EXPERIMENTAL INVESTIGATION OF FORCED CONVECTIVE HEAT TRANSFER THROUGH ROUGH AND SMOOTH SURFACE ALUMINIUM 6063-T6 ROD BY USING PIN FIN APPARATUS

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Abstract: In reciprocating engines, transfer of heat is the primary task for increasing the engine efficiency and effectiveness rather than liquid cooling; the air cooling is most preferable for its simplicity. By increasing the contact surface and usage of high value heat transfer coefficient metals air cooling is highly possible compared to other metals aluminium fin heat exchanger provides better corrosion resistance due to a better galvanic balance of the materials and more cost effective . In this experiment, we have take Aluminium 6063-T6 rod with different surface roughness to analyze heat transfer for better rate of heat transfer. Usually smooth surfaced aluminium 6063 alloy is used as heat exchangers here same aluminium 6063 alloy with rough surface fin has been tested. The high contact between air and the metal surface this is one of the heat transfer enhancement method used traditionally and not in practical applications. In this paper comparison has been done on for the Aluminium 6063 rod with three different surface roughness values. Fins are surface that extend from an object to increase the rate of heat transfer to or from environment by increasing convection. In engine for better heat transfer even in mode of convection, heat is exchanged efficiently

***IndexTerms* - Heat transfer coefficient, Pin-Fin apparatus, Aluminium 6063 Rod, Rough and Smooth surface.**

I. INTRODUCTION

In the study of heat transfer, fins are surfaces that extend from an object to increase the rate of heat transfer to or from the environment by increasing convection. The amount of conduction, convection, or radiation of an object determines the amount of heat it transfers. Increasing the temperature gradient between the object and In the study of heat transfer, fins are surfaces that extend from an object to increase the rate of heat transfer to or from the environment by increasing convection. The amount of conduction, convection, or radiation of an object determines the amount of heat it transfers. Increasing the temperature gradient between the object and the environment, increasing the convection heat transfer coefficient, or increasing the surface area of the object increases the heat transfer. Sometimes it is not feasible or economical to change the first two options. Thus, adding a fin to an object, increases the surface area and can sometimes be an economical solution to heat transfer problems Units.
Aluminium alloy 6063 is a medium strength alloy commonly referred to as an architectural alloy. It is normally used in intricate extrusions. It has a good surface finish, high corrosion resistance is readily suited to welding and can be easily anodized. Most commonly available as T6 temper, in the T4 condition it has good formability. Applications of 6063 is typically used in Architectural applications, Extrusions, Window frames, Doors, Shop fittings, Irrigation tubing. In balustrading the rails and posts are normally in the T6 temper and formed elbows and bends are T4. T4 temper 6063 aluminium is also finding applications in hydro formed tube for chassis. Aluminium 6063 alloy having greater strength and also some surface finish qualities.

II. HEAT RANSFER

The study of thermodynamics reveals that energy transfers such as heat and work can take place between system and surroundings when the bodies are in non-equilibrium state. Work is the form of energy due to force and heat is the form of energy transfer required to bring a system into equilibrium. However, the time require to attain the equilibrium can’t be found using laws of thermodynamics. Heat transfer deals with the rate of energy transfer. To find the status at intermediate states we need to introduce the time factor thus needed to study the heat transfer. The study of heat transfer includes the physical process where thermal enrgy is transferred as a result of a temperature difference. There are basically two distinct processes for the transport of heat energy viz., Conduction and Radiation. If conduction occurs in a medium where there is relative motion of particles it is called convection. Therefore the study of heat transfer requires the knowledge of the three modes of heat transfer – Conduction, Convection and Radiation.

2.1 Conduction and Fourier’s law:

This is the mode of heat transfer, which occurs in a medium without any relative motion of particles, though it is impermeable to any other kind of radiation. This is more dominant in solids. The governing equation is

$$Q = (K\ A\ \Delta T)/L$$

Q = Rate of heat transfer (Watts or Kilo watts)

K = Thermal conductivity of the material (W/ m-K)
A = Area normal to the direction of heat flow (m^2)
ΔT = Temperature difference across the material (K)
L = Thickness of the material (m)

2.2 Convection and Newton's law:

This is the mode of heat transfer, which occurs due to the motion of molecules carrying heat from one zone to another zone. The governing equation is

$$Q = h\, A_s\, \Delta T$$

Q = Rate of heat transfer (Watts or Kilo watts)
h = Convective heat transfer coefficient (W/ m^2-K)
A_s = Exposed surface area (m^2)
ΔT = Temperature difference across the material (K)

2.3 Radiation and Stefan-Boltzmann law:

Radiation is an electromagnetic phenomenon in which heat energy is carried by the waves in quantum. This can happen between the bodies without any presence of medium as earth is receiving heat from sun through space. In radiation whenever a body is at a temperature greater than 0 K, i.e., - 273^0 C, it experiences molecular motion, vibration and collision which result in emitting energy at different wavelengths. The governing equation is

$$Q_b = \sigma A T^4$$

Q_b = Heat energy emitted by black body (Watts or Kilo Watts)
A = Area (m^2)
T = Absolute temperature (K)
σ = Stefan-Boltzmann constant
= $5.67 * 10^{-8}$ W/m^2 K^4

III. SELECTION OF MATERIAL

Aluminium 6063 has been chosen as a testing specimen for heat transfer process. Following properties has given the chance for selection of material.

Table 3.1. Chemical composition of aluminum 6063 alloy [1]

TYPE OF ELEMENT	% PRESENT
Magnesium	0.45-0.90
Silicon	0.2-0.6
Iron	0.1-0.35
Chromium	0.0-0.10
Copper	0.0-0.10
Titanium	0.0-0.10
Manganese	0.0-0.10
Zinc	0.0-0.10
Aluminum	Remaining

Table 3.2. Physical properties of aluminium 6063 alloy [1]

Property	Value
Density	2.70 g/cm^3
Melting point	655^0 C
Thermal Expansion	$23.5*10^{-6}$/K
Modulus of Elasticity	69.5 GPa
Thermal Conductivity	201 W/m-K
Electrical Resistivity	52% IACS
Electrical Resistivity	$0.033*10^{-6}$ Ω-m

Table 3.3. Mechanical properties of aluminium 6063 alloy [1]

To BS EN 755-2: 2008 Rod & Bar Up To 150mm Dia. & A/F	
Property	**Value**
Proof Stress	170 Min MPa
Tensile Strength	215 Min MPa
Elongation A50 mm	8 Min %
Hardness Brinell	75 HB
Elongation A	10 Min %

3.1 Testing specimen measurements.

Three different surface roughness values of Aluminium 6063 alloy has been tested through forced convection.

Table 3.4 Surface Roughness values

S. No	Type of specimen	Average value (microns)
1	Rough rod	7.65 microns
2	Medium rod	3.25 microns
3	Smooth rod	0.64 microns

Fig.3.1 Sample specimens

IV. EXPERIMENTAL SETUP

Our experimental set up has been done on a Pin-Fin apparatus as shown in the fig. The testing specimen was included in an enclosed area. The blower is attached to one end is used for the air flow over the surface of specimen. While doing the experiment we have varied the velocity of air with respect to the specimen. The other end is connected to the heater to supply the current which interns heat the specimen.

It is obvious that a fin surface sticks out from the primary heat transfer surface. The temperature difference with surrounding fluid will steadily diminish as one moves out along the fin. The design of the fins therefore required knowledge of the temperature distribution in the fin. The main objective of this experimental set up is to study temperature distribution in a simple pin fin.

Fig 4.1 Experimental setup

4.1.Experimental Readings :

Table 4.1 Smooth material readings

Air velocity	Surface temperatures			In let	Out let	Voltage	Current
U	T2	T3	T4	T1	T5	V	I
6	59	49.3	46.3	26.1	26.7	34	32
5	70	62.5	59	26.3	27.2	34	33
4	78	71	67.7	27	28	36	34
3	81	74	70.6	27.3	28.7	36	34
2	90	83.6	81	27.6	29.3	37	35
1	98	90	87.2	27.9	29.7	38	36

Table 4.2 Light rough material readings

Air velocity	Surface temperatures			In let	Out let	Voltage	Current
U	T2	T3	T4	T1	T5	V	I
6	60.5	49.5	46.7	26.1	26.7	34	32
5	71.2	59.5	55.6	27.7	28.2	34	33
4	83	72.5	70	28	28.8	36	34
3	97.3	86	84.1	28.3	30	36	34
2	104.1	91.6	88.9	29	30.6	37	35
1	107.4	95.6	92	29.3	31.5	38	36

Table 4.3 Rough material readings

Air velocity	Surface temperatures			In let	Out let	Voltage	Current
U	T2	T3	T4	T1	T5	V	I
6	67.5	57.9	52.3	26.1	27.5	34	32
5	88.6	78.4	72.1	27.4	28.2	36	33
4	93.7	83.6	77.3	28.1	29.6	36	34
3	98.1	88.6	83.2	29.5	330.5	38	34
2	102.4	92.4	87	30.3	30.9	38	35
1	109	101	98.1	31	32.5	40	36

4.2 Model Calculations:

Rough material calculation from velocity at 6

$T_{avg}=(T_2+T_3+T_4)/3$

$= (67.5+57.9+52.3)/3$

$= 59.23^0C$

T_a = Ambient temperature $=T_1$

$= 26.1^0C$

T_f = Film temperature

= $(T_{avg}+ T_a)/2$ = (59.23+26.1)/2

= 42.67^0C

Properties of Air at Temp 42.67^0C

Thermal conductivity (K_a) = 0.02774 W/m-K

Kinematic viscosity (v) = $17.22*10^{-6}$ m^2/s

P = perimeter of the fin = 3.14 *d

d = Diameter of the fin = 0.02 m

P = 3.14 * 0.02 = 0.06283 m

A = Cross section area of the fin

A = $3.14* (0.02)^2 / 4 = 3.14*10^{-4}$ m^2

K_f= thermal conductivity of the martial

= 218 W/m K

Reynolds number (Re) = (u *d) / ν

= $(6 *0.020)/17.22*10^{-6})$

= 6966.9014

Nusselt number (Nu) = $0.614(Re)^{0.466}$

= 37.93

h = heat transfer co efficient = (Nu * K_a) /d = (37.93 * 0.02774)/0.02

= 52.645 W/m^2K

$$m = \sqrt{\frac{hP}{K_f A}}$$

= $(52.645 *0.06283 / 218*3.14*10^{-4})^{1/2}$

= 6.94

L = length of the fin =0.12 m

mL_c = 0.125 * 6.94 = 0.8675

$Q_{actual} = (T_s – T_f) (h\ P\ A\ K)^{1/2}Tanh\ (mL_c)$

if $T_s = T_2, T_f = T_1$

Q_{actual}=$(67.5-26.1)(52.645* 218*0.06283*3.14*10^{-4})^{1/2}$ * Tanh (0.8675)

= 13.7916 Watts

Q_{ideal} = h P L ($T_s – T_f$)

= 52.645*0.06283*102*(67.5-26.1)

= 16.432 Watts.

Efficiency (η) = Q_{actual} / Q_{ideal}

= 84.02 %

V. RESULTS AND DISUSSIONS:

The Aluminium 6063 rod has been tested with three different surface roughness values in Pin-Fin apparatus by forced convection.

The experimental results show that by increasing the velocity the convective heat transfer coefficient is also an increase which is mostly applicable in IC engines. At the same time the convective heat transfer coefficient high rough surface.

The heat transfer rate is also more in rough surface. But the efficiency of the material decreases as the surface roughness increases.

5.1 Variation of Heat Transfer Coefficient with Surface Roughness

Table 5.1 Variation of h and R_a and U

S.No	Specimen	R_a	Convective heat transfer coefficient (h)					
			At U=6 m/s	At U=5 m/s	At U=4 m/s	At U=3 m/s	At U=2 m/s	At U=1 m/s
1	Smooth rod	0.64	52.63	48.16	43.35	38.09	32.01	22.60
2	Medium rod	3.25	52.64	48.26	43.43	38.15	32.09	22.66
3	Rough rod	7.65	52.65	48.32	43.52	38.23	32.15	22.71

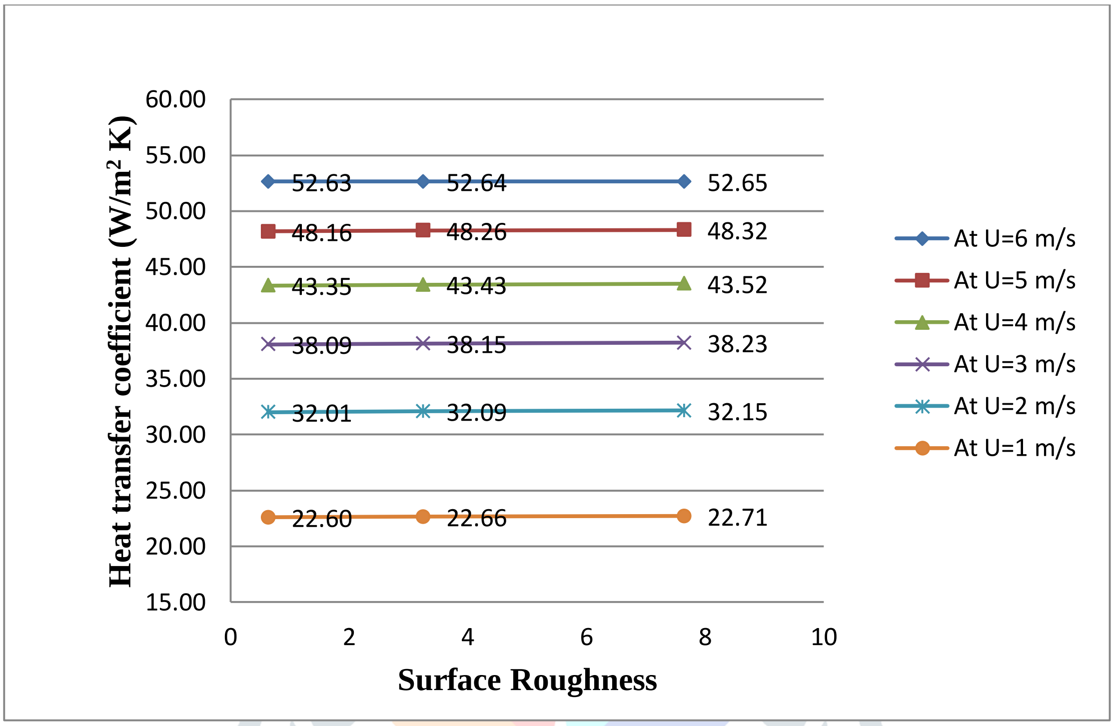

Fig 5.1 Heat transfer coefficient vs Surface Roughness

5.2 Variation of Heat Transfer Rate with Surface Roughness

Table 5.2 Variation of Q and R_a and U

S.No	Specimen	R_a	Heat transfer (Q_{actual})					
			At U=6 m/s	At U=5 m/s	At U=4 m/s	At U=3 m/s	At U=2 m/s	At U=1 m/s
1	Smooth rod	0.64	10.97	13.55	14.48	13.66	13.66	11.25
2	Medium rod	3.25	11.47	13.51	15.64	17.58	16.47	12.57
3	Rough rod	7.65	13.81	19.02	18.69	17.51	15.84	12.58

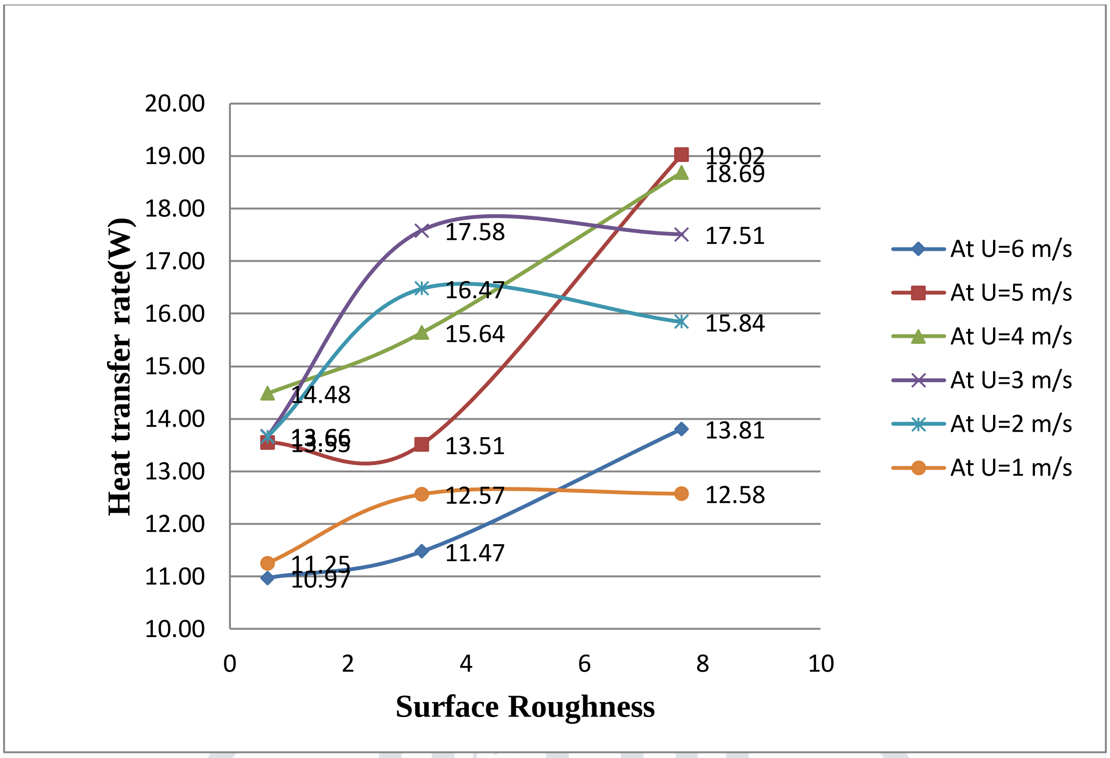

Fig 5.2 Heat transfer rate vs Surface Roughness

5.3 Variation of Efficiency with Surface Roughness

Table 5.3 Variation of η and R_a and U

S.No	Specimen	R_a	Efficiency (η) %					
			At U=6 m/s	At U=5 m/s	At U=4 m/s	At U=3 m/s	At U=2 m/s	At U=1 m/s
1	Smooth rod	0.64	84.03	85.37	86.87	88.60	90.70	94.21
2	Medium rod	3.25	84.03	85.34	86.85	88.58	90.67	94.18
3	Rough rod	7.65	84.02	85.32	86.82	88.55	90.65	94.16

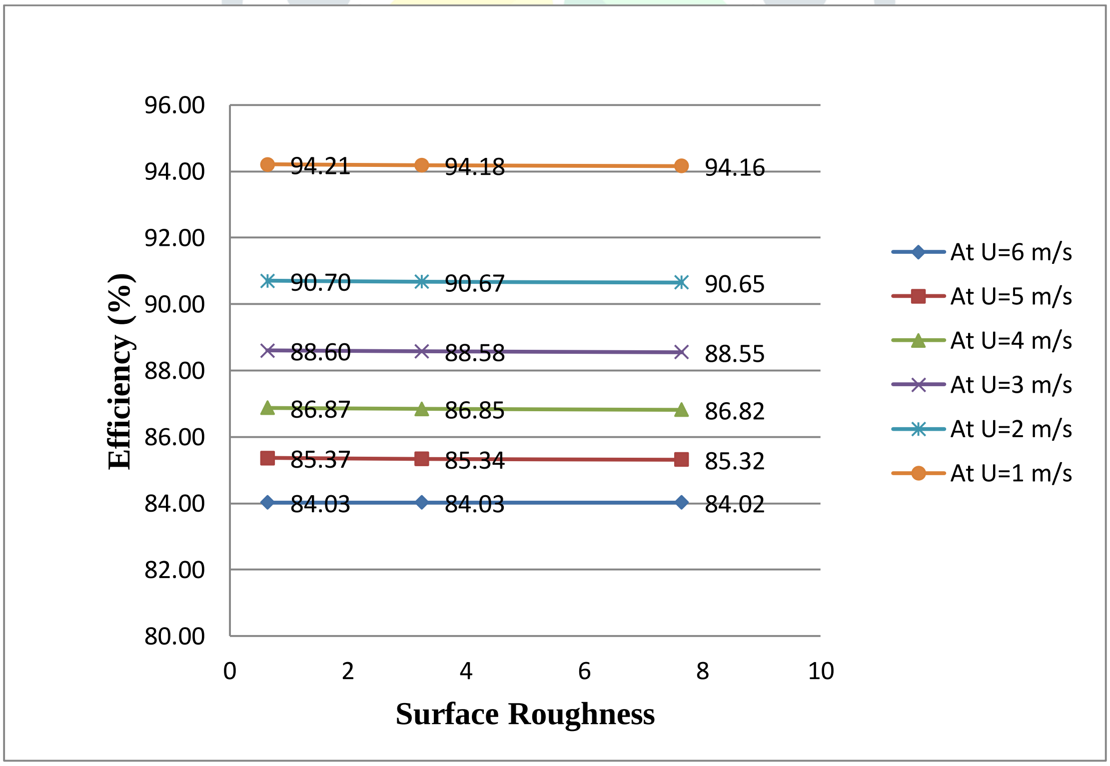

Fig. 5.3 Efficiency vs Surface Roughness

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