Fig. 1—*Appearance of the surface of hardened and tempered carbon spring steel after shot blasting, shown at 12 diameters*

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Shot Blasting

. . . . prolongs life of leaf, torsion and helical springs

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THE SHOT BLASTING of springs as a means to promote increased fatigue life has been recognized and practiced for many years. The advantages to be obtained from blasting were recognized from the outset; but extensive acceptance of the process has been delayed until recent years, when better equipment and methods of control were developed and a better understanding of the process was made available. J. O. Almen of the Research Laboratories Division of General Motors Corp. has been outstanding in developing the scientific objectives of the shot-blasting process by postulating the basic elastic theory involved and by showing the necessity for controlling and measuring the operation in order to obtain optimum results.

In basic terms, shot blasting is effected by slinging round chilled iron shot at a relatively high speed against the surface of the work in process. Considerable experimental work is in progress to determine the proper size of shot and speed of impingement with respect to the size of the work being blasted in order to obtain the best results, but for most springs current practice is to use shot of 0.025 to 0.030-inch diameter and an impingement velocity of about 200 feet per second. In consequence to the impingement of the shot, the surface of the work assumes a rough, pockmarked appearance due to the brinelling of the shot, much as if the work had been pounded by innumerable minute ballpeen hammers as shown in Fig. 1.

The peening action of the shot causes the surface of the metal being blasted to stretch in all directions during the time of impingement. This causes a plastic flow of the surface fibers which are stretched beyond their yield point in tension. Fibers a rather short distance below the surface, however, are not stretched to their yield point and retain their elasticity. After impingement, these inner fibers force the outer fibers to return to a shorter length than the length at which the overstrained outer fibers tend to remain; and the equilibrium which results *finds the outer fibers subject to a residual compressive stress* while the inner fibers are in tension.

Experimental work by several investigators indicates that the residual compressive stress extends to a depth of 0.005 to 0.010-inch below the surface and that the value of the compression stress on the surface is several times that of the tension stress in the interior of the section.

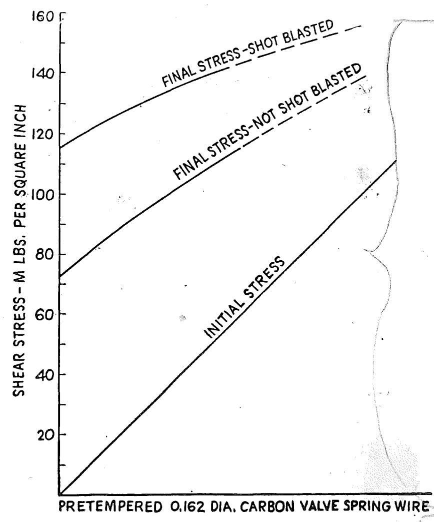

Fig. 2 — *Modified Goodman diagram showing final stress to which a spring may be subjected for any given initial stress in the operating cycle, the spring to have indefinite life without failure*

The compression stresses which are caused to exist in the unloaded state by the shot-blasting operation directly reduce the tension stresses produced by the bending of such springs as leaf springs and torsion springs. The residual compression stresses do not affect the value of the shear stresses existing when helical springs such as automotive valve springs and chassis suspension coil springs are loaded; but on the other hand, the residual compression stresses respectively decrease the tension component and increase the compression component of the shear stress. *In both cases, the net effect is a gain in life,* an index which lends credence to the concept advanced by J. O. Almen that *fatigue failures result from tension stresses, never from compressive stresses.*

In the shot blasting of springs, the Eaton Mfg. Co. pays particular attention to the development and selection of equipment for the proper exposure of the work to the blast stream. The details of the equipment, therefore, are varied to suit the type of spring to be blasted, but the use of high speed slinger wheels is common to all units. The shot flows by gravity through a feed tunnel into the hub of the slinger wheel. The shot then travels from the hub to the periphery of the slinger wheel along radial blades, gaining momentum as it moves outwardly by centrifugal force along the rapidly revolving blades. A control cage between the feed tunnel and the slinger hub permits adjustment of the direction of the blast stream.

After impingement on the work, the shot falls to the bottom of the blast chamber from which it is carried by conveying and elevating means to an overhead storage. From the storage point the shot again travels by gravity to the feed tunnel and the impeller to repeat its working cycle. Means are provided to exhaust the dust incidental to the operation, and to provide for the removal of scale, dirt and fine broken shot.

The practice at Eaton is to convey large coil springs through the blast stream by a conveyor chain arrangement carrying pins, which push the springs axially as the springs rotate on two revolving pipes. Medium size coil springs are shot blasted in equipment similarly arranged, the main difference being that narrower faced slinger wheels are used as less shot feed is required.

Smaller coil springs, such as automotive and aircraft engine valve springs, are treated in another manner whereby pins on a conveyor chain cause the springs to roll through the blast stream, the axis of the springs being normal to the major axis of the shot stream. Still smaller coil springs, as well as small flat springs, spring stampings and other items which do not permit individual exposure to the blast stream are blasted in a tumbling chamber which tumbles and cascades the work beneath the slinger wheel. The individual plates of leaf springs are blasted as they are carried through the blast chamber by a conveyor chain arrangement containing pins over which the center bolt hole in each plate is inserted. It has been found necessary only to shot blast the concave, tension side of leaf spring plates to obtain optimum results.

If shot blasting is performed in a careless, haphazard manner, the operation degenerates into a mere cleaning operation having slight, if any, measurable effect on fatigue life. Every effort must be made to assure that the shot be kept in good condition and be used generously; that sufficient impingement time is allowed, and that the equipment be maintained in satisfactory operating condition. Maintenance costs are high and the operation is by no means a cheap one; but the overall expense is nominal when one considers the return in terms of results.

It is apparent then that the shot blasting must be subjected to controls to make sure that optimum results are being obtained in production. The degree of blasting to be given any particular design of spring can be determined by judgment based on a background of fatigue testing of similar springs, but the control of this degree of blasting involves many factors.

The shot blasting of leaf springs is more amenable to control than that of coil springs. In the case of leaf springs, the shot blasting produces a change in the curvature (increases the curvature) of the plate. This change in shape requires that the plates must be formed initially to a lesser radius of curvature than is required to carry the specified loading in the finished state. Gaging the shape of the plates after shot blasting by one means or another, is therefore a valuable indicator or guide for use in controlling the shot blasting of leaf springs.

The control for shot blasting coil springs is more difficult, as there are no measurably apparent external distortions to serve as a guide to show amount of peening action that has taken place. For coil springs, however, use can be made of flat strips fastened to a heavy flat base by set screws, and passed through the shot blasting machine in a manner assuring that the same impingement is given the strip as is given the surface of the spring. After release from the base, the impinged surface becomes convex and the curvature can be measured. Such control specimens, as developed by J. O. Almen, can be used to facilitate production control of any type spring so long as care is exercised to assure that the specimens are subjected to the same impingement as the springs.

Some idea of the advantages of shot blasting where endurance life is concerned can be obtained by considering the modified Goodman diagram of Fig. 2. This diagram shows the final stress to which a spring may be subjected for any given initial stress in the operating stress cycle, the spring to have indefinite life without failure.

Springs were made from pretempered ASTM 230-41 carbon valve spring wire of 0.162-inch diameter and were fatigue tested after half the total number of springs had been shot blasted while the remainder received no surface treatment. It is to be noted that the shot blasting increased the endurance limit above zero stress from 72,000 to 115,000 pounds per square inch.

Another point of interest concerns itself with the spread in fatigue life of springs made from the material used in the determination of the endurance diagram of Fig. 2. In each case, 33 of these springs when tested through a range of stress from zero to 120,000 pounds per square inch showed a comparative scatter in the cycles for failure as follows:

Cycles	Shot Blasted	Not Treated
Minimum	400,000	40,000
Maximum	5,000,000	200,000
Average	2,000,000	50,000

Numerous investigators have found that the scatter obtained in their fatigue test results increases as the test stress approaches the endurance limit. In the test of the shot blasted springs in a zero to 120,000 pounds per square inch test cycle, the spread from the longest life to the shortest was 20 to 1. But note that the endurance limit was zero to 115,000 pounds per square inch —very close to the test stress. When the untreated springs were tested through the same test stress range, the corresponding scatter was 5 to 1. The endurance limit was but zero to 72,000 pounds per square inch for these untreated springs.

In testing shot-blasted springs against untreated springs through a given stress cycle, therefore, one should expect a greater scatter in the test results of the shot-blasted springs as the endurance limit of the latter is raised and approaches the test stress in value.

There is some experimental evidence to indicate that minor surface imperfections which are harmful to untreated springs, can be tolerated in the shot-blasted product. Perhaps the reason for this tolerance lies in the 0.005 to 0.010-inch deep compression layer existing on the surface of the metal due to the peening action of the blasting. However, any seams or other defects *which*

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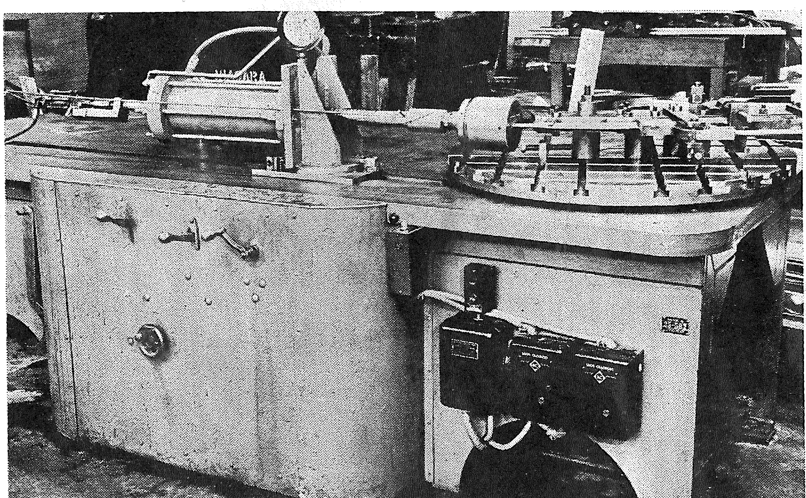

ROTO-STRETCHER: This unusual machine has been developed by Goodyear Aircraft Corp. to bend and stretch metal parts for aircraft. Supplanting an earlier parts forming system which employed conventional metal dies and a considerable amount of hand labor, this piece of equipment shapes wrinkle-free parts with speed and economy never attained before. Arrangement of keyways across face of mandrel permits wide range of adjustment in positioning radius pins

kilovolt amperes with these new cores; a 7½-kilovolt ampere unit gets a new rating of 10 kilovolt amperes, etc. This is accomplished without requiring additional core, copper or insulating material and also saves tank, bushings, etc.

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extend well into the shallow compression layer lose none of their objectionable nature despite the blasting treatment.

On specimens where only a portion of the surface is to be shot blasted, the portion where peening is not desired can be masked effectively by a layer of ordinary adhesive tape. It is believed that an excessive layer of total decarburization on the surface of the metal behaves much as the adhesive tape does. In any case, the gain in life secured from shot blasting badly decarburized steel is so slight as to make the blasting scarcely worthwhile. Where the original as-received surface of stock is considered in conjunction with its subsequent heat treatment, all the results secured to date warrant the generalization that *shot blasting makes good steel better, but has little, if any, beneficial effect on poor steel.*