L.5: A new hybrid laser surface treatment rejuvenates stress corrosion cracking damaged type 304L stainless steel

Stress corrosion cracking (SCC) is a serious problem encountered by austenitic stainless steel (SS) components in Boiling Water Reactors (BWR) as well as in chemical industry. In a recent collaborative research study between RRCAT and BARC a new hybrid laser surface treatment, combining laser surface melting (LSM) and laser shock peening (LSP), has been developed for rejuvenation of SCC-damaged type 304L SS. The approach adopted for rejuvenation of SCC-damaged SS part involved sealing of surface cracks through LSM, while subsequent LSP treatment served to modify resultant residual tensile surface stresses into compression.

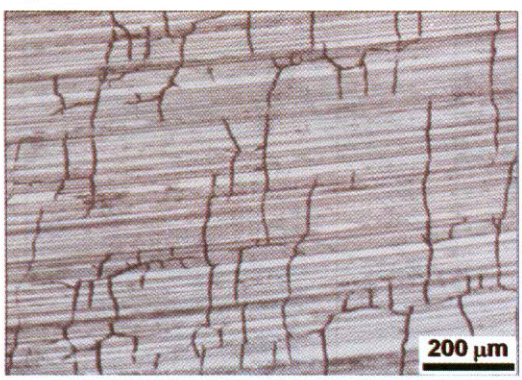

Fig. L.5.1: Surface cracks in stress corrosion cracking damaged type 304L stainless specimen.

The methodology adopted to introduce SCC-damage into 304L SS involved surface machining followed by specimen's exposure to ten-hour long accelerated SCC test in boiling $MgCl_2$ solution as per ASTM G36. Fig.L.5.1 shows long cracks on the surface of SCC-damaged 304L SS specimen. The SCC-damaged SS specimens were subjected to LSM treatment with an indigenously developed 100 W diode side pumped continuous wave Nd:YAG laser while the subsequent LSP treatment was performed with an indigenously developed 2.5 J/7ns flash lamp pumped Electro-Optically (E-O) Q-switched Nd:YAG laser.

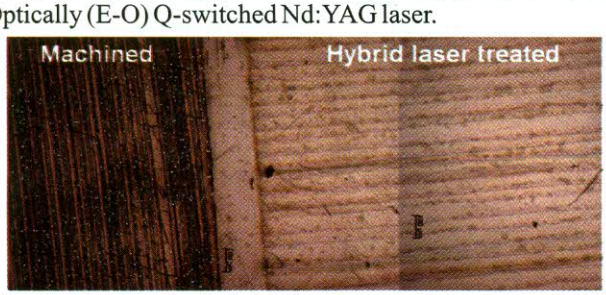

Fig. L.5.2: Partly hybrid laser treated surface of SCC-damaged 304L SS specimen.

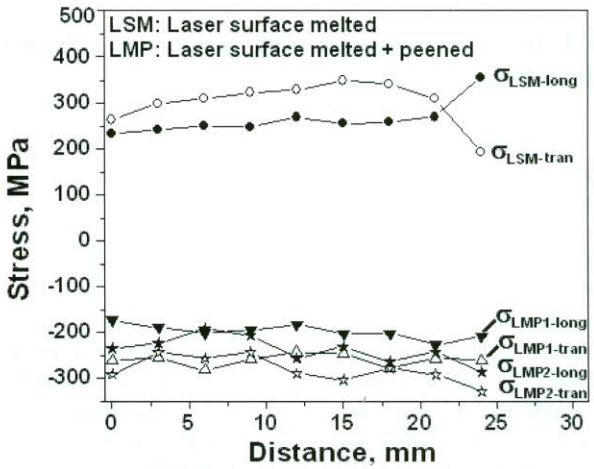

Fig. L.5.3: Surface profile of residual stress on (i) laser surface melted and (ii) laser surface melted & peened "SCC-damaged" 304L SS specimens.

Hybrid laser surface treatment brought about complete sealing of surface cracks (Fig.L.5.2) with modest increase in mean surface roughness (Ra) from 0.8 to 1.1 µm. Laser shock peening of laser melted surface effectively transformed associated residual tensile surface stress into compressive stress (Fig.L.5.3). Ten hour long accelerated SCC testing of hybrid laser surface treated specimens in boiling $MgCl_2$ solution as per ASTM G36 demonstrated their drastically reduced SCC susceptibility (measured in terms of total crack length in a given surface area) with respect to as machined specimens (Fig.L.5.4). On SCC-tested surface of hybrid laser treated specimens no cracks were noticed at 100 X magnification, although a few very fine cracks (~ 20 m long) were seen at 9000 X magnification. The results of the study, although particularly applicable to shallow SCC damage, are important for life extension of in-service SS components operating in corrosive environment.

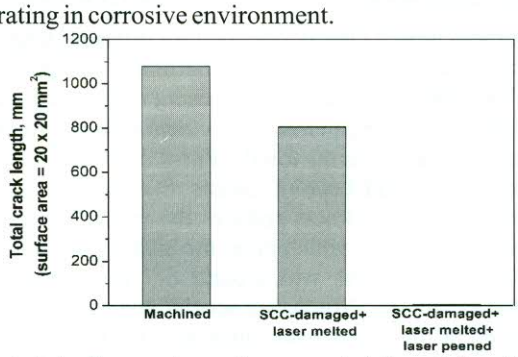

Fig. L.5.4: Comparison of average total crack length (in 400 mm² area) in SCC-tested (i) machined and (ii) laser surface melted & hybrid laser surface treated SCC-damaged SS specimens. Measurements made at 100X magnification.

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