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# Investigation of Heat Transfer Coefficient in 'Square Shaped Pin-Fin'.

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***Abstract:*** *Pin-fin is one of the most convenient ways of heat transfer. Square shaped pin fin is a non-exposed analysis. In this paper we have done analysis of square shaped pin fin with and without hole. We used aluminium and stainless steel as a fin material. Analysis content observations and results with heat input 70 volt(16.31W). We compared the heat transfer coefficient of square shaped fin with and without hole. The result show heat transfer coefficient of with hole square shaped fin is higher than without hole square shaped fin.*
***Keywords-*** *Pin Fin, Heat transfer coefficient, Square shaped, Aluminium, Stainless Steel.*

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## I. Introduction

Heat is a most well-known form of energy. Heat is being transferred by various ways. Convection heat transfer between a hot solid surface and the surrounding colder fluid is governed by the Newton's cooling law which states that "the rate of convection heat transfer is directly proportional to the temperature difference between the hot surface and the surrounding fluid and is also directly proportional to the- area of contact or exposure between them". By comparing the results of square shaped fin with and without hole we are going to show that whose coefficient is better. Gawali et.al.[1] It is observed that for the same fin material, the trapezoidal fin experienced the least temperature drop over its length, the parabolic fin is the most efficient in dissipating heat to its surroundings, Due to their greater thermal conductivity, copper fins were, in general, more efficient than aluminium fins. Pin fins were, in general, more efficient than straight fins at dissipating heat. Yet, the latter were more preferred owing to the ease in manufacturing and the ease in clustering them over small areas. However, a recent paradigm shift indicates that designers were turning towards the greater heat dissipation potential offered by pin fins. Pin fins have found applications in fields where thermal dissipation plays a very crucial role. Saurabh Bahadure et al [2] have done theoretical and experimental study on thermal performance of pin fin with circular perforations. The results show that perforations increases heat transfer rate. Amol Dhumne et al [3] have done analysis on heat transfer enhancement by experimentation. In addition, analysis of pressure drop over a flat surface with cylindrical pin fin in rectangular channel was done. The performance parameters considered were Reynolds number and Nusselt number. The correlation equations for friction factor, heat transfer and enhancement efficiency were developed. The results shows that the cylindrical perforated pin fins have higher heat transfer rate than cylindrical fins. It was observed that efficiency of fins vary depending on the inter-fin spacing ratio and clearance ratio. A low inter-fin spacing ratio assured high heat transfer. Richard [4] from the experimental analysis in this project the enhancement of heat transfer of fin for different materials was analyzed and it could be improve. Fin efficiencies of materials are 66%, 91%, 94% were achieved. And among these materials from the analysis that copper has high thermal conductivity than brass and aluminium. In this paper the system follows forced convection as the mode of heat transfer instead of it in future we can use natural convection as a mode of heat transfer.

There are various types of shapes of pin-fins available in to the market. Some of these are rectangular, cylindrical, annular, tapered. We have done analysis of square shaped fins and square shaped drilled pin-fins for heat transfer analysis with Aluminium and stainless steel with heat input of 70 volts. Analysis of elliptical, circular, porous and rectangular fins is available. But specific analysis of square shaped pin-fin with hole is not available till now.

**NOMENCLATURE**

Q Heat transfer rate
h Convective heat transfer coefficient
P Perimeter of fin
k Thermal conductivity
Ac/s Cross section area
L Length of fin
Tatm Atmospheric temperature
Cd Coefficient of discharge
Tm Mean film temperature

T∞ Ambient temperature
Re Reynolds number
dh Hydraulic diameter
Nu Nusselt number
g Gravitational acceleration
Temperature difference between fin and ambient
Kinematic viscosity
Hw Water head

The heat transfer from pin fin by convection is expressed as:

$$Q = \sqrt{hpkA} \times (Tb - T\infty) \times \tanh(mL) \qquad (1)$$

Reynolds's number

$$Re = V \times d/\upsilon \qquad (2)$$

Discharge of air through rectangular cross section

$$Q = Cd \times \pi/4 \times d^2 \times \sqrt{2gh\,((\rho_w/\rho_a) - 1)} \qquad (3)$$

Nusselt Number

$$Nu = 0.615 \times (Re)^{0.456} \qquad (4)$$

We have to calculate the temperatures theoretically,

$$(T1 - Tf) / (To - Tf) = \{\cosh[m \times (L - X)]\}/\cosh(m \times L) \qquad (5)$$

$$h = Nu \times Kair/dh \qquad (6)$$

$$m = \sqrt{hp / (k_{Al} \times A_{c/s})} \qquad (7)$$

Hydraulic Diameter

$$Dh = 4Ac/s/P \qquad (8)$$

## II. Experimental Setup

The experimental setup consists of heater to which test specimen is attached which is to be analyzed. A blower is used as forced convection device whose inlet is connected to a rectangular duct and outlet is connected to flow control valve. To measure the supply to heater, a dimmer stat is provided. An ammeter and a voltmeter are also provided. For experimentation, the heater is switched on and the readings from the thermocouples are taken once the temperature is stabilized with help of temperature indicator. Five thermocouples are fitted along the length of the fin. First thermocouple is fitted at 10mm from the base surface. Second thermocouple is fitted at 30 mm from the base surface. Third thermocouple is fitted at 50mm from the base surface. Fourth thermocouple is fitted at 70 mm from the base surface. Fifth thermocouple is fitted at 90mm from the base surface.

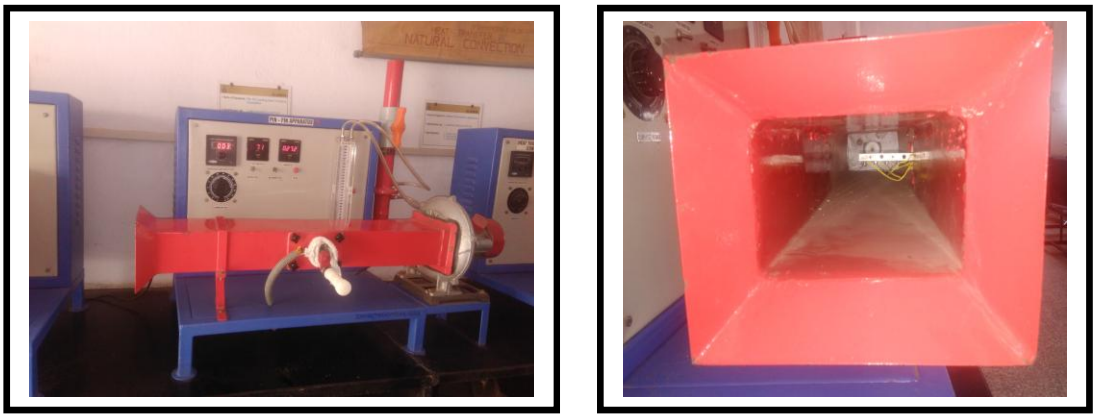


**Fig. 1: Pin-Fin Apparatus**

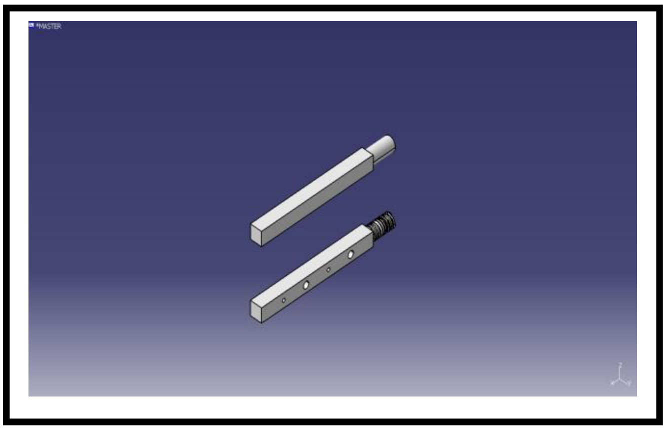


**Fig. 2: Design of Square Shaped Pin-Fin Rods**

**OBSERVATIONS**

4.1 Observation No 1:
Material: Aluminium (without Hole) at 70 V, 0.271 A
Manometer Readings:

1. Full Flow- 185mm-100mm= 85mm
2. Partial Flow- 178mm-110mm= 68mm
3. Half Flow- 165mm-120mm= 45mm

| Sr. No. | Flow Type | T1 ˚c | T2 ˚c | T3 ˚c | T4 ˚c | T5 ˚c | Tatm ˚c |
|---|---|---|---|---|---|---|---|
| 1 | Full | 34 | 32 | 32 | 31 | 30 | 27 |
| 2 | Partial | 34 | 32 | 32 | 31 | 30 | 27 |
| 3 | Half | 35 | 32 | 32 | 32 | 31 | 27 |

**Table No:-4.1 Aluminium (without Hole) at 70V**

4.2 Observation No 2:-
Material: Aluminium (with Hole) at 70V, 0.271A
Manometer Readings:

1. Full Flow- 185mm-100mm= 85mm
2. Partial Flow- 178mm-110mm= 68mm
3. Half Flow- 165mm-120mm= 45mm

| Sr. No. | Flow Type | T1 ˚c | T2 ˚c | T3 ˚c | T4 ˚c | T5 ˚c | Tatm ˚c |
|---|---|---|---|---|---|---|---|
| 1 | Full | 34 | 31 | 28 | 29 | 28 | 28 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 | Partial | 35 | 32 | 29 | 29 | 29 | 28 |
| 3 | Half | 37 | 33 | 30 | 31 | 30 | 28 |

**Table No:-4.2 Aluminium (with Hole) at 70V**

4.3 Observation No 3:

Material: Stainless Steel (without Hole) at 70 V, 0.271 A

Manometer Readings:

1. Full Flow- 185mm-100mm= 85mm
2. Partial Flow- 178mm-110mm= 68mm
3. Half Flow- 165mm-120mm= 45mm

| Sr. No. | Flow Type | T1 °c | T2 °c | T3 °c | T4 °c | T5 °c | Tatm °c |
|---|---|---|---|---|---|---|---|
| 1 | Full | 31 | 24 | 21 | 19 | 17 | 29 |
| 2 | Partial | 33 | 26 | 23 | 21 | 18 | 29 |
| 3 | Half | 35 | 29 | 25 | 23 | 19 | 29 |

**Table No:-4.3 Stainless Steel (with Hole) at 70V**

Material: Stainless Steel (with Hole) at 70 V, 0.271 A

Manometer Readings:

1. Full Flow- 185mm-100mm= 85mm
2. Partial Flow- 178mm-110mm= 68mm
3. Half Flow- 165mm-120mm= 45mm

| Sr. No. | Flow Type | T1 °c | T2 °c | T3 °c | T4 °c | T5 °c | Tatm °c |
|---|---|---|---|---|---|---|---|
| 1 | Full | 31 | 20 | 17 | 15 | 14 | 29 |
| 2 | Partial | 32 | 21 | 18 | 16 | 15 | 29 |
| 3 | Half | 34 | 22 | 19 | 17 | 16 | 29 |

**Table No:-4.4 Stainless Steel (without Hole) at 70V**

After taking a look at observations we can notice that the normal temperature of stainless steel rod is below atmospheric temperature due to its surrounding conditions at night period. It takes more time to come at normal temperature due to less thermal conductivity of stainless steel

## III. Results

After processing on all the inputs, we get following outcomes

| Vtg. or W | Flow Type | Temperature (Experimental) | | | | | Temperature (Theoretical) | | | | | Q (Exp.) W | Q (Th.) W | h (Exp.) | h (Th.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | T1 | T2 | T3 | T4 | T5 | T1 | T2 | T3 | T4 | T5 | | | | |
| 70 | Full | 34 | 32 | 32 | 31 | 30 | 33.50 | 32.29 | 30.87 | 29.63 | 28.71 | 0.8927 | 16.31 | 42.31 | 60.95 |
| or | Parti. | 34 | 32 | 32 | 31 | 30 | 33.52 | 32.35 | 30.97 | 29.74 | 28.82 | 0.8775 | 16.31 | 41.97 | 58.11 |
| 16.31 | Half | 35 | 32 | 32 | 32 | 31 | 34.49 | 33.25 | 31.74 | 30.37 | 29.31 | 0.9604 | 16.31 | 42.09 | 52.57 |

**Table No-5.1 Aluminium (without hole)**

| Vtg. or W | Flow Type | Temperature (Experimental) | | | | | Temperature (Theoretical) | | | | | Q (Exp.) W | Q (Th.) W | h (Exp.) | h (Th.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | T1 | T2 | T3 | T4 | T5 | T1 | T2 | T3 | T4 | T5 | | | | |
| 70 | Full | 34 | 31 | 28 | 29 | 28 | 33.61 | 32.67 | 31.54 | 30.51 | 29.72 | 0.722 | 16.31 | 172.58 | 53.06 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| or | Parti. | 35 | 32 | 29 | 29 | 29 | 34.57 | 33.51 | 32.23 | 31.05 | 30.13 | 0.824 | 16.31 | 118.47 | 50.29 |
| 16.31 | Half | 37 | 33 | 30 | 31 | 30 | 36.49 | 35.65 | 33.99 | 32.43 | 31.18 | 1.055 | 16.31 | 91.45 | 45.77 |

**Table No-5.2 Aluminium (with hole)**

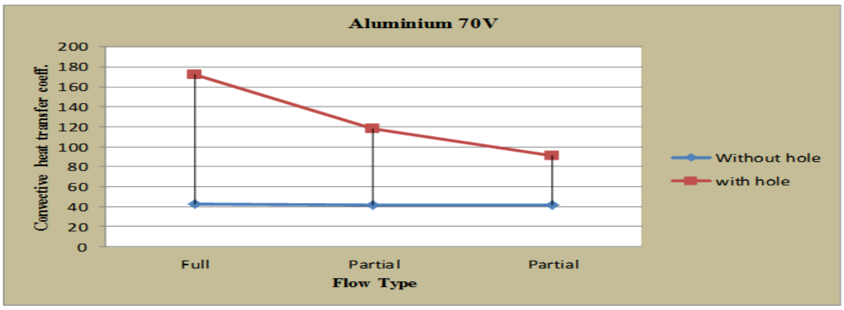
| Vtg. or W | Flow Type | Temperature (Experimental ) | | | | | Temperature (Theoretical) | | | | | Q (Exp.) W | Q (Th.) W | h (Exp.) | h (Th.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | T1 | T2 | T3 | T4 | T5 | T1 | T2 | T3 | T4 | T5 | | | | |
| 70 | Full | 31 | 24 | 21 | 19 | 17 | 30.40 | 29.48 | 29.08 | 29.00 | 29 | 0.0320 | 16.31 | 0.213 | 60.95 |
| or | Parti. | 33 | 26 | 23 | 21 | 18 | 31.82 | 29.91 | 29.18 | 29.01 | 29 | 0.064 | 16.31 | 1.613 | 58.11 |
| 16.31 | Half | 35 | 29 | 25 | 23 | 19 | 33.31 | 30.61 | 29.31 | 29.03 | 29 | 0.0952 | 16.31 | 10.50 | 52.57 |

**Table No-5.3 Stainless Steel (with hole)**

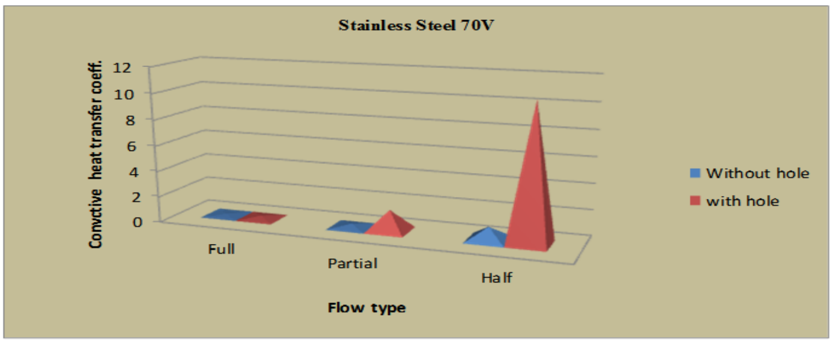
| Vtg. or W | Flow Type | Temperature (Experimental ) | | | | | Temperature (Theoretical) | | | | | Q (Exp.) W | Q (Th.) W | h (Exp.) | h (Th.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | T1 | T2 | T3 | T4 | T5 | T1 | T2 | T3 | T4 | T5 | | | | |
| 70 | Full | 31 | 20 | 17 | 15 | 14 | 30.44 | 29.53 | 29.10 | 29.01 | 29 | 0.0313 | 16.31 | 0.096 | 53.06 |
| or | Parti. | 32 | 21 | 18 | 16 | 15 | 31.17 | 29.82 | 29.16 | 29 | 29 | 0.0468 | 16.31 | 0.269 | 50.29 |
| 16.31 | Half | 34 | 22 | 19 | 17 | 16 | 32.67 | 30.46 | 29.32 | 29.04 | 29 | 0.0772 | 16.31 | 1.017 | 45.77 |

**Table No-5.4 Stainless Steel (without hole)**

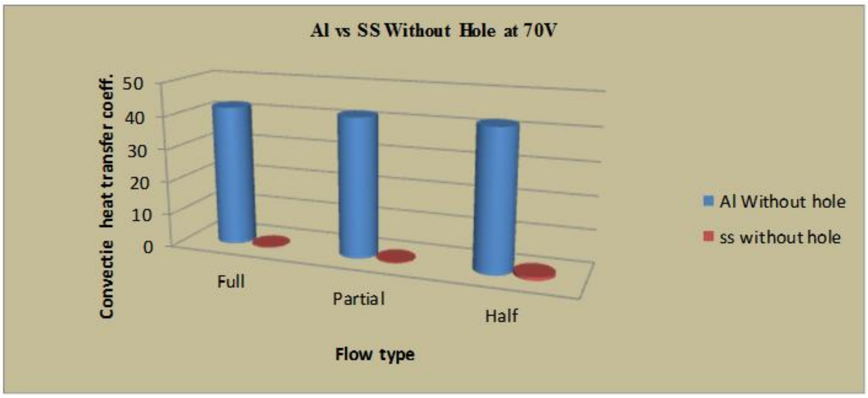
In this paper, the heat transfer rate of square shaped fin with and without hole is studied. The experimentation results show that with hole square shaped fin has higher heat transfer rate than without hole square shaped fin.



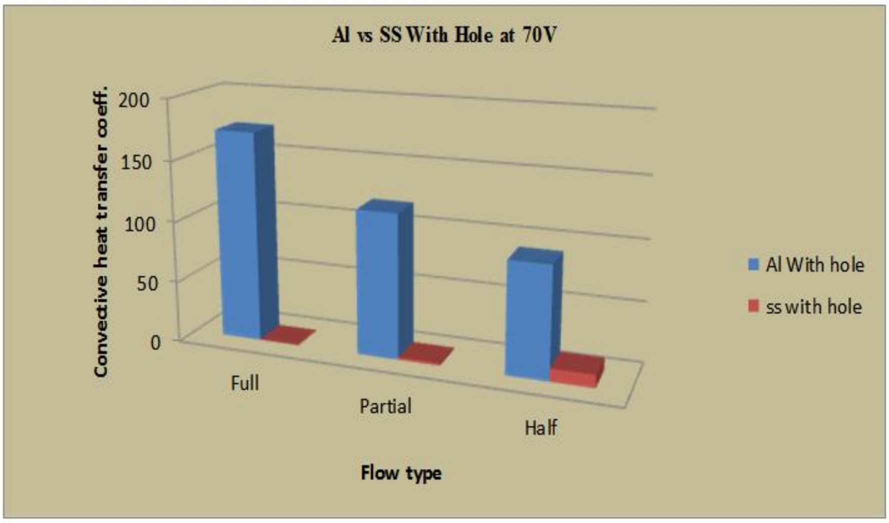

**Graph No. 5.1: Aluminium Without Hole vs With Hole at 70V**




**Graph No. 5.2: Stainless Steel Without Hole vs With Hole at 70V**




**Graph No. 5.3: Aluminium vs Stainless Steel Without Hole at 70V**




**Graph No. 5.3: Aluminium vs Stainless Steel With Hole at 70V**

## IV. Conclusion

The conclusion of this paper was to investigate and compare the heat transfer rate of the pin fin forAluminium and stainless steel material using with and without hole square shaped fins. Temperature distribution along the length of fin for 70V base parameter is studied. At the end of the study we came to know that

1) the fin performance is better with hole than without hole in both materials. Further we can see
2) the performance of aluminium material is good with compare to stainless steel material.

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