens at different loading conditions.

The improvement of fatigue life of laser peened samples is due to the combined effects of the work hardening, high magnitude of compressive residual stress and the sub-structural evolution near surface. Further, XRD based texture analysis revealed the strengthening of {011}<100> (Goss) and {011}<111> texture components in both un-peened and laser peened specimens. However, the increment in texture intensity of laser peened specimens is found to be lower than that of the un-peened ones due to the lower ratcheting strain accumulation, which enhances the fatigue life. Thus, it is shown that LSP contributes significantly to improve the ratcheting fatigue life of HSLA steel. This work has been carried out in collaboration with Laser Material Processing Division (LMPD), RRCAT and NIT Rourkela.

Reported by:
Arun Kumar Rai (akrai@rrcat.gov.in)