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BOILING HEAT TRANSFER FROM SHOT PEENED ALUMINIUM SURFACE TO GLYCOL SOLUTION

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ABSTRACT

Boiling heat transfer is largely affected by the surface condition of the work piece and its surrounding boiling media (coolant). In the present investigation coolant used was same as commonly used in car engines that is 95% ethylene glycol with some inhibitor to prevent corrosion. It was used as mixture of water and glycol in 3:1 ratio. Work piece was of Aluminium. The optimum surface roughness obtained by shot peening was 6.27 μm which gave maximum heat transfer coefficient of 17 kw/M$^{2\,0}$ *c at 200V heat input. The percentage improvement in boiling heat transfer compared to original surface was found to be 90% at this optimum roughness. While the percentage improvement with only water as cooling media was still higher and was 148% but at 95kw/M*$^{2\,0}$ *c heat transfer coefficient. Therefore with Glycol solution higher heat transfer coefficient was obtained compared to water, though percentage improvement was lower.*

KEY WORDS:

Boiling Heat Transfer, Glycol as Coolant, Shot Peened Surface, Heat Transfer Equipment, Optimum Surface Roughness, Surface Integrity.

INTRODUCTION

Aluminium alloys have lot of applications in automobile, air craft and heat exchanger manufacturing industries. In order to improve fatigue resistance, boiling heat transfer or both together, aluminium components when shot peened with glass beads or zirconium oxide shots show appreciable improvement while maintaining surface integrity [1]. Peening with nonmetallic shots avoid the effect of contamination which otherwise may lead to electrochemical corrosion.

Boiling heat transfer coefficient is largely affected by the condition of surface, its roughness and length of time it had been used. Water as boiling heat exchanger media produced deposits over the surface and changed the surface condition depending upon the length of time. Therefore the car engine coolent, which is used in most of the car engines contains approximately 95% ethylene glycol and some inhibitors to prevent the corrosion. It is used by making a mixture of water and glycol in a ratio of 3:1.

Earlier investigations showed that surface roughness created by shot peening and grit blasting over ferrous and nonferrous metals were benefitial in improving boiling heat transfer coefficient. However controlled shot peening not only improves boiling heat transfer but also enhances fatigue resistance maintaining surface integrity. It was reported that boiling heat transfer coefficient of brass was found to be improved by 44 to 118% [2]. The optimum surface roughness for brass surface was reported to be 5.6 micron and higher roughness of 7.2 microns started declining the benefits.

GLYCOL SOLUTION

It is excellent anti-freeze and better anti corrosion liquid, however this property is absent with water alone. It is also good heat transfer carrier. Glycol in water solutions are safe and not flammable if combintion of the solution is with in limit. However it is costlier and are not easily available [3]. Hand book of heat transfer media by Paul L. Shrinagar et.

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 [4].

OBSERVATION FOR BOILING HEAT TRANSFER AND SURFACE PREPARATION

1. Resistance of heating element = 550 ohms.
2. Saturation temperature of Glycol solution $t_s = 103^0c$
3. Volume of Glycol solution in boiling chamber = 350ml.
4. Diameter of Aluminium block d = 0.083 m
5. 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/cm^2 . 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 varried to get different surface roughness.

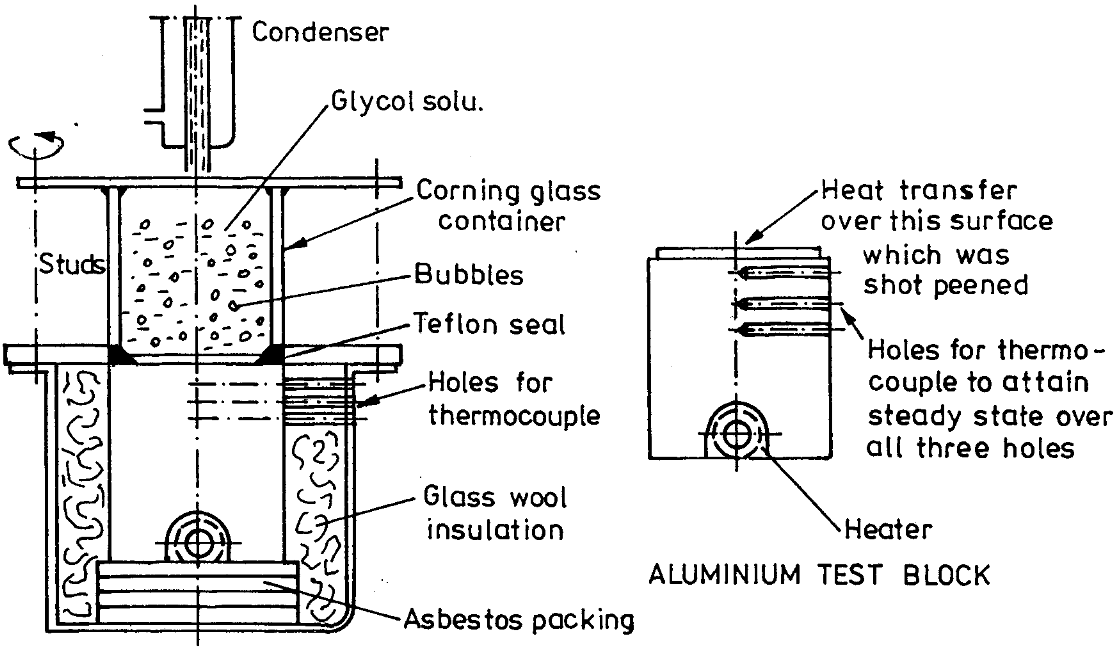

Fig.1 Boiling Heat Unit and Aluminium Test Block

SETS OF SURFACE CONDITIONS OBTAINED

(I) SET - I
Test block face was turned on lathe and finished by 00 - emery paper, R_a obtained was = 0.25 microns.
(II) SET - II
Fine glass beads G - 8, chamber pressure 1.5 kg/cm^2 Nozzle bore - 8mm exposure tune 10 sec. Roughness obtained R_a = 2.2 microns.
(III) SET - III
Parameters same as in set II except exposure time increased to 30 seconds and surface roughness achieved was R_a = 4.2 microns coverage 100%.
(IV) SET - IV
Steel shots 0.6mm dia, chamber pressure 1.5 kg/cm^2 Nozzle bore 6mm exposure time 10 seconds. Surface roughness obtained was R_a = 4.2 microns.
(V) SET - V
Steel shots dia = 0.8mm, chamber pressure 1.5 kg/cm^2 Nozzle bore 6mm exposure time 10 seconds. Surface roughness obtained was R_a = 6.27 microns.
(VI) SET - VI
Chilled C.I. Grit G.39 (1 to 1.4mm) chamber pressure 1.5 kg/cm^2 Nozzle bore 6mm exposure time 10 seconds. On the initial rough surface, R_a = 8.0 microns was obtained.

RESULTS AND DISCUSSIONS

In the present investigation the boiling heat transfer coefficient of Aluminium was found To be improved by 28.24-95.9% (at 180 volts input), 28.8-89.8% (at 190 volts input), 28.0-88.9% (at 200 volts input), where surface roughness was varied from 2.2 microns to 8.0 microns as shown is Chart 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)	Corresponding Surface Temp. 0_c (t)	Surface Temp. 0_c (t)	Excess Temp. dt = t - t	Boiling Heat transfer coeff. H = q/dt kw/ m^{20} c	% Improvement in h over virgin surface
Set - I	Ra = 0.25 µ m								
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 -I I	Ra = 4.2 µ m								
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 = 2.2 µ m								
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	1112.3	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 = 6.27 µ m								
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 = 2.2 µ m								
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 µ m								
1.	180	589.1	108.9×10^3	4.48	111.2	103	8.2	13.3	72.3 %
2.	190	654.4	121.3×10^3	4.56	112.0	103	9.0	13.5	59.2 %
3.	200	727.3	134.4×10^3	4.59	112.3	103	9.3	14.9	67.4 %

Results show that shot peening has resulted in improvement of boiling heat transfer coefficient. Roughness occurred by shot peening was responsible for creating active nucleation sites which were favourable for nucleate boiling mode.

It was also evident from the results that for initial surface roughness, increase in boiling heat transfer coefficient was more rapid and after certain roughness, it became constant.

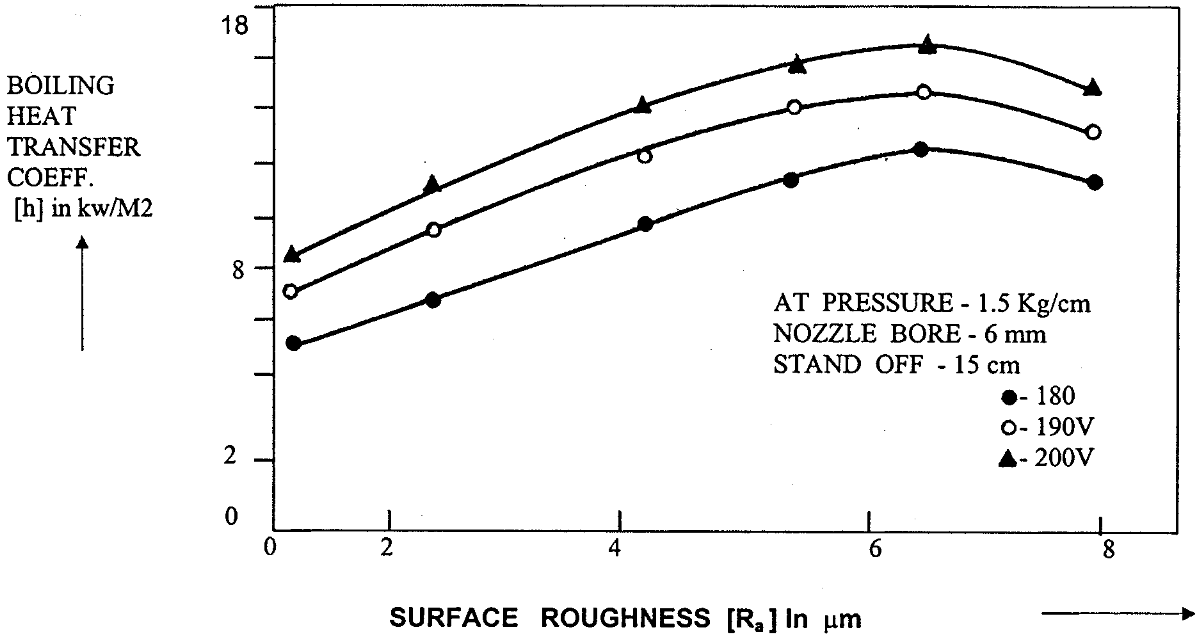

FIG. 2 Variation of boiling heat transfer coefficient with shot peened roughness

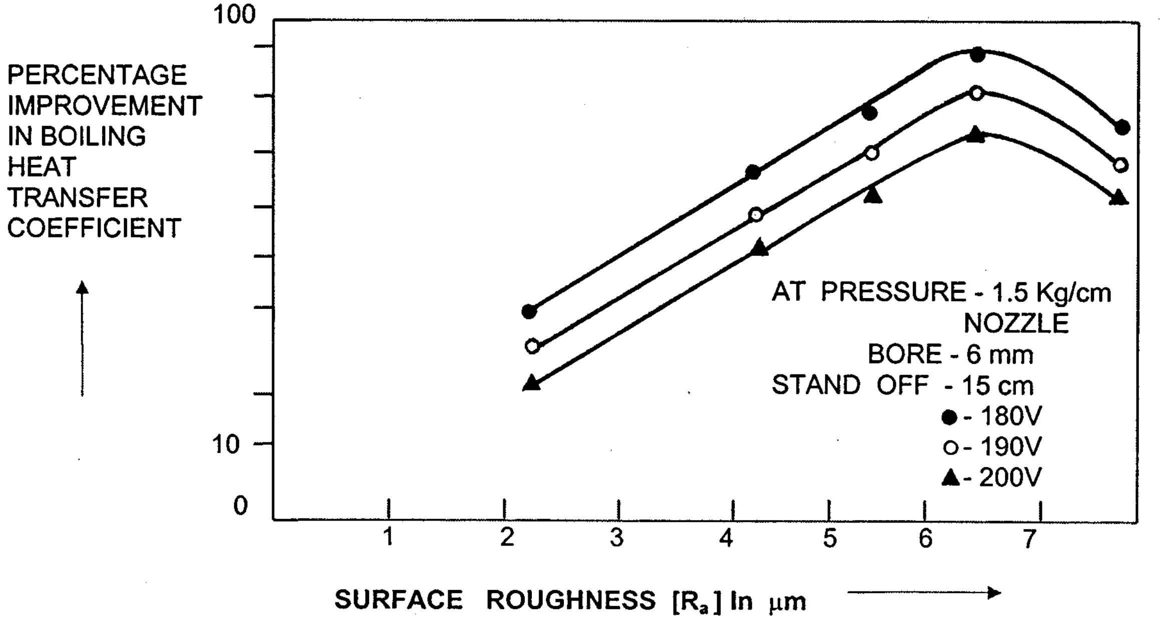

FIG. 3 % improvement in boiling heat transfer coefficient by shot peening

Such typical behaviour of the curve may be attributed due to the increase in nucleation sites and formation of more number of bubbles initially. But as the surface roughness increased beyond a unit the depth of the dent increased, size of the bubbles get increased, which, in turn, reduced the number of bubbles, there by reducing nucleation sites. This shows that for a constant heat transfer area, there has to be certain optimum size of the bubbles. It is evident from the graph that optimum size was reached at surface roughness of 6.27 microns So, this surface roughness may be taken as an optimum roughness for maximum heat transfer coefficient of Aluminium surface where spherical shots were used.

It is also found that at very high roughness (i.e. 8μm) obtained by grit peening, coefficient of boiling heat transfer starts decreasing. This was because of increasing in the dent size which enlarge the size of bubble and hence less number of nucleation sites were available. Therefore even the conical shape was not beneficial compared to spherical dent of optimum size.

On comparing the boiling heat transfer coefficient of brass and Aluminium surfaces, the coefficient was higher for Aluminium surface at higher roughness values, but it is nearly equal to the values for brass at higher roughness values. This may be because of higher thermal conductivity of Aluminium (225 W/m^{0}C) in comparison of brass (107 - W/m^{0}C).

The effect of surface roughness on boiling heat transfer coefficient was lower in the case of Aluminium surface. Besides this, the optimum surface roughness was higher for Aluminium surface (6.27 microns) than the brass surface 5.6 microns). The difference is negligible.

It was also observed that there was no indication of corrosion on the surface of aluminium specimen when glycol solution 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.

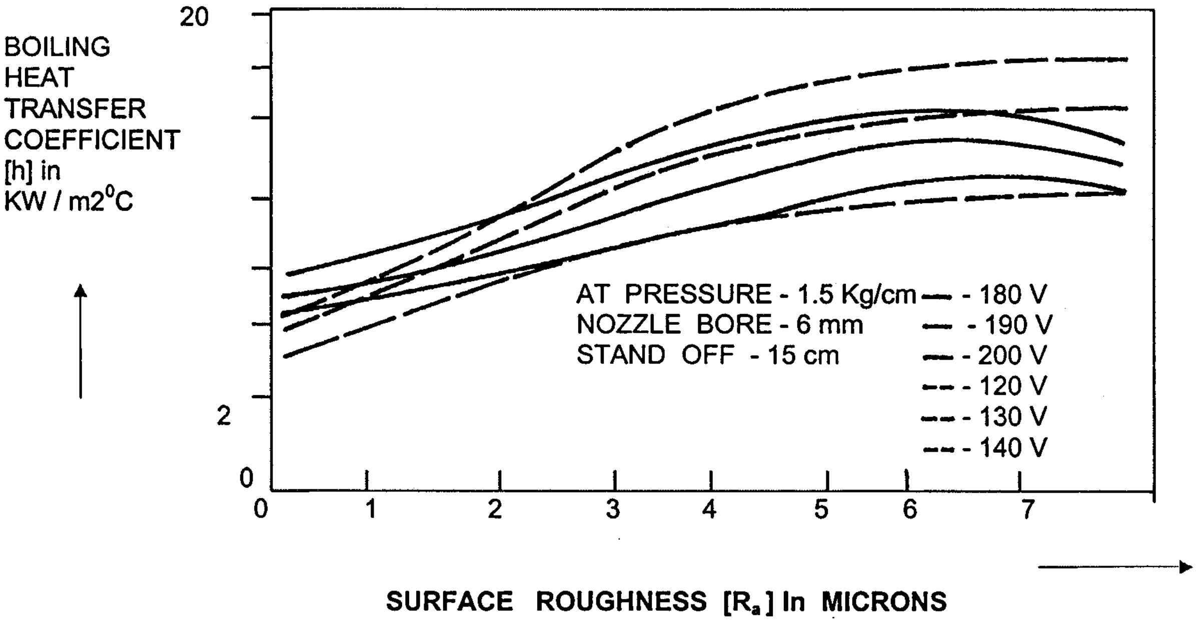

FIG. 4 Variation of boiling heat transfer coefficient with shot peened roughness [aluminium and brass]

CONCLUSION

Although the percentage improvement in boiling heat transfer coefficient for Aluminium surface and glycol solution was lower but because of its excellent antifrrge and corrosion resistant properties it can be used successfully in various heat transfer applications. The data obtained in the present investigation for shot peening can be used for modification of the existing radiator & water jacket of cylinder head and block of cars. The overall size can be reduced by shot peening of the radiator tubes and water jacket of the cylinder head.

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