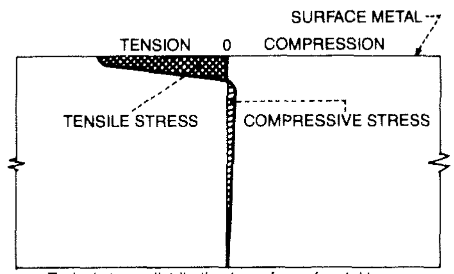
#1976006

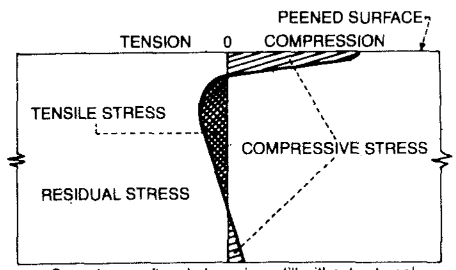
SHOT PEENING CAN HELP BOTH TURBINE BUILDER AND OPERATOR

Shot peening to extend fatigue life and prevent stress corrosion of gas turbine components is not a new practice. Yet, it is often bypassed by engineers whose thinking is oriented to solving premature failure problems through material and design changes.

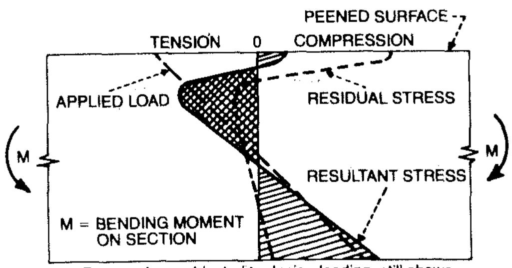
For a great many moving as well as stationary components, shot peening is an easier and less expensive option. But to appreciate its value in helping to increase longevity of compressor discs, tie rods, compressor blades, gears, shafts and the like, one must understand the origin of most fatigue and stress corrosion failure.



Typical stress distribution in surface of metal beam, unloaded by exhibiting residual tensile stress from normal fabricating procedures.



Same beam after shotpeening, still without external load. Surface stress is now compressive.



Beam, when subjected to design loading, still shows some residual compressive stress at surface.

SURFACE TENSILE STRESSES ARE CREATED BY METAL FORMING AND FINISHING

Machining and other forming, as well as grinding of most metals unavoidably create residual surface tensile stress. Surface tensile stress opens microscopic surface cracks or "stress risers" between the metal grain boundaries. As the affected parts undergo cyclic loading during operation of the turbine, the cracks enlarge and propagate inward until premature failure occurs.

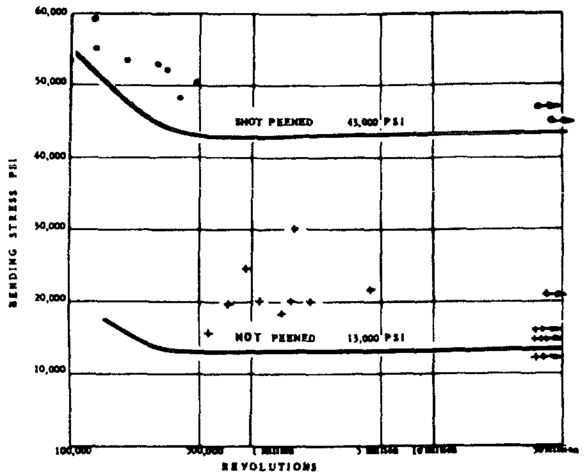
Stress corrosion failure has three prerequisites: 1) a susceptible metal; 2) residual or applied surface tensile stress, and 3) a somewhat corrosive environment. Stress corrosion can take place whether or not the part is cyclically loaded. New parts have been known to show evidence of stress corrosion damage even before installation.

In a gas turbine, the components are operating in a mild corrosive atmosphere. Their failure usually results from stress crack progression hastened by corrosion. Such measures as coating of blades, for example, acts to prevent atmosphere contact and corrosion but it does not eliminate the cause of stress cracking. **Controlled shot peening does.**

WHAT IS CONTROLLED SHOT PEENING?

Controlled shot peening is a means by which surface tensile stress, the precursor of stress cracking, is removed and the surface placed under protective **compression**, so to speak. Cracks are unable to originate or propagate in a compressively stressed layer. In controlled shot peening, the surface is **uniformly** impacted with spherical steel shot and/or glass beads, thereby producing a result best described as that of hundreds of thousands of tiny peening hammers striking with blows of equal intensity.

The resulting compacted layer, several or more thousandths of an inch thick is pleasing in appearance, does not meaningfully affect component dimensions, and actually improves the surface's lubricant-holding properties.



FATIGUE TESTS ON REAR AXLE SHAFTS

SHOT PEENING AS A MANUFACTURING STEP

Controlled shot peening provides a low cost means by which the turbine manufacturer can upgrade his product. Shot peened parts fail less frequently and that spells less customer downtime and great production continuity. The added fatigue strength resulting from shot peening may also allow some manufacturers to achieve an equivalent design based on thinner sections and less costly materials. Peening, to be effective, must always **follow** metal finishing and heat treating operations, but **precede** coating.

WHICH TURBINE COMPONENTS ARE SHOT PEENED?

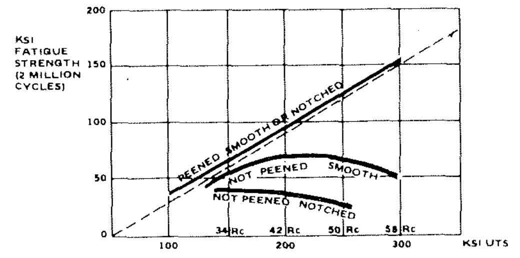
One producer specifies peening of the dovetail portions of hot gas pass buckets and the fillets of compressor blades in the platform-to-airfoil areas. In his design, he found these to be potential trouble centers so, in fact, is improving his quality. Shot peened foils and roots of compressor blades as well as discs are standard with several manufacturers. Other applications include tie rods—where peening of the fillet areas are shown to more than double fatigue life—couplings, gears, distance pieces and shafts.

SHOT PEENING AS PREVENTIVE MAINTENANCE

A case can be made for shot peening any time from the moment of a component's manufacture up until the stress cracks have not progressed too deeply. Actually, controlled peening of fatigue-damaged blades extends their life over that of unpeened new blades, assuming operation at the same stress level. Or, peening fatigue-damaged components permits operation at higher stress levels.

INCREASES FATIGUE LIMIT OF HIGH TENSILE STRENGTH PARTS

Higher tensile strength steels, while they have greater load bearing abilities and wear characteristics, fail faster in fatigue, particularly if the surface has even shallow scratches. Controlled shot peening overcomes much of the effect of the comparative brittleness of these materials by imparting surface ductility in the form of surface compressive stress. Yet, in no way is the strength impaired by this practice. On the other hand, with shot peening, the designer can go higher in the strength category and obtain proportionately greater fatigue life—regardless of whether or not the surface is scratched. The amount of compressive stress possible through shot peening is proportional to the ultimate tensile strength of the material.



COMPARISON OF PEENED AND UNPEENED FATIGUE LIMITS FOR SMOOTH AND NOTCHED SPECIMENS AS A FUNCTION OF ULTIMATE TENSILE STRENGTH OF STEEL

EFFECT OF HEAT ON PEENED AREAS

Many shot peened components attain elevated temperatures in use. A stress-relieving effect or reduction of the protective compressive layer is possible, but seldom experienced at the temperatures usually involved. The table below shows the effect of heat for prolonged periods on the stress corrosion resistance of peened and unpeened U-bend standard test samples of Type 304 stainless steel. Samples were stressed, heated and tested in magnesium chloride solution. The high, maintained stress corrosion resistance is a sure indication that fatigue resistance also remained high, since the prime cause of both—stress cracking—is the same.

Stress Relief Temperature	Time of Exposure To Temperature	Specimen	Time to Failure
1000° F	16 hrs.	Unpeened-1	3 hrs.
		Unpeened-2	7 hrs.
		Peened	103 hrs. NF*
1050° F	144 hrs.	Unpeened	10 hrs.
		Peened	202 hrs. NF*

* NF - No Failure, Test Terminated

REQUIRES CRITICAL CONTROL

While shot peening essentially utilizes steel shot and sometimes, glass beads under pressure to accomplish its effect, the practice is by no means conventional in terms of equipment and methods. Necessary areas of coverage must first be determined and here is where experience and judgment not to mention economics come into play. With some components, overall rather than selective, peening is more practical because of the extra protection afforded and the masking required with the latter.

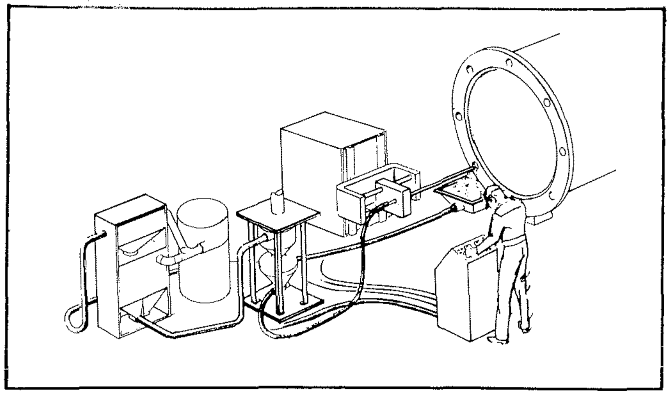
Required peening intensity and exposure time to attain so-called **saturation** of the surface should be critically ascertained through a test strip program. The peening process must guarantee uniform coverage of required areas as well as absolute reproducibility of results. All of this calls for highly specialized peening equipment, procedures and quality control. With regard to the latter, it is necessary not only to establish strictest standards for shot roundness and uniformity, but to institute a program by which these can be continuously monitored. Broken shot and mixed sizes can produce harmful results.

One company which has built a business doing shot peening work for manufacturers and users of turbines, diesels, and aerospace components is Metal Improvement Company of Teaneck, New Jersey, a subsidiary of Curtiss-Wright Corporation.

Metal Improvement has ten domestic and two European plants solely engaged in this work as well as the personnel to make engineering recommendations and to supervise a sophisticated, but vital quality control program. The company's peening machines are of their own design and include several numerically controlled systems. Peening is done on an individual job as well as regular production basis. In addition, special equipment and trained crews are maintained for on-site assignments.

LEAST COSTLY PROTECTION

While it is admitted that shot peening is not the only way to put a surface under compression, and thereby extend fatigue life, there can be no doubt that it is the least expensive way. The peening itself averages less than 1% of the cost of the part—and the user has no investment in high price machinery and training.



Portable Field Peening Unit

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