Laser Peening for Improved Fatigue and Corrosion Resistance

EWI TECHNICAL BRIEF

People have long observed that fatigue and stress corrosion cracking (SCC) resistance of engineering components can be improved by introducing compressive stress to the surface layer. Various methods have been developed to mechanically introduce the compressive stress, such as shot peening, sand blasting, and surface rolling. However, due to the capabilities of the above methods, the magnitude and location of the compressive stress are limited. Laser peening, which is capable of providing much more precisely placed compressive stress, makes it possible to improve fatigue and SCC resistance of components exactly where it is required on a component.

In laser peening process, the component to be processed is coated with an absorbing layer (usually black paint or tape), and a transparent overlay (usually water or glass) is applied on top of this surface. When a laser pulse penetrates the transparent overlay and strikes the opaque overlay, it generates high-intensity plasma. Since the rapidly expanding plasma is restricted by the transparent overlay, the high pressure it creates propagates into the component as a shock wave. As a result, the surface layer of the component is plastically deformed which yields compressive stress in the surface layer after the laser peening process. Due to the high energy laser pulse, a laser beam can generate compressive stress as high as 200 ksi at the surface with the depth of the compressive stress as deep as 0.05 in.

Engineering components are often subjected to cyclically varying loads in their lifetime. A series of factors, such as the changing service and environment conditions, cause the load to fluctuate in a certain range. Under cyclic load, fatigue cracks develop in components which can lead to their failure. Typically, fatigue cracks initiate on the surface of components, at locations having high stress concentrations and surface defects. A well-accepted theory for the initiation of fatigue crack is as follows. The cyclic applied load causes cyclic slip bands in microstructures. The cyclic displacement of the slip bands is best facilitated on component surface because it has smallest constraints there, particularly when the slip direction is perpendicular to the surface. As a result, notch-like geometry irregularities are generated on the component surface, thus promoting further stress concentration, slip displacement, and the eventual formation of macro-scale cracks. However, if laser peening is applied on the component surface, the introduced compressive stress imposes constraints on the motion of the slip bands. This delays the formation of fatigue cracks. In addition, the compressive residual stress also reduces the maximum tensile stress at the surface layer of components. Therefore, even if a fatigue crack is formed, the compressive residual stress will suppress its propagation.

Many engineering components are subjected to corrosive environments to some extent. When tensile stress is present, the combined action of corrosion and stress accelerates the deterioration of component material. This phenomenon is called stress corrosion cracking (SCC). In a normal corrosion process, the grain boundary of most metallic alloys is much more susceptible to the corrosive environment because the segregation impurity level at grain boundaries is much higher than within the grain. Intergranular corrosion can occur along grain boundaries, starting from the component surface and advancing to the interior. In SCC the applied tensile stress makes it easy for corrosion products to diffuse away from the newly corroded boundary, allowing the corrosion to progress faster. When compressive stress is introduced by laser peening, more resistance will be imposed onto the above-mentioned SCC process, which will prolong the lifetime of components.

If you have questions or would like to learn more about automatic inspection of welds, contact:

Junde Xu, Ph.D.
Principal Engineer
Structural Integrity Group
614.688.5176
jxu@ewi.org

Mark Schimming
Engineering Manager
Structural Integrity Group
614.688.5139
mschimming@ewi.org

Laser peening improves fatigue and corrosion resistance of components at the exact location it is required on a component.
