Design and Development of Air Blast Shot Peening Machine to Study the Effect of Shot Peening Process on Microstructure and Residual Stress in Al-2024 Aluminum Alloy

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Abstract: Shot peening is a cold working process used to produce a compressive residual stress layer and modify the mechanical properties which enhances the surface hardness, roughness, residual stress and fatigue life of the components by striking a surface with shot to create plastic deformation. Shot peening can be done using air blast systems and centrifugal blast wheels. In the air blast systems, shots are made to strike on a peened surface with high pressure air and accelerated through a nozzle and in the centrifugal blast wheel shots are introduced through rotating wheel by the centrifugal force. Selection of the peening process depends on the type of material and size of the components. In this paper attempts are made to design and develop air blast shot peening machine to study the effect of peening on Al-2024 aluminium alloy. It is evident from the results that use of peening process enhances hardness, surface roughness and residual stress in the material.

Keywords- *Air Blast Shot Peening Machine, Al-2024 aluminium alloy, Residual stress*

I. INTRODUCTION

Al2024 aluminium alloys are extensively used in vehicle and aerospace industries because of low weight and high strengths. Al alloys have good mechanical properties, corrosion resistance and good fatigue life. Due to this many researchers select Al alloys to enhance its properties by various surface treatment techniques.

Surface remedy procedure gaining interest as it modifies micro structure due to plastic deformation and stress hardening which alters mechanical properties [1]. Mechanical components fail due to repetitive loading which induces surface crack. Shot peening is surface treatment process used to enhance mechanical properties by inducing compressive residual stresses. Shots are made to strike on metal surface and plastic deformation takes place. Surface modification and fine crystallization makes material with high hardness, corrosion resistance, fatigue strength and wear resistance [2]. Induction type shot peening machine was used to carryout shot peening process with spherical conditioned cut wires(SCCW14),standoff distance 9cm,and time duration of 40s.To cover 100% peening specimen was rotated continuously. Surface roughness increased with increase in almen intensity also for 0.3mmA higher roughness value 3.42Ais achieved. As almen intensity was increased Micro harness and Residual stress profiles are increased. Fatigue performance was increased for 0.1mmA almen intensity but no further improvement for 0.3mmA because of high surface roughness and micro cracks over peening induces micro cracks which reduce the fatigue life [3].

Effect of peening parameters such as nozzle angle and peening distance on Al2024-T3 alloy used for ship building application. Wrong selection of process parameters leads to over peening and it decreases the mechanical properties. For different thickness specimens different parameters are to be selected and experiment method is best method for proper selection of process parameters [4]. Wheel blast shot peening machine with following parameters shots average speed 40m/s, low carbon steel shots of diameter 1.2mm and 20minute time period [5].

Fatigue behavior of magnesium, titanium and Al2024 alloys after shot peening process was carried through Injector system type shot peening with steel shots of 0.36mm (SCCW14), 080mm (S330) and glass beads with average size 0.65mm. Compressive residual stress leads to lower crack growth rate [6].

In the present work air blast shot peening machine was designed and fabricated. It's working principle and operation is explained. Shot peening was carried out with various time period on Al2024 aluminium alloy to know effect of peening on various properties such as residual stresses, hardness, roughness and microstructure.

II. WORKING OF AIR BLAST SHOT PEENING MACHINE

Air blast shot peening Fig. 1works on the principle of venture sucking shots from a hopper. Nozzle Fig. 2contains two ports on vertical port high pressure air is passed and inclined port carries shots due to negative pressure. Air is passed through the air inlet port and it creates a low pressure which sucks the media from the hopper into the air stream and strikes the metal surface. Pressure gauge is used to regulate the air pressure from the compressor. Shots continuously blasted as long as there is blasting media in the collecting tray and recirculating the shot once again.

Fig 1: Air blast shot peening Machine

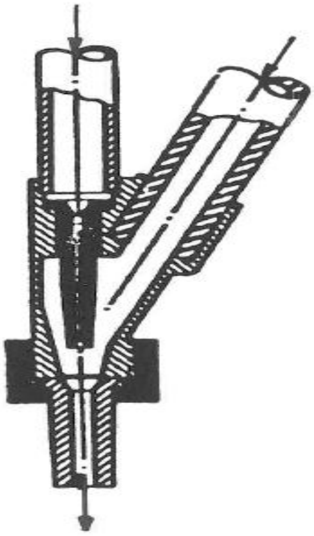

Fig 2: Nozzle

Fig 3:Work table

Fig 4:Cast Steel shots

III. DESCRIPTION OF SHOT PEENING MACHINE

Chamber forms skeleton for the machine which holds all the individual part on it. Chamber is made with mild steel sheet having a thickness of 2mm and width of 600mm on all side. Sheets are cut as required dimension and it was welded by an electric arc welding process. On the top trapezoid shape chamber is made for nozzle mechanism. Nozzle is used to mix air and shots. It can be adjust to required standoff distance and can be inclined to required angle. Pressure gauge is mounted to monitor air pressure from compressor. A work table Fig. 3 is used to hold the specimen and can be moved in X and Y direction by handle. Hopper is placed at bottom of the chamber which collects the shots after the peening process and circulates for the continuous process.

Parameters Consider for Shot Peening

1. NTD (nozzle tip distance)
2. Air pressures
3. Nozzle angle
4. Shot size
5. Axis movement of the table
6. Surface coverage

Shot size and material

0.8mm (S330) diameter cast steel shots Fig. 4.

IV. MATERIALS AND EXPERIMENTAL PROCEDURE

Material selection

The material considered in the present study was Al2024 compositions are shown in table-1.Mainly used for aerospace wings and pressure cabins. The mechanical properties are Tensile strength –212 MPa, Yield strength – 98 MPa, Elongation – 12-24 %, Density – 2.8g/cm^3, young's modulus – 74 GPa.

Table 1. Chemical Composition in wt %

Materia l	**Chemical Composition in wt %**									
	Al	Mg	Si	Fe	**Cu**	**Cr**	**Zn**	**Ti**	**Mn**	**other**
Al6061	94.7	1.8	0.5	0.5	4.9	0.1	0.25	0.15	0.9	0.15

Shot peening process is carried out by using fabricated air blast shot peening machine. Specimens were prepared to dimensions 100mmX25mmX6mm were held on a table and movement was given to cover entire specimen. Peening parameters such as standoff distance 125mm, cast steel shots of 0.8mm diameter, duration of peening 10,20,30 minutes, angle of impingent 600 and 100% coverage were maintained.

Fig 5: Before Peening

Fig 6: After peening

Microstructures of Shot peened specimens were examined by using scanning electron microscopy (SEM). Surface roughness was measured by mark talk measuring instrument. Hardness was measured before and after various time durations of peening. Residual stress field was measured in advanced machine tool testing facility lab (AMTTF), Bengaluru.

V. RESULTS AND DISCUSSION

Micro Hardness

Hardness is defined as resistance to indentation or penetration. Results reveal that increasing time duration in shot peening process hardness value was increased. Before peening, value of RHN was 72, for highest peening time of 30 minute hardness value increased to 92. Due to strain hardening effect it was increased.

Table 2. Hardness value RHN

Peening duration, minutes	**Before Peening**	10 minute	20 minute	30 minute
Hardness	72	83	87	92

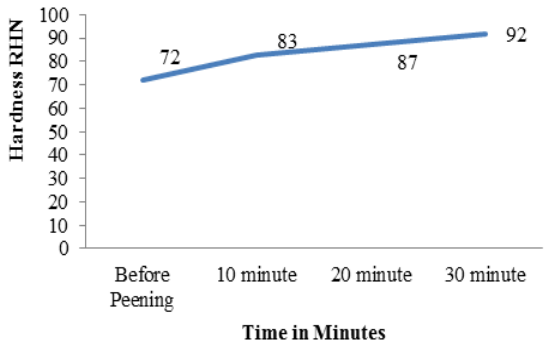

Fig 7: Hardness/time

Surface Roughness

With varying Shot peening duration surface roughness was increased. It was observed that For 10 minute duration the value was 11.584 µm and for maximum duration 27.678 µm. The optimal duration will leads to increased fatigue life of the component. More roughness can reduce fatigue life because of micro cracks present during high intensity peening. To avoid more roughness minute layer of material can be removed through machining after peening.

Table 3. Surface roughness (µm)

Peening duration, minutes	**Before Peening**	10 minute	20 minute	30 minute
Surface roughness(µm)	x- 0.779 y- 1.001 z-5.191	x- 2.386 y- 3.736 z-11.584	x- 3.546 y- 4.411 z-18.383	x- 4.342 y- 5.437 z-27.678

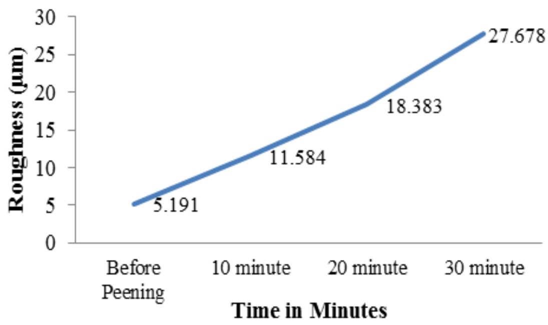

Fig 8. Roughness v/s Time duration

Residual stress

These stresses are present in the body after removal of load. Desirable Compressive residual stresses plays vital role to retard crack propagation and minimizes the tensile stresses hence it increases fatigue life of the component. Measured value for unpeened specimen was -37.2MPa and for different period peened specimens were -183.4,-212.6 and -234MPa.Results reveals that increased duration leads higher compressive residual stresses.

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Fig 9: XRD Machine to measure Residual stress

Table 4. Residual stress MPa

Time	Residual stress MPa
Before Shot peening	-37.2±3.1
10 minute	-183.4±6.3
20 minute	-212.6±7.9
30minute	-234±3.2

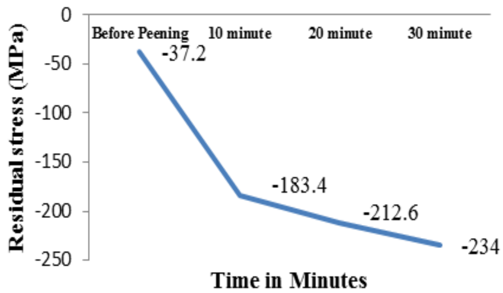
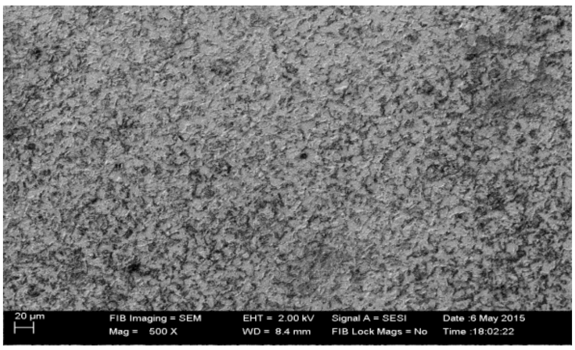


Fig 10: Residual stress v/s Time duration

Microstructure

Continuous blasted shots makes plastic deformation at the surface of the specimen. Fig shows microstructure of peened and unpeened specimens obtained by scanning electron microstructure. Shot peened specimen exhibited Fine microstructure and small grain size. Also dimples were more due to impact of shots.



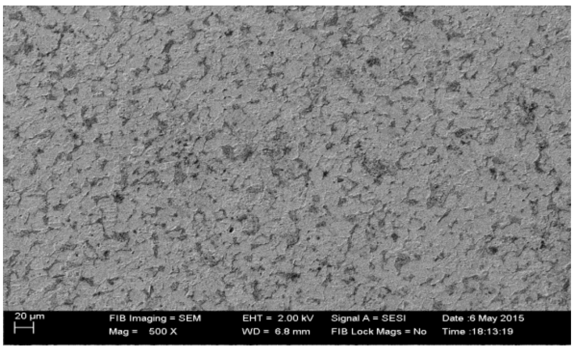


Fig 11: SEM microstructure of unpeened specimen

Fig 12: SEM microstructure of peened specimen

Conclusions

Shot peening process was conducted for different time duration on Al 2024 aluminium to determine residual stresses, hardness, roughness and microstructure. Mechanical properties and residual stresses are compared with peened and unpeened specimens. The following conclusions are achieved.

- Air blast Shot peening machine is designed and fabricated successfully.
- Peening can be done on various ferrous, nonferrous and composite metals and provisions are made for conducting peening with different parameters such as pressure, standoff distance and angle of nozzle.
- Shot peening increases hardness value due to plastic deformation and fine crystalline structure. With increased time duration hardness is increased to 92RHN.Also peened specimen exhibits more hardness compared to unpeened one.
- Roughness value has obtained up to 27.678 μm
- Compressive Residual stresses increased to -234 MPa at higher duration of peening.
- Grain size is reduced and fine crystalline microstructure is obtained.

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