Effect of Shot Velocity on Residual Stresses in Shot Peening

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Abstract: **Shot peening process improve the fatigue life by reducing the crack initiation and crack propagation. This happen because of compressive residual stresses induced during process. Shot peening process can be simulate by Finite Element Modeling (FEM). FEM can predict the residual stresses induced in process. Shot peening process has some important parameters like shot velocity, shot size, shot distance, impact angle, exposure time etc. which will significantly increase or decrease the compressive residual stresses. In this paper effect of shot velocity is studied on YL12CZ Aluminum alloy by FEM.**

Keywords: **Shot Peening, Shot Velocity, FEM, Residual stresses.**

I. INTRODUCTION:

Shot peening is viewed as a process involving multiple and progressively repeated impact. In this process, the result is accomplished by bombarding relatively hard particles, usually spherical chilled shots (0.25 to 1 mm diameter) having impact velocities ranging from 20 to 150 m/s. They are projected against the surface being peened with sufficient velocities to indent the surface.

In this complex process, involves millions of shots. Typically, shots are delivered from either a nozzle or a centrifugal wheel as schematically shown in fig.1. The kinetic energy is derived by the shots either from the pneumatic pressure from the nozzle or the centrifugal force from the wheel. The shot is made in different sizes from different materials such as cast steel, carbon steel, ceramics, glass etc.[1]. Fig 1 is schematic representation of shot peening.

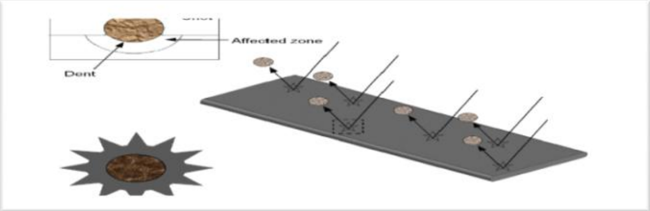

Fig.1- Schematic Diagram of Shot Peening

In principle when on rebound of the shot, the balanced system of residual stresses are trapped in the target, the plastically deformed zone recovers only some part of the elastic portion of its total strain. The resulting trapped compressive stresses assume their positions in a thin subsurface layer with tensile residual stresses distributed throughout the lower region.[2]If we want to plot stress curve for the component after shot peening, it will be like fig 2.

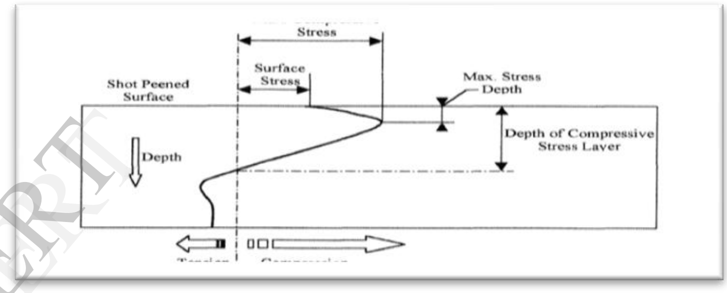

Fig 2- Effect of Shot Peening

II. SHOT PEENING AND FINITE ELEMENT MODELING:

Shot peening is very complex process. It involves many parameters at a time. Also cost of actual experimentation is also high. But Finite Element modeling will reduce the cost of experimentation, efforts and time required for the same.

Many researchers showed that FEM can be used for prediction of the residual stresses in the process[1,3,4,5,6,7,8,9,10,11,12,13,14]

There are many ways they have used like analytical model then data used for FEM, numerical simulation. But most popular method is by using commercial code like ABAQUS, LS-Dyna.

III. PARAMETERS IN SHOT PEENING PROCESS:

The shot peening process has to be a precisely controlled and repeatable process for optimum benefit. To achieve this, all its process variables must be identified and controlled. There are many fundamental parameters affecting the shot peening process.[7]

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1. Shot Density
2. Hardness of the shot
3. Shot Size
4. Nozzle diameter
5. Air Pressure
6. Impact Angle
7. Distance from nozzle to work-piece.
8. Exposure time
9. Number of passes
10. Linear and rotational speed of work-piece relative to nozzle
11. Shot Velocity.

In this Shot Density, hardness of shot, shot size, distance from nozzle to work piece and shot velocity can be simulated in FEM. Other parameters are controlled or studied during physical experimentation only.

IV. Effect of Shot Velocity:

In this paper, we studied effect of shot velocity on Aluminum Alloy YL12CZ. Yuansong Zeng from Beijing Aeronautical Manufacturing Technology Research Institute, Beijing, P. R. China studied the same[8]. But during the FEM author didn't specify the impact angle as well as impact distance. So by comparing the results we found out the effect of shot velocity on residual stresses as well as effect of shot angle and impact distance in combination.

Specifications of material:

Young's Modulus: 71000 Mpa

Shear Modulus: 27000 Mpa

Poisson's Ratio: 0.32

Yield Stress: 300 MPa

Strength: 426 Mpa

Finite Element Modeling

The shot size used for this FEM is 0.046 inch (1.16 mm) with variable velocities of 32,40,48,56,64 and 72 m/s.

Plate thickness 3 mm

Fine Meshing

Impact angle 90˚

Nozzle Distance 150 mm

The modeling and meshing is done by using hyper mesh as shown in fig.3

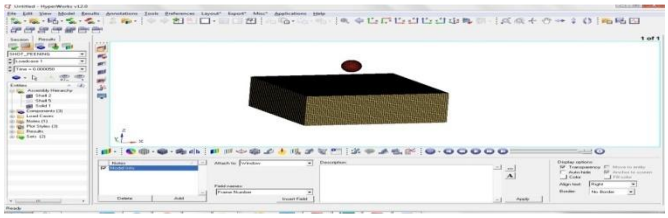

Fig. 3- Meshing in Hypermensh

During each iteration i.e. for each velocity we plot graph for comparison with Zeng's results.

The X-axis of graph represents distance from shot peened surface in mm while Y-axis represents Residual stresses induced in MPa, Positive side indicates tensile stresses while Negative side indicates compressive stresses.

Comparison of Results:

Fig. 4 represents the iteration 1 i.e. for Shot Velocity 32 m/s

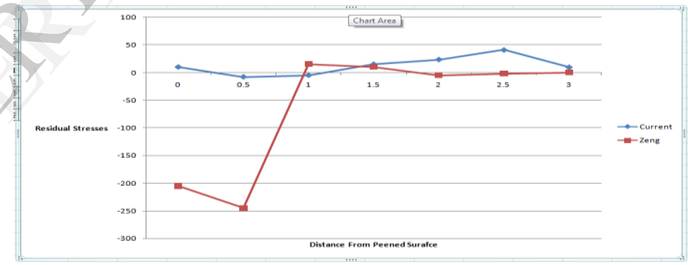

Fig 4- Iteration 1

Fig. 5 represents the iteration 2 i.e. for Shot Velocity 40 m/s

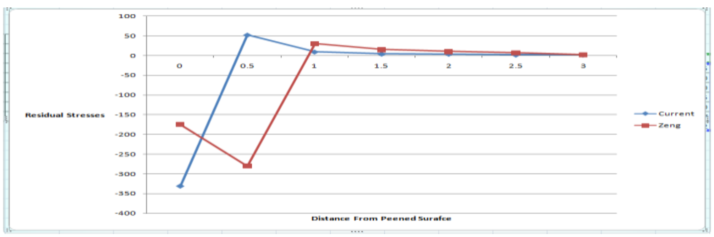

Fig 5- Iteration 2

Fig. 6 represents the iteration 3 i.e. for Shot Velocity 48 m/s

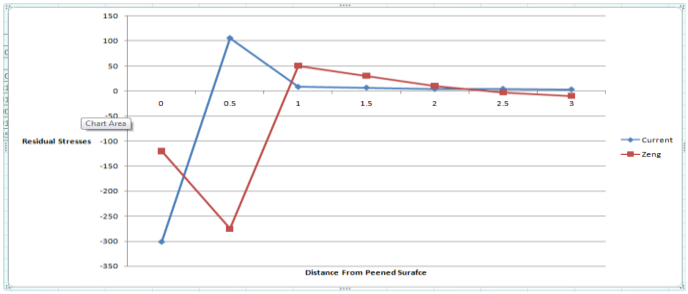

Fig 6- Iteration 3

Fig. 7 represents the iteration 4 i.e. for Shot Velocity 56 m/s

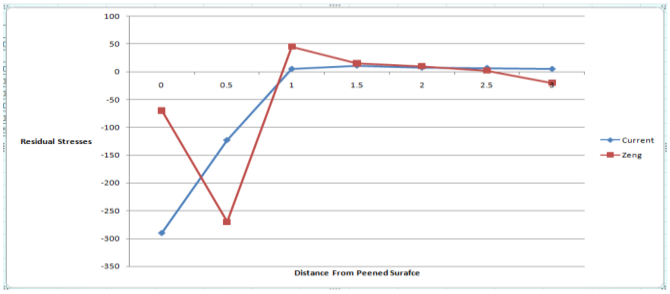

Fig. 7- Iteration 4

Fig. 8 represents the iteration 5 i.e. for Shot Velocity 64 m/s

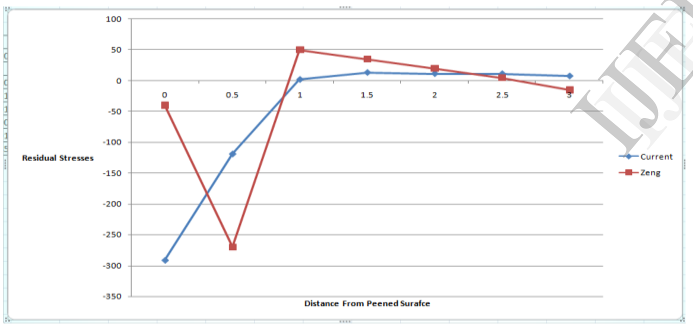

Fig 8- Iteration 5

Fig. 9 represents the iteration 6 i.e. for Shot Velocity 72 m/s

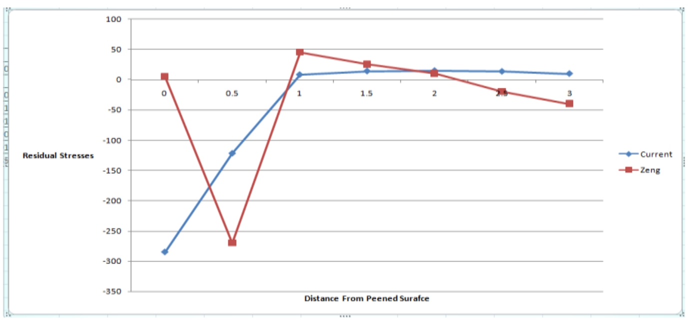

Fig 9- Iteration 6

Table 1 gives tabular results of our simulation

Table 1

D in mm	0	0.5	1	1.5	2	2.5	3
Vin m/s							
32	10	-8	-5	15	23.5	41	9.5
40	-331	52.1	9.2	3.9	3.6	1.6	1.4
48	-301	106	8.6	7	4.3	4.6	3.4
56	-290	-123	5.3	11	7.5	6.9	5.2
64	-291	-119	1.6	12.8	11	10.8	7.2
72	-285	-122	8	13.9	14.6	13.3	9.7

D- Distance from Shot Peened Surface, V- Shot Velocity

Fig . 10 gives graph of table 1

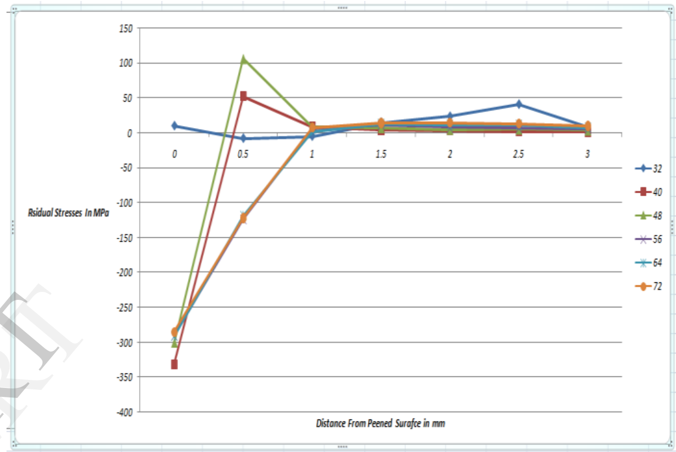

Fig 10- Result Graph

V. CONCLUSION:

The conclusion can be put in three different parts

1. *Effect of shot velocity on residual stresses*

- With increase in velocity the sign of stress changes from negative to positive i.e. from compressive to tensile
- The effect of stress is max up to 1 mm from peened surface.
- After 1 mm velocity doesn't affect the residual stresses much
- Shot velocity is significantly important parameter for induction of residual stresses.
- Using higher velocities will not induce desired compressive residual stresses, rather it will induce the tensile stresses.
- Tensile stresses will not improve the fatigue life. So, while choosing any velocity for shot peening we must take proper care for its effect on residual stresses.

2. *By comparison with Zeng's research:*

The pattern of residual stresses was similar but as the difference between results are because of following reasons

- Assuming the shot angle to 90˚ i.e. angle must be less than 90˚ in Zeng's analysis
- Assuming the shot distance to 150 i.e. distance must be less than 150 mm in Zeng's analysis

3. Shot peening is complex process. Prediction or simulation of process by FEM can be done in effective manner. *Shot velocity, shot distance, Impact angle and shot size* are the most significant parameters for effective shot peening.

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