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# Performance Analysis of Water Heat Pipe Under Different Kinds of Converter Cooling System

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*Abstract*— **The heat pipe is a device, which does not require any external power to transport heat over a large distance, with minimal temperature difference. The surface resistance on the condenser section is one of the important parameters which also decides the operating temperature of the heat pipe. In the present work, three heat pipes of the same dimensions of 1 m length and 0.031m outer diameter were constructed with some modifications in the condenser section, in order to provide three different modes of cooling, viz, air cooling, water cooling and cooling with extended surfaces in the condenser section. Analysis is conducted to determine the surface and vapour temperature distribution, at steady and transient conditions for all the above said three modes of cooling in the condenser section. An analysis was also carried out, and the results under steady state conditions are compared with the results obtained from the experiments and reported.**

## I. INTRODUCTION

Transporting thermal energy at a high rate over a small temperature difference is an important requirement for many heat transfer applications. Of the many different types of systems which transport heat, the heat pipe is one of the most efficient systems known today. The advantage of using a heat pipe overother conventional method is that, large quantities of heat can be transported through a small cross sectional area a considerable distance, with no additional power input to the systems. Further more design and manufacturing simplicity, small end to end temperature drops,and the ability to control and transport high heat rates at various temperature levels are unique features of heat pipes

### A. *THE HEAT PIPE*

The heat pipe is an evapouration condensation device for transferring heat, in which the latent heat of vapourization is exploited to transport heat over long distances, with a corresponding small temperature difference. The heat pipe generally consists of a long sealed container that encloses a working fluid and a capillary wicking structure as shown in Figure 1.1. Heat added at the evaporator section causes a temperature increase and evapouration of the working fluid. Mass addition to the vapour space and the temperature rise produce a vapour pressure gradient, resulting in a vapour flow from the heated evaporator to the cool condenser where condensation occurs. The condensate is returned to the heated end by the action of capillary forces in the wicking material. Since the primary mode of heat transfer is through the latent heat of vapourization, the steady state operation is nearly isothermal, even while maintaining a high heat transfer rate.

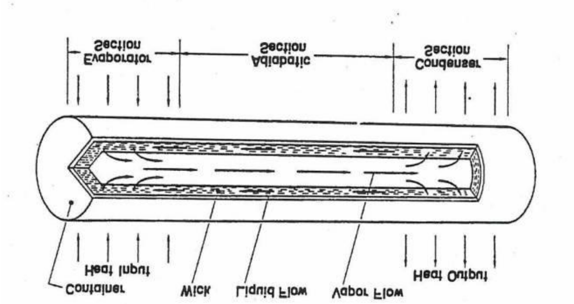


FIG: A. REPRESENTATIVE HEAT PIPE

### B. *HISTORY OF THE HEAT PIPE*

The heat pipe was first developed in the mid 19th century by Perkins (1982). The device, known as the Perkins Pipe, consisted of an unpicked sealed container, in which heat transfer as accomplished through evapouration and vapour transport to a cool condensing point. The circulation of liquid was accomplished through gravitational forces. This device was a wickless heat pipe, known in current terminology as the thermosyphon. The novel idea of using capillary forces to replace or supplement gravitational forces in circulating the working fluid is attributed to Gaugler (1944). The device was a true heat pipe consisting of a sealed container with a capillary wick and working fluid. The invention was intended for use in the refrigeration industry, but was not utilized.

The development of space power systems, some twenty years after Gaugler's patent, introduced a viable application for the capillary heat transfer device. The term heat pipe was introduced by Grover and his coworkers at the Los Alamos Scientific Laboratory. Limited experimental work by Grover in 1964, using water as the working fluid followed by liquid sodium, showed the great promise of heat pipes serving as highly efficient conductors, (Grover 1964).

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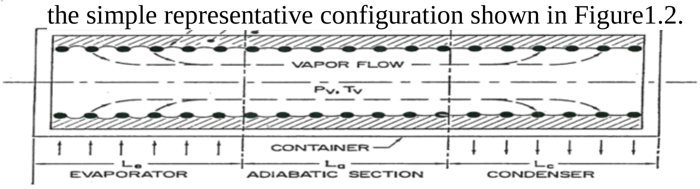
The theoretical basis for heat pipe operation and analysis was first formulated by Cotter (1965). In recent years, the heat pipe has received major attention in the field of cooling of electronic components.

*C. OPERATING PRINCIPLE*

The term heat pipe refers to a large class of heat transport devices. The operating principles provide great flexibility in tailoring the heat pipe design to a specific application. The fluid dynamics and heat transfer principles are integral to the specific design configuration, such that each unique design requires a dedicated analysis. However, the general operating principles can be described in terms of the simple representative configuration shown in Figure1.2.




A heat pipe generally consists of a long sealed container enclosing a working fluid and a capillary wick structure. The liquid and vapour have distinct flow paths, but share a common interface which allows them to communicate in all parts of the system. The quantity of working fluid is sufficient to at least saturate the wicking material. The wick can be constructed of essentially any porous material, screen, gauze, sintered material, packed spheres, grooves in the container wall, perforated shields, etc. The heat pipe can use any working fluid that has a liquid and vapour phase at the operating temperature that wets the wicking material, and is chemically compatible with the container and wick material. Proper selection of the working fluid, container, and wick allow the heat pipe to be designed for specific temperature range

- The cryogenic temperature
- The low temperature range
- The high temperature range

A heat pipe generally has three distinct zones: the evaporator section, the adiabatic section, and the condenser section. The adiabatic section is optional and serves only to span the distance between the evaporator and condenser There are three basic types of heat transfer/fluid dynamics problems to consider:

1. Vapour flow in the core
2. Liquid flow in the wick
3. Phase transition between liquid and vapour

If the pressure drop from the liquid saturation vapour pressure to the vapour phase pressure is larger than the pressure drop required for phase change, net evapouration will occur. The evapourating mass flux carries the thermal energy transferred to the liquid vapour interface through the latent heat of vapourization. Mass injection and increased temperature raises the evaporator vapour phase pressure, and establish a pressure gradient that drive the vapour through the adiabatic region to the condenser The pressure of the vapour in the condenser becomes higher than the liquid saturation vapour pressure. The pressure imbalance results in net condensation on the cooler liquid, if again the pressure drop is greater than that required for the phase change. Since thermal energy is transferred in the form of latent heat of vapourization rather than sensible heat, high heat transfer rates can be achieved with a low mass flow. If heat is transferred by high density, low velocity vapour, the heat transfer is nearly isothermal due to the low vapour pressure gradient.

*D. APPLICATIONS*

Heat pipes have found applications in a wide variety of areas, such as energy conversion systems, cooling of nuclear and isotope reactors, cooling of electronic equipment, and high performance space applications. In general, the applications can be classified into broad groups, each of which describes a property of the heat pipe. Groups are

- Separation of heat source and sink
- temperature flattening
- Heat flux transformation
- Temperature control
- Thermal diodes and switches

The high effective thermal conductivity of a heat pipe enables heat to be transferred at high efficiency over considerable distances.In many applications where component cooling is required, it may be inconvenient or undesirable thermally to dissipate the heat via a heat sink or radiator located immediately adjacent to the component. For example, heat dissipation from a high power device within a module containing other temperature sensitive components would be effected by using the heat pipe to connect the component to a remote heat sink located outside the module. Thermal insulation could minimize heat losses from intermediate sections of the heat pipe.

- 150 to 750 K

## II. BACKGROUND AND HISTORY

Many developed countries have activenon edible oilprograms. Currentlynon edible oilis produced mainly from field crop oil like rapeseed, sunflower etc. in Europe and soybean in US. Malaysia utilizes palm oil fornon edible oilproduction while in Nicaragua it is jatropha oil. At present the country is relying on imported technology, which is extremely expensive and is also proven for edible oil as feedstock. There are risks associated with the technology for its costs and compatibility.

| | MT | OIL | MT | OIL | MT |
|---|---|---|---|---|---|
| SOYA BEAN | 27.8 | PALM KERNEL | 2.9 | SESAME | 0.26 |
| RAPESEED | 13.7 | OLIVE | 2.7 | CASTOR | 0.25 |
| COTTONSEED | 4 | CORN | 2 | NIGER | 0.03 |
| SUNFLOWER | 8.2 | CASTOR | 0.5 | COCOCNUT | 0.55 |
| PEANUT | 5.1 | GROUNDNUT | 1.4 | RICE BRAN | 0.55 |

## III. METHODOLOGY

About 30 g of finely grounded seed of the test plant were used to extract the essential oil in 250 mL of n-hexane by using soxhlet extraction for about three hour. Then, the solvent was separated from the oil by using Rota evaporator and suction pump. The extracted phase was distilled to separate the oil from the solvent and the distillate were collected and stored in a refrigerator for further experiment.

| PROPERTIES | LINSEED OIL |
|---|---|
| Density (kg/m3) | 911.5 |
| Calorific value (kJ/kg) | 39700 |
| Cetane number | 41.3 |
| Viscosity@40 oC | 37 |
| Oil content wt% | 25-35 |
| Flash point oC | 246 |
| Fire point oC | 257 |
| Pour point oC | -31.7 |

| PROPERTIES | MAHUA OIL |
|---|---|
| Density (kg/m3) | 924 |
| Calorific value (kJ/kg) | 37614 |
| Cetane number | 40 |
| Viscosity@40 oC | 39.45 |
| Oil content wt% | 35-50 |
| Flash point oC | 276 |
| Fire point oC | 282 |
| Pour point oC | 14 |

### *A. OIL MIXING PROCESS*

Magnetic stirrers are one of the most useful instruments in research and product development laboratories because they work tirelessly in performing mundane tasks without being paid or collecting benefits. These compact bench top units are used in a variety of applications to stir or mix fluid samples in industries including food processing, chemical production, and biotechnology.

### *B. THE ROLE OF THE TEMPERATURE PROBE*

Pt100 temperature probes serve multiple functions, chief of which is monitoring the operation of the magnetic stirrer. They are electronically connected to the stirrer's microprocessor control and provide control of and feedback on sample temperature. They also perform a vital safety function in that should the temperature drop quickly (which can be caused by a broken container) the probe will shut down the equipment.

### *C. INTUITIVE MAGNETIC STIRRER CONTROL PANEL*

Magnetic stirrer control panels vary depending on model. Continuing with the CAT MC S66 as an example, by using up and down keys the LED display keypad controls functions including:

- Power off/on
- Heating plate off/on
- Magnet motor off/on
- Plate temperature
- Motor RPM
- Probe temperature (set and actual will be displayed)
- Safety temperature (to shut the unit down if it exceeds the set probe temperature)

Ramp (controlling application of heat)

- Operation timer in days/hours/minutes

## IV. RESULTS AND DISCUSSION

The following points explain the major differences between vegetable oils and non edible oil:

1) Viscosities of the vegetable oils are significantly higher and densities are slightly higher.
2) Heating values of vegetable oils are about 10% lower (on mass basis).
3) The presence of molecular oxygen in vegetable oils raises the stochiometric fuel/air ratio.
4) Vegetable oils could experience thermal cracking by the fuel spray in naturally aspirated engines [28].
5) The cetane number of vegetable oils is 32-40% lower than diesel, while the sulphur content is negligible in vegetable oils compared to 0.45% in diesel

| PROPERTIES | COTTONSEED OIL |
|---|---|
| Density (kg/m3) | 907 |
| Calorific value (kJ/kg) | 39500 |
| Cetane number | 41.8 |
| Viscosity@40 oC | 33.5 |
| Oil content wt% | 17-25 |
| Flash point oC | 232 |
| Fire point oC | 240 |
| Pour point oC | -4 |

| PROPERTIES | KARANJA OIL |
|---|---|
| Calorific value (kJ/kg) | 388879 |
| Viscosity@40 oC | 35.98 |
| Oil content wt% | 25-50 |
| Pour point oC | 3 |

| PROPERTIES | PONGAMIA OIL |
|---|---|
| Density (kg/m3) | 924 |
| Calorific value (kJ/kg) | 36576.53 |
| Cetane number | 42 |
| Viscosity@40 °C | 40.2 |
| Oil content wt% | 26-35 |
| Flash point °C | 272 |
| Fire point °C | 288 |
| Pour point °C | -3 |

| PROPERTIES | NEEM OIL |
|---|---|
| Calorifi value (kJ/kg) | 29.97 |
| Cetane number | 31 |
| Viscosity@40 oC | 72.4 |
| Oil content wt% | 20-31 |
| Flash point oC | 252 |
| Fire point oC | 268 |
| Pour point oC | 11 |

| PROPERTIES | JULIFLORA OIL |
|---|---|
| Density (kg/m3) | 1060 |
| Calorific value (kJ/kg) | 22.6 |
| PH value | 4.9 |
| Viscosity@40 oC | 8 |
| water content wt% | 27.5 |
| Flash point oC | 272 |
| Fire point oC | 282 |

| PROPERTIES | KUSUM OIL |
|---|---|
| Density (kg/m3) | 860 |
| Calorific value (kJ/kg) | 38140 |
| Cetane number | 40 |
| Viscosity@40 °C | 40.36 |
| Oil content wt% | 25-36 |
| Flash point °C | 225 |
| Fire point °C | 234 |
| Pour point °C | -11 |

| PROPERTIES | JATROPHA OIL |
|---|---|
| Density (kg/m3) | 917 |
| Calorific value (kJ/kg) | 39071 |
| Cetane number | 23 |
| Viscosity@40 oC | 35.98 |
| Oil content wt% | 20.6 |
| Flash point oC | 229 |
| Fire point oC | 240 |
| Pour point oC | 4 |

## *OPERATIONAL PROBLEMS*

1) Fuel Filter Plugging: Crude vegetable oil when used for long hours chokes the fuel filter because of high viscosity of crude oil. To avoid this, the oil must be filtered and then re-filtered. Within 3-12 hours the filter usually gets choked.

2) Cold Starting: Starting ability of engine gets impaired due to high viscosity and low cetane number in certain cases

3). Injector Coking: In long run tests carbon deposits build up in and around the nozzle between 70-150 hours. Carbon build up interferes with the fuel flow and can ultimately stop it.

4)Carbon Deposition in Combustion Chamber: - Very hard carbon deposits of 3-4 mm thickness have been found in the vicinity of exhaust area

5) Piston Ring Sticking: - Top or fine ring sticks to the groove due to gum formation and this makes the other ring to suffer more.

6).Lubricating Oil Contamination: Lubricating oil has been found contaminated with reasonably high percentage of iron, zinc etc., along with nominal increase in viscosity after 100-200 hrs.

7).Effect on Performance Parameters: Fuel consumption increases sharply, power developed reduces, thermal efficiency reduces, blow-by losses reduce and exhaust temperature rises sharply.

7).Effect on Performance Parameters: Fuel consumption increases sharply, power developed reduces, thermal efficiency reduces, blow-by losses reduce and exhaust temperature rises sharply.

## *A. DURABILITY PROBLEMS*

1.The high viscosity of the vegetable oils results in degraded fuel atomization, which in turn results in the observed durability problems.

2.The durability problems associated with the use of vegetable oils as fuels result directly from the chemical structure of the oils and the affect of these structures on the combustion chemistry.

3.The durability problems are a result of incomplete combustion of the fuels (either spray or chemically induced) and the subsequent reaction of the fuels and/or partial combustion products on the metal surface and in the lube oil.

4. Fuel filter pressure drop can increase ten times faster than on Non edible oil due to starch particles in the vegetable oil. Crude degummed oils are typically filtered to 12 µ level.

5. The fuel supply should not have fuel exposed to surface temperature greater than 90ºC. Local oxidation will generate gums that will plug lines & filters

## *B. REMEDIAL MEASURES*

At least three major proposals have been made to alleviate the problems associated with the use of vegetable oils as fuels.

1. Heating the fuel to temperatures sufficient to bring the viscosity to near specification range. At 145oC, the viscosity of vegetable oil is about 4.0 Cst.

2. Conversion of the vegetable oils to the simple esters of Methyl, Ethyl or Butyl type. Results till date indicate that the esters are superior fuels for D.I. engine

3. Dilution of vegetable oils with other materials to bring the viscosity to near specification e.g. mixture (50/50) of these oils with non edible oil have viscosities in the range of 4-8 times that of non edible oil.

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