L.2: Development of high energy nano-second Nd:YAG laser and laser shock peening study

A high energy 3J flash lamp pumped Electro-Optically (E-O) Q-switched Nd:YAG laser system is being developed at SSLD for laser shock peening (LSP) applications. As the first stage, a laser oscillator capable of delivering 1.1 J pulse energy in 8 ns, has been developed. Beam diameter is 9 mm ($1/e^2$ points). Oscillator has been designed to operate in positive branch unstable resonator configuration. In order to maximize output energy and also to maintain a good M^2 parameter of the output from the oscillator, a variable reflectivity mirror with super Gaussian output coupler (SGVRM) has been used. The resonator assembly consisted of a 5 m concave rear mirror and a 4m convex SGVRM output coupler, separated by 55 cm. E-O switching is performed with polarizer, Pockels cell and quarter wave plate configuration. The flash lamps are powered by pulse forming network (PFN), delivering an electrical energy of 100 J in 220µs with a maximum repetition rate of 10 Hz. However, currently the system is being operated with a maximum repetition rate of 3 Hz. Resonator configuration of the laser system is presented in Fig.1. In future, it is proposed to amplify this 1.1 J from the oscillator by single stage single pass amplifier to higher energies. The output beam from the oscillator exhibits a super Gaussian profile with M^2 value close to 4. Temporal profile is also smooth and a pulse width of 8-10 ns has been recorded.

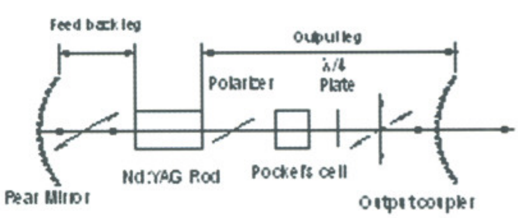

Fig.L.2.1: Schematic diagram of resonator configuration.

The in-house developed 1.1 J/8 ns Nd:YAG laser is being used in an experimental LSP study, performed in collaboration with M/s. Tata Motors Ltd. Laser shock peening is an upcoming non-contact surface treatment process for inducing high level of surface compressive stresses, without adversely affecting surface finish of the substrate. The process has large untapped potential in enhancing life of engineering components operating under fatigue and stress corrosion testing. It involves irradiation of painted surface of substrate by high-energy nano second laser pulses, while maintaining a layer of flowing water on the surface. Instantaneous formation of high pressure plasma causes a shock wave to travel into the material thereby generating compressive residual stresses on the surface of the substrate (Figs. L.2.2 and L.2.3). Although, LSP is being performed in different laboratories across the world with pulse energies more than 25J, we are trying to achieve LSP with a 3J table-top laser system, as these lasers are not only simple to operate but also easy to maintain in industrial environment.

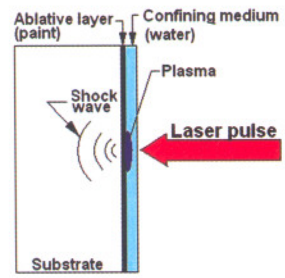

Fig.L.2.2: Schematic illustration of LSP process.

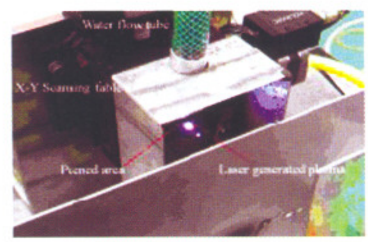

Fig.L.2.3: Close up of laser-interaction zone.

LSP experiments have been performed on 5 mm thick SAE 9260 spring steel specimens in hardened and tempered condition. LSP-induced surface residual stress has been found to be a sensitive function of incident laser power density, paint thickness and laser shot density. Initial experiments revealed that laser shock peened surface developed about 450µm thick compressed layer with surface stress lying in the range of -375 to -550 MPa (Fig.L.2.4). On the other hand, conventionally shot peened (SP) surfaces exhibited about 650µm thick compressed layers with surface stress lied in the range of -400 to -550 MPa. In contrast to SP, which exhibited deterioration in surface roughness (Ra) from 2.6 - 4.25µm (on the untreated surface) to (6 - 8.25µm) on the peened surface, LSP did not introduce any noticeable change in surface roughness.

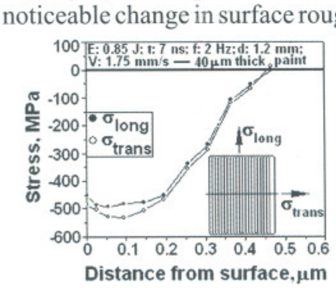

Fig.L.2.4: Depth profiles of residual stresses induced in laser shock peened spring steel specimen.

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