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FATIGUE AND HEAT TRANSFER BEHAVIOUR OF SHOT PEENED ALUMINIUM ALLOY FOR AUTOMOBILE APPLICATIONS

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ABSTRACT

In the present investigation glass beads and zirconium oxide shots were used as media, to shot peen alluminium 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 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. Effect of corrosive (3N NaCl) environment on fatigue strength was also studied. Zir shots were found to be economical.

The commercial application of shot peening in automobiles to enhance boiling heat transfer was also studied. The heat transfer media then used was the coolant commonly used in Car radiators. That was 95% ethylene glycol with some inhibitor to prevent corrosion. This was a mixture of water and glycol in 3:1 ratio. The optimum surface roughness was $6.2 \mu\text{m}$ which gave optimum heat transfer at 90% improvement in boiling heat transfer compared to unpeened samples.

KEY WORDS

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

Equipment used was as shown below. Nadkarni and Sharma(2,3).

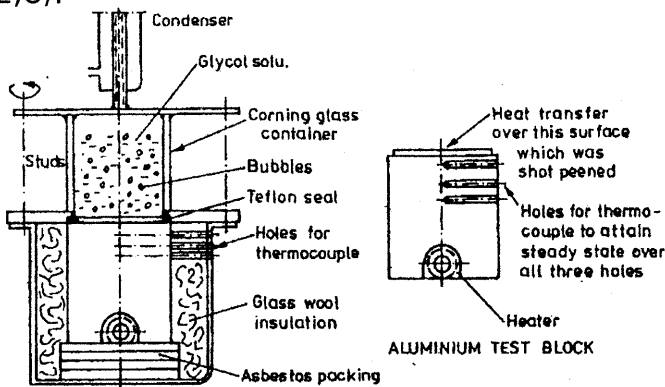


Fig.1 Boiling Heat Unit and Aluminium Test Block

d = Diameter of Aluminium block exposed to Glycol Solution = 0.083m

t_s = Saturation temperature of boiling Glycol Solution = 103°C

R = Resistance of the heating coil = 550.00 Ohms

Surface roughness was controlled by controlling shot peening pressure and exposure time.

Coverage was 98%

Surface roughness was measured by Handy Surf equipment.

Sets of roughness used were 2.2 μ m to 8.0 μ m

Shot peening was carried out using pressure peening unit, keeping Nozzle bore of 8mm, and pressure pot was kept at constant pressure of 1.5 kg/cm². Only mass flow rate was controlled by controlling full way air supply valve opening and keeping shotfed orifice diameter constant. Thus only media quantity and media velocity were varied to get different surface roughness. The observations of Boiling heat Transfer are given in Table 1.

OBSERVATION TABLE

S.No.	Voltage(V) Volts	Heat Flow $Q=V^2/R$ Watt	Heat Flux Density $q=Q/A$ W/m^2	Steady State emf (mv)	Corres- ponding Surface Temp $O_c(t_s)$	Satura- tion Temp. $O_c(t)$	Excess Temp. $dt=t-t$	Boiling Heat Transfer coeff. $H=q/dt$ $kw/m^2 \text{ } ^\circ C$	% Improvement in h over virging surface
Set - I Ra = 0.25 μm									
1.	180	589.1	108.9×10^3	4.34	117.1	103	14.1	7.72	—
2.	190	654.4	121.3×10^3	4.35	117.3	103	14.3	8.48	—
3.	200	727.3	134.4×10^3	4.39	118.1	103	15.1	8.9	—
Set - II Ra = 2.2 μm									
1.	180	589.1	108.9×10^3	4.68	114.0	103	11.0	9.90	28.24%
2.	190	654.4	121.3×10^3	4.69	114.1	103	11.1	10.92	28.8%
3.	200	727.3	134.4×10^3	4.73	114.8	103	11.8	11.3	28.0%
Set - III Ra = 4.2 μm									
1.	180	589.1	108.9×10^3	4.69	111.5	103	8.5	12.8	56.7%
2.	190	654.4	121.3×10^3	4.84	112.3	103	9.3	13.0	53.4%
3.	200	727.3	134.4×10^3	4.89	112.7	103	9.7	13.3	55.0%
Set - IV Ra = 5.27 μm									
1.	180	589.1	108.9×10^3	5.55	110.5	103	7.5	14.52	88.0%
2.	190	654.4	121.3×10^3	5.61	110.9	103	7.9	15.4	81.1%
3.	200	727.3	134.4×10^3	5.66	111.5	103	8.5	13.8	77.7%
Set - V Ra = 6.2 μm									
1.	180	589.1	108.9×10^3	5.62	110.2	103	7.2	15.12	95.9%
2.	190	654.4	121.3×10^3	5.64	110.5	103	7.5	16.1	89.8%
3.	200	727.3	134.4×10^3	5.68	111.0	103	8.0	16.8	89.9%
Set - VI Ra = 8.0 μm									
1.	180	589.1	108.9×10^3	4.48	111.2	103	8.2	1 13.3	72.3%
2.	190	654.4	121.3×10^3	4.56	112.0	103	9.0	3 13.5	59.2%
3.	200	727.3	134.4×10^3	4.59	112.3	103	9.3	1 14.9	67.4%

Table 1. Observations for boiling heat transfer.

OBSERVATION FOR FATIGUE BEHAVIOUR OF ALUMINIUM ALLOY UNDER VARIOUS CONDITIONS

The chemical composition and mechanical properties of aluminium alloy were as follows:

Si 2.5-3.5% UTS 180Mpa, % elongation 6 - 8%, Hardness 50HB

Welding

The samples were welded by TIG welding process at 80Amp. DC, with 3mm aluminium alloy bare electrode, containing Mg 2.1% Si 5%

Corrodent

3N - NaCl solution was allowed to drop over the specimen gauge diameter. Gravity flow of corrodent was regulated by a stop cock at the outlet.

PEENING PARAMETERS

The following shot peening parameters were used for the different test conditions, as tabulated in Table 2.

S.No	Shot peening parameters	Virgin	under corrodent	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 - 0.4 N	0.4N	0.4N	
6.	Peening Media			
i.	Material	Glass beads &	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 5×10^6 life cycles and the estimated median fatigue strength with percentage improvement under various test conditions were tabulated in **Table 3**. The up and down stair case methods were used for calculation.

SURFACE ROUGHNESS

The following change in surface roughness were observed after

shot peening by (i) glass beads 0.60 to 3.20mm (ii) zirconium oxide 0.26 to 0.65 m m.

Typical chemical composition of ZIRSHOT beads.

ZrO₂ = 68%

SiO₂ = 31%

Others (Al₂O₃, Fe₂O₃, TiO₂) = 1%

THE OBERVED STAIRCASE DATA AND ESTIMATED MEDIAN FATIGUE

S.No.	Test conditions	Applied Stress Level	The Staircase data X : Failure Survival : O	Estimated Median Fatigue Strength MPa	% age Impro-ment
1.	Virgin	100	X	72	-
	90		O X		
	80		O X		
	70		O X		
2.	Glass beads	100	X		
	0.2N	90	X X X	82	14
		80	O O		
3.	Under Corredent	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 0.4 N	110	X X	92	28
		100	O O X X		
		90	O		
6.	Zirconium peened 0.4 N	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.	Weldedpeened 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 3. The stair case data were plotted as shown in Table 3. Aluminium shows a marginal improvement 10-14% when peened with glass beads alone to 0.2 N intensity and under corrosive conditions, and when peened to 0.4 N with same media the improvement goes to 28%. On the other hand when it was peened with zirconium oxide to 0.4 N the improvement was 45% at 5×10^6 cycles, the probable cause must be the higher residual stress induced with zirconium oxide shot peening and better surface finish.

CONCLUSION

Thus the zirconium oxide shots are beneficial as compared to glass beads shots which creates the higher surface roughness and more breakage thus process becomes less economical to peen aluminium. Since the greater roughness obtained by shot peening with glass beads on aluminium to achieve 0.4 N 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 sample 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 0.6 N intensity with Zir shot peening improved boiling heat transfer appreciably. Increase in surface roughness to a value ranging 3-6 microns could improve heat transfer from 100 to 150% respectively, when water was used as coolant. But water had blakened the surface. Thus Glycol solution as coolant was used.

It was observed that there was no indication of corrosion on the surface of Aluminium specimen when glycol was heated on it. But water boiled on the Aluminium specimen gave colour change to slight blackness. Therefore glycol solution was better boiling heat transfer media for Aluminium because of its excellent anti freeze in corosion resistance properties. The percentage improvement for optimum roughness of 6.62 μm was about 100% only.

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