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Enhancement in Thermos Flask A Review

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Abstract

In the modern world, economics of a product is of prime importance and so is the quality. The cost of a product depends on various factors such as process undergone, material, and time taken for the completion of the product. The current model of thermos flask is analysed in terms of efficiency and cost; the authors propose a new model which is both cost effective and of good quality. This new model proposes a new low price insulating flask in the market. For this, aerogel blanket is used as insulating medium instead of vacuum, resulting in better insulation for a longer period, at an affordable price.
Keywords- Thermal Conductivity, SS1, SS2, Economics, Aerogel Blanket

I. INTRODUCTION

The resistance and reduction in the heat transfer is known as thermal insulation. It depends on several factors like:-Thermal conductivity, surface emissivity, insulation thickness, specific heat, etc. The object of this paper is to develop a new model of thermos flask which uses aerogel blanket instead of vacuum for insulation. Aspen Aerogel Spaceloft is the flexible aerogel composite for the said purpose. Properties of Spaceloft are: - Nominal thickness: 5.0 mm, Thermal conductivity: 14 mW/mK, Density: 0.16 g/cc, Max. Use temperature: 473 K, Market price: $2.91 per sq. feet. It has the lowest thermal conductivity among the solids. New insulation designs are always introduced over the course of time and the existing designs are also modified to meet the need and interests of the population.

Fig. 1: Aerogel blanket (5mm thick)

II. MANUFACTURING DETAILS

The primary material used is stainless steel (AISI 304). For efficient insulation, double walls of stainless steel are used as it has low thermal conductivity of 14.9 W/mK at 293K. The welding of individual steel flasks is done longitudinally. A blanket of aerogel is filled between the two flask layers, which leads to better insulation properties. Thus, double-walled flask with aerogel insulation increases its performance.

For the proposed flask, deep drawing process is used. The inner layer is fixed inside the outer layer and the upper end is sealed by welding. This leads to a double-walled flask with aerogel between the two layers, to minimize heat transfer. A cap is fitted on the bottom of outer layer for protection.

Fig. 2: Section view & 3-D Model of Bottle

To further improve insulation, layers of oxide are provided on the surface between the two steel layers. For economic reasons, layer of silver mirror is applied only on outer surface of inner bottle.

Max. loss or gain of heat takes place through the neck of flask when cap is removed, as it is directly in contact with the surrounding air. To overcome this, neck is elongated to minimize heat loss. For the cap, the outer cup is of stainless steel and then insulating material is added along with liner. Finally, paint job is done.

III. DISCUSSION

The negative side of vacuum insulation bottles is discussed here. The workload of these machines is considerable as the furnaces are never shut off and this can reach 9-10 hours of operations per year. Highly reliable vacuum pumps are thus vital and require low maintenance and low consumption of energy. For example, Pump with capacity of 800 m^3/h is used for operation of line with 16 sections. Setting aside easy installation and low purchase cost, they are quite expensive in operation.

A test was carried out on the model of the flask. The flask was filled with boiling water at 373K and then it was allowed to stand for a day at surrounding temperature of 298K.

IV. MATHEMATICAL ANALYSIS

Considering the dimension for 1 liter bottle as:-
Inner radius of bottle, r1 = 0.0365m; Thickness of steel used = 0.001m
Thickness of insulating material = 0.005m; Length of inner bottle, L = 0.225m
Required surface area of aerogel blanket = $2\pi rh + \pi r2$ = 0.0697m2
Convective heat transfer for air, h2 = 10W/m2K
Convective heat transfer for water, h1 = 100W/m2K
Thermal coefficient for conduction of steel (AISI 3014), Ks at 100°C is = 16.3 W/mK; & at 27°C is = 14.9 W/mK

Table 1: Thermal Properties of Aerogel Blanket

T(degree Celsius)	*K(W/mK)*	*Cp(J/KgK*
-50	*0.0130*	*637*
0	*0.0141*	*864*
40	*0.0160*	*1000*
100	*0.0183*	*1150*

According to Fourier's law of heat conduction, heat transfer through the cylindrical layer can be expressed as:

Qcond, cyl. = - kAdt/dr in W (1)

Where: A = $2\pi rL$ is the heat transfer area at location r. As A depends on r, thus it varies in the direction of heat transfer.
Upon integration, we get

Qcond.cyl. = (T1-T2)/Rtotal (2)

Where: Rtotal = Rcylinder surface + Rcylinder base

1) Rcylinder surface = ln(r2/r1)/2(pi)rl ; is the thermal resistance of the cylindrical layer against heat conduction, or conduction resistance. Thus the thermal resistance network for heat transfer through the three layered composite cylinder (i.e. bottle: SS1-Blanket-SS2) subjected to convection on both sides is given as:

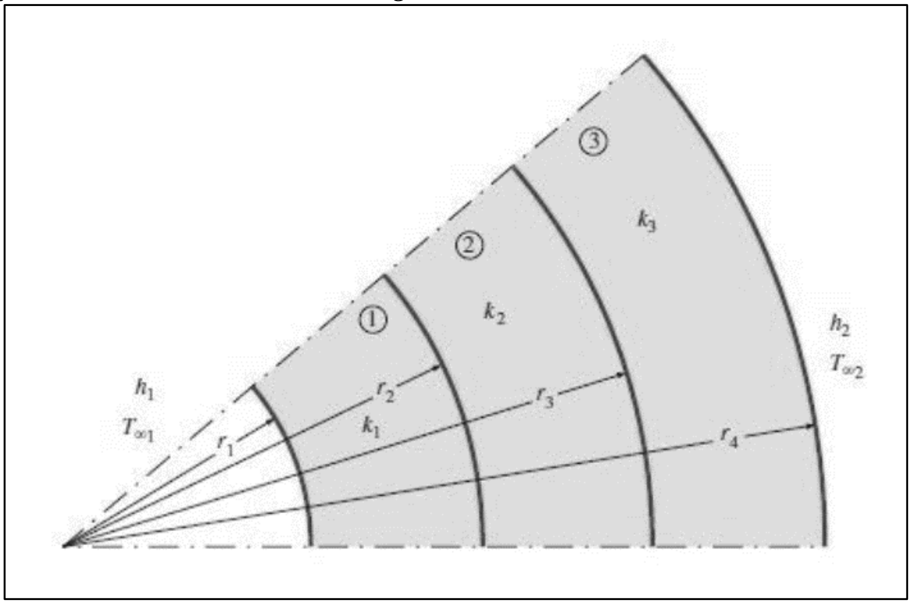

Fig. 3: Schematic showing layers of the bottle

Rcyl.surface total = Rconv,1 + Rcyl,1+ Rcyl,2+ Rcyl,3+ Rconv,2

=1/(h1A1) + (ln(r2/r1))/2(pi)Lk1+ (ln(r3/r2))/2(pi)Lk2 + (ln(r4/r3))/2(pi)Lk3 + 1/(h2A4) (3)

Equation (3) represents total resistance offered to the heat flow i.e. convective heat transfer of water, conduction resistance of curved surface and convective heat transfer of air (surrounding) respectively. Thus substituting the values of variables in equation (3) and finding the values of heat transfer through the curved surface.

2) Rcyl. Base = L/kA ; is the thermal resistance of the wall against heat conduction. Note that the thermal resistance of the medium depends on the geometry and the thermal properties of the medium. The thermal resistance network for heat transfer through the three layered composite cylinder (i.e. bottle: SS1-Blanket-SS2) subjected to convection on both sides is given as:

Rcyl.base total = Rconv,1+ Rb1+Rb2+Rb3+Rconv,2

= 1/h1A + L1/k1A + L2/k2A + L3/k3A + 1/h2A (4)

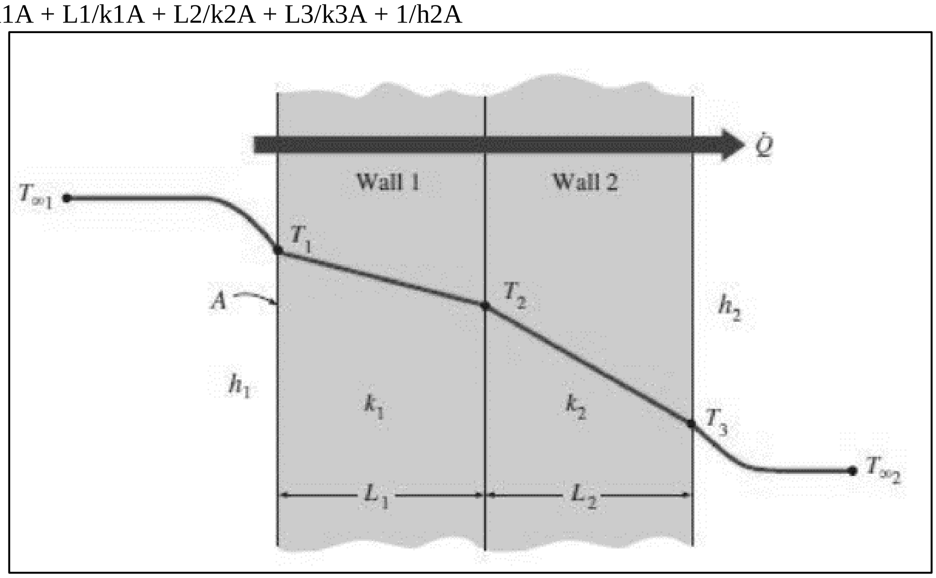

Fig. 4: Schematic of base of the bottle (Concept behind the base of bottle i.e. SS1-blanket-SS2)

Equation (4) represents total resistance offered to the heat flow i.e. convective heat transfer of water, conduction resistance of curved surface and convective heat transfer of air (surrounding) respectively. Where A = area of base & L1, L2, L3 are the thickness of SS1, blanket, SS2 respectively. Now substituting the values of variables in equation (4) and finding the values of thermal resistance. Thus replacing the values of resistances we get Rtotal and thereafter Qcond.cyl. The value obtained for heat transfer has the unit J/sec. Thus we get heat transfer after 1hour. The value of heat regained by water will be heat power available for the next hour calculations and so on.

V. RESULT

The temperature variation along the thickness of bottle is shown in the 3D model in the fig. The excellent insulating properties of aerogel can be clearly seen as there is a great change in temperature of outer layer. This makes aerogel the best insulating medium among the various solids available. Also, due to its low cost and ease of manufacture, flask using aerogel as the insulating medium serves as the best possible alternative to vacuum insulated thermos flask.

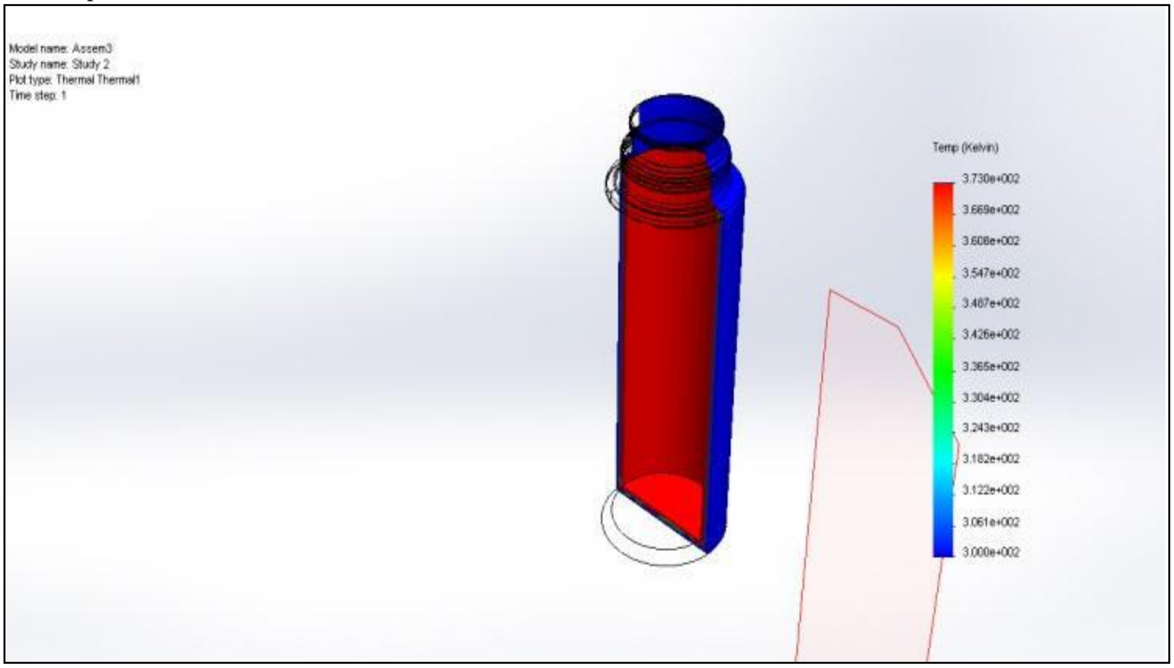

Fig. 5: Thermal analysis of 3-D model at high temperatures

VI. CONCLUSION

Thus, by using the above proposed model, we get a low cost insulated flask, having price of about Rs 350/- , which can be employed for various purposes like thermos, icebox, insulated lunch box, etc. As the production cost is much smaller than that of vacuum insulated flask, the selling price will be obviously smaller as well. Also, less energy is required during manufacture which improves the cost effectiveness of the model. The proposed model being cost effective can be used by people having low budget.

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