Effect of Shot Peening on Pool Boiling Heat Transfer of Non Ferrous Alloys

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ABSTRACT

Pool boiling heat transfer coefficient has been found to improve by 12 to 33% in case of cupro nickel tubes after the outer surface was peened with C.I. grits of G-25 size. Similar treatment on admiralty brass tube resulted improvement of heat transfer coefficient of 11 to 32%. Peening treatment on the surface of condenser tube, thus, shows a good promise for increasing heat transfer coefficients.

Key Words:

Pool boiling, heat transfer coefficient, heat flux, shot/grit peening.

Introduction:

In several familiar processes in engineering the heat transfer from inside of a tube to outside takes place due to conversion of liquid to vapour in contact with outer surface. The boiler, the distillation column, the refrigerator evaporator and several cooling applications are examples. Cooling problems in nuclear reactors and rocket motors where dissipation of heat is at very high rate(10^8 K cal/hr m^2) are of great importance of this type (1). The results of several observers for heat transfer from an electrically heated wire indicate the existence of several regimes for this type of boiling as shown in Fig.1. Here Δt is the temperature difference between the surface of wire and saturation temperature of water and Q/A is the heat transfer rate from the surface of a heated platinum wire submerged in water.

In the natural convection regime, A to B, Q/A is proportional to $(\Delta t)^{5/4}$. In the nucleate boiling regime, B to C, Q/A varies as $(\Delta t)^n$ where n lies between 3 to 4. with increase in n the bubble formation becomes so rapid that the bubbles can not get away before they tend to merge and spread out over the surface. The heat has to be conducted through vapour film so formed. This results in a critical Δt corresponding to point C. The point C can be raised if the rapidly forming bubbles are made to break away from the surface, such increasing heat transfers have been achieved by increasing the wettability of surface by way of either adding some reagents into boiling medium or roughening the surface. Mechanical slotting or emery paper treatments were sometime given to the surfaces of tubes but proved time consuming and uncontrollable.

In the present investigation it was proposed to give shot/grit peening treatment to the outer surface of the tube to create roughness. It was proposed to study the heat transfer coefficient of such tubes in the nucleate boiling regime. It may be pointed out here the shot/grit peening is highly contrallable in as much as the penetration (size or cavities) and uniformity are concerned. Further this process is now mechanised to an extent that large scale peening is quite economical.

Experimental Work:

Tube samples of length 97 mm were chosen for study. The samples were made in two materials cupro nickel and admiralty brass. Tables 1 and 2 describe their composition and mechanical properties.

Table.1

Cupro Nickel (IS:1545, Cu Ni 31-Mn 1 Fe)

Condition : Solid drawn, O.D : 25.0 mm, I.D : 22 mm

Chemical Composition %

Ni : 30-32, Fe : 04-1.00, Mn : 0.5-1.5, Pb : 0.01, S : 0.08
C : 0.06 Impurities : 0.3, Cu : Rest

Mechanical Properties

UTS : 353-432 N/m^2, Elong : 40-55%, Hardness : 90-110 H_v5

Table.2

Admiralty Brass (IS:1545 : 1969 Cu Zu 29 Su 1 As)

Condition. Solid drawn, OD:26.7 mm, 1.D : 22 mm

Chemical Composition %

Cu : 70-73.0, Sn : 1.0- 1.5, As : 0.02-0.06, Pb : 0.075,
Fe : 0.06 Impurities : 0.30, Zn : Rest

Mechanical Properties

UTS : 343-441 N/m^2, Elong : 55-65%, Hardness : 80-105 H_v 5.

Fig. 2 shows the details of tube samples and Fig.3 shows its photograph. The tube carries a heating element (main heater) carried in porcelain tubes at the ends. The porcelain tubes in turn pass through wooden end plugs which are shielded from main heater by asbestos washers. The main heater terminals are carried through porcelain tube to PVC tubes covering the porcelain tubes, and then connected to regulated power supply. The whole assembly is immersed in water contained in glass container. All the joints are sealed with M-seal compound and air from inside of tube can escape through porcelain tube to PVC tube and then out. Failure of sealing may cause water entering into tube whereby main heater may be damaged. Two hollow tubes are brazed transversely to outer tube surface at whose bottom the thermo-couple joints are soldered. The thermo-couple leads are again carried in PVC tube not allowing the water enter the trans-verse tubes. The complete set-up is shown in outline in Fig.4 and its photograph in Fig.5. Thus the system permits measure-ment of temperature at two points in the surface through a thermo-pile and is an improvement over earlier set-up (2). A secondry heater is kept immersed in water to keep its temperature constant.

The main heater was connected to mains through a manually controlled transformer and current through it can be varied by manipulating voltage. It is assumed that there is no temperature gradient through tube wall. After steady conditions are reached with water temperature kept constant by auxilliary heater (it takes 5-6 minutes) the temperature of wall was read through thermopile. Several such readings were obtained for both materials on untreated and shot/grit peened samples. The peening conditions are described below. Air pressure : 6.0 kg/cm^2, stand off : 25 mm, coverage : 98% Shots : S-330, Grits : G-25, Time of peening : 15 min. The peening was done in the equipment described elsewhere (3).

S-330 shots did not show much improvement in heat transfer coefficient but SAE G-25 (passing through 0.70 mm screen opening) showed the improvement. Tables - 3 and 4 describe the results for cupro-nickel and admiralty brass respectively.

Table - 3

Results of Heat Transfer on Cupro-Nickel

S. No.	Primary Heater Voltage (v)	Heat Input K cal/hr.	Heat Flux (q) K cal/hr m2	Virgin Tube			Grit Peened Tube			% improvement $\frac{h_2-h_1}{h_1}$
				T_1 °C	(T_1-T_{sat}) ° ΔT_1 °C	$h_1=\frac{q}{\Delta T_1}$ K cal/hr m^2 °C	T_2 °C	(T_2-T_{sat}) ΔT_2 °C	$h_2=\frac{q}{\Delta T_2}$ K cal/hr m^2 °C	
1.	40	91.72	13886	99.0	1.0	13886	98.8	0.8	17357	25
2.	50	143.32	21697	100.0	2.0	10848	99.5	1.5	14464.6	33
3.	60	206.40	31504	100.5	2.5	12601	100.0	2.0	15752	25
4.	70	280.92	42880	101.0	3.0	14293	100.5	2.5	17152	19.9
5.	80	366.92	56014	102.0	4.0	14003	101.5	3.5	16004	14.0
6.	90	521.72	79635	102.5	4.5	17696	102.0	4.0	19908	12.5

Table-4

Results of Heat Transfer on Admiralty Brass

S. No.	Primary Heater Voltage (v)	Heat Input K cal/ hr.	Heat Flux (q) K cal/ hr m^2	Virgin Tube			Grit Peened Tube			% improvement
				T_1 °C	$(T_1 - T_{sat})$ ΔT_1 °C	$h_1 = \frac{q}{\Delta T_1}$ K cal/hr m^2 °C	T_2 °C	$(T_2 - T_{sat})$ ΔT_2 °C	$h_2 = \frac{q}{\Delta T_2}$ K cal/hr m^2 °C	$\frac{h_2 - h_1}{h_1}$
1.	40	86.0	10735.	99.90	1.9	5650.41	99.70	1.70	6315.2	11.76
2.	50	134.3	16774	100.40	2.4	6989.48	99.95	1.95	8602.4	23.07
3.	60	193.5	24155	101.00	3.0	8051.83	100.60	2.60	9290.6	15.38
4.	70	263.4	32877	101.55	3.55	9261.50	100.95	2.95	11145.2	20.34
5.	80	344.0	42943	102.15	4.15	10347.7	101.40	3.40	12630.3	22.05
6.	90	435.3	54340	103.25	5.25	10350.5	101.95	3.95	13756.0	32.9

Discussion:

From Tables 3 and 4 it is seen that grit peened surface on outside of the tube has resulted in improvement of heat transfer coefficient. However, it is observed that for both the materials this improvement varies with heat input. In case of cupro nickel it first increases from 25% to 33% and then decreases. In case of admiralty brass it increases gradually from 11.76% to 32-9%. The results on shot-peened samples (S-330 shots) are not described but they showed no improvement.

While it is understood that roughness caused by peening is responsible for breaking away of bubbles formed on the tube surface it is not explained why should it happen with grit peened surface and not with shot peened surface. The irregular nature of the grits may be one reason but work need be done to understand the whole mechanism.

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References:

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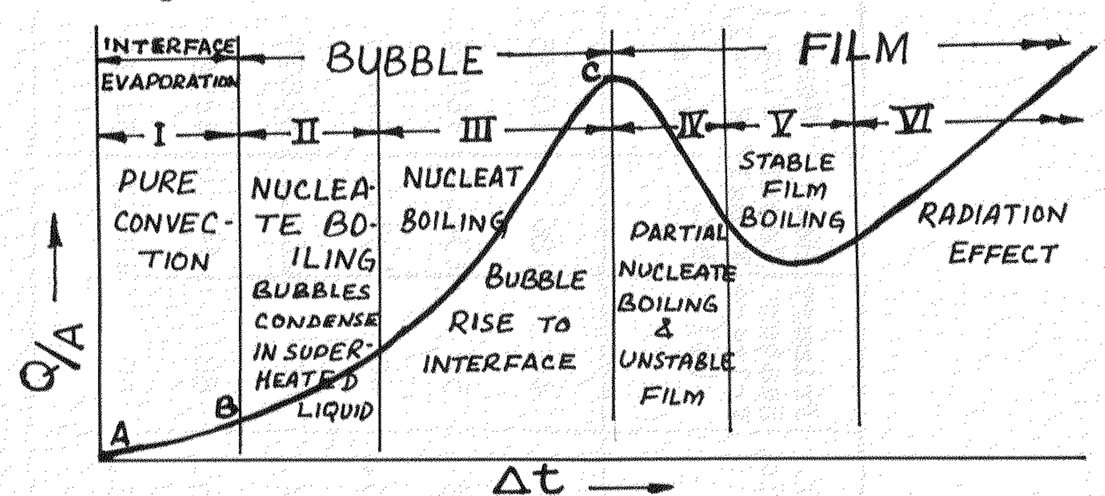

Fig. 1. POOL BOILING REGIMES.

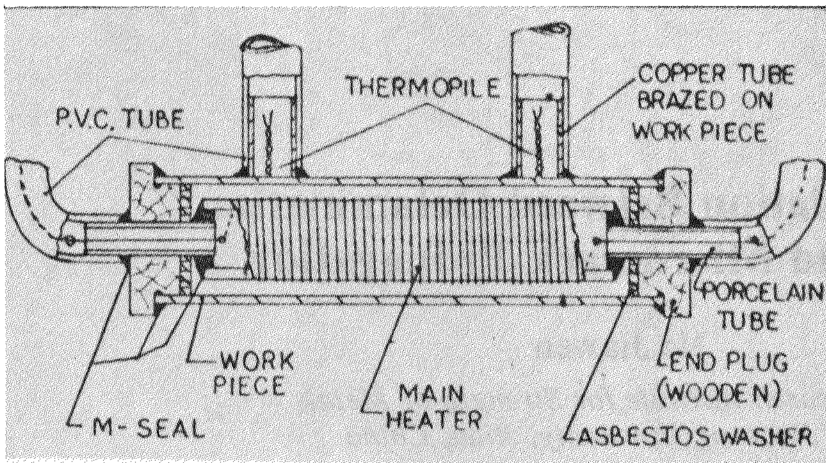

Fig. 2. DETAILS OF SAMPLE

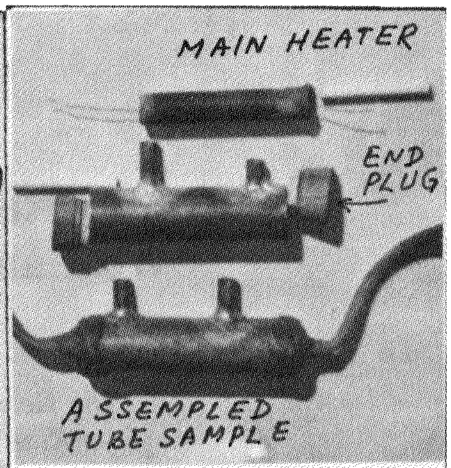

FIG. 3. PHOTOGRAPH.

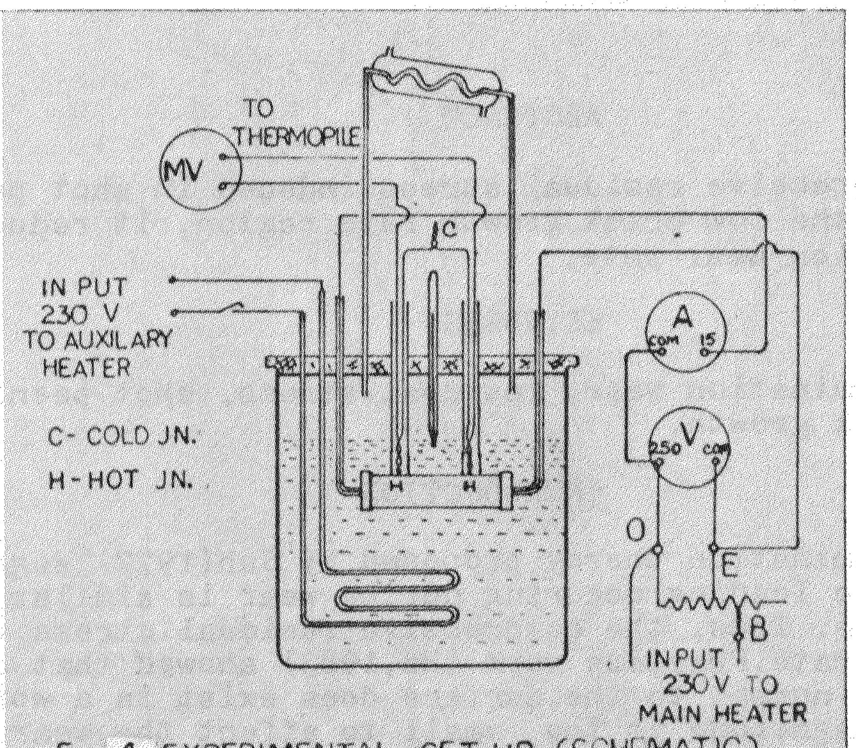

Fig. 4. EXPERIMENTAL SET UP. (SCHEMATIC)

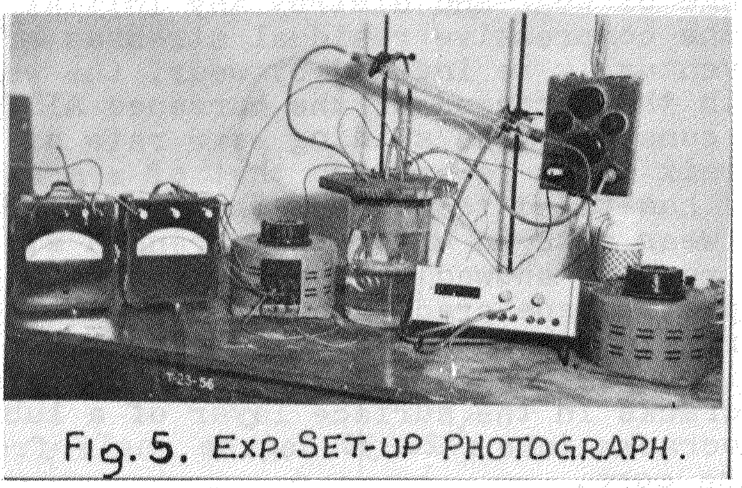

Fig. 5. EXP. SET-UP PHOTOGRAPH.