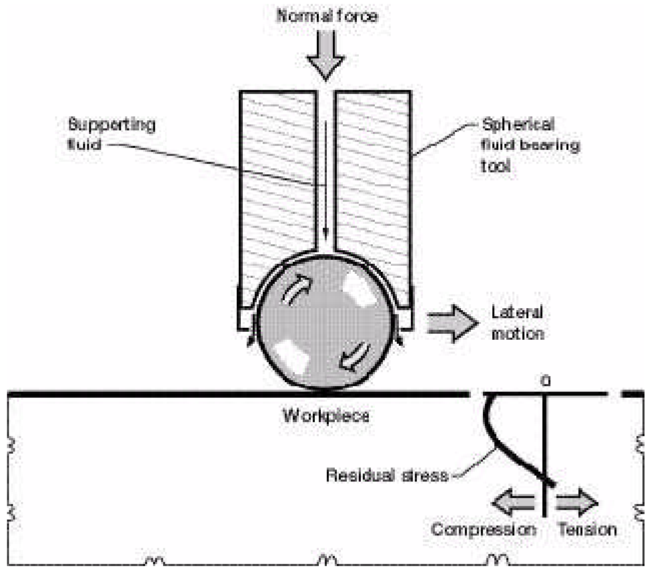
Improved Method Being Developed for Surface Enhancement of Metallic Materials

Surface enhancement methods induce a layer of beneficial residual compressive stress to improve the impact (FOD) resistance and fatigue life of metallic materials. A traditional method of surface enhancement often used is shot peening, in which small steel spheres are repeatedly impinged on metallic surfaces. Shot peening is inexpensive and widely used, but the plastic deformation of 20 to 40 percent imparted by the impacts can be harmful. This plastic deformation can damage the microstructure, severely limiting the ductility and durability of the material near the surface. It has also been shown to promote accelerated relaxation of the beneficial compressive residual stresses at elevated temperatures. Low-plasticity burnishing (LPB) is being developed as an improved method for the surface enhancement of metallic materials.

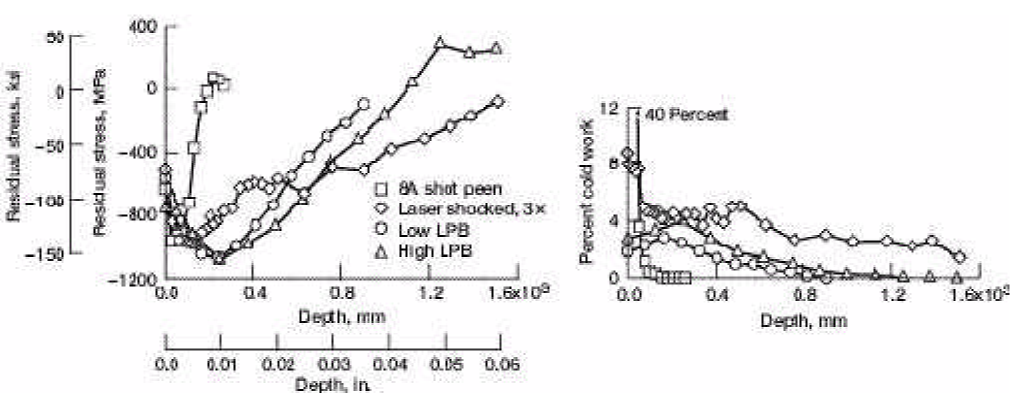
LPB is being investigated as a rapid, inexpensive surface enhancement method under NASA Small Business Innovation Research contracts NAS3-98034 and NAS3-99116, with supporting characterization work at NASA.

Previously, roller burnishing had been employed to refine surface finish. This concept was adopted and then optimized as a means of producing a layer of compressive stress of high magnitude and depth, with minimal plastic deformation (ref. 1). A simplified diagram of the developed process is given in the following figure. A single pass of a smooth, free-rolling spherical ball under a normal force deforms the surface of the material in tension, creating a compressive layer of residual stress. The ball is supported in a fluid with sufficient pressure to lift the ball off the surface of the retaining spherical socket. The ball is only in mechanical contact with the surface of the material being burnished and is free to roll on the surface. This apparatus is designed to be mounted in the conventional lathes and vertical mills currently used to machine parts. The process has been successfully applied to nickel-base superalloys by a team from the NASA Glenn Research Center, Lambda Research, and METCUT Research, as supported by the NASA Small Business Innovation Research Phase I and II programs, the Ultra Safe program, and the Ultra-Efficient Engine Technology (UEET) Program.



Low-plasticity burnishing apparatus.

A comparison of the residual stresses and plasticity produced by shot peening and LPB on the nickel-base alloy IN718 is shown in the following figure. The residual stress and plasticity profiles were measured using x-ray diffraction peak shift and broadening after repeatedly electropolishing a material layer. LPB clearly can produce deeper compressive residual stresses with much less plasticity (percent cold work) than shot peening. The high-cycle fatigue resistance of this alloy increases with the application of this LPB treatment. Shot peen and LPB-treated high-cycle fatigue specimens were exposed at 600 °C for 10 hr and then tested at room temperature. LPB-treated specimens had 2 to 5 times longer lives, even when given surface scratches normal to the load axis to simulate foreign object damage. The shot-peened specimens failed at the scratches with reduced fatigue lives. Crack-growth specimens were notched, precracked, and LPB treated. The notch was then machined away before crack growth testing at room temperature. The LPB treatment was highly effective, completely arresting crack growth into the material. This LPB process has been successfully applied to several nickel, titanium, and aluminum alloys (ref. 2) used in aerospace gas turbine engine and airframe applications. LPB has recently been shown surprisingly effective for treating corroded airframe materials after extended service, restoring fatigue lives to the unaged levels. LPB processing is now being extended to other alloys and applications.



Comparison of the residual stresses and percent cold work produced by shot peening, laser shock treatment, and low-plasticity burnishing (LPB) in IN718 (ref. 1). Top: Perpendicular residual stress distribution. Bottom: Percent cold work distribution.

References

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