It seems certain that the field of usefulness of shotpeening will be much enlarged in the near future, according to H. F. Moore, research professor of engineering materials, emeritus, University of Illinois. It is a process which was used but very little in the aircraft industry only two years ago but is now employed on a great number of engine parts. The automobile industry was one of the first to appreciate its advantages, especially on springs and other parts subject to fatigue.

In the aircraft industry it is used for parts where an increase in fatigue strength is of primary importance and surface finish secondary. It makes for the strongest part where minimum weight is required.

Shotpeening increases the life of a part, as realized by laboratory tests and by observations in actual service. Prof. Moore states that values of percentage increase in life in actual service have been reported for springs and automobile parts and the increase in life due to shotpeening ranges from 3 to 20 times. In one case a 15 sec. exposure to 75 lb. of No. 25 steel shot increased the fatigue life of leaf springs up to 1000%, according to the American Foundry Equipment Co.

In the Chicago plant of the Burton Auto Spring Corp. the peening machine is used 10 hr. a day, six days a week. An average of 25,000 lb. of springs have been peened daily for over a year at a cost of under $0.12 per lb. The springs for heavy duty trailers range from 10 to 60 in. long, weighing from 3 to 32 lb.

Basically, shotpeening is stretching the surface of...
Shot as purchased look like this under a magnification of 10X.

a metal part by a rain of round metallic shot thrown at high velocity. Each shot acts as a tiny peen hammer, making a small indentation in the metal surface and stretching it radially as it strikes. Stretching of the external surface, in a 0.005 to 0.010 in. layer, places it in residual compression, while the substance, not being deformed, is in a state of tension.

It might seem that the rough surface of peened steel must set up localized stress concentrations. However, there is a lowering of stress concentration at any one notch or pit by the presence of other notches or pits nearby. Many notches or pits, close together, seem to share the stress concentrations among them, while an isolated pit has no such relief from the full stress concentration.

Again the maximum stress concentration is at the bottom of a pit or notch, the spherical shot insuring a smooth pit bottom, which is a further lessening of stress concentration. Shotpeening sets up compressive stresses near the surface of the metal and these are balanced by residual tensile stresses in the metal’s interior.

Shotpeening is especially effective in cases where the part is not polished or cannot keep a polished surface. It is effective on parts subject to repeated fatigue or torsion. One must guard against overpeening and so few reliable formulas have been worked out for every case—such factors as size of shot, material of shot, striking velocity, length of exposure and angle of impact. As Prof. Moore states: “At the present time experience, developed judgment and records of performance in service of parts similar to those to be peened constitute the best basis for determining the optimum intensity of peening for any given batch of parts.”

Shotpeening can be applied to irregular shapes in which heat-treating processes might cause excessive distortion and in which rolling or drawing processes are not feasible. It can be applied to finished parts or to specific areas on structural and machine parts, as the fillet of a shaft to offset stress concentration, or to the body to resist pitting corrosion. It can be applied to gear teeth without appreciable distortion. Often it can be used as a surface finish in place of polishing, with gain in fatigue strength and less production cost.

As Applied by Pratt & Whitney Aircraft

Advanced in the aircraft engine application of this modernized process is Pratt & Whitney Aircraft, East Hartford, Conn.

Shotpeening has become standard practice at PWA on certain rocker arms, aluminum pistons, valve spring washers, articulated (or link) rods, around holes and counterweight cheeks on crankshafts and on many gears including the high and low ratio clutch oil vent gears. Experiments are being conducted on other parts such as crankcases.

How do the aircraft engineers know what parts to shotpeen? First, they learn by experience what parts have shorter life than other parts of an assembly.

Rocker arms in three stages. At top, after tumbling, but before shotpeening; at center, after peening; at bottom, completely machined before assembly, showing black oxide treatment.
Like a merry-go-round, rocker arms, with rubber masks and on individual fixtures, whirl around their track, this being a front view of the Pangborn shotpeening machine.

Second, they can anticipate potential failures in parts that are subjected to similar stresses involving flexing, vibration and other fatigue strains.

P&W A engineers claim other than the conventional advantages from peening. The surfaces hold lubricating oil better than unpeened parts, which also applies to parts that have been given a black oxide finish after peening. The peening operation in some cases, whenever it is necessary to break sharp edges, follows tumbling. Link rods and pistons, however, are not tumbled.

One of the chief secrets of the peening process is the masking of those areas not to be so treated. Two principal materials are used for masking, one a hard rubber, (70-80 Durometer reading) and the other a high speed steel of 60-65 Rockwell C. Some ingenious equipment has been devised for both applying and removing the masks in mass production style.

Presently Pratt & Whitney Aircraft, at its East Hartford, Conn. plant and at some of its satellite plants, is peening both ferrous and non-ferrous metals. The shot is of two kinds, chilled cast iron and "mallabrasive," the latter, softer than the chilled cast iron, being used for peening non-ferrous metal. Chilled cast iron shot has been found imbedded in soft metals such as aluminum, which is one reason why P&W A is using the "mallabrasive" shot for peening soft metals. Magnesium parts are not peened in production but tests as to its practicability are presently being conducted.

When that arc height is determined, nozzle locations, blast pressure, angles of shot stream and periods of exposure are set up to bring about that arc height.

The peening intensity used on Pratt & Whitney Aircraft parts is checked and controlled by inspection through the use of the Almen test strip and Almen No. 2 gage. The strips are fastened to a standard test strip block and passed under the spray of shot, with conditions simulating as closely as possible those to which a part would be subjected. This procedure is carried out twice each time the machine is started.

Peening the test strip causes the strip to arc and the arc height obtained is measured over 1.25 in. chordal length on the concave or non-peened side of the test strip. The Almen No. 2 gage indicates the arc height and it must fall within the range specified on the drawing of the part before any of the parts may be peened. Should the arc height fall out of the range specified, a change in air pressure or wheel speed, depending upon the type machine being used, will often correct the arc height to that required. The gage, with test strip in place, is presented in one of the illustrations.

Equipment for Shot Peening

Inasmuch as a rocker arm is one of the major engine parts shotpeened and originally involved several typical problems, it is well to consider tech-

Basic Principles of the Process

Pratt & Whitney engineers prefer air blast peening when it is desired to direct shot at definite small areas and mechanical or centrifugal peening for large surface areas. An essentially practical device is used to check the necessary amount of peening, since over-peening is decidedly harmful. Preliminary peening is conducted on a test strip of steel of 44-50 Rockwell C hardness to determine the size of the Norbide [boron carbide, an ultra-hard material made by Norton Co., Worcester, Mass., and described in E. L. Cady’s article in this issue] nozzle to be used, its angle of stream against the work, the air blast pressure and the number of minutes of exposure.

It is the nature of peening, whether manual or machine, to stretch the surface on which work is expended. Hence, in the case of a metal strip, the elongated top surface causes the strip to bow or arc. By experiment the ideal amount of arc is determined.

At the left is a new type rubber plate fixture to hold the rocker arm as it goes beneath the shot stream; at the right, the older type.
Here are fixtures that hold the test strip used to determine the proper "arc height" for the job in hand. The one at the left is for the horizontal nozzle; at the right, for the vertical nozzle test.

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Here are the various masks to prevent the shot from striking at unwanted areas. Called "plug tams," the various styles are large flange, taper, small flange and cylindrical.

nozzles, 3½ in. Test strips revealed the following arc height readings for the four nozzles: 0.0195 in., 0.017 in., 0.015 in. and 0.0155 in.

Only rarely are dimensions of a piece changed seriously by shotpeening. However, it was found that the I.D. dimension of high and low ratio clutch oil vent gears was definitely altered by the peening hence the gear was so dimensioned as to be 0.001 in. less in I.D. than the desired measurement after the peening.

Shotpeening, followed by sandblasting, has purposes other than improving fatigue resistance as here-tofore described. Where the finished gear is to be silver plated this procedure gives the surface a finely grained appearance, cuts down some of the turned-over edge effects and produces a more satisfactory base for the plating.

P&W A is attempting to standardize the arc heights according to hardness by establishing an arc height for steel, case hardened parts, oil hardened parts, and aluminum. In steels, the specification is not so important as the hardness.

Peening is not to be considered a cure all for such surface defects as: Magnaflux indications that are harmful, tool marks, and sharp edges. Harmful magnaflux indications are not eliminated by peening, those that appear at magnaflux before peening will appear after the peening operation, should the part be again magnafluxed. Tool marks will show more prominently after peening but the part peened will be a much stronger part if the shot used is of a size that will peen the root of the tool mark. Sharp edges on parts before peening will not be removed by this process as peening does not remove metal from the part being peened. The sharp edges should be broken before the peening operation, otherwise a rolled edge will result and should the rolled edge be allowed, the part should be peened so the edge is rolled away from the tension side of the part.

Peening, under control, at Pratt & Whitney Aircraft is becoming a widely used process and will be undoubtedly used on a great percentage of the parts going into the engine. It is of especially great value to the aircraft industry because lightness is, and always will be, an important factor, and shotpeening at the present time presents the strongest part where the minimum amount of weight is required.