PROPOSING AN APPLIED INFORMATION BASED SOLUTION IN STUDYING SHOT-PEENING PROCESS

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R. Azizi* and B. Disfani*

*Mechanical Engineering Department, Faculty of Engineering, Bu-Ali Sina University, Hamadan, Iran

ABSTRACT
Many investigations have been done to provide an overall insight into the shot peening mechanism. But reviewing most of the existing works in this area reveals a number of shortcomings. This is probably due to the sheer mechanical approach of studying such problems. On the other hand, since many parameters affect shot peening, it must be considered as a complex system. Thus some other procedures must be applied in analyzing such a system. Information based solutions are among the suitable approaches which can be used along with mechanical procedures. This new solution does not definitely leadus to get a n overall perception of the shot-peening mechanism; however, it opens new outlines in which recent results are incorporated. In this paper, a new approach is tried to be proposed to consider problems of understanding shot-peening mechanism.

SUBJECT INDEX
Shot-Peening, Numerical Simulation, Complex Systems, Information-Based Solution

1- INTRODUCTION
In a complex system, there are many parameters, upon which the system behavior depends. Therefore, the role of each parameter individually and the interactions between them, must be clear in order to predict the system behavior. Because of the variety of parameters, using classical approaches to investigate these systems seems to be insufficient. These classical approaches produce a lot of data and information, which is more like a huge and non-dynamic archive. However, achieving overall knowledge about the system behavior is really difficult. On the other hand, some procedures like Information Technology based solutions must be used to provide us with comprehensive insight of the system behavior. In the above mentioned techniques, primarily it is necessary to collect the data and then form a database including the data and the interrelations between them . Constructing this database requires a basic concept to be introduced which is further, used to predict and analyze the system and behavior of thesubsystems .
Today, information based solutions are among well-known approaches in analyzing the complex systems.

2- SHOT-PEENING AND NEW APPROACH OF STUDY
Shot-peening is a complex cold-working process involving many disciplines of static and dynamic elasticity and plasticity. This is a surface cold-working process which is usually employed to improve the fatigue strength of metallic parts or members. Turbine and compressor discs, blades, rotor spindles, landing gear components, springs, gears, connecting rods, cam shafts and torsion bars are typical components which are usually surface treated by shot-peening. This process is accomplished by bombarding the surface of the members with small spherical shots made of hardened materials at high velocities. As a result of collision of a shot with the surface of a component, an indentation is created which is surrounded by a plastic region

followed by an elastic zone. Upon the rebound of the shot, the recovery of elastic zone creates a large compressive residual stress on the surface. This layer of compressive residual stress postpones the crack propagation which usually initiates from the surface. According to this recent definition of shot peening, the result of shot-peening can be drastically affected by the shot parameters such as shot size, shape, velocity, hardness and material along with the component properties such as hardness, strength, shape and material specifications. It also depends on process properties such as coverage, temperature, duration of shot-peening, nozzle angle and so on (Fig.1). However, the material behavior under this process is not directly influenced by these parameters individually; actually this behavior depends on the superposition or interrelation of the effect of these parameters.

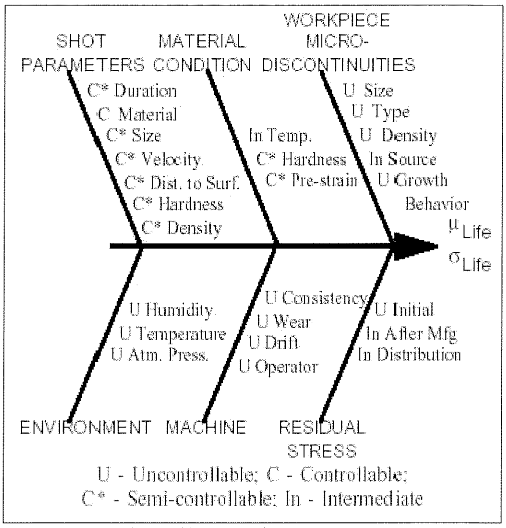

Fig. 1: Shot-peening parameters

Since there is a variety of distinct parameters involved in this process, shot-peening can be considered as a complex system. The analysis of this process can be divided into three major parts: (a) role of each parameter, (b) interrelations between these roles and (c) the weight of effects of each parameter.

In the recent years, numerous investigations have been performed in shot-peening process and now there is a rich archive of data and information available describing the role of each parameter. Unlike the availability of such a rich archive, a profound understanding of the material behavior under this process has not yet been achieved. This is probably, due to the lack of inclusive research in the area of interrelations between the roles of each parameter. For instance, interaction between the residual stress fields, due to each impact, is not clearly understood. Furthermore, it can be easily seen that increasing the number of impacts will dramatically increase the complexity of the interactions. Since an identified stress distribution leads to a better understanding of the shot peening operation mechanism, it is essential to obtain the mentioned interactions. Therefore, developing a procedure to obtain the stress distribution is justified in the first step.

This database has been developed by recording the material properties which have been obtained by the variation of each parameter. The main objective of the developing such a database is understanding the complexity of these interrelations.

In fact, this database may consist of tables where rows and columns have direct relations with each other. The arrays of these tables have been directly derived from the recent numerical, experimental and analytical procedures. Furthermore, intelligence, ability of the users or using expert systems can help us to draw out a new concept which can clearly illustrate the process mechanisms.
The aforementioned shortcomings in the studies related to this process, can be eliminated by the "knowledge" inferred from this database. This can be done by applying several disciplines such as mechanical, information based and statistical procedures. By applying this database, new domains can be created as the continuation of the previous studies. In fact the continuity of the previous studies in the analysis of the complex systems can prevent repetitive work.

3- CASE STUDY (MODELING AND RESULTS)

Following the recent work done on shot-peening [1], a new case study has been presented in this paper to direct us toward further studies.
In This section, a mechanical solution with information-based approach has been presented which can be used in studying a common case. In this special case study, the numerical simulation has been regarded as a mechanical solution.
In the recent studies LS-DYNA code was validated [1] and a new multiple impact simulation was developed. It was found that for a given shot velocity and diameter there is a certain number and position of shot impacts which result in a good coverage. Consequently, an approximately uniform stress distribution has been obtained. The comparison of this stress distribution with the experimental results demonstrates an acceptable compatibility. The simulation procedure can also be used to simulate a gear tooth under shot-peening. If the tooth throat and nozzle are not of the same size (as shown in Fig. 2), the nozzle can not similarly meet the internal surfaces of the gear tooth. This will cause the nozzle to turn so as to take normal position to the surface, which is not possible in this case. Consequently peening of some surfaces is performed obliquely and thus, the stress distribution in regions like 1, 2 and 3 will be completely different. For example, the impact angles are normal in regions 1, but not in regions 2 and 3.

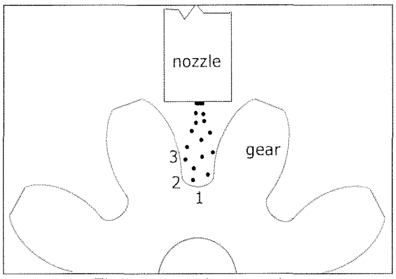

Fig. 2: Gear shot-peening

Schematic geometry and finite element meshing has been depicted in Fig. 3 while model properties are presented here:

Model properties

Shot diameter: 0.8 mm
Shot material: Steel with properties: $E = 210GPa$, $\rho = 7800 kg/m^3$, $\nu = 0.3$
Shot material model: Rigid
Work piece: Steel with properties:

$E = 210\,GPa$, $\rho = 7800\,kg/m^3$, $\nu = 0.3$, $\sigma_y = 1500\,MPa$, $E_p = 1600\,MPa$

$\beta = 0$, $c = 2e5$, $p = 3.3$, where β is the hardening parameter which verifies between 0 to 1. β=1 means the isotropic hardening and β=0 means the kinematic hardening. *c* and *p* are the Cowper-Symonds constants ($\sigma_y/\sigma_y^o = 1 + (\dot{\varepsilon}/c)^{1/p}$) [2]. Also E_p is the slope of the stress-strain curve in plastic section for bilinear model of this curve.
Work piece material model: Bilinear elastic-plastic model, yield stress scales with Cowper-Symonds relation.

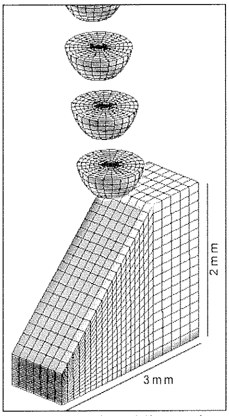

Fig. 3: Schematic finite element model for oblique shot impacts on 45 deg. surface

The residual stress profiles of flat and oblique surfaces for 30, 45 and 60 degrees which have been obtained from LS-DYNA simulations are illustrated in Fig. 4. As it can be seen from Fig. 4, when the oblique and horizontal surfaces are shot-peened under the same condition, the maximum stress induced in oblique surface is less than that produced in horizontal surface. The magnitude of this difference depends on the surface angle and becomes more profound as the surface angle increases. As it is clear, the tooth curve slope (involute curve) varies locally.

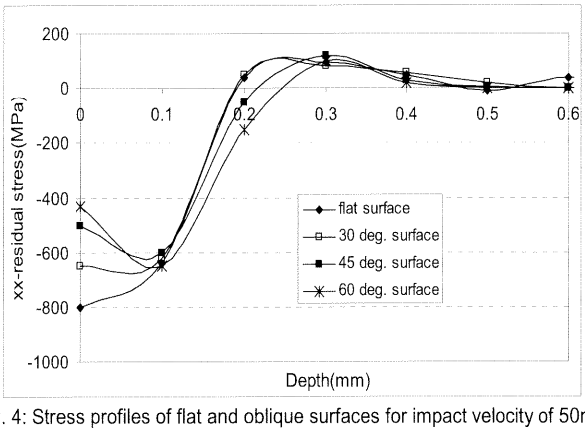

Fig. 4: Stress profiles of flat and oblique surfaces for impact velocity of 50m/s

This considerable difference between these states is not permtt ed, since this dispersion may be harmful to material strength and fatigue life. In such cases, it is found that the stress distribution is not uniform and thus a new process condition must be designed to decrease the dispersion. To plan for a procedure to overcome this dispersion, the velocity of impacts is increased until the stress profile of these oblique surfaces reach the flat surface. This has been shown in Fig. 5.

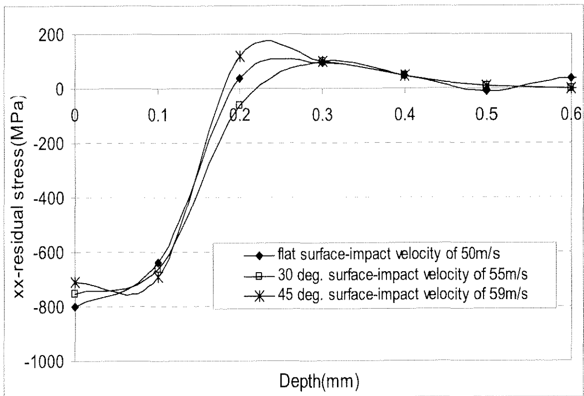

Fig. 5: Increasing the velocity until the stress profiles are similar

In Fig. 5 it is shown that an increase of 10m/s in impacts velocity results in an increase in the maximum stress, which is approximately the same as in horizontal surface.

As a result of this case study, having an explicit knowledge about the interrelation between the parameters helps us to decide about the designing of the parameters and optimizing of the mechanism in order to overcome such problems.

There are many parts of machines in industries in which shot-peening can cause some problems. Thus it is essential to control the parameters during the process of shot-peening. These activities, depending on the facilities, include controlling the variation of shots velocities, duration of peening, nozzle angle and so on.

Having knowledge about the role of each parameter and superposition of these roles may help engineers to design the optimized parameters to yield the desirable results.

4-CONCLUSION

As mentioned above, through this way the engineers can record the material properties and behavior related to the parameter changes under shot-peening process that result in a database. This database can be used to draw out (a) role of each parameter, (b) interrelation of these roles and (c) the weight of effects of each parameter. Therefore this information can raise the engineers to a higher level of knowledge which give them the ability to predict the material behavior through specified parameters of the process. This knowledge helps them to design the process parameters under the new conditions such as a new work piece at a minimum time and cost.

References

1- GH. Majzoobi, R. Azizi, *A 3-D Numerical Study of Shot Peening Process Using Multiple Shot Impacts*, 9th ICSP, Paris, Sep2005
2- LS-DYNA Keyword User's Manual, Version 950, 1999.