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Experimental and Simulation of the Effect of Shot Peening on the Residual Stress to Surface and Sub-surface or Aluminum Alloy 2024 -T3 Used in Aerial Pieces

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ABSTRACT

Shot peening a work piece surface bombardment by thousands of shot that leads to the creation of compressive residual stress in the work piece surface and the amount of stress under the influence of the parameters of the process such as the diameter of the shot, throw the shot velocity, nozzle distance and nozzle angle relative to the work piece, is today, because of the extent of surface operations can be simulated effect of these parameters on the amount of residual stress on the surface and sub-surface of the simulation, the aim of this paper is experimental and simulation of residual stress generated on the surface and sub-surface of the alloy 2024-T3 (Because of good strength to weight ratio in the shell body aircraft structures under tensile stresses frequently are used to improve the fatigue resistance of the alloy from the shot peening used) as well as the effect of different parameters of the process on the residual stress in order to reduce the simulation time and money to help The results of this study showed that the parameters of the shot velocity and low angle greater impact compared with other parameters on the stress.

KEYWORDS

Shot peening, simulation, residual stress, Sub-surface

INTRODUCTION

As a whole, different mechanical and thermochemical ways are used to create compressive residual stress. Of mechanical ways to create resided stress are shot peening and local rolling surface. Shot peening is a cold work process that collision of different materials like ferrous metals, cost iron, ceramic and glass by ting spherical particles to surface; causes creating compressive residual stress on segment's surfaces, and surface involves cold work because of stress and compressive residual stress is saving in it[1]. This process is known as one of the best processes in creating compressive residual stress[2], that generally used to increase some mechanical properties like fatigue life enhancement and resistance to impact and corrosion on different segments[3]. 'Fig.1 represents schematic look of shot peening process.

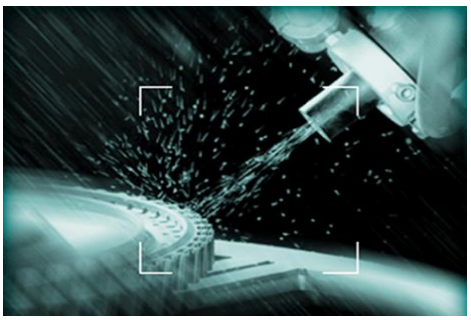

Fig.1. shot peening process schematic

Improvement of segment's fatigue behavior is arising of two factors after shot peening: 1-Deformation of plastic and hard work of surface layers affected by kinetic energy of shots progress that causes to stress enhancement; is submitted. 2- Creating compressive resided stress in surface layers that caused by shot peening [1]. At the time of shot's collision with high kinetic energy to intended surface, place of shot collision on metal's surface; arrive in plastic area. While beneath layers of this part are still in elastic condition. Shot rising of surface and elastic return of beneath layers in shot collision area; surface is affected by compressive stress arising of this return[4]. 'Fig.2 represents residual stress creation on segment at the time of shot peening.

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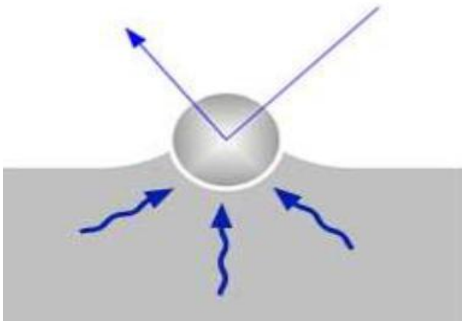

Fig.2. residual stress creation on segment at the time of shot peening[3]

Measurement of residual stresses and their distribution in the depth of segment is Very important Since, quality and affection amount of shot peening is based on different factors like; shots; size and species, shot peening intensity, surface cover, and materials properties. There fore, the effect of shot peening process parameters on the size and distribution of residual stresses and also determining essential conditions due to attainment of stresses best distribution is very considerable, and because of daily progress of simulation function in predicting materials behavior that one using surface operations, the effect of shot peening parameters on stress amount on surface and sub-surface can be predicted by simulation.

There are different ways to simulate shot peening process. For instance, assuming shot as an elastic shape that results were more reliable in compare with empirical results, majzoobi et al[5], Behavior of shot was considered as elastic plastic and results were considerable in company with empirical data, Zoin[6]. Researchers sued two methods; 2D and 3D for their modeling and number of different mesh. For instance, Schwarz, et al [3], considered 3D mesh with 372000 networks and 8 nods Boyce, et al[7] ware modeled 2D mesh with 4000 mesh and 8 nods. Analysis of residual stress and penetration depth measurement in shot peening process can be attained by considering different surfaces of shot surface in segment. Shot peening process analysis was done for the place of collision of 7 Shots in the segment Schwarzer, et al [3]. Intended analysis was done for 4 shots, majzoobi, et al [5], Analysis was done for 1 shot and results showed; area of changes in residual stress for analysis of different collision of shots with surface differs less that 15%, Guagliano, et al[8,9].

Alloy 2024 – T3 of Aluminum alloys 2XXX family, having proper. Strength to weight ration; is practical and useful in making of body shell of aircraft structures and due to alternative tensile stresses; shot peening operation is used on it to increase resistance to fatigue and neutralizing of such operation. The aim of the present paper is studying the effect of shot peening operation parameters such as; shot velocity, shot diameter, nozzle angle, nozzle distance according to the sample, in the amount of stress on surface and sub–surface simulating by Abaqus 6.14-2 software and also the residual stress of shot peening sample is determined by empirical method; X-ray diffraction test.

MATERIALS AND METHODS

The purpose of empirical experiment in the present study is to show the accuracy of simulation results. Sample used is Aluminum Alloy 2024 - T3 that is useful in aircraft industry specially in the body shell. ‘Tab.1 shown chemical composition of Aluminum 2024.

Tab.1. Aluminum Alloy 2024 - T3 chemical composition

Element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
%wt	0.07	0.17	4/6	0.64	1/5	0.01	0.15	0.03

Intended prepared sample of alloy for shot peening was like cylinder with 2 cm diameter and 4 mm thickness. Selected parameters for shot peening process are shown in ‘Tab.2.

Tab.2. parameters for shot peening process

Shot diameter	nozzle distance(cm)	nozzle angle(˚)	Shot velocity (m/s)
0.6	18	45	28

After shot peening of sample, the amount of residual stress by X-ray test in 5 micron and 350 micron distances, after exfoliation by Keller's solution (the rate of corrosion of Aluminum in Keller's solution is 70 micron each minute). and catching depth of 350 of sample; in which residual stress is changing because of total forces on solid that is zero and changes to tensile stress; are shown in ‘Fig.5 [10].

In measurement of residual stress by X-ray method, for a sample without stress, is reflected by crystal network that satisfies. Bragg's law (n=2dsin), in which d is plates distances in crystal network, (n=1) is reflection rank, is X-ray wavelength, and is Bragg’s angle). Plates' distance is changing when loading therefore the angle that Bragg's law happened is being changed. The amount of change in reflected... position is a strain that is being happened because of stress.

In measurement of residual stress by Z-ray diffraction; strain is being measured by severed angles in which are the same family of crystallography plates in which Bragg’s angle is in 120<2 (180. The strength line slope of chart is determined by sin. Then residual stress is determined by line slop and fixed elastic X-ray[11].

SIMULATION

Because of symmetrical from of shot peening, half of model is used to have on easy process. Also following hypothesis are used. The behavior of sample is considered as Elastic-Plastic in simulation process.

Thermal effects were disregarded. The way of shots collision to the segment was considered perpendicular. The analysis method during simulation process is dynamic. The coefficient of friction during process is assumed as a fixed amount.

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In order to have on easy simulation process; shot and segment are being considered as 2D. shot is considered heaved.

In order to determine the properties of aluminum sample of table 3-1, and also analysis; Johnson cook's moss in which A, B, C, n, m are fixed parameters and Tm, To, T are material's melting point, environment temperature and material's temperature respectively and used[12]. The units of elastic-Plastic behavior determination are calculated based on pa and all dimensions based on m. Material of shots was steel (SAE 1827) with density of 7200 kg/ m^3.

Tab.3. Johnson–Cook material model parameters[11]

property	units	Value
ρ	Kg/m^3	2770
υ	(-)	0.33
E	GPa	73.084
A	MPa	369
B	MPa	684
n	(-)	0.73
C	(-)	0.0083
m	(-)	1.7
T_0	^oK	294
T_{melt}	^oK	775
C_p	g/kg-^oK	875

The 4-Sided element is used to solve the problem that sub-dements are used to increase accuracy of solution in which all distributed dements are 16000, time of solution is %10 second, and number of solution are 400.

DISCUSSION OF RESULTS

After shot peening of sample, the rate of residual stress is calculated by X- ray test in distances of 5,350 micron of surface.

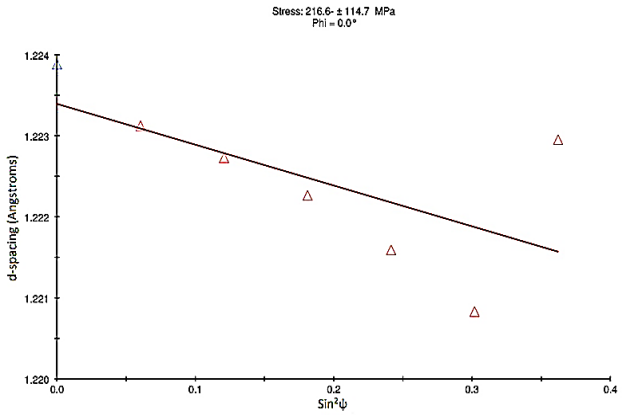

Fig.3. The results of X-rays at a depth of 5 microns from the surface

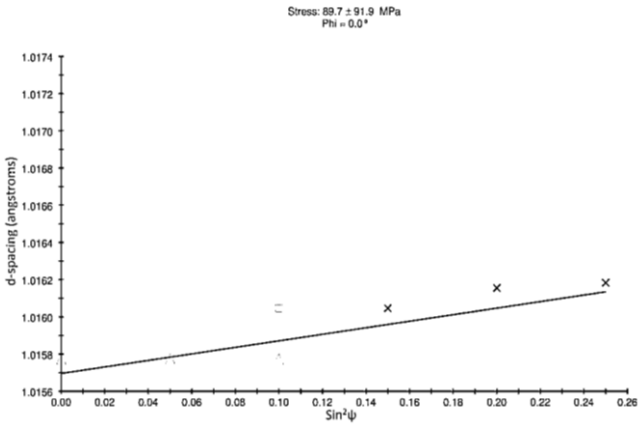

Fig.4. The results of X-rays at a depth of 350 microns from the surface

According to X-ray results, line slope in negative in the depth of 5 micron because of shot collision with surface and compression of crystal plates, stress is compressive, while sub-surface stress in 350 micron is tensioned and shown by positive line slope that shows depart ion of crystal plates of each other.

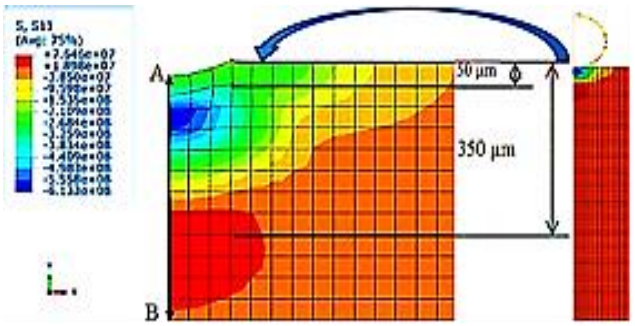

Fig.5. Simulation results for s11

Shot collision with high kinetic to the surface of sample cause to create compressive stress in this area. since there be balanced between forces and stresses in a segment in order to have a stable segment; compressive residual stresses in shot peening segment is being distributed in a way; algebraic number of produced residual stress is zero at all over the segment.

In means there is a balance between produced residual stresses in the cross line segment. There fore, this stress is being changed in sub-surface in which the amount of compressive residual stress is maximum, this change continues until all the amount of residual stress becomes zero. Surface is being deformed by the collision of shot to the samples surface and enters plastic area. It is being happened when sub-surface is still elastic and tries to invert the surface to the initial state (‘fig.2). Pressure of the surface arising of shot collision and pressure of sub-surface elastic and plastic cause to enhancement of the amount of stress in the center of deformed area (blue part)[6].

According to fig.4 created tooth arising of shot collision to surface in the depth of 520 micron. is begin continued in

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which stress's changes in such tooth is like A to B path in ‘fig.3; ss is strained stress and, CS is compressive residual stress, and TS is tensional residual stress. According to fig; compressive residual stress; Continues from surface to the depth of 300 micron this area is bigger than tensional residual stress to the depth of 320 micron because of shot collision and being compressed.

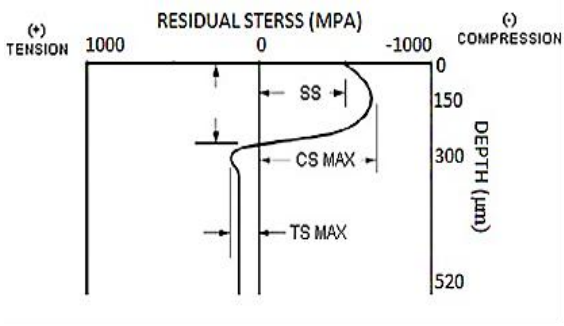

Fig.6. There dent in the body of a shot peening

In the study of model accuracy, empirical and simulation results were compered that are shown in ta.3.

Tab.4. The results

simulation	Experimental	Distance of surface
-210.9 to -268.4 Mpa	-216.6±114 Mpa	5 micron
76.4 to 18.9 Mpa	89.7±91.9 Mpa	350 micron

According to the result of X-ray test, the amount of compressive resided stress is -216/6 $\pm$ 114/7 Mpa. This stress amount is in the distance of 5 micron of surface (due to the depth of X-ray penetration in which is 5 micron for aluminum).

Also, Simulation results of the same surface (‘fig.5) is reported -210/9 to -268/4 Mpa. In the study of stress amount in the depth of sample and obtained tensional stress by X-ray in the distance of 350 micron of sample's surface (‘fig.4) equals 89/7 91/9 Mpa and also obtained stress in the same depth by simulation (red parts) is 18/9 Mpa to 76/4.

According to the results that confirm the accuracy of model, we are going to study the effect of shot peening process parameters on the amount of residual stress in 2024 - T3 alloy by simulation.

A) Shot velocity

In order to study the shot velocity on the amount of residual stress, 20, 25, 30, 35 and 40 m/s velocitys were used. Results shows that with the enhancement of velocity of compressive residual stress area and also depth of tooth, due to the enhancement of shot collision intensity to the surface and there fore more deformation in sample will be increased.

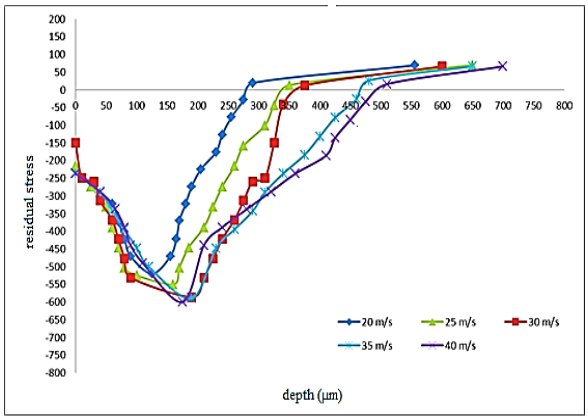

Fig.7. Influence of shot velocity on the residual stress profile

B) shot Diameter

According to ‘fig.8, due to small amount of shot diameter in the 0/2 mm diameter, Compressive residual stress over and depth of tooth is low and centimes to catch optimized state; 0/6 mm diameter.

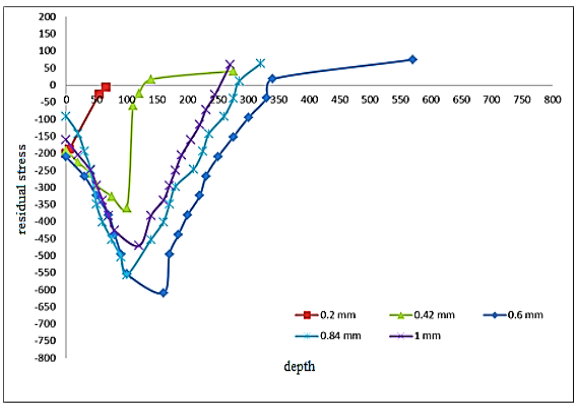

Fig.8. Influence of shot diameter on the residual stress profile

In the 0/6 mm diameter of shot, residual stress area and depth of tooth are achieved to the most optimized state because of connection between shot diameter and speed. Increasing diameter to 0/8 and 1, residual stress in surface is increased because of enhancement of shot diameter that causes stress deduction in depth due to elastic area enhancement in sub-surface and preventing stress increase in such area.

The hurling speed of shot should be increased to stress enhancement in sub-surface using big shot diameter.

C) Nozzle Angle

The effect of nozzle angle on amount of residual stress in 25, 35, 45, 55 ,65 angle is studied. Results shown in ‘fig.9 represents, compressive residual stress is begin increased and depth of tooth is increased too by the enhancement of nozzle angle and getting closer to perpendicular state.

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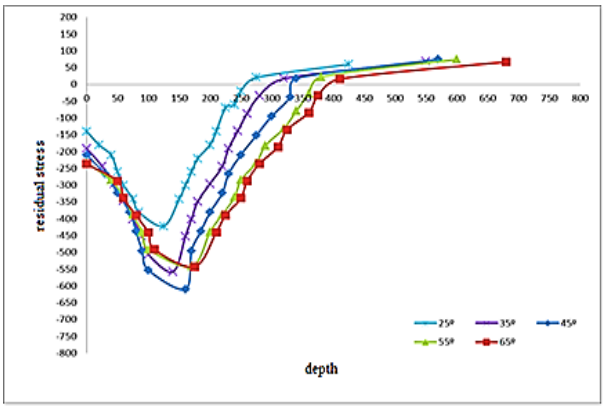

Fig.9. Influence of Nozzle Angle on the residual stress profile

D) Distance of nozzle regarded to sample

Results are shown, the effect of nozzle to sample on resided stress area and depth of tooth in compare with change of nozzle distance is low because of high speed of shot that this parameter can be disregarded in compare with other parameters. In the study of this parameter, nozzle distance to sample 5, 10, 15, 20, 25 cm is changeable. results are shown in ‘fig.10.

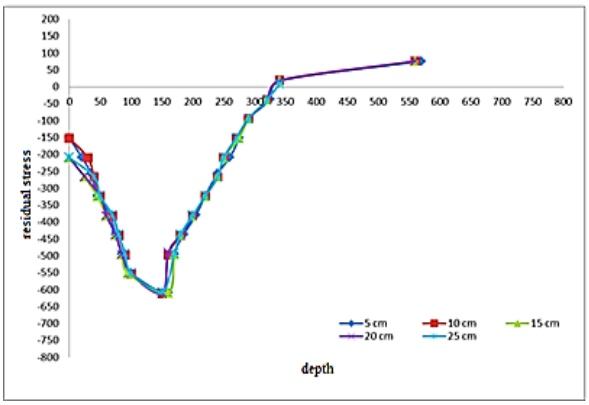

Fig.10. Influence of Distance of nozzle regarded to sample on the residual stress profile

CONCLUSION

Simulation of different shot peening parameters affection on the amount of stress on 2024 - T3 alloy was dine. Results are showed that. the amount of each parameters for the process com be achieved by simulation in order to catch the intended amount of stress for the segment. Also would be economic in time and expenses. Overall results are shown below:

1. Compressive residual stress area and depth of tooth is being increased by the speed enhancement of shot hurling due to increasing the speed intensity of shot collision to the sample.
2. stress is focused on surface in small diameters of shot because of lower amount of deformed area. Compressive residual stress area is decreased because of the enhancement of density in large diameters of shot. So, it can be said, there is a straight connection between shot diameter and hurling speed.
3. Increasing the angle of hurling and getting closer to perpendicular state causes to the enhancement of compressive residual stress area and depth of tooth depth to increase of shot collision surface to sample.
4. In the study of parameter , nozzle distance to sample with distance change, stress changes was low in which it can be disregarded in compere with other parameters affection on stress.

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