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Experimental Investigation of Wire Wicked and Mesh Wicked Heat Pipe

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Abstract

An experimental investigation is carried out for determining heat pipes heat transfer rate involving wire wick and mesh wick. The investigation is conducted in order to examine the efficiency of wire wicked heat pipe. The wire wick is investigated for heat transfer rate and efficiency by comparing it with the widely used economic and efficient mesh wick structure. The investigation function involved detecting the heat transfer at different angle of inclinations. Both the heat pipes considered have the same thickness of wick layers and same working fluid tested under ideal situations.

INTRODUCTION

A heat pipe is a heat switch tool that mixes the principles of each thermal conductivity and segment transition to efficiently manage the switch of heat among two solid interfaces. At the new interface of a warmness pipe a liquid in touch with a thermally conductive solid surface becomes a vapour by means of absorbing warmness from that surface. The vapour then travels alongside the warmth pipe to the cold interface and condenses again into liquid releasing the latent warmness. The liquid then returns to the recent interface through either capillary motion or centrifugal pressure and the cycle repeats. due to the very high heat switch coefficient for boiling and condensation, heat pipes are extraordinarily effective thermal conductors. Spacecraft, laptop structures, sun thermal, Permafrost cooling, Cooking, ventilation heat recovery, Nuclear power conversion and Wankel rotary combustion engines are the applications.

Jung-Yuan Wu, et al. published a magazine approximately, “technique for creating a warmth Pipe”: in line with this examine the capillary pressure of the display mesh increases because of decrease a pore size of the display mesh. waft resistance to the condensed operating fluid also increases due to lower in pore size of the display mesh. As a end result, a warmth pipe with a display screen mesh that has too large or too small pore size frequently surface dry out hassle on the evaporating phase because the condensed working fluid cannot be well timed dispatched lower back to the evaporating segment of the heat pipe.

Sheng-Lin Wu, et al. published a journal about, “Heat Pipe including a Main Wick Structure and at least One Auxiliary Wick Structure”: According to this study the heat pipes have excellent heat transfer performance due to their low thermal resistance and are therefore an effective means for transfer or dissipation of heat from heat sources. A heat pipe is usually a vacuum casing containing therein a working medium, which is employed to carry, under phase transitions between liquid state and vapor state, thermal energy from one section of the heat pipe (typically referring to as the “evaporator section”) to another section there of (typically referring to as the “condenser section”). Preferably, a wick structure is provided within the heat pipe, lining an internal wall of the casing, for drawing the operating medium lower back to the evaporator section after it is condensed on the condenser segment. In operation, the evaporator segment of the warmth pipe is maintained in thermal contact with a warmth generating thing. The working medium contained at the evaporator section absorbs warmth generated through the heat-producing issue and then will become vapor. due to the difference of vapor stress among the 2 sections of the heat pipe, the generated vapor moves and accordingly carries the warmth closer to the condenser phase where the vapor is condensed into condensate after releasing the warmth into ambient environment because of the difference in capillary pressure which develops within the wick structure between the two sections, the condensate is then brought back by using the wick shape to the evaporator section where it's miles again available for evaporation. The wick shape provided in the warmth pipe is expected to provide a excessive capillary pressure and in the meantime generate a low flow resistance for the condensate. In ordinary use, the heat pipe wishes to be flattened to permit the miniaturization of digital products, which ends inside the Wick shape of the warmth pipe being broken. Therefore, the flow resistance of the Wick structure is increased and the capillary force provided by the Wick structure is decreased, which reduces the heat transfer capability of the heat pipe. If the condensate is not quickly brought back from the condenser section, the heat pipe will suffer a dry out problem at the evaporator section.

Frank G. Arcella, and Bethel Park published a journal about, “Heat Pipe Wick Fabrication”: According to this study this invention pertains to heat pipe wicks, and more particularly to a new economical heat pipe wick fabrication technique. Heat pipe wicks of the prior art are fabricated in many ways. For liquid metal working fluids, several critical properties must be retained. The wick liquid/vapor interface must possess extremely small pore sizes for optimum capillary drawing forces. Thus, for effective heat pipe operation, the pressure differential due to capillary action, must be equal to or exceed the sum of the vapor and liquid pressure drops experienced in the vapor region and the wick respectively. The greater the difference, the greater the heat switch functionality of the heat pipe. If the wick have been definitely manufactured from nice pore fabric, the liquid friction float thing would be excessively huge due to the restrictions to float. The previous artwork has retained the aforementioned important properties via fabricating channels into the warmth pipe partitions through a broaching technique. The channels, which allow unrestricted fluid drift from the warmth pipe condenser to the evaporator section, are included by using a high-quality mesh screen to establish extra capillary wicking forces. Composite wicks have additionally been fabricated by placing layers of heavy mesh display (30 to 60 mesh)underneath the liquid/vapor interface layers of nice mesh screen (2 hundred to four hundred mesh).

Some other technique incorporates the fabrication of open annulus wicks with the aid of swaging several turns of display screen wound among copper tubes. The copper tubes are then etched away and the porous rigid wick is sinter bonded. Upon insertion in to a warmth pipe with an open annulus among the wick and the warmth pipe walls, this wick presents an most beneficial arrangement for liquid steel charged warmth pipes. the first of the aforementioned techniques have the negative aspects of being each uneconomical and time consuming and the latter approach is best suitable for liquid metal operating fluids, on account that a low thermal conductivity fluid might boil under the capillary drawing free wick. despite the fact that different wick structures were fabricated, the 3 referred to above are the ones most frequently hired. At the warmth supply the cold liquid is evaporated, the hot vapour glide is afterwards transported to the warmth sink wherein the vapour condensates again and is transported lower back to the heat supply. The hassle of this process is the distance consumption; for this reason it become necessary to broaden a compacter manner to transport the warmth electricity with the shown manner. The idea of a heat pipe is now to include the whole convective shipping in one pipe, wherein the vapour glide is inside the centre of the pipe and the liquid flow takes location at the outside of the cylinder. Sintered powder metallic (Fig. 1.1), Grooved wick type (Fig. 1.2) and steel mesh (felt) wick kind (Fig. 1.3) are the generally used wick structures.

Fig. 1.1: *Sintered Powder Metal*

Fig. 1.2: *Grooved Wick Type*

Fig. 1.3: *Metal Mesh (Felt) Wick Type*

The most commonly used envelope (and wick) fluid pairs include:

1. Copper envelope water working fluid for electronics cooling. This is by far the most common type of heat pipe.
2. Copper or Steel envelope Refrigerant R134a working fluid for energy recovery in HVAC systems.
3. Aluminum envelope Ammonia working fluid for Spacecraft Thermal Control.
4. Super alloy envelope Alkali Metal (Cesium, Potassium, Sodium) working fluid for high temperature heat pipes, most commonly used for calibrating primary temperature measurement devices.

different pairs encompass chrome steel envelopes with nitro- gen, oxygen, neon, hydrogen, or helium running fluids at temperatures underneath a hundred k, copper methanol warmness pipes for electronics cooling when the heat pipe must function beneath the water variety, aluminum ethane heat pipes for spacecraft thermal manage in environments whilst ammonia can freeze, and refractory metal envelope lithium operating fluid for excessive temperature (above 1050 °C) programs.

CONSTRUCTION AND EXPERIMENTAL SETUP

The experimental setup mainly consists of heating coil, digital ammeter and voltmeter to provide the necessary power to the heating coil. The temperature of the heat pipe is measured by using a digital temperature indicator with T-type thermocouples at different location. The digital temperature indicator is used to record the thermocouple readings at different points of the heat pipe. In total thirteen thermocouples are attached on the heat pipe wall, i.e., four at the evaporation and condenser section, two at the adiabatic section and one thermocouple for measuring the room temperature .The thermocouples are welded over the floor of the heat pipe. The whole warmth pipe is insulated with the aid of the usage of insulating cloth to avoid warmth loss from the gadget. A water jacket, which includes inlet and outlet ports for cooling water is fabricated. The temperature of cooling water on the inlet and outlet are measured the use of T-type thermocouples. The apparatus concerned in an test concerning the heat pipe consists of:

1. Heat source.
2. Cooling unit.
3. Coolant flow measuring system.
4. Thermocouple (T-type).
5. Data logger.
6. Digital ammeter.
7. Digital voltmeter.
8.

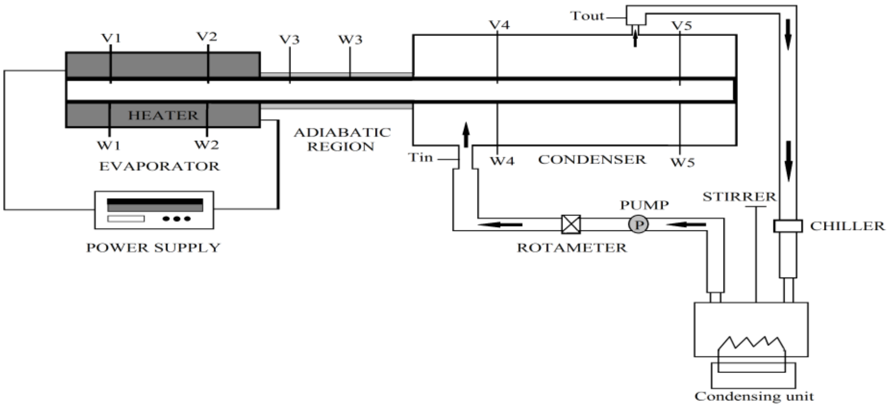

Fig. 2.1: *Schematic Line Diagram*

Fig. 2.2: Experimental Setup

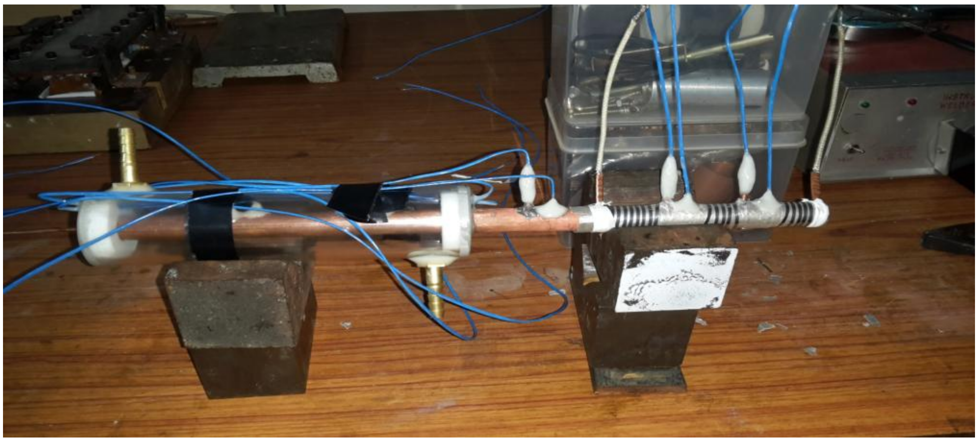

Fig. 2.3: Heat Pipe with Thermocouples

EXPERIMENTAL PROCUDURE

- The heat pipe connected with thermocouples is taken.
- An insulation tape is wound over the heating coil.
- The condenser region is set up in order to ensure the flow of coolant without any disturbance or leakage.
- The Heat sensors attached to the heat pipe are checked and a layer of plastic material is painted over these welded regions.
- Then the heat pipe is set up in the test rig.
- The heat is applied from a transformer.
- The flow of coolant is measured using a rotameter.
- The heat load is adjusted to next higher level (in this experiment 50, 100, 150, 200, 250) while the steady state is achieved by the heat pipe.
- After completing these five heat loads the angle of inclination of the heat pipe is changed 0, 45, 90 degrees.
- The results from the data logger are filed and it s used for finding the heat transfer rate, thermal conductivity, thermal resistance and efficiency of each heat pipe in each inclination.

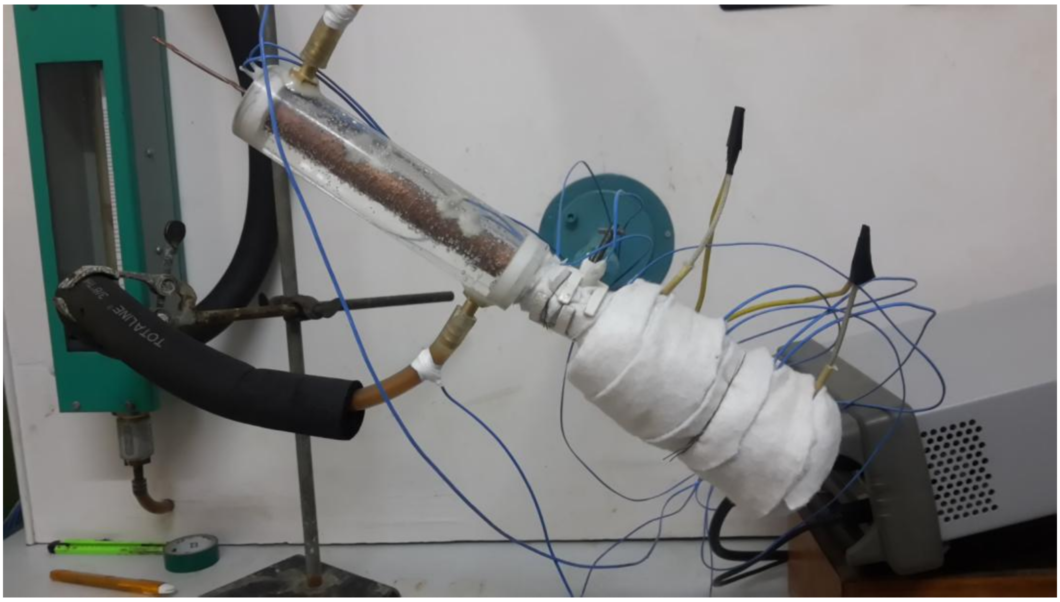

Fig. 3.1: Heat Pipe at 45 Degree Inclination

GRAPH AND RESULT

4.1. Comparison of Thermal Resistance between Wire Wick and Mesh Wick - Zero Degree

(X-axis in Watts (W) and Y-axis in Kelvin per Watt (K/W))

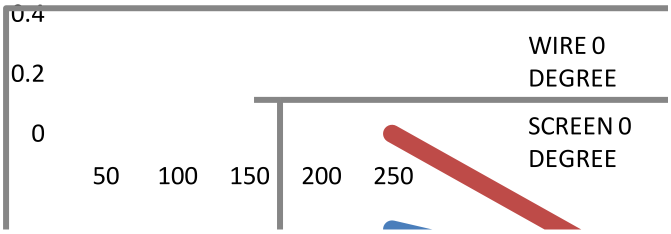

Fig. 4.1: Thermal Resistance - Zero Degree

Table 4.1: Thermal Resistance - Zero degree

HEAT INPUT (W)	WIRE ZERO DEGREE (K/W)	SCREEN ZERO DEGREE (K/W)
50	0.2615498	0.3632191
100	0.2043109	0.229609
150	0.1448034	0.1991893
200	0.1571883	0.2061098
250	0.1732789	0.1973555

Comparison of Thermal Conductivity between Wire Wick and Mesh Wick - Zero Degree

(X-axis in Watts (W) and Y-axis in Watt per millimeter Kelvin (W/m.K))

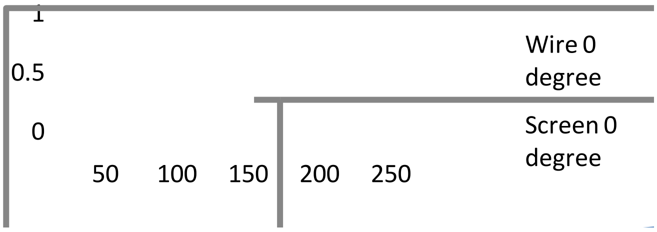

Fig. 4.2: Thermal Conductivity - Zero Degree

Table 4.2: Thermal Conductivity - Zero Degree

HEAT INPUT (W)	WIRE ZERO DEGREE (W/Mk)	SCREEN ZERO DEGREE (W/mK)
50	358983404	0.299172245
100	0.62220084	0.467906371
150	0.67606226	0.531547618
200	0.707663372	0.427100778
250	0.5642349	0.46321234

Comparison of Efficiency between Wire Wick and Mesh Wick - Zero Degree

(X-axis in Watts (W) and Y-axis in %)

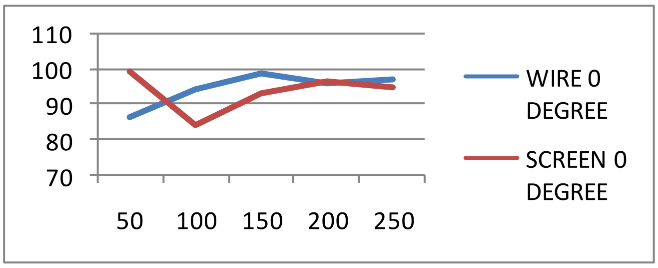

Fig. 4.3: Efficiency - Zero Degree

Table 4.3: Efficiency – Zero Degree

HEAT INPUT (W)	WIRE ZERO DEGREE (%)	SCREEN ZERO DEGREE (%)
50	86.375846	99.525735
100	94.249875	84.140005
150	99.101594	93.143683
200	96.096725	96.863263
250	97.270434	95.042523

Comparison of Thermal Resistance between Wire Wick and Mesh Wick - 45 Degree

(X-axis in Watts (W) and Y-axis in Kelvin per Watt (K/W))

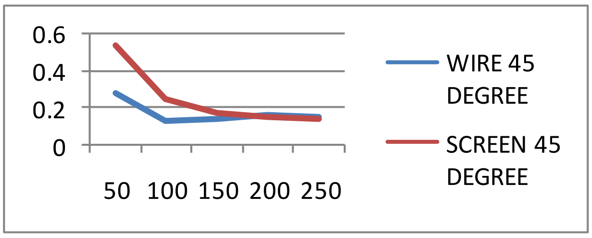

Fig. 4.4: Thermal Resistance - 45 Degree

Table 4.4: Thermal Resistance - 45 Degree

HEAT INPUT (W)	WIRE 45 DEGREE (K/W)	SCREEN 45 DEGREE (K/W)
50	0.2809094	0.5432183
100	0.1273423	0.2512512
150	0.1364434	0.1774108
200	0.1559027	0.1538846
250	0.1517133	0.142727

Comparison of Thermal Conductivity between Wire Wick and Mesh Wick - 45 degree

(X-axis in Watts (W) and Y-axis in Watt per millimeter Kelvin (W/m.K))

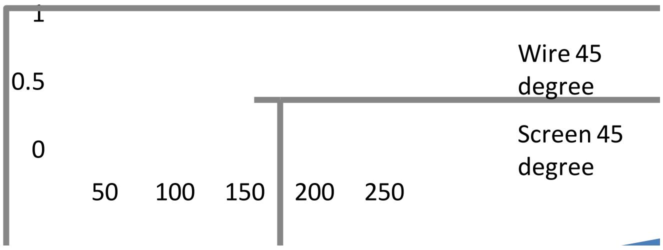

Fig. 4.5: Thermal Conductivity - 45 Degree

Table 4.5: Thermal Conductivity - 45 Degree

HEAT INPUT (W)	WIRE 45 DEGREE (W/mK)	SCREEN 45 DEGREE (W/mK)
50	0.388607915	0.184761804
100	0.62409877	0.444156704
150	0.72007481	0.579813875
200	0.671320206	0.652080068
250	0.15062415	0.672562997

Comparison of Efficiency between Wire Wick and Mesh Wick - 45 Degree
(X-axis in Watts (W) and Y-axis in %)

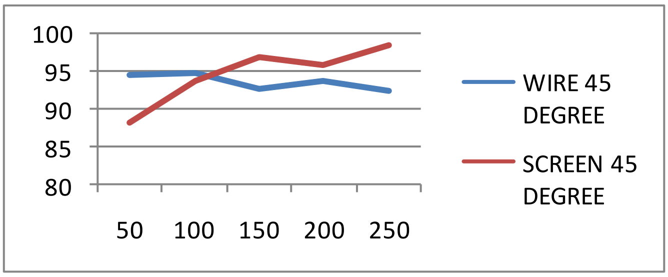

Fig. 4.6: Efficiency - 45 Degree

Table 4.6: Efficiency - 45 Degree

HEAT INPUT (W)	WIRE 45 DEGREE (%)	SCREEN 45 DEGREE (%)
50	94.573206	88.096434
100	94.823473	93.831099
150	92.6608	97.034628
200	93.721769	95.972563
250	92.313878	98.512231

Comparison of Thermal Resistance between Wire Wick and Mesh Wick - 90 Degree
(X-axis in Watts (W) and Y-axis in Kelvin per Watt (K/W))

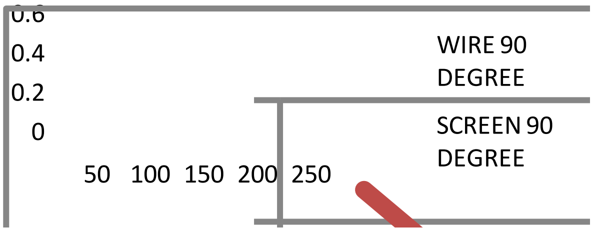

Fig. 4.7: Thermal Resistance - 90 Degree

Table 4.7: Thermal Resistance - 90 Degree

HEAT INPUT (W)	WIRE 90 DGEREE (K/W)	SCREEN 90 DEGREE (K/W)
50	0.2936324	0.4522576
100	0.1933559	0.2234119
150	0.1501195	0.1716092
200	0.1545112	0.156592
250	0.1401633	0.2675887

Comparison of Thermal Conductivity between Wire Wick and Mesh Wick - 90 Degree
(X-axis in Watts (W) and Y-axis in Watt per millimeter Kelvin (W/m.K))

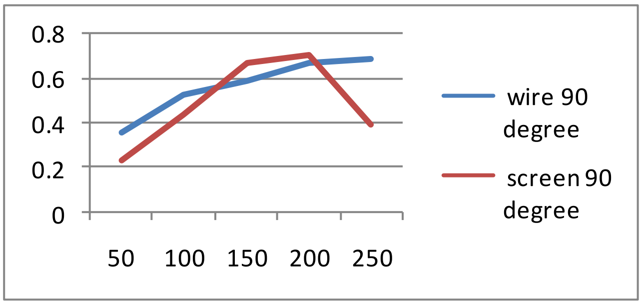

Fig. 4.8: Thermal Conductivity - 90 Degree

Table 4.8: Thermal Conductivity - 90 Degree

HEAT INPUT (W)	WIRE 90 DEGREE (W/mK)	SCREEN 90 DEGREE (W/mK)
50	0.356135893	0.235593719
100	0.52337548	0.442383222
150	0.591454324	0.672932183
200	0.667995545	0.70443545
250	0.686597944	0.398388157

Comparison of Efficiency between Wire Wick and Mesh Wick - 45 Degree
(X-axis in Watts (W) and Y-axis in %)

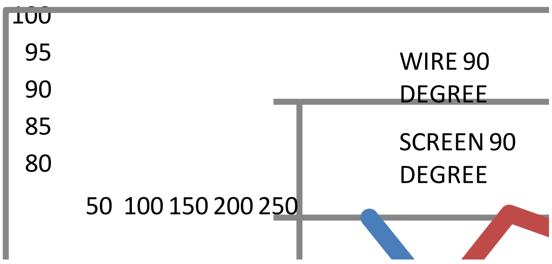

Fig. 4.9: Efficiency - 90 Degree

Table 4.9: Efficiency - 90 Degree

HEAT INPUT (W)	WIRE 90 DEGREE (%)	SCREEN 90 DEGREE (%)
50	94.992417	87.521123
100	87.468908	95.126028
150	96.708221	92.969681
200	86.040497	90.824215
250	95.41999	88.916304

CONCLUSION

The basic theory of heat and mass transfer is necessary to understand the working principle of a heat pipe. On a first look a heat pipe seems to be a very easy tool to transport energy, but if one looks closer, it is a very complex heat and mass transfer process which takes place in a heat pipe. First of all one has convective heat transfer in the adiabatic transport range and convection through porous materials also. The second major point is mass transfer due to vaporization and condensation, also through porous media. Furthermore there are capillary effects, pressure effects and heat conduction effects involved, which creates a complex structure of heat transfer, where a lot of knowledge is involved. Likewise the usage of wire wicks in heat pipes is effective and according to our thesis it’s in par with the performance of the mesh wick.

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