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# An experimental investigation of annular fins under forced convection

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***Abstract*— Fins are the extended surfaces, generally used to enhance the heat transfer rates from the objects and safeguard them from failure. Heat transfer characteristics under forced convection are investigated on fins experimentally by varying parameters like surface area, temperature difference and Reynolds number and heat transfer distribution is analyzed at different loads.**

**During the experimental investigation, variations of Reynolds number and surface areas greatly affect the heat transfer rates. Base temperature for annular fins is reduced by 30% when compared to 11mm diameter fin due to increase in surface area about 40%. Base temperature for annular fins is reduced by 10% when compared to 31mm diameter fin due to decrease in surface area about 41%. It is also observed that at higher heat load 45W, overall fin efficiency of annular fins is increased by 44 % and 8% when compared to fin with diameter 11mm and 31mm respectively.**

***Index Terms*—About four key words or phrases in alphabetical order, separated by commas.**

## I. INTRODUCTION

Fins are used on electric transformers and electric motors, cooling of electronic components, cylinders and cylinder heads of air cooled IC engines and on a large variety of heat exchangers. An annular fin is a specific type of fin used in heat transfer that varies radially. Adding an annular fin to an object increases the amount of surface area in contact with the surrounding fluid, which increases the heat transfer (convective) between the object and surrounding fluid. An annular fin transfers more heat than a similar pin fin at any given length.

The rate of heat dissipation from the surface can be increased by increasing convective heat transfer coefficient or by increasing the surface area. An enhanced value of heat transfer coefficient can usually be achieved by creating appropriate conditions of forced flow over the surface.

## II. CONSTRUCTION OF EXPERIMENTAL SET-UP:

An air sealed duct which is made from Australian wood was taken for conducting experiments, one end of duct is connected to induce draft fan and other end is made to set free. Fan is connected to regulator to control the flow of the velocity. Annular fins of rod 31mm diameter of length 300 mm long is inserted into the duct. The rod is heated with the help of band heater and to provide insulation asbestos rope is wounded to band heater. Thermocouples were placed on the rod to know temperature distribution; these thermocouples are connected to the digital temperature indicator.

*A. Specifications:*

TABLE I. COMPONENTS OF EXPERIMENTAL SETUP

| **Component** | **Specifications** |
|---|---|
| Fin | Aluminum Al-6063 |
| Band heater | 550 W |
| Dimmerstat | 10 A |
| Ammeter | 0.1A Resolution, ±0.5% Accuracy |
| Voltmeter | 1V Resolution, ±0.5% Accuracy |
| Digital Temperature Indicator | Digital, 1/0.1$^0$ Resolution, ±0.25% Accuracy |
| Induced draft Fan | 12×12 mm, 4.5 m/s velocity |
| J – Type thermocouples | Range -40 to 750$^0$C |

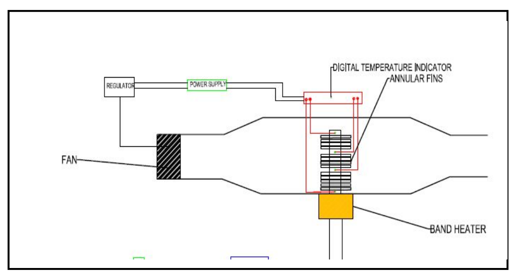


Fig. 1. Circuit diagram of experimental set up

## III. EXPERIMENTAL WORK

In this experiment convective heat transfer distribution is analyzed by using annular fins under forced convection. The different types of fins of material Aluminum 6063 are taken as specimens to analyze the heat distribution are:

- Fin of 31mm diameter with 300mm long

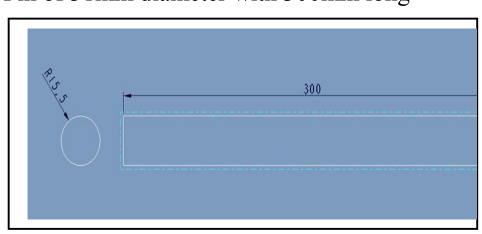


Fig. 2. Fin of 31mm diameter

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An Aluminum rod of 31mm diameter of 300mm long is taken and it is machined to form annular fins of 31mm diameter on base diameter 11mm with 150mm long on it.

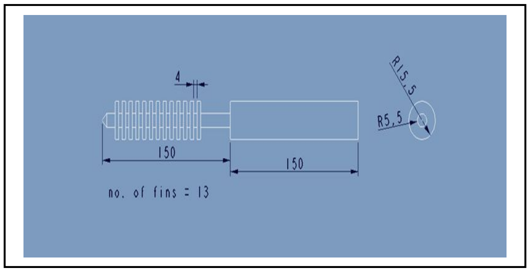



Fig. 3. Annular fins of 31mm diameter

Fin of 11mm diameter of 150mm long without annular fins

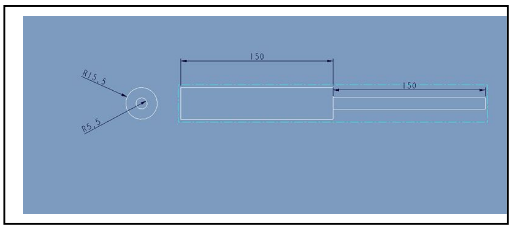



Fig. 4. Fin of 11mm diameter

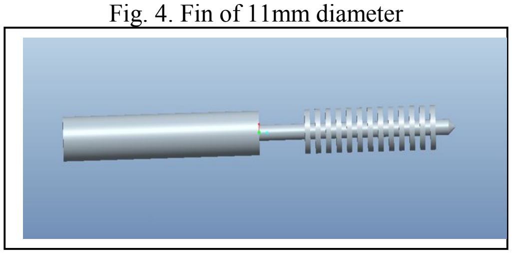


Fig. 5. Annular fins with 31mm diameter

*B. Fin specifications:*

Material used – Aluminium 6063
Thermal conductivity of metal – $220W/m^2K$
Number of circumferential fins – 13
Thickness of each fin – 4mm
Gap between two fins – 4 mm
Effective length – 150mm

Experiment is carried out by heating the specimen i.e., annular fins by using band heater at different loads (25W, 35W, 45W). Loads are varied by using the dimmer stat. Specified load is adjusted by varying inputs, current and voltage. At different loads the velocity (1.5 to 3 m/s)of air is varied with induced draft fan with the help of regulator. Thermocouples were equidistantly placed on rod and they were connected to the digital temperature indicator to indicate the temperature.For these power inputs, experiment is conducted for various velocities of air to vary the Reynolds number and convective heat transfer coefficient on different geometries of fins to study the heat transfer rates under forced convection.

*C. Governing Equations:*

Reynolds number $Re = \rho V d / \mu$
Nusselt number $Nu_D = C.Re_D^m.Pr^{0.333}$
Actual heat transfer through fin $Q_{fin} = (hpkA)^{0.5}\theta_0 \tanh(mL)$
Maximum heat transfer $Q_{max} = hA\Delta T$
Efficiency as $\eta = \tanh(mL)/mL$
Effectiveness $E = Q_{with\ fin} / Q_{without\ fin}$

Maximum heat transfer $Q_{max} = 2\pi h (r_{2c}^2 - r_1^2)\ \Delta T$
Heat transfer through fin $Q_{fin}$= Number of fins$\times \eta \times Q_{max}$
Total heat transfer $Q_{total} = Q_{primary\ surface} + Q_{fin}$
Heat transfer from primary surface $Q = A_0 h \theta_0$
Effectiveness $E = Q_{fin}/(hA_b \Delta T)$

## IV. RESULTS AND DISCUSSIONS

This experiment has been conducted for various power inputs such as 25 W, 35 W, 45 W.For these power inputs the experiment is conducted for various velocities (1.5 to 3 m/s) of air to vary the Reynolds number and heat transfer coefficient on different geometries of fins to study the heat transfer rates.

*Sample Results:*

TABLE II. RESULTS FOR ANNULAR FINS

| Q (W) | V (m/s) | $T_1\,^0C$ | $T_2\,^0C$ | $T_3\,^0C$ | $T_4\,^0C$ |
|---|---|---|---|---|---|
| 45 | 1.5 | 98 | 106 | 108 | 110 |
| | 2 | 89 | 94 | 97 | 99 |
| | 2.5 | 82 | 88 | 89 | 91 |
| | 3 | 76 | 83 | 85 | 86 |
| 35 | 1.5 | 85 | 90 | 92 | 94 |
| | 2 | 73 | 79 | 82 | 84 |
| | 2.5 | 70 | 77 | 79 | 80 |
| | 3 | 65 | 70 | 72 | 75 |
| 25 | 1.5 | 67 | 72 | 73 | 76 |
| | 2 | 63 | 66 | 69 | 69 |
| | 2.5 | 61 | 65 | 68 | 70 |
| | 3 | 59 | 66 | 67 | 68 |

TABLE III. HEAT TRANSFER CHARACTERISTICS FOR ANNULAR FINS

| Re | Nu | h ($W/m^2\,^0C$) | $Q_{fin}$(W) | $Q_{max}$ (W) | $\eta$ | $\varepsilon$ |
|---|---|---|---|---|---|---|
| 2330.1 | 22.4292 | 21.43 | 23.587 | 25.984 | 90.8 | 17.6 |
| 3200.2 | 26.0169 | 24.54 | 23.124 | 25.806 | 89.6 | 17.3 |
| 4087.1 | 29.1742 | 27.25 | 22.575 | 25.476 | 88.6 | 17.2 |
| 4998.6 | 33.0475 | 30.69 | 23.11 | 26.443 | 87.4 | 16.9 |
| 2432.6 | 22.901 | 21.47 | 19.07 | 21.012 | 90.8 | 17.6 |
| 3343 | 26.5718 | 24.54 | 18.307 | 20.43 | 89.6 | 17.3 |
| 4225.2 | 29.7968 | 27.43 | 18.803 | 21.235 | 88.6 | 17.1 |
| 5140.8 | 33.6446 | 30.78 | 18.854 | 21.582 | 87.4 | 16.9 |
| 2563.3 | 23.4878 | 21.62 | 14.037 | 15.476 | 90.7 | 17.6 |
| 3475.4 | 27.0742 | 24.62 | 13.528 | 15.62 | 89.6 | 17.3 |
| 4356.7 | 30.3802 | 27.59 | 15.334 | 17.329 | 88.5 | 17.1 |
| 5242.9 | 34.0643 | 30.9 | 16.157 | 18.504 | 87.3 | 16.9 |

TABLE IV. RESULTS FOR FIN WITH 11MM DIAMETER WITHOUT CIRCUMFERENTIAL FINS

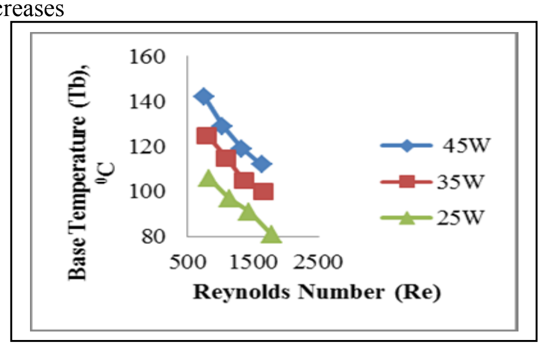
| Q (W) | V (m/s) | $T_1\,^0C$ | $T_2\,^0C$ | $T_3\,^0C$ | $T_4\,^0C$ |
|---|---|---|---|---|---|
| 45 | 1.5 | 121 | 130 | 131 | 142 |
| | 2 | 104 | 113 | 115 | 129 |
| | 2.5 | 92 | 99 | 102 | 119 |
| | 3 | 88 | 94 | 96 | 112 |
| 35 | 1.5 | 105 | 110 | 111 | 125 |
| | 2 | 90 | 98 | 101 | 115 |

| | | | | | |
|---|---|---|---|---|---|
| | 2.5 | 89 | 95 | 97 | 105 |
| | 3 | 86 | 92 | 94 | 100 |
| | 1.5 | 88 | 95 | 97 | 106 |
| | 2 | 81 | 87 | 91 | 97 |
| | 2.5 | 72 | 77 | 78 | 91 |
| 25 | 3 | 66 | 70 | 74 | 81 |

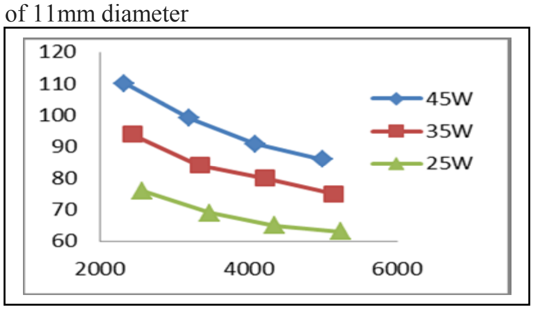
TABLE V. HEAT TRANSFER CHARACTERISTICS FOR FIN WITH 11MM DIAMETER WITHOUT CIRCUMFERENTIAL FINS

| **Re** | **Nu** | **h** (W/m$^2$ $^0$C) | **Q** $_{fin}$(W) | **Q** $_{max}$(W) | $\eta$ | $\varepsilon$ |
|---|---|---|---|---|---|---|
| 764.52 | 13.3 | 37.31 | 15.19 | 22.23 | 68.3 | 37.3 |
| 1043.6 | 15.4 | 42.69 | 14.81 | 22.57 | 65.6 | 35.8 |
| 1339 | 17.3 | 47.33 | 14.33 | 22.57 | 63.5 | 34.6 |
| 1642.8 | 19.1 | 51.74 | 14.05 | 22.79 | 61.6 | 33.6 |
| 801.59 | 13.6 | 37.66 | 13.04 | 19.13 | 68.1 | 37.2 |
| 1094.7 | 15.8 | 42.85 | 12.81 | 19.54 | 65.5 | 35.8 |
| 1367 | 17.5 | 46.99 | 12.09 | 19.78 | 63.6 | 34.7 |
| 1665.4 | 19.2 | 51.25 | 11.99 | 19.98 | 61.8 | 33.7 |
| 835.78 | 13.9 | 37.29 | 10.43 | 15.27 | 68.3 | 37.3 |
| 1141.7 | 16.1 | 42.68 | 10.16 | 15.48 | 65.6 | 35.8 |
| 1450.3 | 18 | 47.39 | 9.976 | 15.72 | 63.5 | 34.6 |
| 1784.7 | 19.8 | 51.65 | 8.914 | 14.85 | 61.7 | 33.6 |

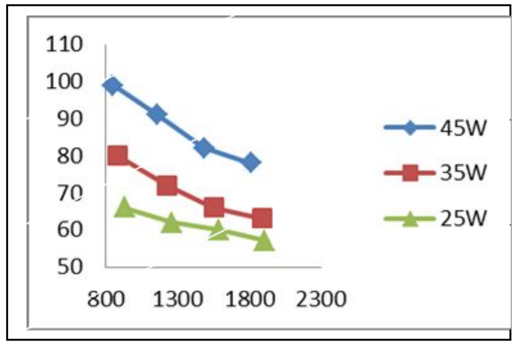
The following graphs are plotted for Reynolds number and base temperature at different loads i.e., 25 W, 35 W and 45 W. From the graph it has been observed that, increase in Reynolds number decrease in base temperature is due to more number of air molecules get in contact with heated surface. So, the heated surface gets cooled and base temperature decreases




Graph. 1. Base temperature (Vs) Reynolds number (Re) for fins of 11mm diameter

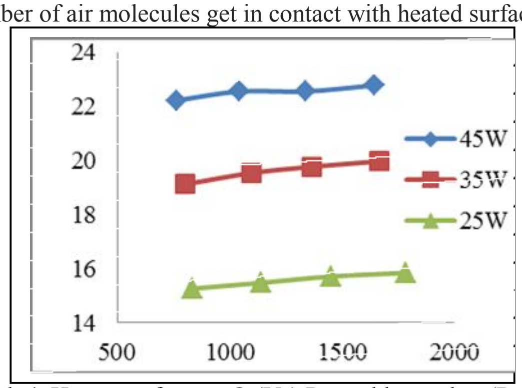



Graph. 2. Reynolds number (Re) (Vs) Base temperature for fins of 31mm diameter

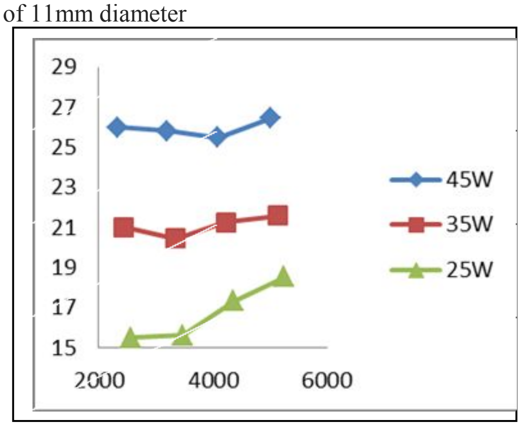



Graph. 3. Reynolds number (Re) (Vs) Base temperature for annular fins

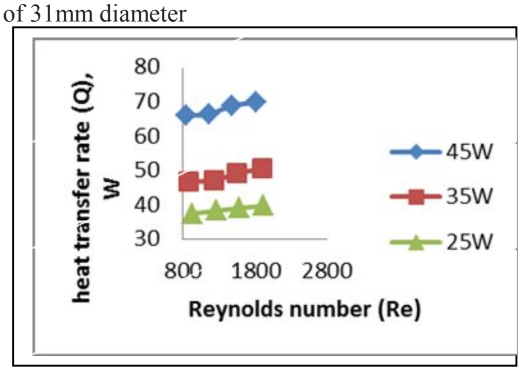
The following graphs are plotted for Reynolds number and heat transfer rate at different loads i.e., 25 W, 35 W and 45 W. From the graph it has been observed that, increase in Reynolds number increase in heat transfer rate is due to more number of air molecules get in contact with heated surface.




Graph.4. Heat transfer rate Q (Vs) Reynolds number (Re) for fins of 11mm diameter

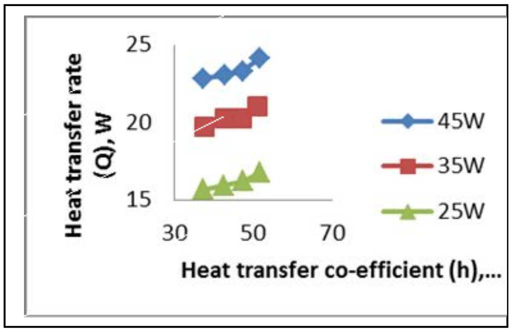



Graph. 5. Reynolds number (Re) (Vs) Heat transfer rate Q for fins of 31mm diameter

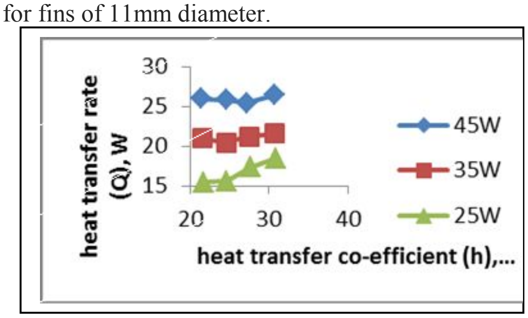



Graph.6. Reynolds number (Re) (Vs) Heat transfer rate Q for annular fins

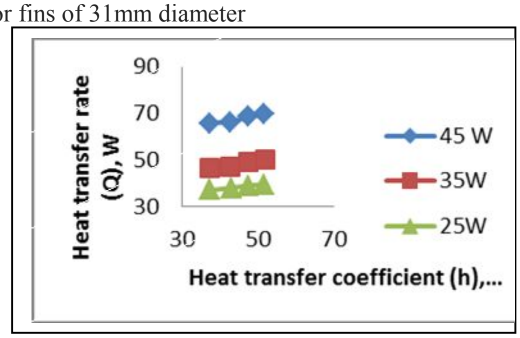
The following graphs are plotted for heat transfer co-efficient (h) and heat transfer rate (Q). From the graph it has been observed that, convective heat transfer rate increases with increase in heat transfer coefficient. From Newton's law of cooling the heat transfer rate is directly proportional to heat transfer coefficient.




Graph. 7. Heat transfer rate Q (Vs) heat transfer co-efficient (h) for fins of 11mm diameter.




Graph.8. Heat transfer co-efficient (h) (Vs) Heat transfer rate Q for fins of 31mm diameter




Graph. 9. Heat transfer co-efficient (h) (Vs) Heat transfer rate Q for annular fin

## CONCLUSION

This experimental investigation is been carried out to study the heat transfer characteristics of fin with 11mm diameter without circumferential fins and fin with 31mm diameter and annular fins with 31 mm diameter under forced convection at different power inputs and the Reynolds number.

The variation of relevant parameters in convective heat transfer with fins has been analyzed in this present experimental investigation under forced convection. During this experimental investigation, variations of the Reynolds number and surface areas greatly affect the heat transfer rates. Base temperature for annular fins is reduced by about 30% when compared to fin with diameter 11mm due to increase in surface area about 40%. Base temperature for annular fins is reduced by about 10% when compared to fin with diameter of 31mm due to decrease in surface area of about 41%. Heat transfer rates increase predominantly with the provision of annular fins due to increase in surface area. It is also observed that at the higher heat load i.e. at 45W, the overall fin efficiency of annular fins is increased by 44 % and 8% when compared to fin with diameter 11mm and 31mm respectively. At higher Reynolds number ranging from 800-2000, heat transfer rate increases in annular fins due to more number of molecules of air get in contact with the heated surface.

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## REFERENCES

[1] K.H.Dhanawade and H.S.Dhanawade., "Enhancement of forced convection heat transfer from fin arrays with circular perforation",IEEE (2010).

[2] Hyung-Suk Kang., **"**Optimization of a rectangular profile annular fin base on fixed fin height", Journal of mechanical science and technology, 3124-3131 (2009).

**[3]** Bassam A/K Abu-Hijleh., "Enhanced forced convection heat transfer from a cylinder using permeable fins", Journal of heat transfer 806/Vol.125 (2003).

[4] Abdul Aziz, Tiegang Fang, "Thermal analysis of an annular fin with (a) simultaneously imposed base temperature and base heat flux and (b) fixed base and tip temperatures", Energy conversion and management 52 , 2467-2478, (2011).

[5] Yatendra Singh Tomar, M.M.Sahu, "Comparative study of performance of pin fin under forced covnection heat transfer", International journal of engineering research and techonology (IJERT), Vol.2 (2013).

[6] Kenichi Hashizume, Takahiro Matsue and Yoshiaki Sueoka., "Effect of fins on forced convection heat transfer around a tube", Heat Transfer, 32 (5), (2003).

[7] VinodK.Maudgal and J.E.Sunderland., "An experimental study of forced convection heat transfer from in-line pin fin arrays", IEEE (1997).

[8] U.V.Awasarmol and Dr.A.T.Pise., "Experimental study of effect of angle of inclination of fins on natural convection heat transfer through permeable fins", "Thermal energy and environment (2011)

[9] A.Güvenc, H.Yüncü., "An experimental investigation on performance of fins on a horizontal base in free convection heat transfer", Heat and mass transfer 37 (2001) 409-416.

[10] Swee-Boon Chin, Ji-Jinn Foo, Yin-Ling Lai, Terry Kin-Keong Yong., "Forced convective heat transfer enhancement with perforated pin fins", Heat Mass Transfer 49:1447-1458 (2013).