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SHOT PEENING TECHNIQUES FOR GREATER FATIGUE LIFE IN SPRINGS

Robert A. Bell
Corporate Vice President,
Manufacturing
Precision Spring Corporation
Detroit, Michigan

A long-accepted practice for extending the fatigue life of high duty springs is shot peening. According to historians, this process was discovered by accident at a time when improving the performance of automotive valve springs was of paramount importance to the rapidly expanding automotive industry. The story goes that some engineers felt that clean springs might give better fatigue life and, to that end, parts were tumbled in sand to remove all of the extraneous matter from the surface of the wire. While this procedure produced some small improvement, it left much to be desired in the final evaluation but, since clean components did perform better than dirty parts, the operation was added to the manufacturing specifications for valve and other types of high-performance springs.

It was not until a shop hand ran out of sand one day and substituted small gravel in the tumbling operation that a significant improvement in performance was attained, and someone finally realized that it was the impact of the media on the surface of the wire, and not cleanliness that was beneficial to extended fatigue life.

From this relatively crude beginning, a whole new world of shot-peening technology opened up for the manufacturer of high performance springs, and this science is still being expanded to keep pace with ever-increasing demands for higher stresses and more restricted operating parameters in the industry. In the October 1982 issue of SPRINGS Magazine the article "Shot Peening Springs" was presented. Since that time, some further information pertaining to state-of-the-art in peening has developed, and this article is intended as a supplement and update to the 1982 presentation.

"Shot peening" and "shot cleaning," are sometimes used interchangeably, but definitely should not be confused as being even remotely related. Shot cleaning (often referred to as "shot blasting") is exactly what the name implies. The process consists of subjecting parts to a tumbling operation for the purpose of cleaning the surface prior to painting or some other secondary operation, and is intended to have no predictable results on the fatigue life of the springs. Old and/or split shot is often used, and certainly is sufficient for the purpose intended.

In contrast, shot peening is a carefully monitored process in which the media is frequently screened to remove split shot, and time and intensity are closely controlled to obtain the desired benefits of this operation. Broken or split shot can frequently negate the beneficial effects of peening, as the sharp edges may actually cause minute stress risers on the surface of the wire, thereby creating a nucleus from which a fracture can spread. This condition was not nearly so serious when springs were subjected to relatively reasonable stress levels, but with current definitions of "high duty" components in certain industries, any imperfection in the surface of the wire is a potential source of stress risers that will be detrimental to fatigue life.

A quotation attributed to the late Dr. Zimmerli of Associated Spring Corporation is "You cannot make good springs out of bad wire by shot-peening," and while this operation may well improve the life of parts fabricated of seamy or pitted wire by rounding the edges of the imperfection and making the defects more shallow, the results are totally unpredictable and cannot be translated into a finite percentage of improved life span for the defective unit.

With the advent of smaller cars, space and weight parameters were reduced accordingly, and the necessity for power train and clutch springs to operate at higher stresses in these confined areas became a matter of paramount importance. Significant improvements in the quality of carbon and alloy valve spring wires permitted designing to high stresses and justified the premium material costs, but the drive for smaller and more highly stressed parts continued.

Until recently, the amount of compressive stresses remaining in the surface of the wire after peening was largely a matter of conjecture, but, with the development of x-ray diffraction, the measurement of residual stresses and their magnitude have become a much more exact science. Without going into a technical explanation of the process, it is sufficient to say that x-ray diffraction has made it feasible for engineers to measure residual stresses both on the surface and sub-surface of the wire, and enables them to evaluate the effects of various processes implemented to improve peening results in the effort to increase fatigue life. While this method of evaluation still has some shortcomings in supplying finite information, it is presently far and away the best currently available procedure for comparing results to known data to determine the effects of changes in peening processes.

At the present time, the effects of double shot peening operations are being studied, and the results to date seem to indicate that a significant improvement in fatigue life can be realized by the utilization of this program. Although the added peening represents an extra operation and thereby increases costs, some customers are finding that this is of secondary importance in view of the high stresses and greater fatigue life obtainable in the finished product.

In double shot peening, the first peening operation is performed in the conventional fashion (12 min. using SAE J 827 cast steel shot to attain an arc height of .012-.018 in. on Almen A strip #2 gage) with a subsequent heat treatment of 425-450°F (220-260°C) for 30 min. The specifics of this operation may be varied slightly to attain desired results for various types of materials in certain applications, and should be determined by actual fatigue tests to obtain optimum properties.

This treatment is then followed by a second peening operation with smaller shot at lower intensity (example: S-170 shot size peening to .006-.012 in. on Almen A strip #2 gage) followed with a similar heat treatment. While the first peening cycle tends to drive the compressive stresses deep into the wire (.005-.020 in.), the secondary operation results in higher values at or close to the material surface. Preliminary data seems to indicate that this combination produces a marked improvement over a single treatment procedure. Reversing the procedure (small shot—low intensity first, larger shot—higher intensity second) proves to have very few, if any beneficial effects over the single peening system, and, therefore, seems to merit no further investigation at this time as an additive to fatigue life.

It may also be significant that, under high magnification, the single shot peened surface tends to show distinct peaks and valleys, while the secondary operation smooths out the high spots theoretically eliminating potential stress risers. The fact that, under high magnification, fatigue breaks appear to start at these high points would seem to indicate that this theory has some validity and the double peening may be expected to add materially to fatigue life of springs stressed above that which is now considered to be safe levels.

With the advent of alloy steels into the valve spring arena, further investigation was conducted into the feasibility of employing harder shot in the peening operation. While cast steel shot at 42-50 "C" Rockwell may have been sufficient for carbon valve springs, there is always some question as to how much benefit is being obtained by peening parts with a material that is no harder (and in some cases softer) than the wire being processed. Investigation discloses that shot in the 55-60 Rc range added substantially to the fatigue life of chrome silicon springs when compared to those processed in a softer media, but also broke down faster, necessitating more frequent screening and adding of new shot, thereby increasing the cost of the operation.

At this point, however, the combination of better material, double shot peening, and the necessity of increased surveillance of harder shot materials has resulted in costs which certain segments of the industry have accepted as the price which must be paid to obtain high performance parts that will operate in the confined spaces being allocated for springs in the "Smaller is Better" philosophy that is the keynote of today's technologies.

One problem that has yet to be satisfactorily solved is the tendency of some springs to tangle in peening. If the wire size of the spring is less than the opening between coils, tangling tends to occur, and this situation is aggravated by the rotary tumbling action employed in most batch-type shot peening machines. Aside from the fact that tangled parts complicate any subsequent operations (assembly, testing, identifying, etc.), there is some question as to whether or not the inside diameter (I.D.) of tangled springs is receiving full benefit from the peening process. To date, no significant comparison figures are available to the industry, but with the continuing efforts to impose high stresses on existing spring materials, such studies will soon be underway, as the results may have a very marked effect on the design of future high performance parts.

At least three remedies for the tangling problem have been tried by various springmakers, but all results seem to leave something to be desired. "In-Line" peening is being used in Europe and, to some extent, in this country as well. This method consists of utilizing a belt to carry the parts through a chamber where they are individually exposed to various streams of shot. Some systems rotate the parts as they pass through the chamber, thereby insuring better exposure to the peening media. While no published data is readily available, there is some question, however, as to how much shot penetrates the I.D. of the spring ends, and this may result in insufficient coverage of the last active coil(s) of the part.

While this system may have some advantage over batch peening, it does not seem suitable for high-production implementation as it appears to be far slower than conven-

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tional methods and would add considerably to the cost of the parts. This procedure may prove to be beneficial for smaller lots of high-performance parts, such as are employed in racing engines, but in its present state, would probably be much too costly for automotive valve springs or other high-volume applications.

Another remedy for tangled parts due to tumbling in a shotpeen machine is to design the springs with additional dead coils on the ends. This practice has proven to be an asset in preventing the meshing of coils that produce tangling, but is counter-productive in the effort to reduce the envelope in which the parts must operate, in that it increases the solid height of the springs. It also adds additional weight to the parts, and, thereby, is a questionable solution at best.

Some springmakers have attempted to sort out the tangled parts, separate them, and re-peen those that may have received insufficient coverage as a result of being meshed together. In addition to being time consuming, however, this method calls for a judgment decision as to how much peening the tangled parts have received, and therefore is impractical for large production jobs.

At the present time, shot peening is certainly a very vital asset to increasing the fatigue life of high-performance springs, but we may have only scratched the surface of the potentials of this treatment. With more research being performed on double peening, shot size and type, and in-line or directional exposure, it is possible that, with new and improved raw materials and production methods, stress levels and endurance life that seem impossible today may well be commonly accepted practices in the very near future.

At this time, under carefully controlled manufacturing conditions, wire quality surveillance, and monitored shot peening, springs have run in excess of 20-million cycles stresssed up to 185,000 psi and working through a stress range of 100,000 psi. Five years ago such life would have seemed to be as remote as manned space flight once was. Of course, to attain these levels, the raw materials must be free of any imperfections, manufacturing must impart no tool marks, and peening must be done to insure full coverage of all parts. However, the fact that these levels were reached with equipment available to the industry over 20 years ago indicates that we were unaware of the potential that was already in our hands.