Comparative Experimental Analysis of Herringbone wavy & Smooth Wavy fin Heat Exchanger for Hydraulic Oil Cooling

Mr. Ahirrao Narendra[1], Mr.Awale Shubham[2], Mr.Bankar Akshay[3], Mr.Bansode Bhavik[4], Prof. Shitole Vishal[5]

[1]*Student , Mechanical Engineering Department, Zeal College of Engineering and Research,Pune,* *ahirrao.narendra1996@gmail.com*
[2]*Student , Mechanical Engineering Department, Zeal College of Engineering and Research,Pune,* *shubhamawale39@gmail.com*
[3]*Student , Mechanical Engineering Department, Zeal College of Engineering and Research,Pune,* *akshayb442@gmail.com*
[4]*Student , Mechanical Engineering Department, Zeal College of Engineering and Research,Pune,* *bhavikbansode50@gmail.com*
[5]*Assistant Professor, Mechanical Engineering Department, Zeal College of Engineering and Research,Pune,* *shitolevishal13@gmail.com*

ABSTRACT

Heat exchangers are devices used to transfer heat energy from one fluid to another. Typical heat exchangers experienced consists of condensers and evaporators, boilers and condensers in thermal power plants ,heat exchangers in automobiles in the form of radiators and oil coolers, in chemical and process industries.
Heat transfer enhancement is the process of improving the performance of a heat transfer system by increasing the heat transfer coefficient. There are many devices like IC engines, electrical motors, transformers, for automobiles in the form of radiators and oil coolers where heat is to be removed at the required rate so as to cool and keep the temperature below a certain level. Due to space limitation one cannot increase the surface area of the equipments beyond a certain limit. In such case the extended surface (fins) plays a major role to increase the heat removal rate. Extended surfaces (fins) are one of the heat exchanging devices that are employed extensively to increase heat transfer rate. The rate of heat transfer depends on surface area of fin.
The current study is focused on two fin configurations, first one is smooth wavy fin and second one is herringbone wavy fin. These two fin configurations are experimentally investigated for cooling of hot oil. In this work performance of two heat exchangers are analyzed, one is with smooth wavy fin and another is with herringbone wavy fin heat exchanger. The hot oil is passed through both heat exchangers alternately and, its performance is evaluated and compared. The rate of cooling of oil is analyzed for both type of heat exchangers and results shows that smooth wavy fins are more effective than herringbone fin heat exchanger.

Keywords: *Heat Exchanger, Herringbone wavy fin, smooth wavy fin, Heat transfer coefficient, Temperature difference, Mean mass flow rate etc.*

---

1. INTRODUCTION

Compact heat exchangers offer the ability to transfer heat between large volumes of gas with minimum footprint. A gas to fluid exchanger is considered compact if it has a heat transfer area to volume ratio greater than 700 m2 /m3 on at least one of the fluid sides. Compactness is a good indication of performance, the higher the compactness generally the higher the effectiveness for a given pressure drop. Increased compactness can be achieved by reducing the size of the heat exchanger passages or by adding secondary surfaces (fins) within the passage. Compact heat exchangers are generally characterized by having a large frontal area and a short flow length. Flow maldistribution can be an undesirable result of this, so that header and distributor design becomes more important as compactness increases. High compactness is desirable for performance, although increased compactness yields increased thermal stress, which can reduce heat exchanger life). However, when employing temperature ramping rates consistent with high temperature fuel cells, a heat exchanger with higher compactness and equal pressure drop can be employed without reducing service life, given that severe thermal transients are mitigated. The different type of enhanced surfaces or fins which are used in compact heat exchangers according to a designer's requirement. Operating temperature, cost, bonding of fins to plates, choice of materials is the important factors to selecting fins for the heat exchangers. Wavy fins are particularly demandable for their simplicity to manufacture. Their performance is also competitive with that of most efficient offset strip fins. A wavy fin specimen is manufactured by placing a number of fins (same length and height) side by side and bonding with each other to a number of equal spacing wavy fin channels. There are two basic types of wavy fin geometries.

These are herringbone and smooth wavy fins. A lot of work has been done on the wavy fins but only a few works have examined smooth wavy fins and herringbone fins. Though wavy fins are not currently widely used but in recent future wavy fins can be used for many applications. Use of wavy fins will provide great option for heat transfer enhancement in passive methods, wavy fins are simple to construct hence it can be also economically beneficial for process industries.

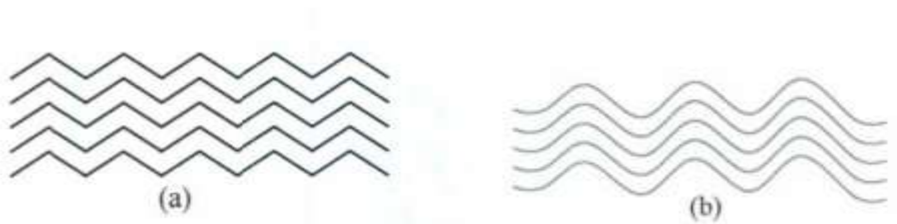

Fig-1: (a) Herringbone wavy fin module **(b)** Smooth wavy fin

2. EXPERIMENTAL INVESTIGATION

The schematic diagram of the experimental air- tunnel is shown in Fig. 2. The concept of the wavy fin heat exchanger hydraulic cooler is oil to air cooler that uses wavy fin modules with an radial blower system. The radial blower is 12 volt DC blower that takes cold air in the system axial and discharges it in axial direction. This cold air is then directed on to the wavy fins mounted on the heat exchanger modules. The oil cooler takes in hot oil with help, of hydraulic pump where as the cold oil from the oil cooler is discharged back to the oil tank. The oil cooler can be mounted externally to the oil tank system thereby ensuring contamination free operation as the oil tank be sealed. The enhanced wavy fin heat exchanger has the facility to change the fin structure models , two individual modules are prepared separately , namely,

a) Herringbone wavy fin module
b) Smooth wavy fin module

The heat exchanger module has following specifications:

a) Type: Short flat copper pipe interlinked by header.
b) Material: Copper
c) Working fluid: Oil

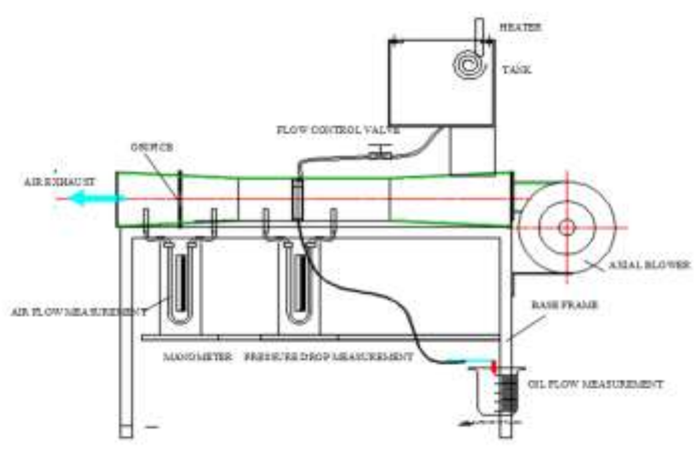

Fig-2: Experimental set-up

Specifications :

1. Heater : 20 W.
2. Axial Blower: 12 volt DC blower
3. Orifice plate : Orifice diameter 1.25cm
4. Thermocouple: J type thermocouple.
5. Digital temperature indicator = 8 point.
6. Oil : SAE 20 W 40

Specific Gravity = 0.913
Specific Heat = 1.87 kJ/kg-K

2.1 Procedure :

1. The airflow rate for 5 different settings of blower is found out.
2. At these five different air flow rates the temperature gradient of air across the heat exchanger module is found out.
3. Simultaneously the mass flow rate of oil and its temperature gradient is observed.
4. From the readings obtained the overall heat transfer coefficient is calculated.
5. Finally the amount of heat transferred is calculated from above parameters.

The above steps are repeated for both smooth wavy fin and herringbone wavy fin heat exchanger.

Setting Up Constant Discharge for Air

SR,.NO	MANOMETER READING (h1) (CM)	MANOMETER READING (h2) (CM)	H (CM)	DISCHARGE LPS
1	**8.3**	**8.1**	**0.2**	**0.001507**
2	**8.45**	**8.2**	**0.25**	**0.001685**
3	**8.4**	**8.1**	**0.3**	**0.001846**
4	**8.3**	**8.0**	**0.3**	**0.001994**
5	**8.3**	**7.9**	**0.4**	**0.002131**

Table-1: Discharge of air

Governing Equations:

$Q = U \times A \times \theta = m \times Cp \times \Delta T$
A = Area of fins
Thus
$U = m \times Cp \times \Delta T / A \times \theta$

2.3 Result for Herringbone wavy fins:

Mass flow rate air	Temp gradient Air θ	Mass flow rate oil	Temp gradient oil	Overall heat transfer coefficient(U)	Heat Transfer rate (Q)
0.001507	2.5	0.001145	7.67	0.547	0.016423
0.001685	3	0.001269	9.833	0.648	0.02334
0.001846	3.8	0.001323	14.133	0.767	0.03496
0.001994	4.4	0.001484	17.067	0.897	0.04736
0.002131	5.2	0.001605	18.967	0.912	0.0569

Table-2: Herringbone observations and result.

2.4 Result for Smooth wavy fins:

Mass flow rate air	Temp gradient Air θ	Mass flow rate oil	Temp gradient oil	Overall heat transfer coefficient(U)	Heat Transfer rate (Q)
0.001507	3	0.001145	9.833	0.6175	0.02771
0.001685	3.5	0.001343	11.833	0.7075	0.037285
0.001846	4.4	0.001371	15	0.7283	0.05178
0.001994	4.9	0.001513	18.4	0.8853	0.06861
0.002131	5.8	0.001657	21	0.9349	0.083684

Table-3: Smooth wavy observations and result.

2.5 Graph and Discussion :

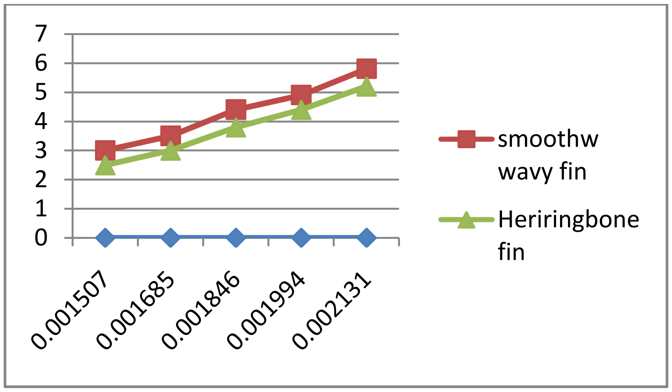

Fig-3: Temperature gradient of air Vs mass flow rate of air

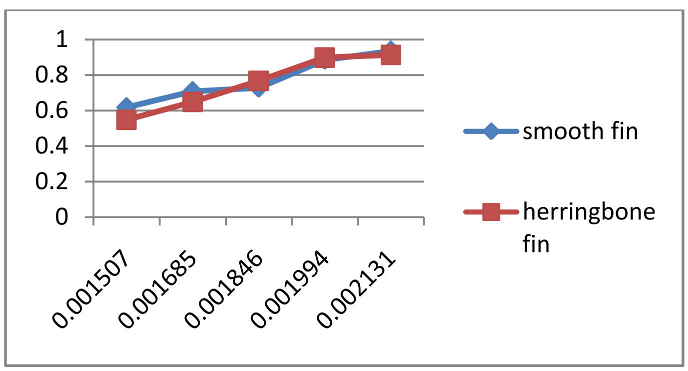

Fig-4: Overall heat transfer co-efficient Vs mass flow rate of air

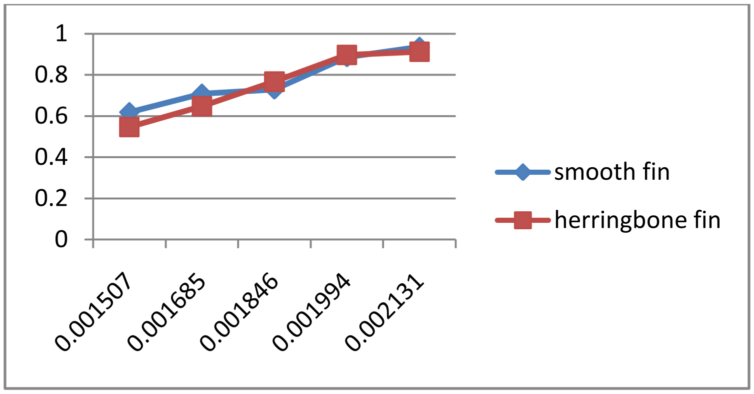

Fig-5: Heat transfer rate Vs mass flow rate of air

3. CONCLUSION

Based on the results obtained in this investigation, the following conclusions are made:

[1] In this work amount of heat transferred from heat exchanger with herringbone wavy fin and smooth wavy has been investigated and studied. In this study it is seen that the amount of heat transferred in case of smooth wavy fin is more than that of in herringbone fin heat exchanger. Maximum 28% enhancement in heat transfer has been observed from heat exchanger in herringbone wavy fin case as compared to smooth wavy fins.

[2] In this work also heat transfer coefficient of both herringbone wavy fin and smooth wavy has been investigated, compared and studied. From comparison it is find out that the heat transfer coefficient of the smooth wavy fin heat exchanger is maximum 38% higher than herringbone wavy fin heat exchanger.
On average 13.37% increase in smooth wavy fin heat exchanger has been observed when compared to the herringbone wavy fin heat exchanger.

[3] The cooling of oil is efficient in the case of smooth wavy fins it is observed that in case of herringbone wavy fin heat exchanger temperature decrease in oil is maximum 19.9^{0}C and in case of smooth wavy fin heat exchanger it is 21.9^{0}C.

Hence, it can be concluded that smooth wavy fin are capable of transferring more heat than herringbone wavy fin.

REFERENCES

[1] Nae-Hyun Kim*, Kang-Jong Lee, Yeong-Bin Jeong[2014] Airside performance of oval tube heat exchangers having sine wave fins under wet condition Applied Thermal Engineering 66 (2014) 580e589

[2] Chi-Chuan Wang, Jane-Sunn Liaw , Bing-Chwen Yang [2010]Airside performance of herringbone wavy fin-and-tube heat exchangers – data with larger diameter tube.International Journal of Heat and Mass Transfer 54 (2011) 1024–1029

[3] Nae-HyunKim, Jung-Ho Ham and Jin-Pyo Cho[2007].Experimental investigation on the airside performance of fin-and-tube heat exchangers having herringbone wave fins and proposal of a new heat transfer and pressure drop correlation. Journal of Mechanical Science and Technology 22 (2008) 545~555.

[4] Thirapat Kuvannarat a, Chi-Chuan Wang b, Somchai Wongwises[2006] Effect of fin thickness on the air-side performance of wavy fin-and-tube heat exchangers under dehumidifying conditions. International Journal of Heat and Mass Transfer 49 (2006) 2587–2596.

[5] Yur-Tsai Lin, Young-Ming Hwang, Chi-Chuan Wang[2002.]Performance of the herringbone wavy fin under dehumidifying conditions. International Journal of Heat and Mass Transfer 45 (2002) 5035–5044