EXPERIMENTAL STUDY OF WICK STRUCTURE MATERIAL AND SCREEN MESH ON HEAT PIPE PERFORMANCE

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ABSTRACT :-

An experimental study has been done on heat pipe 1000mm length and 25.4mm diameter. Evaporator section is formed by adopting a coil heater over 240mm from one side of heat pipe length. The condenser section is formed by adopting a water jacket over 300mm from the other end of heat pipe length. The working fluids used is R-134a. The used wick structure is of square meshes of (Bronze150*150, Bronze200*200 and Copper145*145). The wick structure is formed by turning the square mesh layer six times to form an internal circumference for heat pipe inner diameter. The supplied power over evaporator (20, 30, 40 and 60)W. Thermal conductivity of Copper is 401W/m.C^{o} and Bronze is 51.2 W/m.^{o}C . It is found that the thermal conductivity has no effect on the heat pipe performance. But mesh screen size affected the performance the heat pipe and increases the temperature along the heat pipe.

KEY WORDS : heat pipe, wick structure, R134a in heat pipe

دراسة عملية لهيكل المواد النسيجية على اداء الانبوب الحراري

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الخلاصة :

اجريت دراسة عملية لأنبوب حرارة بطول (1000mm) وقطر(25.4mm) . يتكون المبخر من خلال وضع مسخن حراري على طول (240mm) من الطول الكلي لأنبوب الحراري من أحد طرفيه بينما يكون المكثف من خلال وضع جيب مائي على طول (300mm) من طول الأنبوب . كان مائع التشغيل المستخدم (R134a). بينما كانت المواد النسيجية المستخدمة هي (برونز 150x150 ،برونز200x200 و نحاس 145x145) تم تشكيل المواد النسيجية عن طريق لفها ستة لفات لتكون القطر الداخلي لانبوب الحرارة. القدرة المجهزة للمبخر(20, 30, 40, and 60W) مع كل نوع من المواد النسيجية. الموصلية الحرارية للنحاس (401W/m.^{o}C) وللبرونز(51.2W/m.^{o}C). لقد وجد بأن الموصلية الحرارية لا تؤثر على أداء الأنبوب الحراري. لكن التشبيك النسيجي له تأثير واضح فكلما زاد التشبيك النسيجي انخفض أداء الأنبوب وارتفعت درجة الحرارة على طول الأنبوب .

1-INTRODUCTION :-

Heat transfer applications are needed in wide range of utilization in the modern technology and play an important role in specifying the design of them. Heat pipe application provide more promised technology in heat transfer and for this reason its development be more necessary as noticed by researches and documented books .

To transfer liquid of working fluid in the horizontal heat pipe from condenser to evaporator, the layers of metallic wire screen mesh are used. the liquid moves through the wick structure due to the capillary attraction force. many types of screen mesh were used to examine the effect of the mesh material and porosity on the heat pipe operation and performance. There are many studies about the wick structures and types to study its effect of the heat pipe performance. An experimental study was done by(Bassel 2013)using R134a as a working fluid in a horizontal heat pipe. A copper square mesh was used as wicked structure to transfer condensed liquid to evaporator from condenser. It is concluded that the charge quantity of the working fluid has optimum value, for good performance of the heat pipe. The study has no information about the mesh porosity and material effect. Obaid and Ahmed studied experimentally a heat pipe performance using copper sintered powder metal as wick structure and pure water and pure ethanol as working fluid. The heat pipe was subjected to heat flux of 2.8-13.13 kW/m^2. The heat pipe was tested under horizontal condition. The results showed best thermal performance by using pure water more than using ethanol as working fluid due to the mean evaporator temperature and mean condenser temperature are high in the case of using ethanol. Bert de Leeuw et al studied experimentally heat pipe equipped in a heat exchanger by using R134a as working fluid with two different filling ratios 19% and 59%. Air was used for condenser cooling. The results investigated temperature distribution over evaporator surface to indicate filling ratio effect. This study recommended to use heat pipe based cooling device in the warmer countries.

An analytical study was done by to study the effect of the wick geometry on the heat pipe performance. The result showed that the circular geometry will give a maximum heat transfer rate as compared with rectangular grooved pipe. Experimental study to perform a heat pipe with Ethanol and Acetone as working fluid in the heat pipe. The screen mesh used was sintered powder. The results have been presented a temperature distribution along the heat pipe. It was shown that Ethanol gives good result than that with Acetone. Also copper powder is used as a wick material in a copper square flat plate heat pipe. It was tested with water, methanol, ethanol and acetone as working fluid with different quantity of charge. A study was to investigate experimentally of testing wick structure capillary performance for using in the range from micro-to nano scales. These facilitates are used to develop the nano wick structures for heat pipe high performance. **A**lso for space application sintered nickel powder is used as porous wicks in loop heat pipe. Capillary wicks of Ni for loop heat pipes, are successfully fabricated by novel Metal Injection Molding that used for satellites and space craft's.

Screen mesh is a layer of metallic wires that is used to form the wick structure of heat pipe. Capillary attraction has been generated between the wires and the liquid due to small distance. The used screen meshes in present work are Bronze150*150 with a porosity of 0.767, Bronze 200*200 with a porosity of 0.264 and Copper145*145 with a porosity of 0.747.

The comparison between Bronze 150*150 and Copper145*145 was done to indicate the thermal conductivity effect due to very closed value of porosities.

2-EXPERIMENTAL PROCEDURE :

The study of performance of heat pipe with different type of wicks structure in terms of the material and porosity needs to construct a rig for this aims. A test rig contains two similar heat pipes in order to reduce experimental testing time. One of them includes copper wicked structure while another one includes bronze wicked structure. Heat source zone (evaporator) of each heat pipe is provided with electrical heater and watt meter to regulate the input heat. There is also simple water jacket about a heat sink zone (condenser) to circulate the cooling water for heat dissipation . A water pump is used to circulate the cooling water. A digital thermometers are used to measure water temperatures at inlet and exit of the water jacket. Ten thermocouples are distributed along each heat pipe to measure temperature. The remained length of the heat pipe between evaporator and condenser is coated with thermal insulated layer to insulate it, forming an adiabatic zone. The wick screen is turned to make six layers inserted in the pipe in the adiabatic region. This research is done to examine the thermal conductivity and porosity of wick material on the heat pipe performance.

The experimental rig was constructed for these aims. The two heat pipes were operated together under the same condenser and evaporator conditions. One heat pipe with bronze wick of(150X150)screen mesh and the other one with copper wick of (145X145)screen mesh. This case was used to examine the thermal conductivity effect on the heat pipe operation and performance. These two type of mesh are very closed to each other in the porosity.

The other set of experiments were to examine the porosity effect on the heat pipe operation. This was done by using wick structure of same material and with different screen mesh size. A bronze wick structure of (15X150)screen mesh in one heat pipe and (200X200)screen mesh in the other one were used.

3- RESULTS AND DISCUSSION :

The effects of wick material type an its porosity on the heat pipe performance for different heat load on the evaporator are studied. Also these are studied with change of working fluid charges in the heat pipe. the discussions are divided into the following divisions:

3-1 The thermal resistance of the heat pipe

The thermal resistance of the heat pipe is affected be the wick materials. This is shown from **Fig. 2.** This figure shows that the resistance of heat pipe operating with the bronze as wick material is greater than that of copper wick of the same porosity approximately. It is shown that at low heat flux on the evaporator the thermal resistance with a bronze wick about four times than that of copper. The thermal resistance value of bronze wick decreases rabidly with increasing of heat load on the heat pipe. That was due the effect of the thermal conduction, because at low load the evaporation of liquid was very small so the convection was also small. When the load about 2000W the thermal resistance of the bronze wick be very closed to that of copper. Although, the copper thermal conductivity is about four times that of the bronze but the thermal resistance values in the two cases are closed to each other. As the working fluid charge increased as shown in **Fig. 3 and 4.** The thermal resistance decrease for the two type of wick structure material but be more closer to each other.

The wick structure mesh porosity has a significant effect on the thermal resistance of the heat pipe. The effects of the wick porosity on the thermal resistance of the heat pipe with different working fluid charge as function of the heat flux on the evaporator are shown in **Fig. 5, 6 and 7.** The porosity of the wick has inverse effect on the thermal resistance. When the Porosity is small the thermal resistance be high. But as the heat flux is increased the thermal resistance in general decreased. The small mesh screen prevent the flow of working fluid liquid from condenser to evaporator and make this flow difficult.

3-2 The temperature distribution along the heat tube

The temperature in the evaporator is depending on the pressure in the evaporator. The evaporator pressure is depending on the working fluid charge. The evaporator temperature is in general equal or greater than the saturation temperature at the evaporator pressure. The temperature in the adiabatic region is decreasing until reaching the saturation temperature of the condenser pressure at the end of this region. The heat is removed from the vapor to the water surrounding the condenser. The working fluid condenses due to heat losses until the working fluid becomes saturated liquid. The stability was satisfied at a carton heat load when the pressure reached a constant reading.

Fig.8, 9, and 10. show the temperature distribution along the heat pipe for different charge of the working fluid at constant heat load on the evaporator. It is to study the effect of the wick material on the heat transfer into the heat pipe under working fluid charge only. it is shown from **Fig. 8.** that the temperature in the evaporator and condenser is greater in the heat pipe of bronze wick structure than that of copper wick structure. it is investigated that the thermal conductivity of the wick material affecting the heat transfer between evaporator and condenser. this because of a small charge of the working fluid. But as the working fluid charge is increased the temperature of working fluid as shown in Fig.9. In this case the temperature along the heat pipe for the bronze becomes greater than that of copper. The reason that the thermal conductivity in this case play inversely on the heat transfer. The copper wick structure is absorbing heat more than that of bronze because of higher heat capacity for copper. The difference in temperature is increased when the charge of the working fluid is increased more. The effect of the thermal conductivity be less because the temperature decreased when the thermal conductivity is increased.

The temperatures along the heat pipe are raised as the working fluid charge is increased. This is due to the raised of the pressure in the evaporator and condenser.

The effects of wick structure screen mesh on temperature distribution are shown in **Figs. 11, 12 and 13.** The temperature is increased as the porosity decreased. The temperature is increased as the working fluid charge is increased also. This is due to the increase of the pressure in the evaporator .

4- CONCLUSIONS :

This study aims to find the effect of wick material on the heat pipe performance. The thermal resistance of the heat pipe is one factor that effecting the heat pipe. In general it is need thermal resistance to be small as possible to increase the heat transfer by the heat pipe. The research gives the following conclusions:

Thermal conductivity has no effect on thermal resistance of the heat pipe because the heat transfer in the heat pipe depending on the convection(transmission of vapor of working fluid) from evaporator to condenser.

The high porosity (the screen mesh)of wick structure reduces the thermal resistance of the heat pipe, because it help to return the liquid easily to evaporator, so the cycle of working fluid is completed quickly.

The filling of the heat pipe by the working fluid is also affecting the performance of the heat pipe. The working fluid charge raise the operation temperature of the heat pipe.

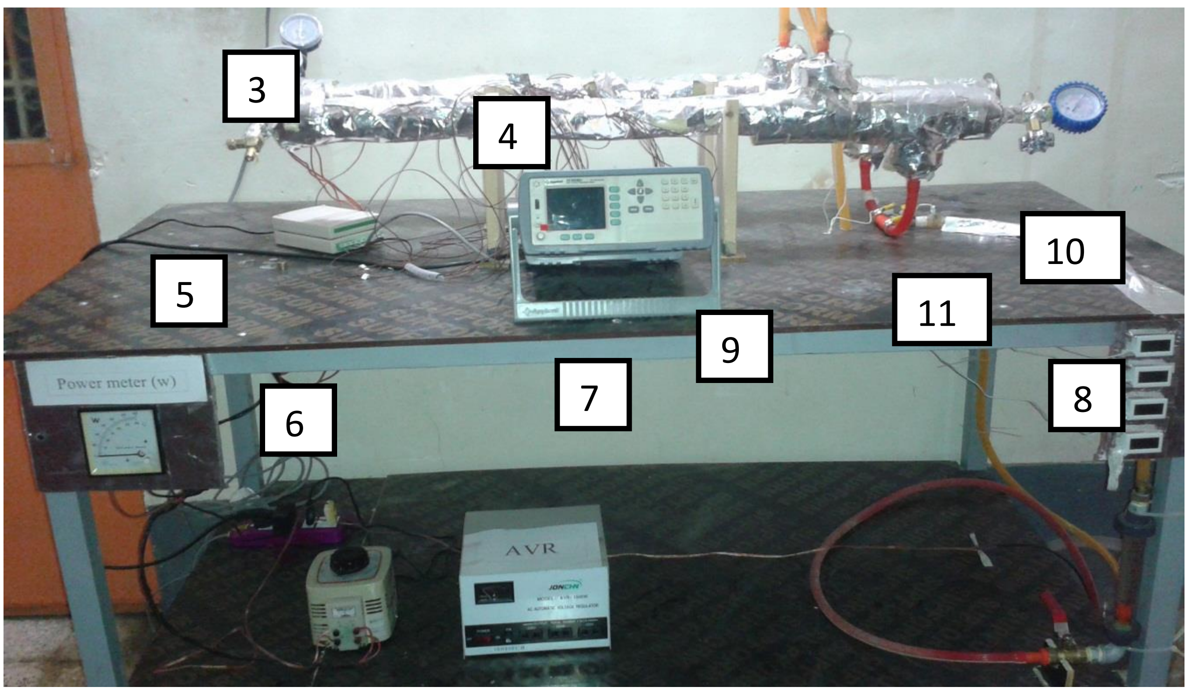

Fig.1 The Experimental Rig where 1-Bourdon gage, 2- Heat Pipe, 3- Thermocouples Extension reader, 4- Data acquisition instrument, 5- Analog Watt meter, 6- Manual power regulator, 7- Automatic voltage regulator, 8- Analog Flow Meter, 10- Thermometer of Coolant Water, 11- Connected flexible pipes

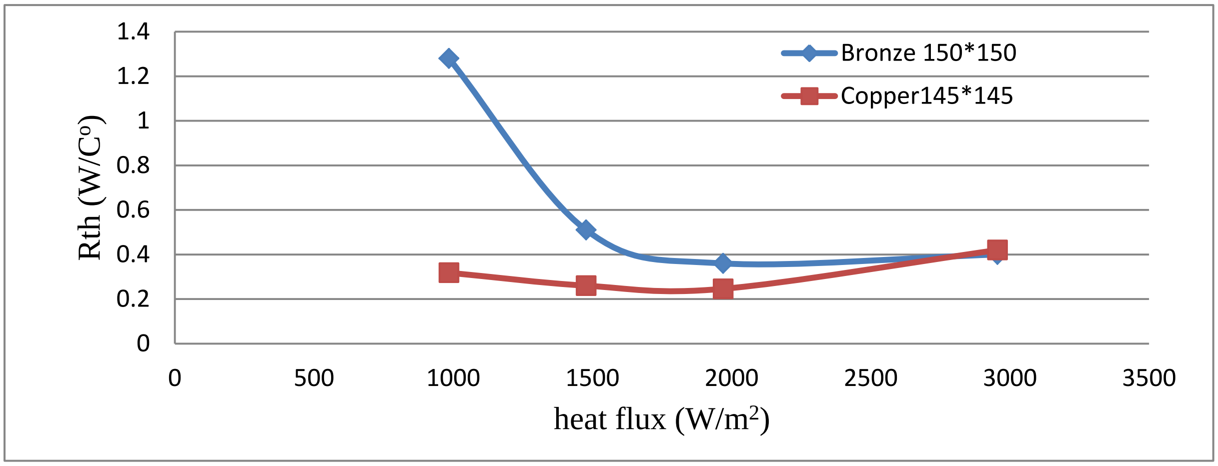

Fig.2. Thermal resistance of heat pipe against heat flux for 200gr charge of R-134a

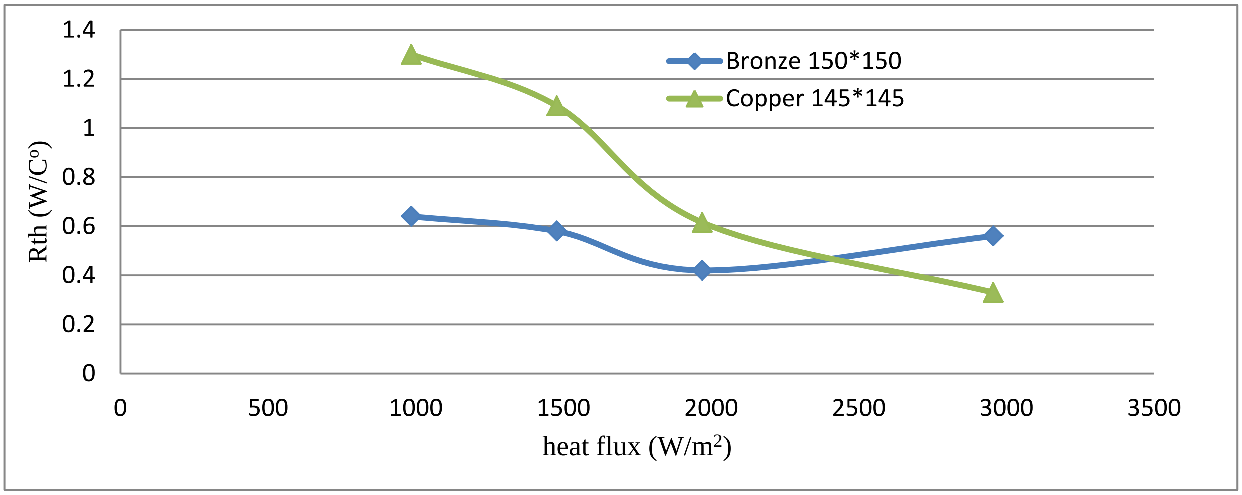

Fig.3. Thermal Resistance of Heat Pipe Against Heat Flux For 250gr Charge of R-134a

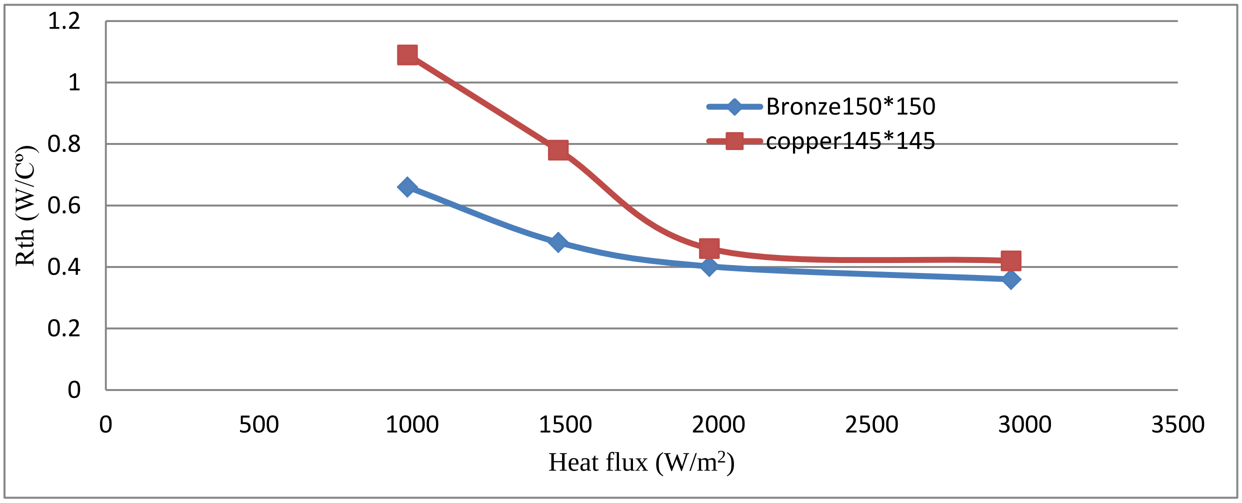

Fig.4. Thermal resistance of heat pipe against heat flux for 320gr charge of R-134a

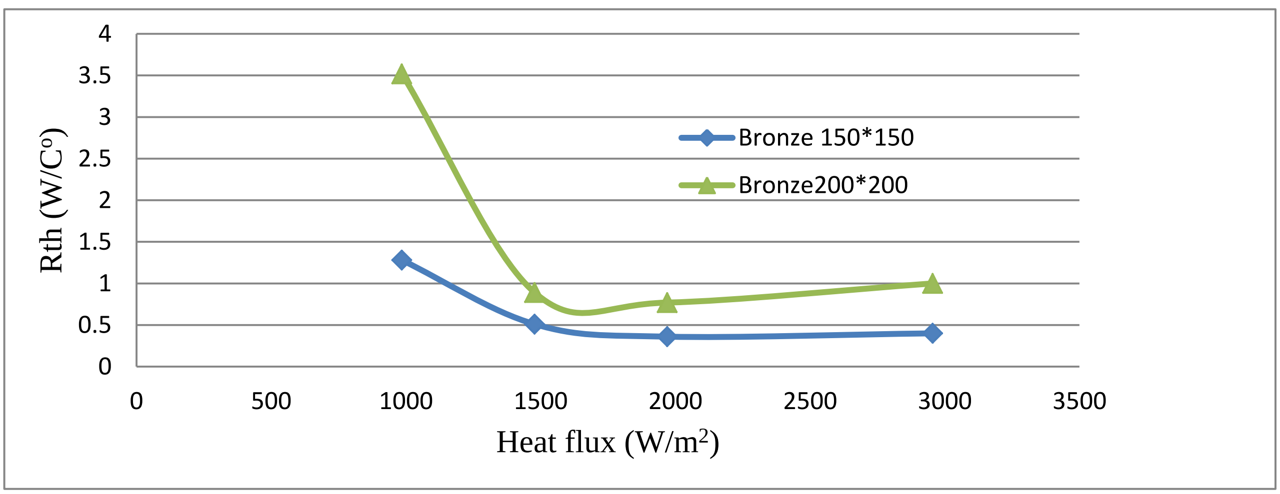

Fig.5. Thermal resistance of heat pipe against heat flux for 200gr charge of R-134a

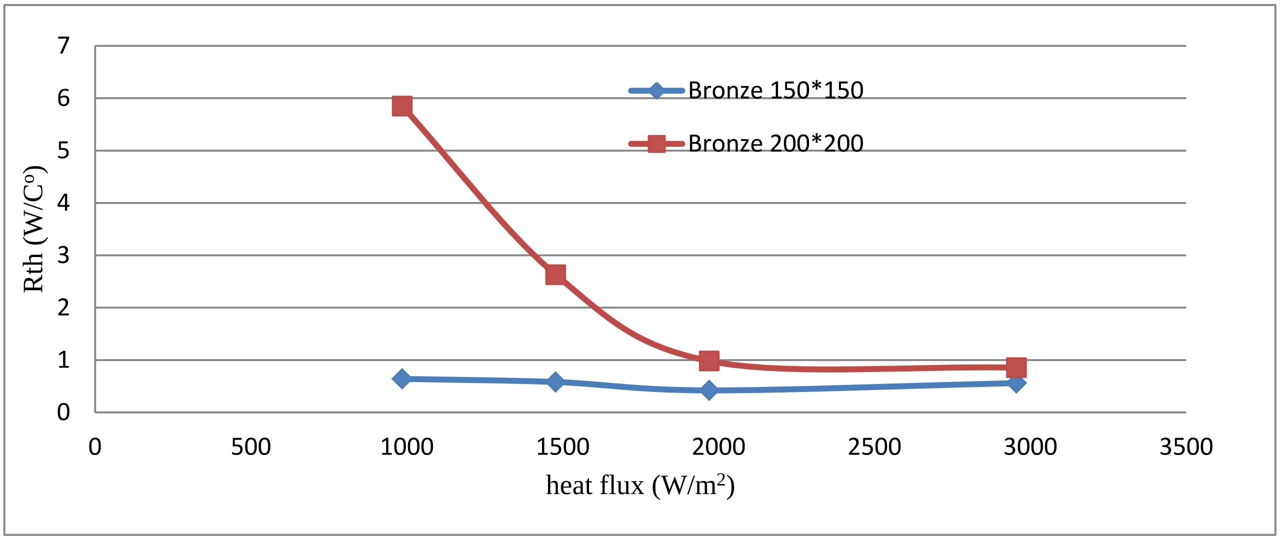

Fig.6. Thermal resistance of heat pipe against heat flux for 250gr charge of R-134a

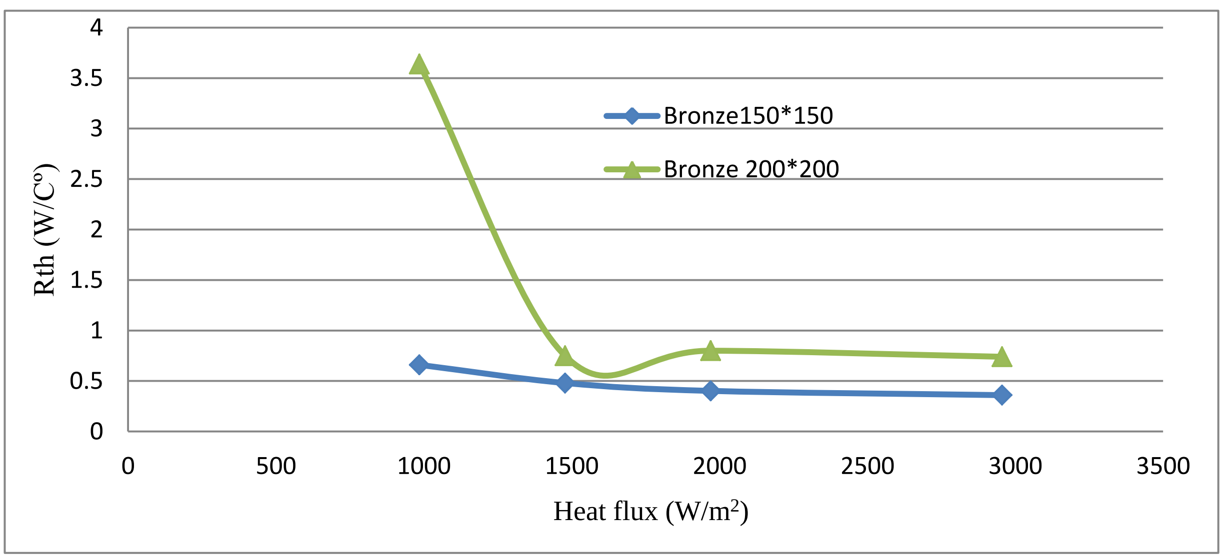

Fig.7. Thermal resistance of heat pipe against heat flux for 320gr charge of R-134a

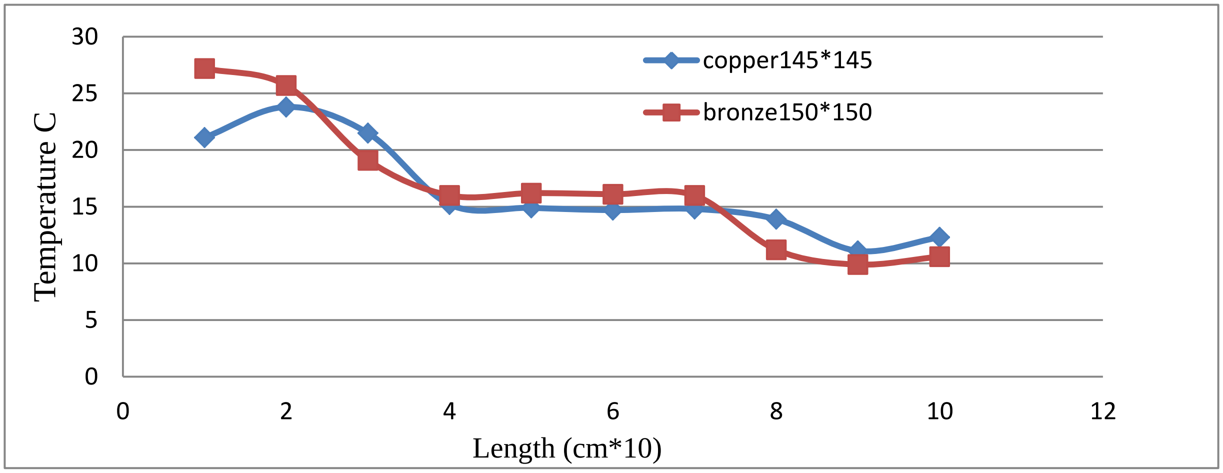

Fig.8. Temperature distribution along the heat pipe for 200gr of R134a 30W heat load

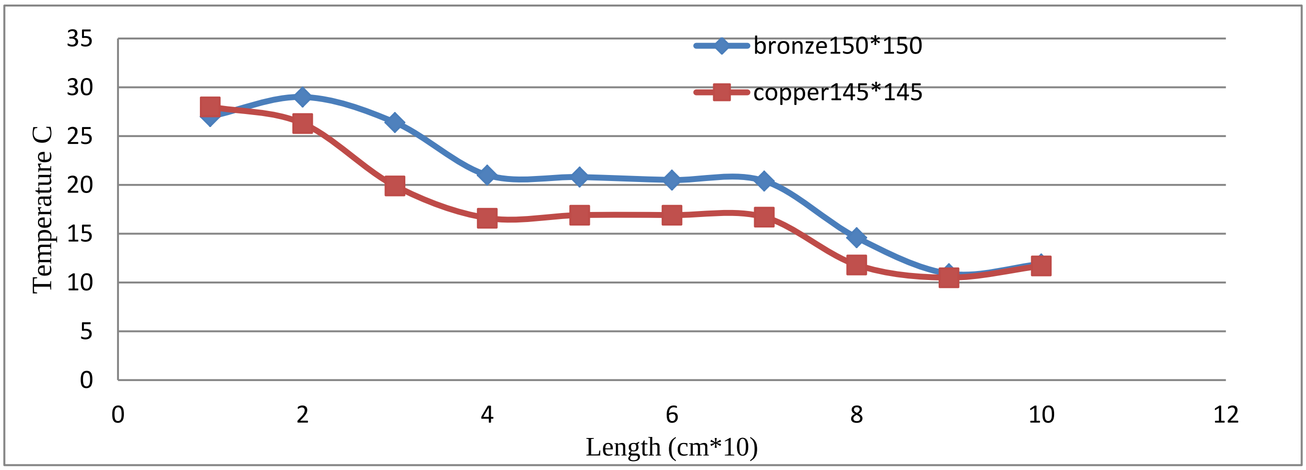

Fig.9. Temperature distribution along the heat pipe for 250gr of R134a 30W heat load

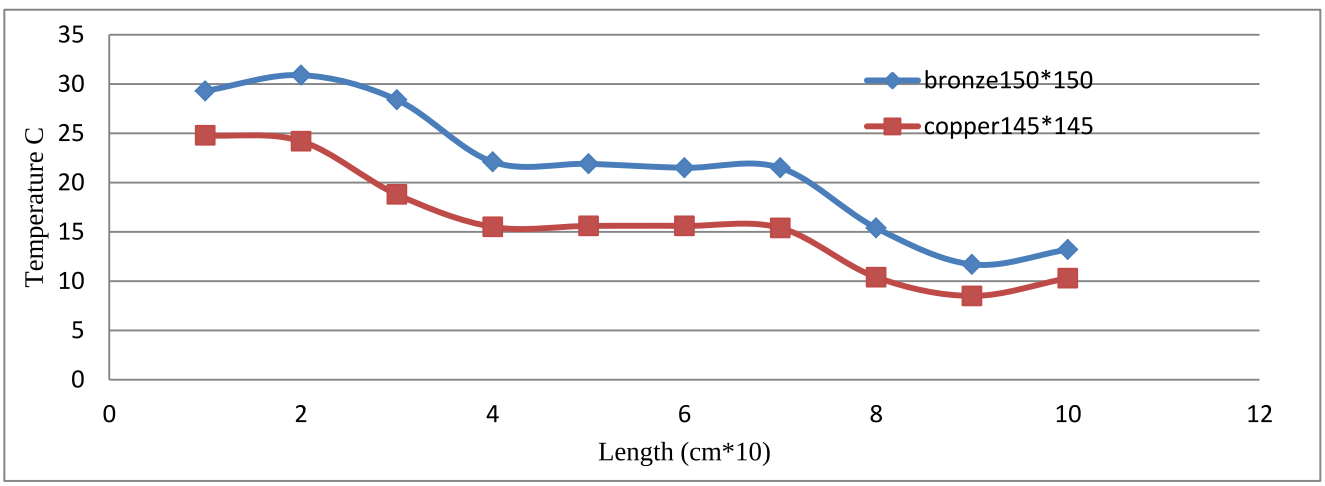

Fig.10. Temperature distribution along the heat pipe for 320gr of R134a 30W heat load

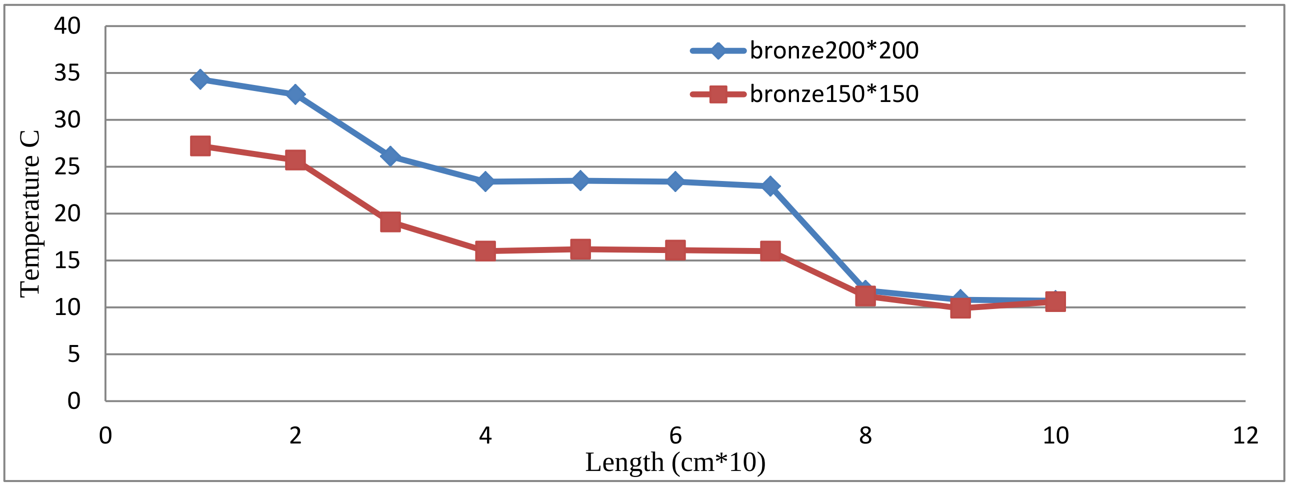

Fig.11. Temperature distribution along the heat pipe for 200gr of R134a 30W heat load

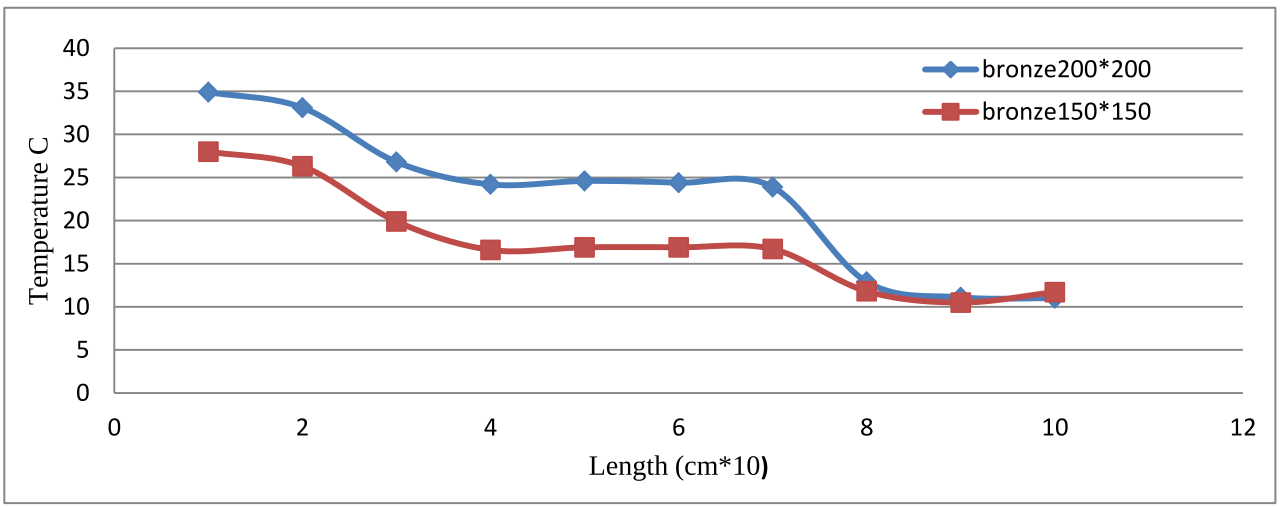

Fig.12. Temperature distribution along the heat pipe for 250gr of R134a 30W heat load

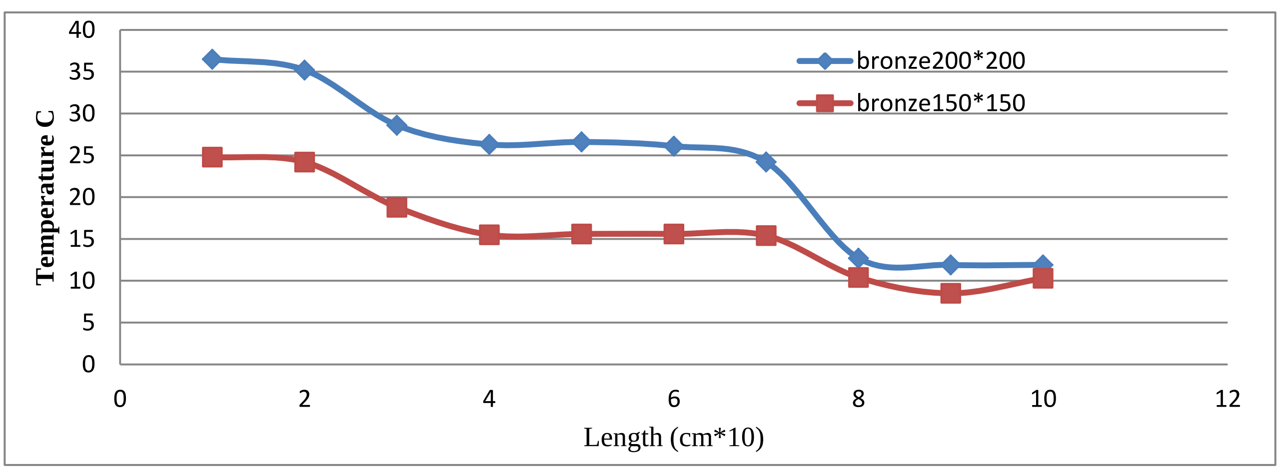

Fig.13. Temperature distribution along the heat pipe for 200gr of R134a 30W heat load

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