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SHOTPEENING

by Fred K. Landecker
Metal Improvement Co.

THE subject of shotpeening belongs in a symposium on "the reduction of mechanical wear" because fatigue failures and breakages caused by repeated use should be included in "wear." Shotpeening is a process that will give sensational increases in fatigue life when applied to suitable parts. It is beneficial to any part which is subject to fatigue, shock, or impact. Some of the parts on automotive equipment which show the greatest life improvement are: springs of all kinds, gears, axle shafts, crankshafts, and connecting rods.

In shotpeening we pelt a metal part with fine, round shot by means of air pressure or centrifugal force. This causes a plastic flow of the surface layers and sets up a high residual compressive stress in the surface. The depth of the layer which is cold forged in this manner varies from 0.005 to 0.015 in., depending on material and intensity of peening.

Shotpeening was formerly also called shotblasting. The term shotblasting is today usually applied to the cleaning process in which grit or broken up shot is used to obtain abrasive action. In contrast to this, it is important for shotpeening that the shot used is round, as the corners of broken shot will produce scratches which will act as stress concentrations, and also it should be as closely as possible of uniform size. The shot itself fatigues and breaks up and must be separated constantly while peening. The common steel shot sizes used vary from 0.016 to 0.065 in. in diameter. The smaller sizes have much wider applications because the shot used should never be more than half the size of the radius of the smallest fillet or corner.

We are able to measure the intensity of shotpeening with a gage developed by J. O. Almen, Research Laboratories, GMC, Detroit. With this gage we use two sizes of standard steel strips, which are bolted to a holding block and passed through the same cycle of operation as the part to be shotpeened. When these strips are shotpeened on one side the compressive stresses developed in the surface cause the strip to assume a curved shape, as shown in Fig. 1. The curvature as read on the dial indicator of the Almen gage (Fig. 2) is a standard method of measuring peening intensity. With this measurement we can accurately duplicate and specify the desired peening intensity at any time. It must be understood that the same Almen intensity can be achieved in many ways, and it is imperative that it is obtained by saturation. Saturation is achieved when the part is uniformly and fully covered by peening to the desired intensity. No advantage can be expected if this is not accomplished. Fig. 3 shows two typical curves which are found when plotting Almen arc height over time of exposure. It can be seen that the curves level out when the saturation point is reached. It is important that the correct combination of variables, such as shot size, nozzle size, and air pressure or wheel speed, is used, so that the desired arc height is obtained on the level part of the curve. If that is not achieved the part will have spots which are not fully peened, and it is likely to fail. Many reports on this subject tell about the dangers of overpeening. In the author's experience,

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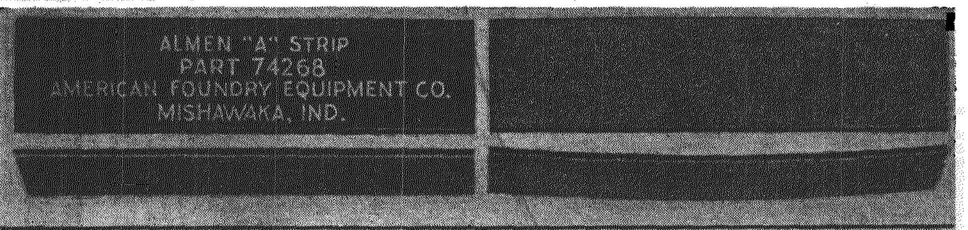

Fig. 1 (top) – Almen test strips, before and after shotpeening

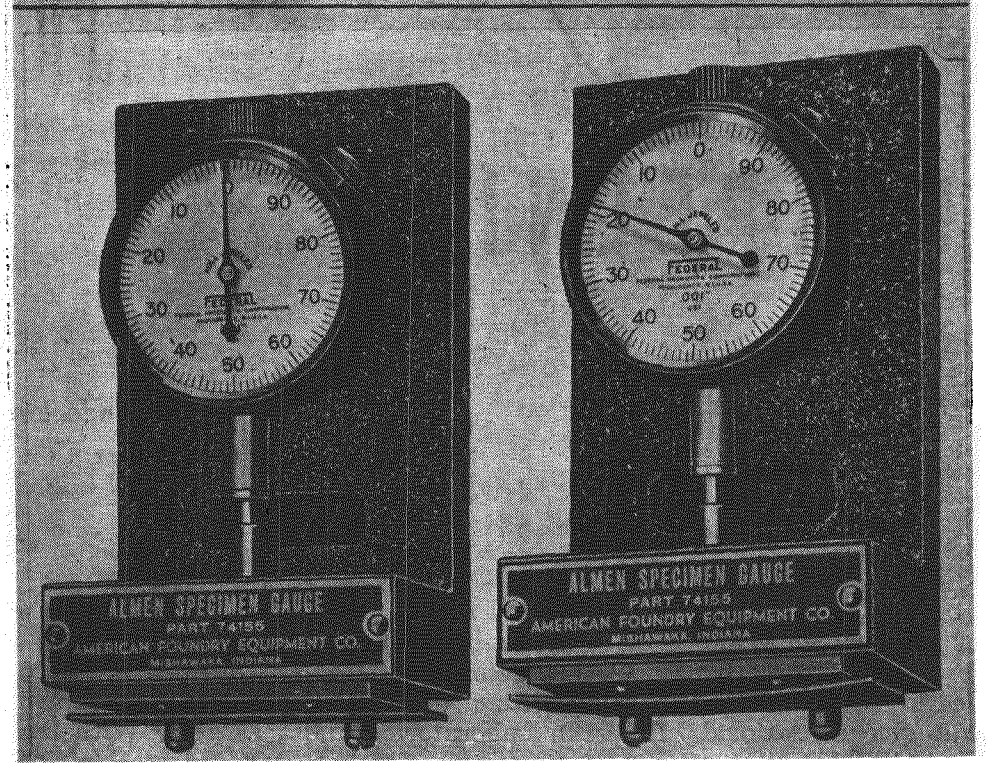

Fig. 2 (bottom) – No. 2 Almen specimen gage for measuring arc height of Almen test strips

it is nearly impossible to overpeen, while, as has been shown, underpeening is a constant danger.

Under the auspices of the National Defense Research Committee, Mr. Almen's laboratories made many tests on shotpeening during the war. The case histories of these tests have been compiled in three books. Some of the charts from them will be presented here. Fig. 4 shows the test results of the valve rocker arms used in the GM truck engine. It can be seen that the four parts which were not peened had a life ranging from 17 to 57 hr, while the 12 peened ones were tested for 140 hr, at which time one rocker arm failed. The engine which was used for this test was run at a speed of 4000 rpm.

Test results on the fork type of connecting rod for the Rolls Royce engine built by Packard Motor Car Co. are shown in Fig. 5. This chart is especially interesting because it shows that shotpeening can save many man- and machine-hours by eliminating costly grinding and polishing operations. It is indicated that the rods which were shotpeened after rough finish outlasted many times over those which were polished.

Another way how shotpeening can save money to the manufacturer is proved in Fig. 6. This shows tests on carburized, low-speed sliding gears of a Fuller transmission. The two groups of bars on the left show the life comparison of unpeened and shotpeened gears made of SAE 4620 steel. The group on the right shows that the fatigue life of carburized shotpeened gears made of SAE 1020 steel is at least as high as that of the unpeened gears made of alloy steel. Considerable savings can be obtained when facts like these are kept in mind by the designing engineer.

Test results of another gear are shown in Fig. 7. This represents the fatigue life on final-drive ring

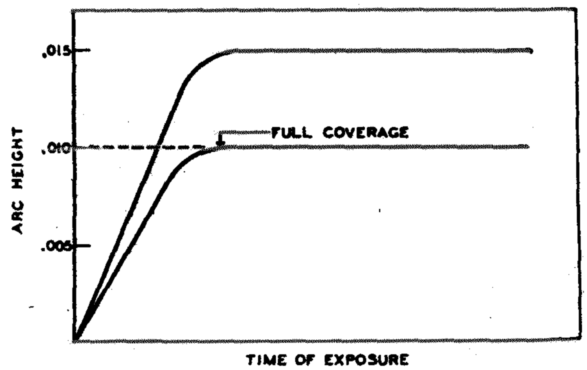

Fig. 3 – Coverage curves for two pure blasts

gears used on Allis Chalmers tractors. This picture is self-explanatory, for it shows life increases of 400 to 600%, depending on the machining process. This gear has a diameter of over 24 in. It was carburized to a hardness varying from 58 to 65 Rockwell C. The slightly rough surface obtained by shotpeening also tends to give a better lubricated part as the small indentations act as tiny oil reservoirs.

As already mentioned, springs are ideal parts for shotpeening. Fig. 8 shows an interesting test made on coil springs. The group of three bars on the right indicates minimum, average, and maximum life of 32 shotpeened production springs which have a hardness of 52 to 53 Rockwell C. The other springs were not drawn but left at a hardness of 61 to 63 Rockwell C. Those which were not peened broke very rapidly because they were too brittle. The shotpeened springs, however, lasted considerably longer than the conventional ones. This shows that the compressive stress set up in the surface by shotpeening will relieve brittleness and notch sensitivity. This fact is especially valuable if limited space makes it necessary to use high stresses in springs.

It will be easily understood that shotpeening has to be the last operation. Grinding and machining will destroy the thin compressive surface. Only a light lapping or honing operation has frequently been found to be beneficial. Fig. 9 will prove the point in a very extreme case. This shows the test results of compressor discharge valves only 0.044 in. thick. The usual high increase in fatigue life through shotpeening is shown in bar groups No. 4 and No. 5. Group No. 6 indicates another considerable increase in life as 0.002 in. was lapped from the surface. The next set of bars, No. 7, indicates that by lapping 0.003 in. from the surface, the advantages from shotpeening have nearly all vanished. This test is particularly interesting

The Author

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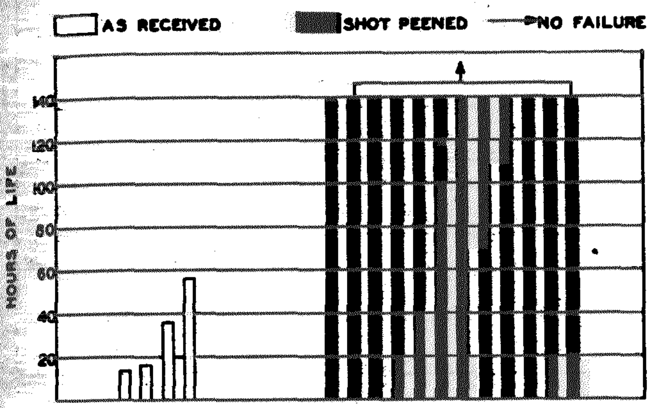


Fig. 4 – Effect of shotpeening on fatigue durability of malleablized iron valve rocker arms, engine tested

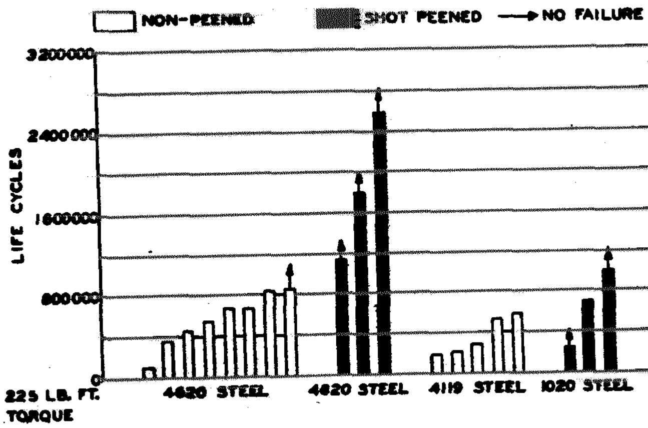


Fig. 6 – Effect of shotpeening on fatigue life of carburized transmission gears

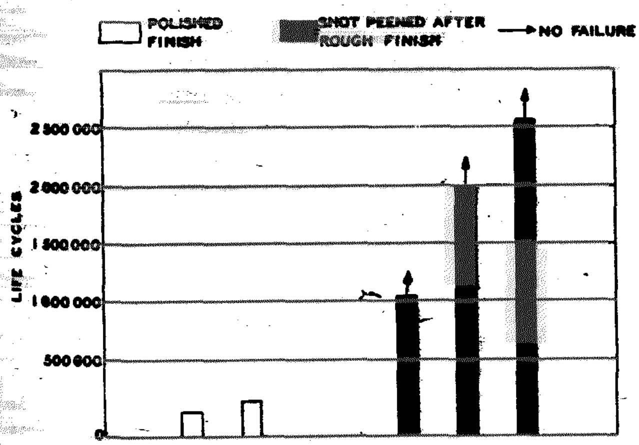


Fig. 5 – Comparative fatigue durability of polished and rough finished, shotpeened fork type of connecting rod

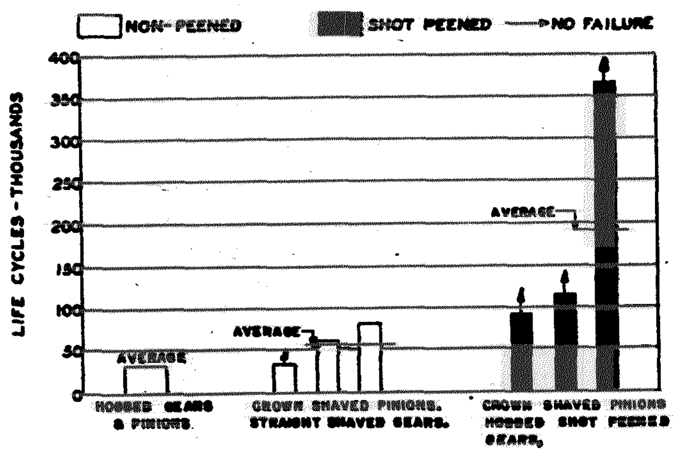
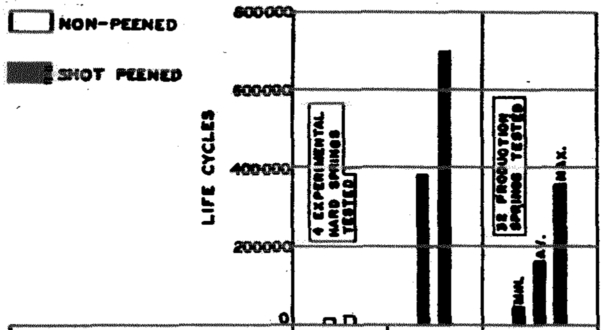
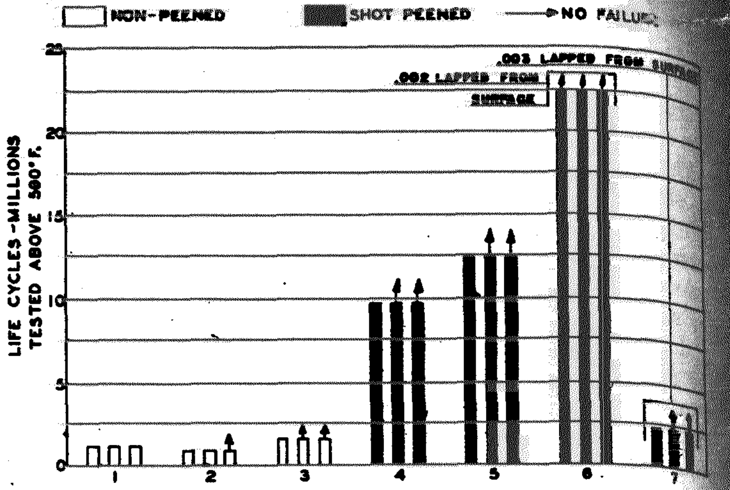


Fig. 7 – Comparative fatigue durability of tractor final-drive gears



HARDNESS ROCKWELL C	61-63	61-63	52-53
COLD PRESSED	NO	NO	YES
PEENING INTENSITY	—	—	.012 A
HOT PRESSED 50 TIMES AT	300° F.	300° F.	575° F.
PEENING INTENSITY	—	.018 A	—
DRAW	NO	NO	TO HARDNESS

OPERATIONS ARRANGED IN SEQUENCE



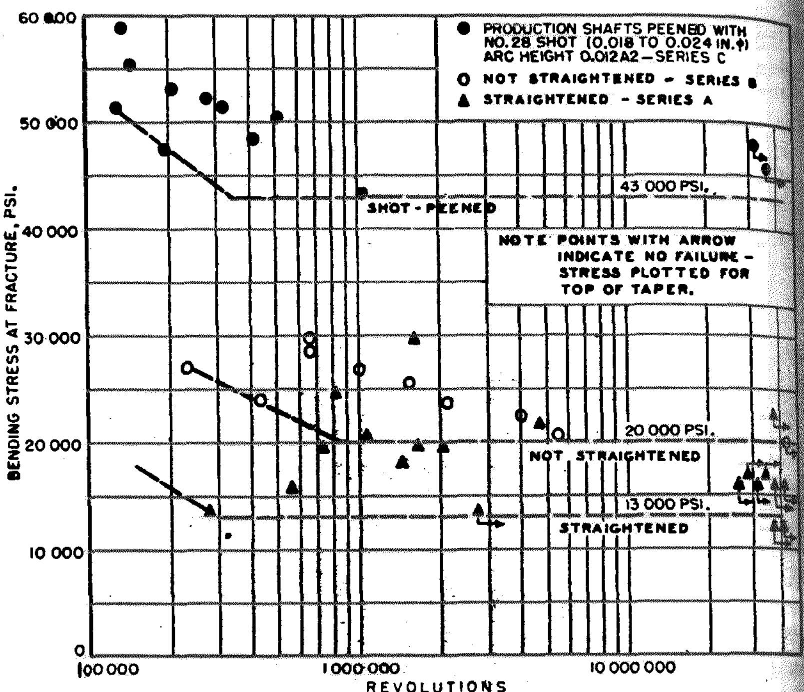


Fig. 8 (top, left — Effect of shotpeening on fatigue durability of brittle springs as compared with that of softer, production springs

Fig. 9 (top, right) — Comparative fatigue durability of air compressor discharge valves shotpeened, nonpeened, and shotpeened and lapped — tested at over 500 F

Fig. 10 (right) — *S-N* data on fatigue tests of rear-axle shafts

because the valves are very thin and had to be peened very lightly and because they were operated at a temperature above 500 F.

Fig. 10 is taken from a paper by O. J. Horger and C. H. Lipson.[1] They report that shotpeening of straightened axles gives about three times the endurance limit of those not peened. This chart gives the *S-N* data on fatigue tests of rear-axle shafts. It indicates an endurance limit of 13,000 psi for the straightened, 20,000 psi for the not-straightened shafts that were not peened, and 43,000 for the shotpeened, production shafts.

These charts should give some idea of the tremendous increases in fatigue life which can be obtained by shotpeening steel. Shotpeening has been found to be just as effective on nonferrous metals. On some of these, as on magnesium and soft aluminum, it is necessary to use nonmetallic shot made of walnut shells, apricot pits, plastic, or glass. Shotpeening, as any work-hardening process, also produces a slightly harder surface. In some of the work-hardening metals as high manganese steel and inconel, the increase in skin hardness is quite substantial.

It was mentioned in the beginning that shotpeening sets up a residual compressive stress in the surface. Usually, we read about residual stresses only as harmful stresses. Residual stresses can also be used to our advantage and this is done very frequently, chemically by nitriding and carburizing and mechanically by shotpeening and surface rolling. To be valuable these residual stresses in the surface must be compressive because it has been proved frequently that a surface in compression will not fail. As practically all fatigue failures

(concluded on page 200)

[1] See "Automotive Rear Axles and Means of Improving Their Fatigue Resistance," by O. J. Horger and C. H. Lipson, in ASTM Technical Publication No. 72, 1946, "Symposium on Testing of Parts and Assemblies."