# Experimental Analysis of Heat Transfer Enhancement on Rotating Heat Pipe

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***Abstract:*** *The performance of heat pipe on the waste heat recovery from the industrial waste by using rotation technique. The heat transfer enhancement will carry the heat from the evaporator (heat addition zone) to the condenser (heat rejection zone) section for preheating. In this phase change mechanism is experimentally analysed by sensible heating, charging and discharging at the two zones for thermal equilibrium. An active technique of the heat pipe is rotated by the external power supply. The operating temperature is maintained in between 30 ℃ - 80 ℃ at a moderate level for neglecting the pressure loss. From the experimental observation, the results were plotted and the improvement in heat transfer due to the rotation of heat pipe is justified and discussed.*

***Keywords:*** *Aluminium Heat Pipe, Rotating Heat Pipe, Heat Transfer Enhancement, Overall Heat Transfer Co- Efficient.*

## 1. Introduction

The basic requirement of the heat pipe is the transmission of the heat or energy from one region to another region due to the temperature difference. This can be improved by minimizing the pressure loss and increasing the heat transfer in the device. This heat transfermethodology may also be applied in the heat exchanger and it is more efficient in the combination of conduction and convective heat transfer (i.e Active and Passive method ). Normally the passive mode of the heat transfer enhancement as explained by [1]. is more effective than the active mode, this is due to the ***h*A** value will be maximum at passive method. The heat transfer is vastly classified into three different modes as,

- Active mode
- Passive mode
- Compound mode

Among the above techniques,the compound mode is an intelligent technique for implementing the two different modes at the same period for the heat transfer improvement. This can be quite difficult to install but in some existence its widely used to improve the performance of heat transfer. [2] in their representation of the heat transfer performance is increased by the combination of an external fin and rotational technique. In his research, he clearly shows that the nusselt number correlation will accept accurately only at the increasing speed. During the experimental condition, the setup is being maintained at 2:3 volume filled in the ratio of the working fluid in the heat pipe. Therefore, these kinds of mixed mode of heat transfer will increase the system efficiency and the effectiveness of the heat transfer. Recently, the heat exchanger in exergy system is widely developing technology to reduce the waste heat emission and utilising the most availability of energy in the exhaust.

## 2. Heat Transfer Enhancement

Whenever, there is a temperature difference occurs between the two conduction and non conducting surface there is exchange of heat between the two surface either by conduction or convection or radiation. [3] represents that this is due to the thermodynamic law that the heat is transfered when temperature difference oocurs and its flow from the hot region to the colder region at any cause. For performing the heat transfer enhancent by both the active and the passive technique several hurdles have been restricted. Initially the heat pipe design with the vibrational source and the coiled tube would have chosen but the vibration and the coiled tube will not suited to the improvement in heat transfer and its quite difficult to run and maintain the heat pipe. Finally, [3] explains about the rotating heat pipe by the external supply will had a reasonable improvement in heat transfer enhancement. The attainment of thermal equilibrium under rotating and stable condition were also explained by him in that of the exergy system. Obtained from the steel, power producing and other manufacturing industries by the exhaust gas utilisation with some temperature variant than atmospheric condition. Once this technique is applied in the heat pipe the attainment of the thermal equilibrium is much quicker than the normal technique.

## 3. Effect Of Active Technique

The heat transfer enhancement on the heat pipe using the external supply is done by the Active technique which increases the performance of heat transfer in the heat pipe.

### 3.1 Centrifugal Action

The heat pipe is of sealed at one end and another end have threaded or dummy for the filling of the working fluid. [4] shows that the transfer of a heat from the evaporator section to the condensor section by the centrifugal action. This centrifugal action imposes the heat transfer enhancement by rotating it in the radial action. While for the cylindrical heat pipe held vertically the centrifugal action is perpendicular causes the fluid's the pressure drop due to the fluid flim boiling. Hence, in the axial flow of the working fluid creates the flim condensation reducing the efficiency at condensation zone. Recently the heat exchanger in exergy system is widely developing technology to reduce the waste heat emission and utilising the most availabile of energy in the exhaust

### 3.2 Effect of Rotation

The recent development in the heat pipe phase changing transmission involves by rotation of the heat pipe radially (i.e rotating the heat pipe parallel to its axis ). This development by [5] explains that the heat transfer and the rate of thermal conduction is improved by increasing the rotational speed of the heat pipe. The rotating technique of the heat pipe will catalysis the reaction between the heat pipe and the working fluid to reach the thermal equilibrium.

### 3.3 Viscous Limit

On having ammonia as a working fluid which is also known as the metallic fluid, the ciscous forces dominates due to the very low pressure at the starting stage inside the heat pipe. [6] explains about the pressure difference must be too small so that the viscous force can be overcomed which creates the restriction to vapour flow. As the heat is applied the temperature and pressure will increase this will have the larger tendency to overcome the viscous force.

The operating condition of the heat pipe is varied from $35^0$C to $65^0$C to reach the thermal stability. It is clearly shows that at an moderate operating range upto $80^0$C will have an neglible presssure drop in the heat pipe being operated.

### 3.4 Heat Transfer Performance

[7] explains about the hydrodynamically reduces the surface conduction on the working fluid of the heat pipe. When the surface area of contact has been reduced the heat transfer coefficient also enhanced slowly thereby, reducing the rate of heat transfer. Which affects the phase changing transmission of the vapour in the heat pipe. This limitation can be improved by increasing

the filling ratio of the working fluid in the heat pipe.

### 3.5 Effect Of Change In Heat Flux

It is nothing but the rate of the heat transfer on the specified surface area at an unit time. It is a vector quantity in which the heat flux is opposed to mass or momentum rate. The heat flux is mainly transfered by conduction that also depends on the thermal conductivity of the material. It is given by the temperature profile as T(x) and is denoted by the equation that resulted from fourier law of heat conduction

$$\Phi_q = -K \frac{dT(x)}{dx} \qquad (3.1)$$

Where,

$\Phi_q$ is Specific Heat Rate

K is Thermal Conductivity of the material. ( for Al = 239 $W/m^2$)

dT is Temperature Distribution

Finally, it resulted that the heat transfer from the heat pipe will also denoted by the thermal heat flux on vector representation. So that the heat transfer flow in the heat pipe is determined with its direction specified at their notation either from the condensation to the evaporator zone or vice-versa.

## 4 Experimental Setup

The experimental arrangement if made from the research of [8] on waste heat recovery by the heat pipe. It is a device which works under the condition of lower temperature gradient by transmitting the heat. It is also known as the thermal super conductor. In most of the industries will have the exhaust temperature from their output is lower then the moderate level of temperature $100^0$C. So the heat pipe for the operation is chosen to with stand the temperature more effectively, high heat transfer rate and in the economic range. Therefore, the Aluminium material is chosen for the heat pipe where it is economic and the thermal stability of the heat pipe is made more quicker than other materials. Due to the higher thermal conductivity of Aluminium material 210 W/mK, it has been selected for the heat exchanging process. With the nature of counter flow in the heat pipe under the evaporator, adiabatic and condensor section having the water medium in it. The heat pipe holding the working fluid as ammonia is preferred to enhance the heat transfer rate through the phase change mechanism on its over all length of **1525 mm**. The figure 4.1 shows about the heat transfer process in its three different stages as explained below.

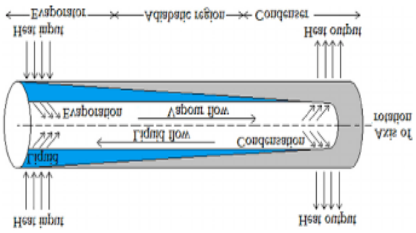

**Figure 4.1 Stages in Heat Pipe**

### 4.1 Evaporator

Evaporator region of the experimental setup is madeup of mild steel material with the outer diameter **230 mm** and its length of **410 mm.** It also having the inlet and the outlet portion for the entry of the hot water or fluid entry path, in which the heat is being added to the heat pipe for transmitting the heat. The heat from this region is absorbed by the working fluid ammonia is transformed into the vapour phase by the latent heat of absorption. During the static and rotating condtion the inital hot temperature is transferring its heat to the other side and performs the thermal stability over the heat pipe with the counter flow. Here, the heat pipe is inserted with an oil seal at the zone ends connected to it. For elimnating friction, leakage during the rotation of the heat pipe the oil seal is used. Now the heat can be tranfered to the other end by the vapourisation of ammonia in the heat pipe.

### 4.2 Adiabatic section

In this region no external environmental impacts such as the temperature, pressure, etc should not affect the performance. At this zone with the length of **300 mm** is insulated with the asbestoes rope which should not conduct any heat transfer or temperature transfer between the two surfaces. In the adiabatic region of the heat pipe the latent heat of vapourisation of the ammonia solution is passes to the another side by sensible heat rejection. During the transmission of the fluid in the heat pipe doesnot have loss in the temperature and the pressure of the fluid.

**4.3 Condensor**

Finally, in the heat pipe the condensor region of the heat pipe comprising of sensible heat rejection and phase transformation of the working fluid. This section have a length of **410 mm** and diameter of **230 mm** in which the sensible heat rejection from the heat is taken place. The working fluid posses the phase change from the vapour state to the liquid state and is send back for the cyclic process either by gravitational force, centrifugal force on rotating heat pipe. The experimental set up is shown in figure 4.2

**Figure 4.2 Photographic View of the Experimental Set up**

**4.4 Phase Changing Mechanism**

It works under the state of two phase change mechanism that the liquid phase of the working fluid transmitting the heat from the evaporator to the condensor area by the vapourisation of the working fluid. Which shows [9] and is then cooled and backed into the liquid state in the heat pipe for the continuous chain process. The two phase chaning process involves for the effectve heat transfer by

1)Latent Heat of vapourization

2) Sensible Heat Rejection

The latent heat of vapourisation of the ammonia will be active at a temperature from the $30^0$C and absorbing heat to the maximum of $80^0$C. At this state the liquid ammonia solution would transforms into the vapour form and transform the heat from the evaporator area to the other end condesor area. Thus, the reasonable amount of heat with negligible pressure drop even at the low temperature gradient is transformed to the other end of the heat pipe.

The absorbed heat from the latent heat of vapouristaion have transformed the heat from the evaporator zone through the phase change mechanism. Now, the sensible heating process emits the heat to the condensor unit at the constant pressure. Due to these heat transfer from the vapourisation state of the working fluid to the liquified state, there would be a reasonable increament in the condensor zone temperature. From this phase transistion the centrifugal force will impact on the heat pipe to rephase the ammonia solution into the evaporator zone for further thermodynamic cyclic process.

On account of having the temperature gradient at a higher range there should be no loss in the temperature loss at an adiabatic section. So that the heat transfer rate can be effectively increased through out the process.

**4.5 Sources and Mode**

The heat pipe transforms its heat by the actively involved technique known as Rotating the heat pipe by external power supply of three phase induction motor. It is capable of working with the power output of 0.75 kW, with the speed of 1450 rpm. The power to the heat pipe is driven by the belt drive connected with the pulley at the end of the heat pipe held horizontally. The heat pipe has a threaded opening at one end for the working fluid filling in the ratio of 3:4 on its volume which is being closed by the threaded screw. The other end of the heatpipe is dummied and connected with the pulley for driving the heat pipe externally. Hence, the active technique of the heat pipe heat transfer enhancement is experimentally fabricated by rotating technique.

## 5 Result and Discussion

The analysis of the heat transfer enhancement and the thermal performance of the heat pipe using the WHRS in various industries have some of the availability of energy in it. These, exhausted heat will retained for some of the useful purposes and it will alternatively reduces the emmission from the industry and the completely utility of the sources available in the industry.Various performances such as the temperature distribution, heat transfer rate , overall heat transfer enhancement on the rotating heat pipe is being discussed along with the new fabricated active technique carrying ammonia soltion as a working fluid.

The evaluation of the performance is dicussed as follows

### 5.1 Heat Transfer Performance On Rotation

Whenever there is a temperature difference in the two region, there will be the transfer of energy from the higher temperature region to the lower temperature region. During this tranformation heat can be transmitted from one region to the another region either through latent heat of addition or by the sensible heat rejection. The rate of heat transfer is maxium at higher temperature gradient, it is clearly explained in the Figure 5.1. At the evaporator region initally at a maximum temperature drop the rate of the heat transfer is maximum initially and decresed to its euilibrium level, In the static condition the heat transfer rate is viable to the long time period but in the rotating state, with in a short period of term it is neutralised to the equilibrium state.

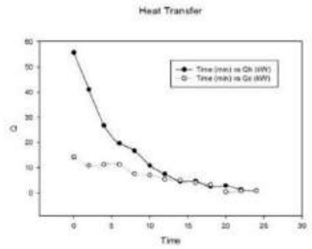


**Figure 5.1 Performance Curve on Heat Transfer**

But on the heat transfer at the condensor region due to the lower temperature gradient the rate of the heat trasnfer is lower than the evaporator transfer rate. In this the equilibrium is reached once the two heat transfer rate will obtain the same level of coincidence on the heat pipe occurs, the time period in rotating technique is as much quicker than the static condition where their condition is clearly explained below.

### 5.2 LMTD Comparison

The LMTD stands as logarthmic mean temperature difference is used to determine the temperature driving force for the heat transfer in flow systems. It is a logarithmic average of the temperature difference between the hot and cold feeds at each end of the HPHE. Explanation by [10] that there is larger the LMTD, the greater the heat will be transmitted. The figure 5.2 Shows about the comparison of LMTD with the time period at static and the rotational technique of the heat pipe

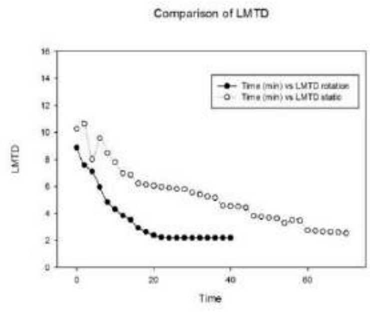


**Figure 5.2 Comparison on LMTD**

The above graph represents that the heat transfer rate is more vigorous on the rotating condition because of the heat transfer enhancement will achieved as quick as possible then the static condition. The obtainability of the thermal equilibrium temperature between the two ends of the HPHE the stability on the heat pipe is being achieved.

**6 Conclusion**

The optimum operating condition of the counter flow HPHE on Aluminium heat pipe with an working fluid of ammonia in the exhaust heat recovery system were tested and analysed in this report. The first and second law is integrated with the experimental setup were described by [11]. The major conclusions were listed to follow

- The first and second law of thermodynamics were introduced in the thermodynamic analysis. It indicated that exergy efficiency increased with increment of the waste water temperature.
- There is a reasonable increament in the rate of heat transfer on rotating the heat pipe. This can reduces the time consumption for the attainment of thermal equilibrium in the heat pipe.
- The heat transfer enhancement of the pipe will also depends on the thermal conductivity of the heat pipe. Though it has a higher operating temperature range, there must be the transfer of heat from the higher to lower temperature without any distruction.
- The heat transfer rate can be increased by rotation of the heat pipe and also there is a reasonable performance once the operating temperature is increased with the minimum pressure drop.
- The centrifugal force obtained from the heat pipe will posses the way for the working fluid to follow the chain path on the process of vapourisation and condensation of the fluid.

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