L.11: Laser peening enhances surface defect tolerance of spring steel with respect to its fatigue life

Presence of surface defects is known to adversely affect fatigue life of engineering components. These surface defects serve as potent stress raisers, thereby facilitating early nucleation of fatigue cracks. A recent in-house study, performed on SAE 9260 spring steel in quenched and tempered condition (microhardness: 410-450 VHN), demonstrated that surface defects can be effectively made harmless by introducing compressive residual stress around it through laser shock peening (LSP). The selection of the material was primarily made on the basis of its wide application as leaf and truncated springs in automotive industry, rail transportation sector and general engineering.

The approach adopted for the study included (i) introduction of reproducible defects on the ground surface of the specimens, (ii) LSP of the defect site and (iii) comparison of fatigue lives of laser peened and unpeened specimens (with surface defects). Mean surface roughness (Ra) of the ground surface of the specimen was in the range of 0.6-0.8 µm. The surface defect used for the study comprised of three successive pyramid-shape indentations along a line (length: ~400 µm; depth: 25 µm), introduced through Vickers micro-hardness indentation. Surface defects were introduced at the center of spring steel specimens (dimensions: 150 mm x 50 mm x 5.7 mm). Laser shock peening of the region, at and around the defect site (surface area: 15 mm x 15 mm), was carried out with an in-house developed 3.5 J/9 ns Nd:YAG laser. Laser peening was repeated twice to ensure the uniformity of residual stress on surface and sub-surface regions. Fatigue testing of the laser peened and unpeened specimens with ~400 µm surface defect at the center, was performed with a 150 kN servo-hydraulic universal testing machine in the 3-point bend configuration such that the surface with the defect experiences the cyclic tensile stress with defect site experiencing maximum magnitude of tensile stress. The parameters of fatigue tests were: maximum stress: 1050 MPa; stress ratio (R) = 0.3.

Laser shock peened surface of the specimen displayed compressive surface stress of about 750 MPa, with about 650 µm deep compressively stressed surface layer (refer Figure L.11.1). The results of fatigue tests demonstrated that LSP at the surface defect (refer Figure L.11.2) region brings about considerable enhancement in the fatigue life of spring steel specimens. Three numbers of laser shock peened spring steel specimens (with defects) remained unfailed even after 50 lakh stress cycles, while their unpeened counterparts displayed fatigue life of about 1-2 lakh cycles, with fatigue crack nucleation from the defect site (refer Figure L.11.2).

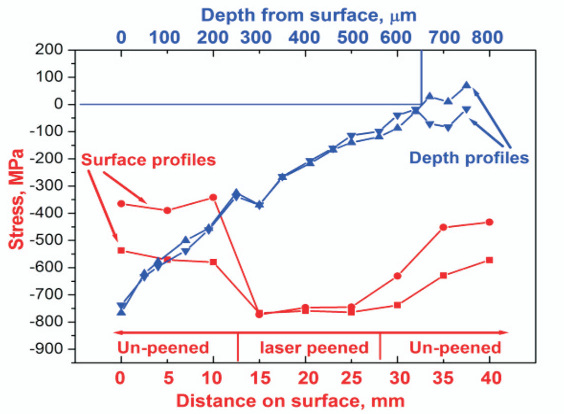

Fig. L.11.1: Surface and depth profiles of residual stress. Two plots each for surface & depth represent stress along length and width of the specimen.

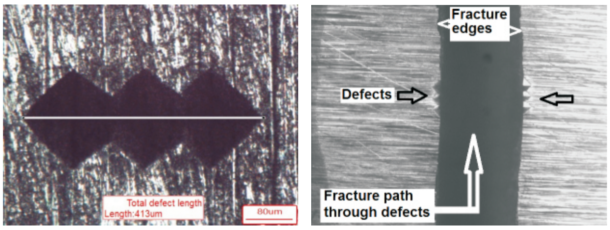

Fig. L.11.2: (Left) Magnified view of the surface defect on the surface of fatigue test specimen; (right) fatigue crack propagation through defect.

The experimental study demonstrated that laser shock peening of defect site brought significant increase in fatigue life of SAE 9260 spring steel specimens (refer Figure L.11.3). The results of the study are important for suppressing adverse effect of pre-existing/service induced surface defects on fatigue life of engineering components.

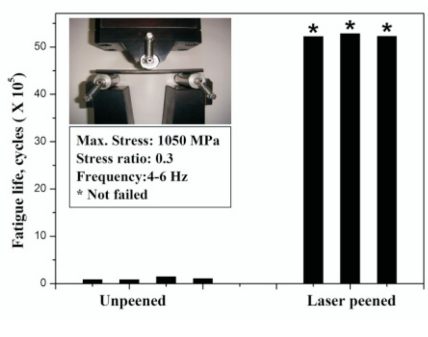

Fig. L.11.3: Comparison of fatigue lives of unpeened and laser peened spring steel specimens with surface defect. Inset shows fatigue testing in 3-point bend configuration.

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