How Shot Blasting Increases Fatigue Life

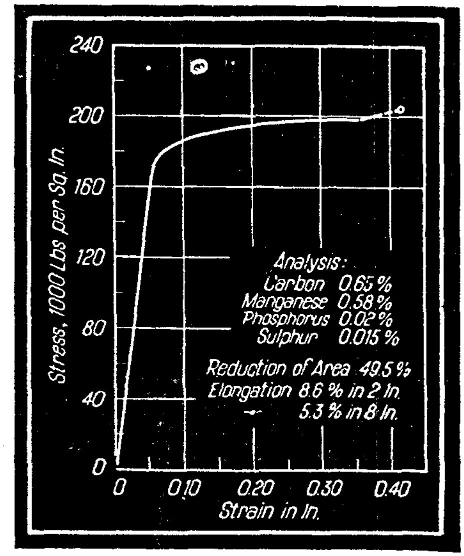

Fig. 1—Stress-strain curve for valve spring wire, heated to 750 degrees Fahr. after coiling but not pressed

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SHOT blasting has done more to increase fatigue life of our small springs than any of the alloy steels ever used. This statement is based on tests conducted on a large number of springs, most sizes being less than ¼-inch in diameter, although some were up to ¾-inch.

In the investigation the first runs were made to study effect of time of exposure to shot blasting, with all other conditions held constant. It was appreciated that this factor was of prime importance and would vary somewhat with each type of spring and method of treating. A bundle of valve spring wire was selected, size .162-inch, for these tests. Physical properties of this wire and its chemical analysis are shown in *Fig.* 1. The springs were 1-7/32-inch outside diameter, 3¾ active coils, 1⅞-inch free length, ends squared and ground. They were heated to 750 degrees Fahr. after coiling and of course were not pressed. Fatigue range before shot blasting was 20,000 to 95,000 pounds per square inch. The astounding results of the shot blasting are shown in the results presented in *Fig.* 2. Maximum stress has increased in this test about 42 per cent, a greater increase than any other known treatment even approaches.

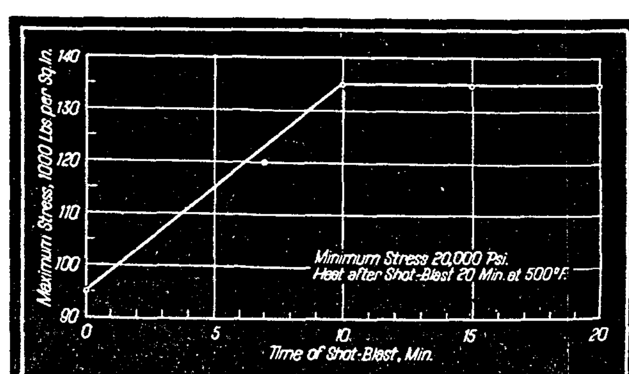
In the commercial shot blasting of small springs the duration of the treatment is a function of the number. When too many springs are put in any machine, mechanical or air type, they will not be properly treated. Exact details depend on the machine and type of work and can be determined only by experiment.

What causes this increase in life and what affects it? More of the springs were properly blasted and heated afterwards to various temperatures, with the results shown in *Fig.* 3. At 825 degrees Fahr. we have the same stress range, 20,000 to 95,000 pounds per square inch as before the blasting. In other words, this heating has removed the beneficial effect of the shot blasting which apparently was nothing but cold work of the outer fibers. Reblasting will reproduce the same high fatigue resistance.

Effect of size of shot was investigated, using shot 1/64 and 3/64-inch in diameter, amounting to a difference in shot volume of 27 times. But the same type of wire gave the same fatigue limit with either shot size, with one slight exception. Springs set high enough in stress range to break ran longer when blasted with the small shot. When larger spring wire was tested, however, results were a little better with heavier shot.

Material in a straight section was carefully polished with jewelers' rouge of the same grade as used to prepare metallographic samples. This was tested and found to have a torsional fatigue life less by far than the blasted springs gave. Further testing indi-

Fig. 2—Maximum stress in wire has increased 42 per cent after shot blasting. Effect of time of shot blast is evident



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cated that wire can be produced and blasted so that the resulting compression spring is self-protecting. This is done by proper heating after coiling so that the spring if overloaded will set to a load corresponding to a stress the material will withstand. This spring will then give, so far as our testing is concerned, infinite life.

A rough surface, it was found, is not a sure cause for spring failure, and even springs with surfaces pitted by shot blasting have a greater fatigue life than those with a normal smooth surface. This result is undoubtedly obtained in spite of, and not because of, the roughness.

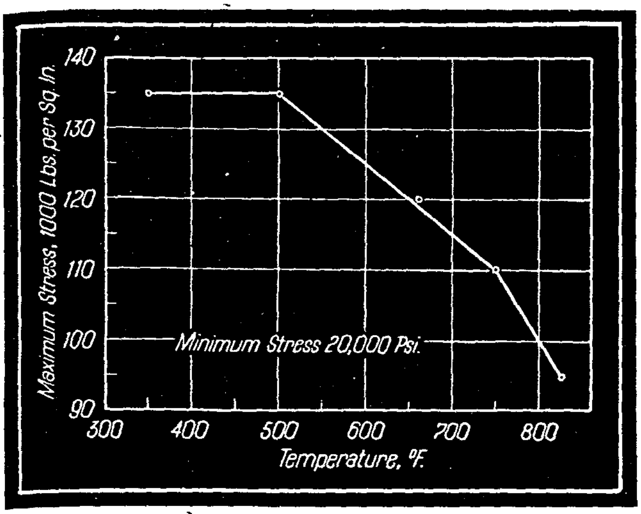

Fig. 3—Heating has removed the beneficial effect of shot blasting. Reblasting will reproduce high fatigue resistance

Unfortunately much material used is not perfect. Tests were run on slightly decarburized wire. As received and tested with no blasting this wire was more than 5000 pounds per square inch below the normal fatigue range, the value taken for this steel being 20,000 to 88,000 pounds per square inch. Springs were shot blasted and found to have a fatigue range of 20,000 to 115,000 pounds per square inch, a loss due to the ferrite of 20,000 pounds per square inch after blasting.

In this case, however, the springs that broke because of overstressing lasted longer when heavier shot was employed in contradiction to the experience with good wire of the same size. This indicates that poor wire cannot be improved as much as sound material. The comparative results between large and small shot on this steel are logical if one pictures the larger shot carrying enough energy to cold work the steel through the decarburized surface. On the better steel this was not necessary. The small shot which cold-worked sufficiently and roughened less was the better until larger wire with lower tensile strength was used. Then the larger shot began to have more effect.

Experiments with softer shot or shot that was heated to reduce its hardness gave on sound wire the same fatigue values despite the fact that the surface appeared smoother. Examination under the binocular microscope showed enough larger pits from the blasting so that, despite the visual appearance, the surface itself was not for practical purposes very much altered.

Tests on springs made of defective wire show that no improvement results from shot blasting if seams or hairlines are present. On wire that is badly gouged, either by the wire maker or the spring producer, shot blasting apparently has not reduced stress concentration or increased life to any great extent. With scratches round enough at the bottom (as most mechanical scratches are) a normal increase in endurance was obtained by shot blasting. Scratches up to ¼ of 1/1000-inch deep can be removed, but except for this and the improved looks of the part, no shot blasting is of help. The process will not be a cure for either defective steel or manufacturing methods.

TABLE I

Material of Spring	Normal Stress Range lbs./sq. in.	Shot Blasted Stress Range lbs./sq. in.
Valve spring wire........	20,000 to 95,000	20,000 to 135,000
Music wire S.A.E. 1095....	20,000 to 90,000	20,000 to 135,000
Electric furnace	20,000 to 90,000	20,000 to 135,000
18-8 Stainless	20,000 to 65,000	20,000 to 110,000
13-2 Stainless	20,000 to 80,000	20,000 to 120,000
Phos. bronze S.A.E. 81....	20,000 to 35,000	20,000 to 50,000

As a result of years of testing we believe that on wire sizes less than .207-inch, TABLE I shows the effect of the shot blasting accurately. Use of the highest stresses is not advised because the springs will set, or lose load to some extent, depending on the temperature to which the springs are exposed. No runs were made at temperatures above atmospheric and few tests were continued beyond ten million cycles. On phosphor bronze or nonferrous metals with indefinite fatigue ranges this must be considered in design. TABLE I is based on using .148-inch wire.

Shot Blasting Provides Longer Life

On wire sizes larger than 7/32-inch, gains have been made in the endurance of the springs, although the stress range does not increase in as great a percentage. These springs have in the most part no great call for a real endurance range. They are used at stresses which will break them in time, but the number of stress applications in the life of the unit is less than they will withstand.

Thus, by shot blasting, coiled automotive chassis springs may now be designed up to the elastic limit since trouble will be encountered not by breakage but by loss of load due to the spring not returning to its original length. In 1934 this was not so; springs were stressed lower to avoid breakage since shot blasting machines were not designed to handle these springs.

It must be realized that the increase in life of the part may be increased several hundred per cent with but a small percentage of increase in fatigue life.

This article has dealt with coiled springs, but the process can be applied to many parts. Thus in clutches using Belleville washers the shot blast has provided safety never before enjoyed. It may be used on torsion bars, base of gear teeth, axle shafts, in fact any highly stressed part if the surface does not need to be exceptionally smooth.