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Shot Peening Before Plating?

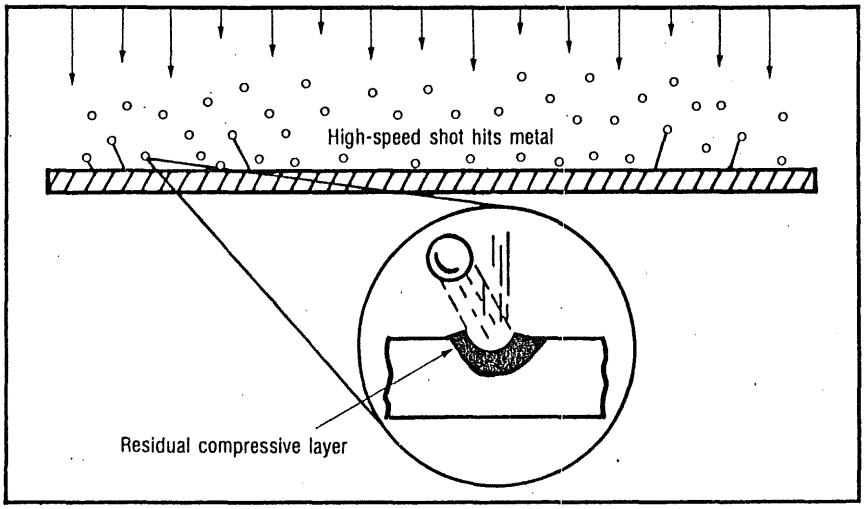
Plating tends to reduce fatigue strength. But by shot peening before plating you can have the benefits of plating without the loss of fatigue strength. Result: more durable parts...

By T. J. MEISTER
Metal Improvement Company, Inc.
Paramus, New Jersey

If you momentarily excused yourself from your metallurgical engineering class, you might have missed what little was said about a cold-working process called "controlled shot peening." You aren't alone, however, since many engineers don't understand how it improves the durability of parts, plated and unplated.

When faced with a fatigue failure, for example, engineers will usually

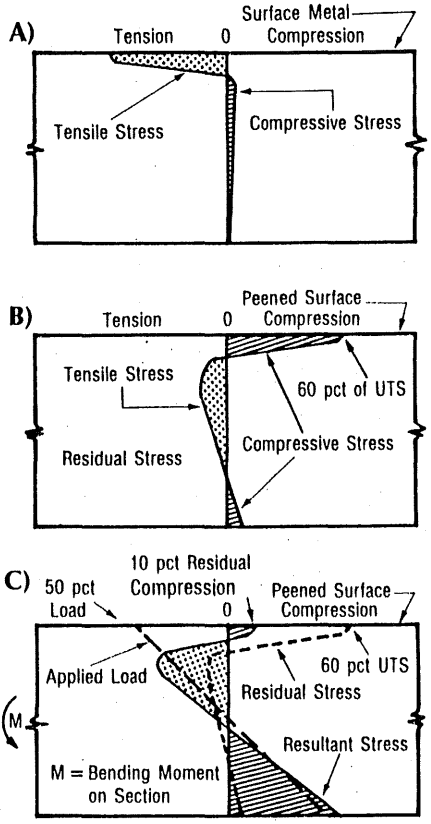
I. PEENING compresses surface layer, compressively stressing it.



redesign, re-alloy, change heat treat and so on. Overlooked is the usually more economical alternative of shot peening.

Compressive Stress. Dr. Henry Fuchs and J.O. Almen observed the life-prolonging benefits of residual compressive stress left by a crude cold working operation. By controlling the variables, they found, residual stress could be enhanced, thus dramatically improving the fatigue life and strength of metals.

Controlled shot peening is one way to compressively stress part surfaces. Shot peening involves bombardment



2. EFFECT of shot peening on tension and compression. A) Typical stress distribution in surface of metal beam, unloaded. It exhibits residual tensile stress from normal fabricating operations. B) Same beam after shot peening, still without external load. Surface stress is now compressive. C) Beam, when subjected to design loading, still shows some residual compressive stress.

TABLE I
Bend Tests of Peened and Unpeened Parts

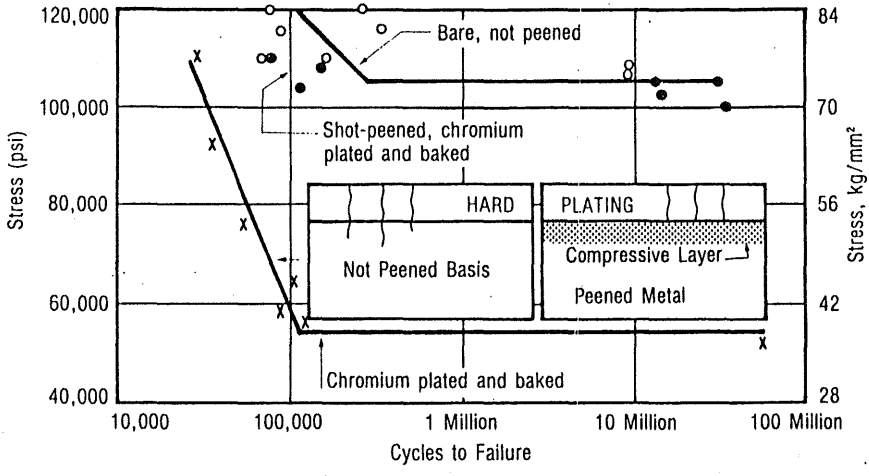
	Bend Cycles
Polished (unplated)	54,000
Shot peened (unplated)	200,000
Electroless nickel plated (unpeened)	39,000
Shot peened and EN plated	141,000

of metal parts with small, spherical, steel, stainless steel, glass or ceramic beads. The peening causes the surface of the part to yield (Fig. 1), residually compressing the sub-surface layer.

Compressive stress generated by shot peening is generally equal to 50 to 60 pct of the ultimate tensile strength of the material being peened. By peening, we have increased the fatigue strength. Since a part is usually designed so that it has to withstand no more than 50 pct of its ultimate tensile strength, a shot-peened part's surface remains in compression by a factor of 10 pct (60 pct residual-50 pct applied) when the designed-for load is applied. Even if the part is overloaded to 75 pct of its ultimate tensile stress, the net surface stress still will be only a mere 15 pct in tension (60 pct residual-75 pct applied). Fig. 2 graphically shows the effect of shot peening on the surface of a part.

Fatigue Cracking. Since nearly all fatigue cracks initiate in highly stressed areas at the surface, their propagation is retarded by a compressive layer. Fatigue cracks will not initiate in or propagate through a

3. SHOT PEENING before chromium plating improves fatigue life, as shown by these rotating-beam tests, involving 4340 steel, 52-53 Rc.



compressively stressed zone. Stress-concentration sites such as machine or tool marks, keyways, drilled holes, threads, splines, and induction-hardening runouts all can markedly benefit.

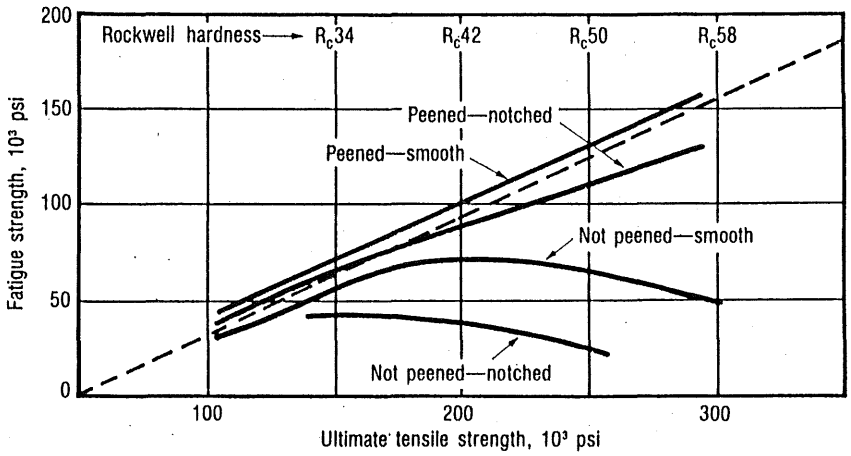
Shot Peen, Electroplate. One of the more common applications of shot peening is its use prior to the application of a nickel or chromium electrodeposit. Plating with such hard materials reduces fatigue strength of the basis metal by as much as 50 pct. Cracking that initiates in the plating may subsequently propagate into the basis material (Fig. 3). This can lead to premature failure.

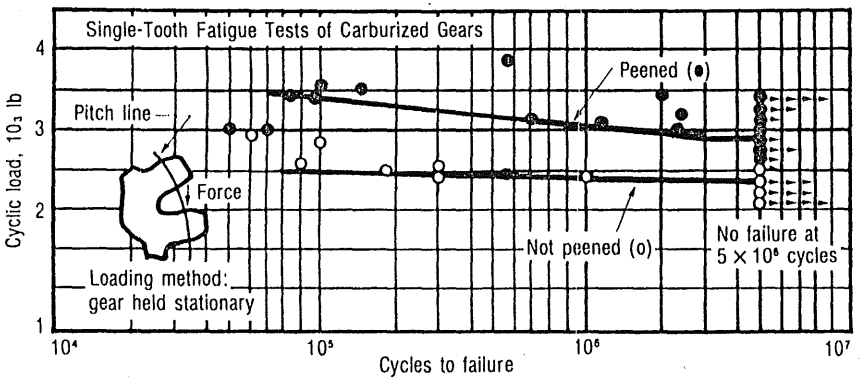
By introducing a compressive barrier on the surface of the basis metal, before the electroplate is applied, you will not prevent formation of cracks in the plating. But those cracks will not propagate into the basis metal. Therefore, a designer could expect to see about the same fatigue life from his peened and plated part that he would have anticipated had he not plated it at all. By shot peening prior to electroplating, he makes a part with excellent fatigue life as well as the wear resistance, corrosion resistance and other properties provided by electroplating. Another plus is that the dimpled surface left by peening favors good plate adhesion.

Bending type 4340 steel plated with 0.001 inch of electroless nickel and tested at 90,000 psi exhibited the results shown in Table I.

Because of such results, the military amended Federal Specification QQC-320. Any parts designed for un-

4. SHOT PEENING keeps fatigue strength from falling as carburization improves tensile strength.





5. CARBURIZED, peened planet gears from 4118 stock show increased load capacity.

limited life, subject to dynamic loads, and having a hardness above Rc40 must be shot peened and baked at 190.5C (375F) for not less than three hours. The harder the part or area (as in the case of localized induction hardening) the greater the life-prolonging results of shot peening.

How Much Compressive Stress? The amount of compressive stress is a function of the ultimate tensile strength of a material. In analysis of many part failures, we have found that increasing part hardness, followed by shot peening, will overcome brittleness and notch sensitivity. Fig. 4 shows fatigue strength improvements of as much as 3X at Rc58.

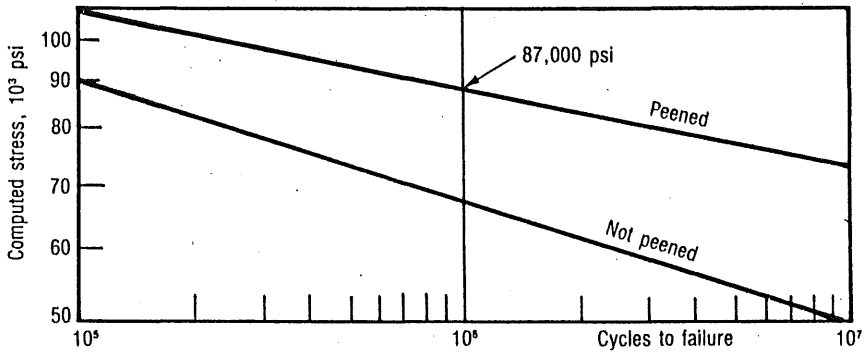
Only when the tensile stress exerted on the part exceeds the residual compression from carburizing, for example, will the part be prone over a number of cycles to fatigue failure.

Tests performed on two sets of gears (4118 stock) clearly and dramatically indicate the value of shot peening. In Fig. 5, the carburized and shot peened gears withstood 20 pct to 30 pct more load than the non-peened specimens.

In similar tests, life-cycle improvement was paramount on carburized 8620 stock. Fig. 6 shows a life-improvement factor of ten fold at a load level of 87,000 psi.

Any gear or spline is in reality nothing more than a series of cantilever beams. Typically gears fail in fatigue at the roots of the teeth or near a spline runout. When a designer must alter a part and its strength because such things as turbo chargers have been added, shot peening may avoid the tremendous cost of his alternatives: redesign or material change.

Residual Tensile Stresses. Scratches, tool marks and machining in general can leave behind residual tensile stresses and stress risers. Such condi-

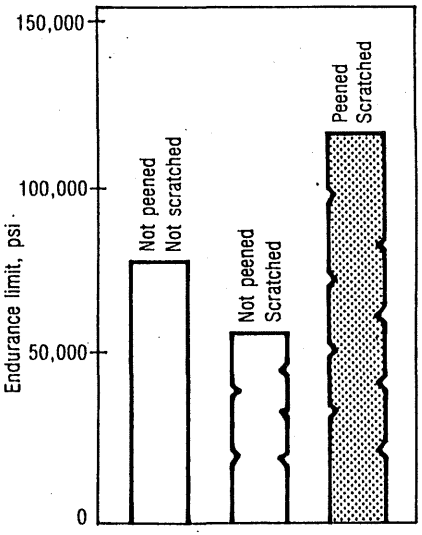


6. SHOT PEENING can improve fatigue life of carburized gears.

tions are detrimental to parts, whether plated or unplated. They can be overcome by shot peening (Fig. 7). Gear-flank frosting and high spots on the pitch line also can be negated by peening, leaving behind the compressive stress and "pounding down" the high spots.

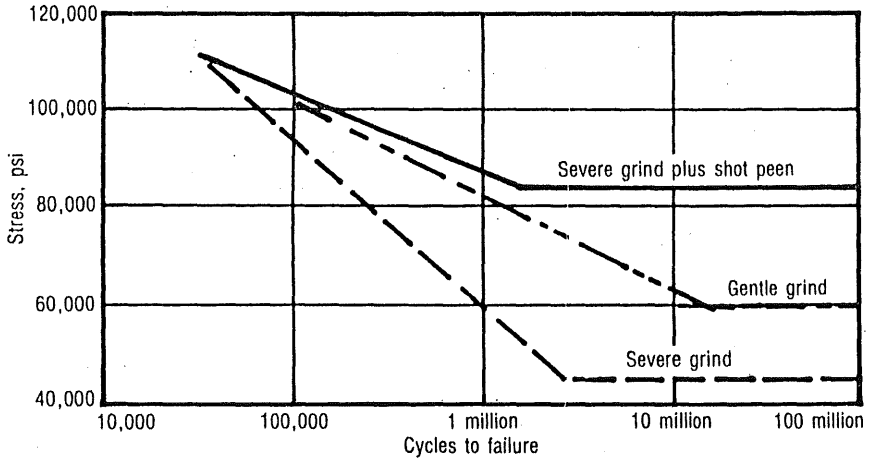
The negative effects of grinding also can be eliminated, as shown in Fig. 8. Many manufacturers have found it more economical to take a "plunge" grind followed by shot peening rather than try to control a gentle grind in a production situation.

Almen Strips. Early on, both Dr. Fuchs and John Almen recognized the need for process controls to achieve reliable, repeatable results in shot peening. A flat metal strip (1070 steel) in three thicknesses (A,N,C) is used to measure the kinetic energy of the shot stream on the target area (Fig. 9). By exposing these Almen strips to the shot stream at increas-



7. EFFECT of peening and scratches on endurance limit of 4340 steel at Rc51.

ing time intervals, an intensity curve is generated during process development. Saturation (knee of curve, Fig. 10) is reached, so that by increasing



8. REVERSED-BENDING fatigue of flat bars of Rc45.

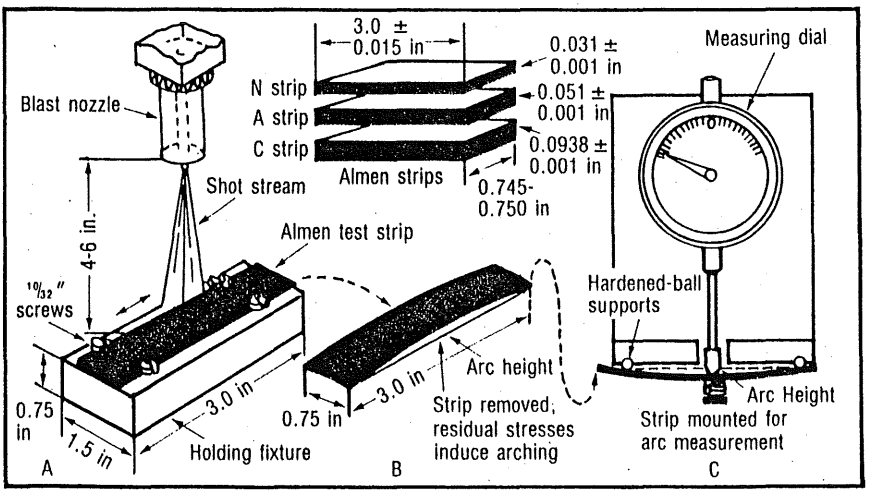
exposure time from T to 2T, no more than a ten pct increase in strip arc height is measured by the Almen gage. The Almen block holding the strips, of necessity, must be mounted in the same plane or area of the part in question before exposure to the shot stream.

Proper Shot Peening. The shot or media used, whether in set-up or production, must be kept round (Mil-S-13165B, shot maintenance). The angle of media impingement must be kept as close to 90 degrees as possible, to assure that maximum residual stress and depth are being generated (Fig.11). If the impingement angle is allowed to vary or is random, loss of kinetic energy due to "ricochet" will result. A lapping or tearing of the part surface (blasting effect) could ensue, producing a part potentially poorer in fatigue strength than the non-peened component. This lapping or tearing would be accentuated when coupled with a breakdown in media shape.

Some researchers have attempted a correlation between these surface tears or laps and fatigue life. This is a dubious exercise, since tears and laps can be avoided by employing proper shot-peening techniques.

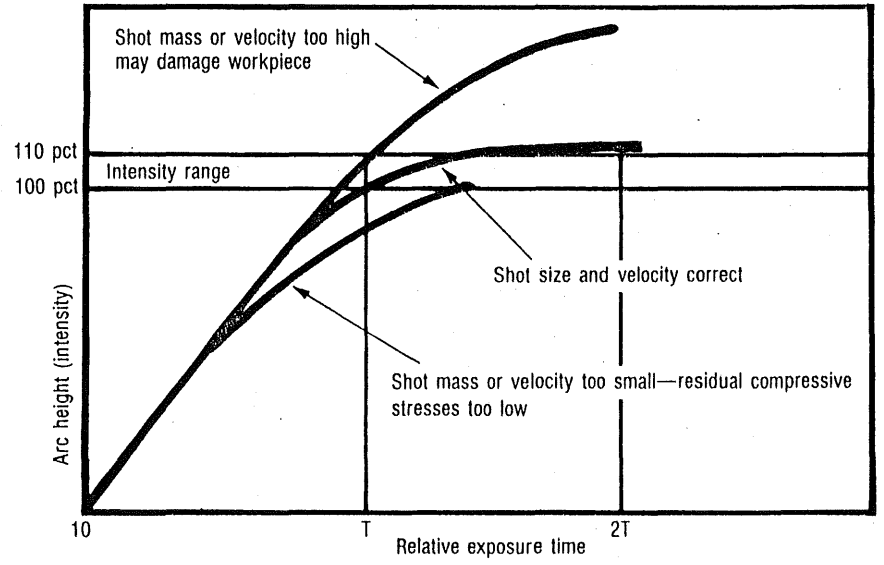
Better Controls. Newer microprocessor controls monitor shot flow, air pressure, wheel speeds, oscillation and rotation of the part. All parameters are kept within tolerances. This is the largest single advancement in shot-peening technology since J.O. Almen developed his strip.

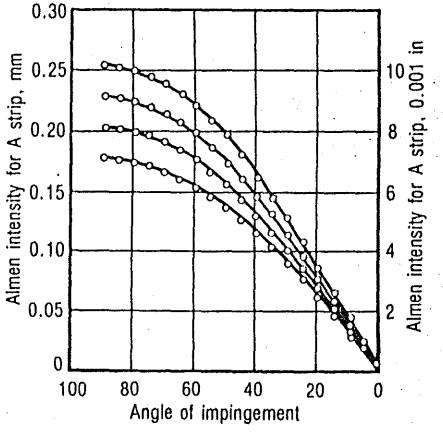
Complete Coverage. Coverage is critical in shot peening. It makes little sense not to assure complete overlapping dimples in the critical area of parts.



9. SHOT BLAST leaves residual stresses that cause Almen strip to arch. Height of arc shows intensity of peening.

10. TIME OF EXPOSURE to shot peening can be determined by running Almen strips.





11. PEENING INTENSITY versus angle of impingement.[1]

Complete coverage is shown by the application of a tracer fluorescent dye (Mil-S-1365B, paragraph 6,10-B) on the critical areas prior to peening. After peening and upon subsequent inspection under ultraviolet light, unpeened or areas ineffectively peened will fluoresce.

Being very tenacious and not readily abraded away, whether in set-up or production, the dye is an immediate indicator of incomplete surface impact or indentation.

On very hard parts, on which dimples are not readily apparent even under 10X magnification, or in hard-to-reach areas such as keyways, drilled holes and bores, the fluorescent dye proves an excellent substitute for inspection at 10X magnification.

Residual peak luminescence indicates that a uniform dimple has not been generated and the greatest compressive stress not obtained. The depth of the compressive layer below the dimple valley is readily indexed from an intensity curve.

Improves Durability. Shot peening causes metal parts to live longer. It's a technique that should not be overlooked in an industrial world that demands quality at lowest possible cost. Shot peened parts with reduced cross sectional areas may be quite adequate for a given application that could not be served if it were not for shot peening. Shot peening restores the fatigue strength a designer might have expected had the material not been electroplated. **PF**

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REFERENCES

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