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Design improvements in heat exchanger using partial differential equations

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ABSTRACT

In today's world, where the loss of energy due to engineering applications is increasing at an alarming rate, therefore efficiency is much needed in order to save the energy. The aim of the paper is to propose a new design of heat exchanger which would result in a substantial increase in the efficiency of the heat exchanger. The basic principle used to increase the efficiency is to change the shape of the tube holding fluid. In this paper, instead of using conventional cylindrical tubes for heating fluid, a cone-shaped tube with cold fluid entering the pipe through the base end and hot fluid coming out of the vertex end is used. This is achieved by tweaking the surface area to volume (SAV) ratio of the fluid carrying tubes. Since the Gaussian curvature through the axis of the tubes is zero, it's a Euclidean surface. Thus there will be no change in properties if the conical tube is bent in the form of a helix. For a given volume, the object with minimum SAV ratio is a sphere as a consequence of isoperimetric inequality in 3 dimensions. Efficiency can be further increased by bending the shape of the tubes in form of a spherical helix. This would create a central heat source and constant temperature at the contact surface. Therefore there is a gradual decrease in volume as we go from base to the vertex of the conical tube would mean that pressure of hot fluid would increase as temperature and degree of freedom is constant.

Keywords*— Heat exchanger efficiency, Energy conservation, Mathematical modeling, Surface area to Volume ratio*

1. INTRODUCTION

This project aims to increase the efficiency of heater tubes of the heat exchanger. This is achieved by altering the shape of the tubes carrying cold fluid without changing the Gaussian curvature of the central axis. This is essential makes the heat exchanger tube a Euclidean surface and thus properties of the tube are maintained.

1.1 Surface area to volume ratio

For a heat exchanger, a high surface area to volume ratio would be favorable as more area for a particular volume of fluid would be available for heat exchange ie fluid would convert into the hot fluid at a faster rate if SAV ratio is high.

On the contrary, a low SAV ratio would mean less area is available for a particular volume of fluid for heat exchange which would result in a slower rate of heat loss.

Considering all these factors, we are proposing a design which has a conical fluid tube shaped in the form of a spherical helix.

1.2 Cone vs. cylinder

Let us consider a right circular conical pipe of saying height 'h' and a right circular conical pipe of lateral length 'l'.

Here l = h

Volume of cylinder = pi*(r^2)*h
Volume of cone = [pi*(r^2)*h]/3
Surface area of cylinder = 2*pi*r*h
Surface area of cone = 2*pi*r*l

For cones where h>>r; h = l (approximately)

Surface area of cone = 2*pi*r*h
Surface to Volume Ratio = SA/V
For cylinder, SAV = 2/r
For cone, SAV = 6/r

This infers that for the same surface area of tubes, a conical tube would provide 3 times more surface area than a cylindrical one for a given volume of fluid.

Since the Gaussian curvature through the axis of the tubes is zero, it's a Euclidean surface.

1.3 Heat equation

Newton's equation for the rate of heat flow is given by:

$$Q/t = [k*A*(T2 - T1)]/d$$

Comparing the heat transfer for the cylindrical tube and conical tube where the direction of heat transfer is normal to the lateral surface.

We can conclude that the only differing factor is 'A'.
Here we shall use SAV for 'A' which gives conical tube an edge over cylindrical ones.

1.4 Two dimensional heat– flow

When the heat– flow is along curves instead of along straight lines, all the curves lying in the parallel lines, then the flow is called two – dimensional. The heat – flow equation in two dimensions is given by

$$du/dt = \alpha^2[(d^2u/dx^2)+(d^2u/dy^2)]$$

Where,

du/dt is rate of heat flow

$\alpha^2 = k/\rho c$ (diffusivity is cm^2/sec)

k is thermal conductivity ,ρ is density ,c is specific heat.

At steady state du/dt becomes zero so the equation becomes

$$(d^2u/dx^2)+(d^2u/dy^2) = 0$$

1.5 Experimental method

Apparatus required – 1-liter cistern with laminar outflow, hose radius 1 inch, metallic cylinder (1 inch * 6 inches) 0.223 pound+2.7318 ounce, metallic cone (1inch * 6 inches), 2 0.9106 ounce temperature probe, naphtha burner, reservoir.

2. PROCEDURE

Fill the one-liter cistern with distilled water up to the brim. Connect the outlet to one end of the hose.

Case 1: Connect another end of the hose to the metallic cylinder.

- Connect the first temperature probe to the metallic part of the cylinder and other to the outflow end of the cylinder. Ignite the burner and make the blue region of flame come in contact with the cylinder. Open the cistern when a constant temperature is reached in the cylinder. Start the stopwatch and tabulate the readings. (T_1 = instantaneous temperature of a metallic cylinder, T_2 = instantaneous temperature of outflow water)

  Plot a graph of time versus temperature with time and temperature being on x-axis and y-axis respectively.

Case 2: Connect another end of the hose to the metallic cone.

- Connect the first temperature probe to the metallic part of the cone and other to the outflow end of the cone. Ignite the burner and make the blue region of flame come in contact with the cone. Open the cistern when a constant temperature is reached in the cone. Start the stopwatch and tabulate the readings. (T_1 = instantaneous temperature of the metallic cone, T_2 = instantaneous temperature of outflow water)

$$Q = mc\Delta T$$

The specific heat of water is 1 calorie/gram °C = 4.186 joule/gram °C which is higher than any other common substance. As a result, water plays a very important role in temperature regulation.

Plot a graph of specific heat versus temperature with time and temperature being on x-axis and y-axis respectively.
The slope is 1/mC and m is 3 times less for cone so, the slope will be 3 times steeper for a cone in Q vs T curve.

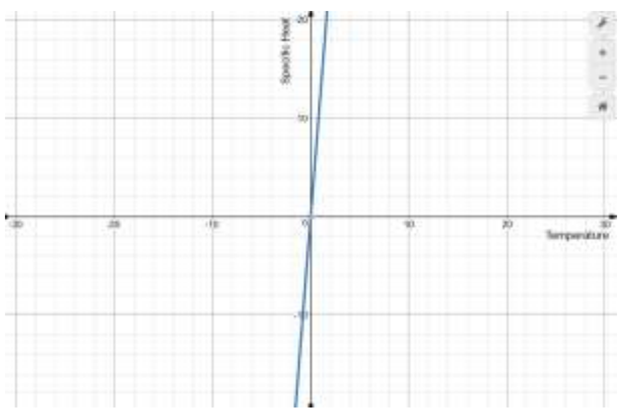

Fig. 1: Q vs. T graph for conical tube

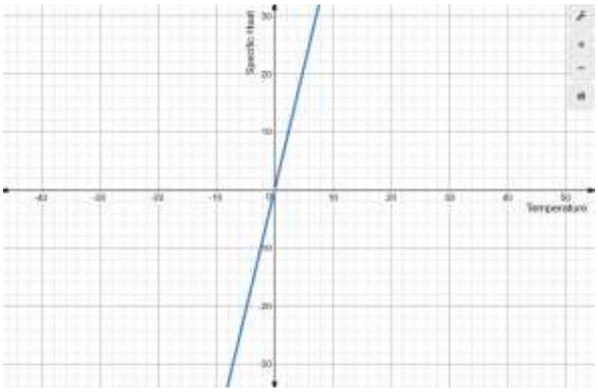

Fig. 2: Q vs. T graph for a cylindrical tube

This infers that for the same surface area of tubes, a conical tube would provide 3 times more surface area than a cylindrical one for a given volume of water.

Since the Gaussian curvature through the axis of the tubes is zero, it's a Euclidean surface

In this type of heat exchangers, the tube containing water comes in direct contact with hot flue gases which heat transfer to the copper tubes.

$$Q /t = [k*A*(T2 - T1)]/d$$

Comparing the heat transfer for the cylindrical tube and conical tube where the direction of heat transfer is normal to the lateral surface,

We can conclude that the only differing factor is 'A'.

Here we shall use SAV for 'A' which gives conical tube an edge over cylindrical ones.

Further improvements can be made in the heat exchanger design by bending the tubes in the form of a spherical helix

For a given volume, the object with minimum SAV is a sphere as a consequence of isoperimetric inequality in 3 dimensions.

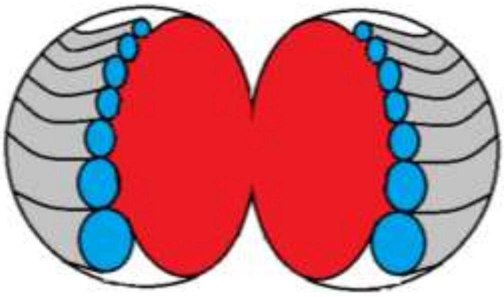

Fig. 3: Cut section of the spherical helix of conical tubes

The blue represents cold fluid and the grey represent conical tubes bent in the form of a spherical helix. The heat source is kept at the center of the spherical helix. The top and bottom of the sphere which cannot be covered by the tubes are covered with a reflective material.

3. ADVANTAGES

- Since SAV is minimum and losses happen only through the outer surface area, more heat is held in the shell.
- The heat that escapes the sphere ends up in maintaining the temperature of the hot fluid in the tubes.
- By the use of modern heat-resistant alloys and atmospheric pressure inside the sphere, the problem of cracking and safety concerns is eliminated.
- This also provides heat in a uniform manner thus eliminating problems of over and under heating.

4. CONCLUSION

We can see from the discussion above that a lot of parameters are altered when the shape of the pipe and the structure of the heater are changed. The experimental and the theoretical proof have given us the following results:-

1. The increase of surface area for a particular volume of water implies heat absorption for that particular volume of water would be more across the lateral surface area which could indicate an increased efficiency in a hot fluid generation in industrial heat exchangers.
2. The gradual decrease in volume as we go from base to the vertex of the conical tube would mean that pressure of hot fluid would increase as temperature and degree of freedom is constant.

$$P*V=n*R*T$$

3. This creates a light natural suction inside the tube with the inlet of the heat exchanger tube at a considerably lower pressure than the outlet
4. With the tubes bent in the form of a spherical helix, the effective heat loss is reduced as the surface area for losses is reduced.

5. REFERENCES

[1] https://www.desmos.com/calculator

[2] Aydin Durmus, Heat transfer and exergy loss in cut out conical turbulators, Energy Conversion and Management 45 (2004) 785–796.

[3] Su Thet Mon Than, Khin Aung Lin, Mi Sandar Mon, Heat Exchanger Design, World Academy of Science, Engineering and Technology International Journal of Mechanical and Mechatronics Engineering Vol:2, No:10, 2008.

