The following is the paper's introduction—the paper is available in its entirety at The Shot Peener online library at www.shotpeener.com/library/index.html.

Relating Shot Peening Process Parameters to Residual Stresses – A Computational/Stochastic Marriage

Shot peening is a surface engineering treatment used to push the fatigue resistance of metals beyond their natural ability. This is achieved through the induction of near surface compressive residual stresses and (or) cold work. The first creates a virtual environment of lower macro-strains compared to those from the farfield source, while the second will either locally increase the dislocation density creating a difficult obstacle for further dislocation movement or, if severe, will deformed the grains minimising the distance between the grain boundaries. Of course there are additional benefits due to interactions between residual stress and cold work, i.e. when the crack propagates inside the cold work area; the plane favouring dislocation motion can change. Another interaction product comes from the increase in the plasticity induce closure for long cracks. Of course it is important to mention that there are also detrimental effects, in terms of fatigue performance; namely, surface roughness creating an amplified stress field and excessive cold work leading to loss of ductility and incorrect distribution of residual stresses leading to premature relaxation. The enhanced stress field, due to surface roughness, can overshadow part of the residual stress field and deliver reduced fatigue performance, especially when the application targets the region of high cycle fatigue. In addition, it can increase the natural scatter of the material in terms of fatigue life. The latter depends on the triangle grain size distribution, surface condition and type of loading. As a result, shot peening can cause an irregular performance which is beyond the design principles for which the material was first chosen. The reader here should keep in mind that there is limited knowledge relating material selection to shot peening and hence unless critically assessed, shot peening might not deliver the maxima. A second problem relating to surface roughness is the average grain size of the material. Herein, fine grains are more sensitive to roughness and usually deliver a less favourable result. Similarly, cold work, both in terms of profile as well as in terms of value, should be specifically designed in order to meet specific requirements. It is of outmost importance to understand that: a) material with natural tendency to cyclic hardening can react badly to increases in the dislocation density; b) the irregularity caused in the development of local plastic strain can significantly affect residual stresses relaxation, etc. The third and equally important factor is related to the geometry of the component and the expected type of fatigue crack. Herein, improvement from shot peening can be found simply by changing the geometry of the generated crack. In other words, we can select the shot peening parameters in order to enforce specific crack geometry with slower a propagation rate. Of course the above is decisively related to the specific industry and engineering component. For example, in the automotive industry where most components operate under conditions of fail safe, increases in the fatigue limit are mostly required. In this case, the engineer should be in a position to select the shot peening parameters so as to provide a crack shape which is most likely to be arrested (fatigue limit). On the other hand, the aerospace industry, with well established inspections, will benefit from crack geometries allowing them to minimise the cost of maintenance.

For many years, all the above have been examined through Almen strips, saturation curves, and coverage. Yet, the above parameters are not necessarily related to either the residual stresses or cold work. There are numerous examples where the selected parameters have not performed as expected. It is therefore important to realize that in order to move away from the time and money consuming process of trial and error, a more scientific procedure should be developed. Computational mechanics is a rather straightforward tool to replicate the mechanical phenomena involved. However, its simplicity can lead to unprecedented and erroneous results if all the phenomena characterising the process are not considered. Herein, the reader can find numerous cases and written scientific reports with unsuccessful results. Perhaps the problem is related to the large number of shot pellets constituting the shot stream. A typical Almen A strip can theoretically receive up to 200,000 shot impacts in one pass. Yet, its true coverage will never achieve 100% since shot interaction, deflections, and turbulence will minimise their impact energy, initial impact angle, contact time, etc. The number of shot pellets is so big as to prevent any deterministic approach and hence the use of stochastic theories is necessary.

In this work the authors try to examine a stochastic methodology able to provide the necessary information to feed a computational model for the prediction of residual stresses. The work represents an on going collaboration for the development of an in-house code for Superior Shot Peening, Inc. to be able to predict the optimum SP parameters as a function of material and operational stress/environment envelop.