FATIGUE AND HEAT TRANSFER BEHAVIOUR OF SHOT PEENED ALUMINIUM ALLOY

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ABSTRACT

In the present investigation glass beads and zirconium oxide shots were used as media to shot peen aluminium alloy specimens. Fatigue and boiling heat transfer behaviour of this alloy after shot peening was studied. Out of 0.2N and 0.4N peening intensities, 0.4N gave higher improvement on fatigue strength and boiling heat transfer. Fatigue behaviour of butt welded aluminium joints were also studied. Shot peening with zirconium oxide shots at 0.4N intensity was found to be more advantageous than glass beads. Welding reduces 19.4% fatigue strength compared to virgin samples, but shot peening could improve fatigue strength by 12% compared to welded samples. Effect of corrosive (3N Nacl) environment on fatigue strength was also studied.

KEYWORDS

Zir shots, boiling heat transfer, fatigue, electrochemical corrosion.

INTRODUCTION

Aluminium alloys have lot of industrial applications in Automobile, aircraft and heat exchanger manufacturing industries. Fatigue strength per unit weight of these alloys can be further improved by the application of controlled shot peening. Shot peening to required intensity with appropriate media shape, size and material should be decided to get maximum benefit for improved boiling heat transfer as well as fatigue strength.

Shot peening with steel shots over aluminium alloys may cause electrochemical corrosion as iron particle may lodge on aluminium surface producing galvanic cell. Therefore it was proposed to use glass beads and zirconium oxide shots. At higher peening intensities glass beads show higher breakage leading to handling problem. This could be avoided with zirconium oxide shots.

Boiling heat transfer

Like shot peening boiling heat transfer is also a surface phenomenon which occurs due to phase change from liquid to vapour. In nucleate boiling, heat transfer is through bubbles which began to appear on heating surface. These bubbles form at favourable spots where nuclei for formation of vapour bubble are present. High rate of heat transfer in nucleate boiling can be explained by specific boiling process, that is nucleation, growth, detachment and collapse of vapour bubble, Franker and Scorch (1).

OBSERVATION FOR BOILING HEAT TRANSFER

- Surface roughness of Aluminium block specimen Ra
  Before Peening 0.43 microns
  After Peening 4.10 microns
- Saturation temperature of water = 97°C.
  Air pressure for shot peening 3kg / cm^2

Glass bead size used for peening = G-20

Resistance of heating element = 67.05 Ohms

Equipment used were as shown below. Details referred by Nadkarni and Sharma (2,3)

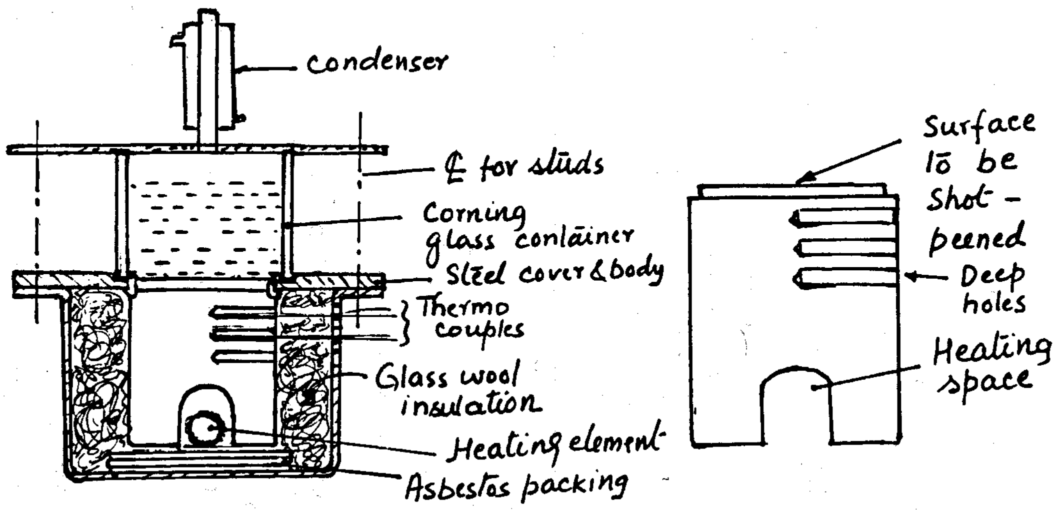

Fig. 1. Boiling heat transfer unit and specimen.

Observation for boiling heat transfer of Aluminium Alloy : Table-I , See next page.

A = Surfae area of Aluminium Block exposed to boiling water = $5.41 \times 10^{-3} m^2$

t_s = Saturation temperature of boiling water = 97°C

R = Resistance of the heating coil 67.05 Ohms

Shot peening media used for Glass beads 0.6 to 0.8mm diameter and zir shots of 1.0 mm dia.

Surface roughness was controlled by controlling Shot-Peening pressure and exposure time.

Coverage was 98%.

Surface roughness was measured by Handy Surg equipment.

Three sets of roughnesses were used.

(a) 0.43 microns, (b) 3.10 microns (c) 6.2 microns.

Observations for fatigue behaviour of Aluminium alloy under various conditions : Table III

The chemical composition and mechanical properties of aluminium alloy were as follows : Si 2.5 - 3.5% UTS 180 MPa, % elongation 6 - 8%, Hardness 50 HB.

Welding

The sample were welded by TIG welding process at 80 Amp. DC, with 3 mm aluminium Mg 21 Si 5% electrode.

Corrodent

3N-NaCl pumped over the specimen.

Table - 1 : Set-I For Surface roughness 0.43 microns (Virgin sample)

S.No.	Input Voltage to heater V volts.	Heat flow rate Q $Q = \frac{V^2}{R}$ Watts(W)	Heat-flux density $q = \frac{Q}{A}$ Watts / meter²	Steady State surface temp. t°C	$dt = (t-t_s)$ $t_s = 97°C$	Boiling heat transfer coefficient $h = \frac{q}{dt}$ watts per m² per °C	%improvement in boiling Heat transfer Coefficient over Virgin sample.
1	2	3	4	5	6	7	8
1.	180	483.22	89319	125.1	28.1	3178	-
2.	190	538.40	99519	125.5	28.55	3485	-
3.	200	596.56	110269	125.77	28.775	3832	-

Set-II For Surface Roughness 3.15 microns A, t_s, R remaining same, short peened sample

1.	180	583.22	89319	109.35	12.4	7183	126%
2.	190	538.40	99519	110.24	13.24	7517	115%
3.	200	596.56	110269	111.12	14.12	7809	104%

Set III. For Surface Roughness 6.20 microns A, t_s, R remaining same, short-peened sample

1.	180	583.22	89319	107.0	10.0	8932	181%
2.	190	538.40	99519	108.0	11.0	9047	159%
3.	200	5968.56	110269	108.6	11.6	9506	148%

Peening Parameters

The following parameters were used for the different test conditions, as tabulated in Table II:-

S.No.	Shot Peening Parameters	Virgin	Test Conditions Corroded	TIG-welded
1.	Pressure; MPa	0.40	0.40	0.40
2.	Standoff; mm	30	30	30
3.	Coverage; %	98-100	98-100	98-100
4.	Nozzle bore; mm	6	6	6
5.	Almen-Intensity	0.2-0.4N	0.4N	0.4N
6.	Peening media			
i.	Material	Glass beads & zirconium oxide	Glass beads	Zirconium oxide
ii.	Size mm	0.6-0.8	0.6-0.8	1.0

Observations

The observed data in rotating bending fatigue test for a cantilever specimen at 5 x 10 E06 life cycles and the estimated median strength with percentage improvement under various test conditions are tabulated in Table III.The up and down stair case methods were used for calculations.

Surface Roughness

The following change in surface roughness were observed after shot peening by (i) glass beads 0.60 to 3.20mm and (ii) zirconium oxide 0.26 to 0.65mm.

Typical chemical composition of ZIRSHOT beads

ZrO_2 = 68%

SiO_2 = 31%

Others (Al_2O_3, Fe_2O_3, TiO_2) = 1%

Typical crystellographic analysis :

Zirconia = 68%

Glassy phase = 32%

Typical Physical Properties

True relative density = 3.85

Bead relative density = 3.76

Mircohardness Vickers = 8 to 10,000 N/mm^2 under 100 gm

Rockwell hardness = 65 RC (equivalent)

Surface Texture = smooth

Table III. The Observed Staircase Data and Estimated Median Fatigue

S.No.	Test Conditions	Applied stress level MPa	The staircase data X:Failure survival:O	Estimated Median fatigue strength MPa	%age improvement
1.	Virgin	100	X	72	-
		90	O X		
		80	O X		
		70	O X		
2.	Glass beads 0.2N	100	X		
		90	X X X	82	14
		80	O O		
3.	Corroded	60	X	20	-
		50	X		
		40	X		
		30	X X		
		20	O		
4.	Corroded glass beads peened 0.2N	50	X	22	10
		40	X		
		30	X X		
		20	O O		
5.	Glass beads peened 0.4N	110	X X	92	28
		100	O O X X		
		90	O		
6.	Zirconium oxide peened 0.4N	130	X	105	45
		120	X X X		
		110	O O		
7.	Welded	100	X	58	-
		90	X		
		80	X		
		70	X X		
		60	O X X		
		50	O		
8.	Welded peened with zir shots to 0.4N	80	X	65	12
		70	O X X		
		60	O O		
		50	O		

DISCUSSION

The object of this investigation was to determine the effect of shot peening over fatigue behaviour of aluminium, we obtained 10-45% improvement in fatigue strength under various test conditions as tabulated in Table III.The stair case data were plotted as shown in Table III.Aluminium shows a marginal improvement 10-14% when peened with glass beads alone to 0.2N intensity and corrosive conditions, and when peened to 0.4N with same media the improvement goes to 28%. On the other hand when it was peened with zirconium oxide to 0.4N the improvement was 45% at 5×10^6 cycles, the probable cause must be the higher residual stress induced with zirconium oxide shot peening.

CONCLUSION

Thus the zirconium oxide shots are beneficial as compared to glass beads shots which creates the higher surface roughness and process becomes uneconomical to peen aluminium. Since the greater roughness obtained by shot peening with glass beads on aluminium to achieve 0.4N intensity might be detrimental to fatigue resistance and which may compensate the beneficial effect of residual stress produced by peening. In present study the zirconium oxide shots show smoother surface and good improvement in fatigue strength than the glass beads peening. In case of welded samples the improvement was limited to 12%, this might be due to the weld defects and metallurgical changes caused in the weldment due to the presence of silicon.

Shot peening at 0.4 to 0.6N intensity with Zir shot peening improved boiling heat transfer appreciably. Increase in surface roughness to a value ranging 3 to 6 microns could improve heat transfer from 100 to 150% respectively.

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