CONFERENCE READINGS

1988

1988010

# Peen Finishing—Advances in Applications and Controls

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## abstract

Controlled shot peening in metal finishing alters the appearance of the surface without abrading and introducing surface tensile stresses or hydrogen embrittlement. New applications in texturizing, forming, overcoming porosity, deburring, and quality control are presented. The state of the art and the use of microprocessor controlled shot peening equipment are reviewed.

## conference

FABTECH EAST '88
April 5-8, 1988
Baltimore, Maryland

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Controlled shot peening as a metal finishing process has the purpose of changing the physical appearance of the surface. The advantage of shot peening instead of grit blasting, mechanical bending, or photographic etching is that the surface change is achieved without abrading the surface and without introducing detrimental surface tensile stresses or hydrogen embrittlement.

The list of peen finishing applications continues to expand. A summary of peenfinishing examples is as follows:

1. Texturizing
    a. Aesthetic appearance
        i. Rolls and molds for the plastics and metals industries
        ii. Automobile accessories - wiper arms to prevent glare
        iii. Architectural surfaces - stainless Statue of Liberty stairs and escalator sides
    b. Change surface roughness
        i. Lower RMS on powder metallurgy coatings
        ii. Raise RMS on automobile seat belt bars
    c. Prevent galling or scuffing - valve seats and press fits
    d. Reduce friction - clutch plates
    e. Introduce turbulent flow - prevent angel hair inside polymer pellet transfer piping
    f. Change dimensions - such as increasing shaft O.D. by as much as 0.002" (.051mm)
2. Straightening or bending
    a. Introducing aerodynamic curvature on aircraft wing skins
    b. Straightening plates or shafts
    c. Correct distortion from heat treatment on ring gears
3. Overcoming porosity
    a. Insure zero leakage on high pressure gas or vacuum containers
    b. Closing surface porosity on powder metallurgy parts or coatings
4. Deburring - remove large burrs that can't be eliminated economically with standard vibratory or tumbling methods
5. Quality control
    a. Expose subsurface imperfections
    b. Check bond on jet engine turbine component coatings and silver plate
    c. Reveal depth of induction hardening

The technology used to insure the uniformity and repeatability of peenfinishing has been transfered from the controlled shot peening process.

Shot peening as a controlled metallurgical process originated with the automotive industry in the 1930's. At this point in time, engine speeds were increased to achieve higher horse power ratings and valve spring's were failing in fatigue. It was the cold working of these compression valve springs with shot peening that provided the necessary fatigue life. As then, shot peening is used today primarily, to extend the fatigue life of crystalline metal parts; second, to retard stress corrosion cracking; and third, work harden austenitic alloys. Please note these reasons for shot peening are to change the <u>mechanical</u> properties and differ from the finishing operations described above. However, the controls are the same.

First let us see how shot peening extends the fatigue life of a metal bar bent repeatedly within the elastic limit. When the bar is flexed tensile stresses begin to build-up with the first bending moment on convex surface of the bar, while the concave surface of the bar is in compression. Eventually a fatigue crack will develop in the surface seeing repetitive tensile stresses. After shot peening the bar all over with uniform round steel shot, there by inducing a layer of compressive stresses, the convex surface will be in compression as well as concave side. The reason for this is the magnitude of compressive stresses induced by shot peening with shot as hard, or harder than the bar will be in the range of 60% of the ultimate tensile strength of the bar alloy. Good design will limit the tensile stress on the convex surface to be less than 50% of the bars ultimate tensile strength, there by leaving the convex surface at least 10% in compression and immune to a fatigue failure.

In order for shot peening to be effective in extending fatigue life the compressively stressed layer must extend below any surface discontinuities such as grinding scratches, machining marks, or heat check cracks introduced by severe grinding.

When a single piece of shot hits the surface at an intensity proportional to its mass times the square of its impact velocity, the surface will move in tension beyond its elastic limit to form a dimple. The overall effected zone is equal to twice the dimple diameter and the depth of cold work is approximately equal to the dimple diameter. The metal surrounding the cold worked impact area moved within the elastic limit and will attempt to push the affected cold worked zone back to its smaller original position, there by introducing compressive stresses. Overlapping of solid blows will guarantee a uniform layer of protective compressive stresses beneath the surface. The harder the shot hits the surface, the larger the dimple, and the deeper the depth of cold work.

The energy imparted by the shot is measured exposing Almen strips held tight on a metal block by four hold down screws, the arc height is then read over an inch and a quarter on a depth gauge called an almen gauge. The Almen strips will bend convexly on the peened side when the compressive stress depth exceeds 10 to 25% of the strips thickness. The arc height measured after 15 seconds, 30 seconds, etc. of exposure time will plot an intensity curve. When this curve levels off and doubling the time does not increase the arc height by 10% of the previous arc height reading, the previous arc height is the Almen intensity of the shot peening machine. Intensities needed for various depth of compressive stresses were developed by independent researchers.

Theoretically, dimpling 80% of the surface in a honeycombed pattern with solid blows of equal almen intensity would cold work the surface to provide a uniform stress profile. Unfortunately, not all parts peened have the flatshape of an Almen strip nor the same hardness (Rc 44-50.). Harder parts require longer peening times. Complex shapes such as helical bevel gear teeth will see impacts at low angles that rob the energy for solid impacts. Looking for overlapping dimples with a 10x glass will not give the inspector adequate indication of solid blows, since glancing blows will give a dimple, but not the proper depth of cold work. Not until a fluorescent tracer liquid was developed which may be sprayed or painted on parts allowed to dry and then shot peened; did the inspector have a means of checking coverage and shot peening machine set-up. By inspecting the peened part with a black (ultraviolet) light, just as the non-destructive testing (ndt) inspector searches for fluorescence visible where the tracer liquid seeped from cracks, the modern shot peening inspector qualifies machine operator and set-up with a black light to look for unpeened areas on the set-up piece. The properties of the fluorescent tracer liquid are such that after it is allowed to dry, glancing blows will abrade some of the dye, but won't remove all of it. Not until the part is saturated with solid blows will the black light expose the dark blue color of properly shot peened metal surface.

The latest shot media gaining acceptance is made of Zirconium Oxide having a density of 3.76 compared to 2.5 of glass, and maintaining peening roundness specifications approximately six to ten times as long as glass. Maximium intensity readings of the zirconium oxide shot approach those of the same diameter steel shot.

Peening by hand was replaced with automatic machines having shot accelerated using compressed air or centrifugal wheels. The latest peening machines have the shotstream flow, angle and position controlled by microprocessors. Computer print outs serve to certify the actual shot flow to each nozzle is maintained within a narrow band. Otherwise, the machine shuts down and flashes the reason for shut down on the viewing screen. These controls, along with replacing shot not meeting size and roundness specifications will assure uniformity and repeatability of shot peening whether it is to change the mechanical properties or peenfinishing.

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