Studies on Performance of Metallic Wick Stove Incorporating External Cooling System

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Abstract—Cotton wicks are normally used for heating stove and lightening lamps. It is felt that frequent changing of cotton wicks can be avoided by developing metallic wicks using powder metallurgy techniques. Conventional stove cannot accommodate these metallic wicks. To accommodate them the wick carrier is slightly modified. Existing lifting mechanism in stove is modified for the sake of simplicity. The wick carrier tubes are slightly enlarged and shortened. According to literature survey not much work is carried out in this direction. Hence the present work is taken up to study the efficiency of metallic wick stove using water cooling system and compare it with metallic wick stove without cooling system. Fabricated metallic wicks are fitted in the wick carrier. Further the performance characteristics using metallic wick such as fuel consumption, fuel tank temperature, flame height and capillary action are studied. The efficiency of metallic wick is compared with conventional stove and the results are tabulated.

As the metallic wick is used for heating, heat transfer increases the fuel temperature unlike cotton wick, limiting the duration of operation of the stove. To enhance the duration of stove operation, cooling system with water bath is adopted in the present work.

Test results reveal that, Capillary action of metallic wicks depends on the depth of immersion and length of wick in kerosene. Flame height of metallic wick depends on fuel level and tip exposure. Flame height is enhanced with increase in diameter of metallic wick. Metallic wick is made to operate for a longer duration by providing circumferential water stored container. Fuel consumption is found to be much less in metallic wicks over conventional cotton wick. Utilization efficiency of metallic wick stove is found greater than that of conventional kerosene stove.

Hence it is concluded that the cooling system is viable for metallic wick stove and it improves performance of metallic wick stove. The temperature is reduced and more working duration gets before reaching the flash point of kerosene, hence problem solved.

I. INTRODUCTION

Wicks are used to transport fuel due to capillary action. Kerosene stoves use cotton wicks which are consumable and are to be replaced frequently. Hence present work is undertaken to use metallic wick, developed using powder metallurgy techniques. Bronze wick is used for the investigation due to its high corrosion resistance and strength. [1-4]

In the present system the metallic wick stove produces fuel temperature up to 55°C within two hours while heating. As the flash point of kerosene is 65°C close to this temperature it is very much needed to reduce the kerosene bath temperature to avoid explosion. Also for running the stove within safe limit for a longer duration cooling the incorporating external water cooling system is adopted.

The objective of the project work is to study the performance characteristic such as rise in water temperature with respect to time, fuel tank temperature without cooling system, fuel tank temperature with cooling system, coolant temperature and kerosene consumption. Also it is intended to design a water-cooling system to reduce the rise in temperature of kerosene for a longer stove operation.

II. PROCESS DETAILS

A. Capillary Action Test

An arrangement has been made as per figure 1 for determination the capillary rise as a function of time. Metallic wicks are coated with chalk powder throughout and marks are made at regular intervals of 5mm. Length of the wicks used are 70mm during the test, specimen is held in the stand by fixing it at the top end. A beaker, which contains kerosene, is raised to required depth of immersion and held at that position. At the same instant, stopwatch is started. The liquid ascends by capillary action and wets the specimen. This wetting is clearly observed by the color of the specimen. The same procedure is repeated for different depths of immersion.

Figure 1. Arrangement for measurement of capillary rise
B. Flame Height Test
The wick is held in position using a wick holder. The wick holder has a retaining screw; using it length of tip exposure may be adjusted. A scale is marked on the bottle to monitor the flame without parallax. After lighting, the flame height is recorded for different fuel levels, different tip exposures and different diameter of wick. Metallic wicks used for the investigation are shown in figure 2.

C. Water Pot Temperature Test
To know the output of the fabricated metallic wick stove a sample test has been conducted. 1000ml of water is taken in an aluminum container and kept over the stove. The time required for reaching boiling point of water both metallic wick stove and conventional wick stove are studied and compared.

D. Fuel Tank Temperature Test
The temperature produced in the fuel tank during heating of 1000ml of water with respect to time is noted. The same test is conducted for metallic wick stove using kerosene and both results are compared.

E. Fuel cooling with external cooling system
Bronze wick used as an alternative for conventional cotton wick conducts heat downward during operation. This increases kerosene temperature. It is very much needed to convert the fuel temperature below 40°C to avoid flash point accidents as flash point of kerosene is 65°C. Hence an external circumferential container with 6 litre water capacity is fabricated by keeping the kerosene stove inside as shown in figure 3. After lighting the kerosene stove, the temperature variation both inside the stove and outside water temperature are noted using thermometer. Also the amount of cooling water needed to keep fuel temperature in safe limit is studied. Temperature is noted at regular interval of 15 minutes for 6 hours working of kerosene stove continuously. Observations are made with and without cooling system and the results are tabulated.

F. Calculation of metallic wick stove efficiency
The fuel consumed during boiling of 1000ml of water is measured both for metallic wick and conventional cotton wick, and are tabulated.

Specifications of metallic wick stove
- Fuel tank Diameter = 24.98 cm
- Fuel tank Height = 6.5 cm
- Wick carrier tube diameter = 1.2 cm
- Maximum lift = 10 cm
- Number of wicks = 10

III RESULTS AND DISCUSSIONS

A. Capillary Action Test
Following observations are made during capillary test on metallic wicks. Capillary rise versus time is an exponential curve indicating that every additional millimeter rise of the liquid takes more time compared to the previous rise there - by indicating that level of fuel does play a role, as shown in figure 4.

B. Flame Height Tests
The effect of wick tip exposure on flame height, wick diameter on flame height, fuel level on flame height are studied and are given in figure 5, 6 and 7a. The actual flame height in relation with wick diameter is shown in figure 7b.
I. Water Pot Temperature Test
The temperature increase is rapid in case of metallic wicks. Graph plotted between temperature of water and time for both conventional and metallic wicks is shown in figure 8.

D. Fuel Tank Temperature Test
It is essential to control the fuel tank temperature below 40°C to avoid flash point hazards. Hence the results on temperature rise of fuel without cooling using conventional cotton wick and metallic wick are given in figure 9. It is found that for 2 hours working the fuel temperature rises to 50°C for conventional wick and 55°C in metallic wick where as flash point of kerosene is 65°C. Hence it is necessary to keep the fuel tank temperature below 40°C. So fuel cooling is provided using external cooling system.
E. Fuel cooling with external cooling system
Cooling is carried out in the metallic stove with 4 litres and 6 litres water externally. For 6 hours working of stove, the maximum temperature rise of fuel is found 42.5°C for 4 litres cooling water as shown in figure 10. As the fuel temperature above 40°C is being controlled, 6 liters of water cooling is adopted and the results are shown in figure 11. It is found that for 6 hours of cooling the maximum temperature rise is only 39.5°C.
Figure 12 shows a combined graph taking results of fuel tank temperature without cooling and with cooling, in the time temperature plot. It is found that external cooling of fuel tank using 6 litres of water gives a temperature control below 40°C for 6 hours continuous working of stove.

F. Calculation of metallic wick stove efficiency
To compare the efficiency of metallic wick stove with conventional cotton wick stove the following procedure is adopted.
Fuel consumed for boiling one liter of water, for one hour in aluminum container for both metallic wicks and cotton wicks are given below. Kerosene used initially is 2 litre.
Fuel consumed for cotton wick = 450 ml
Fuel consumed for metallic wick = 360 ml
The following data is used to calculate the utilization efficiency. This data is obtained by conducting sample experiments on metallic wick stove such as water pot temperature rise test, fuel tank temperature test and fuel consumption test.
Data
Conventional wick
M_k = mass of kerosene initially
   = 2 litre
   = 1.6464Kg
ρ of kerosene = 823.2 Kgm⁻³
Mass of kerosene consumed = 450 ml
= 0.37044 Kg
C.V = calorific value of kerosene = 8359 KJ/Kg
Mw = mass of water taken initially = liter
Mass of water evaporated during one hour operation = 0.74 liter

L_w = Latent heat of vaporization of water = 2257 KJ/Kg
Specific heat of kerosene, C_p = 46.4 × 10⁻⁶ KJ/Kg
ΔT_k = Temperature rise of kerosene = (51 - 30) = 21ºC
ΔT_w = Temperature rise of water = (100 - 31) = 69ºC

Metallic wick:
Mass of kerosene consumed = 360 ml
= 0.2963 Kg
Mass of water evaporated = 0.81 liter

Calculation of utilization efficiency
Utilization Efficiency = Heat utilized for water boiling × 100 / Heat supplied

Conventional wick:
Heatsupplied = M_k Consumed (Kg) x C.V of Kerosene
= 0.37044 × 8359
= 3096.6 KJ
Heat utilized = [M_w x C_p of water x ΔT] + [M_w evaporated x L_w] + [M_k x C_p of kerosene x ΔT_k]
= [1 × 4.186 × 69] + [0.74 × 2257] + [1.6464 x 46.4 × 10⁻⁶ x 21]
= 288.83 + 1670.18 + 0.00159
= 1959.01 KJ
Utilization efficiency = (1959.01/3096.6) x 100
= 63.3 %

Metallic wick:
Heat supplied = M_k*C.V of Kerosene
= 0.2963 × 8359
= 2476.78
Heat utilized = [M_w x C_p of water x ΔT] + [M_w evaporated x L_w] + [M_k x C_p of kerosene x ΔT_k]
= [1 × 4.186 × 69] + [0.81 × 2257] + [1.6464 x 46.4 × 10⁻⁶ x 25]
= [288.83] + [1828.17] + [0.0019]
= 2117 KJ
Utilization efficiency = (2117 / 2476.78) x 100
= 85.47 %

From the above calculation it is found that kerosene stove with metallic wick gives 22 percent more efficiency than kerosene stove with conventional cotton wick. Utilization of metallic wick gives economy during operation.

IV. CONCLUSIONS

From the observations made during the operation of metallic wick stove, the following are the conclusions;
1. Capillary action of metallic wicks depends on the depth of immersion and length of wick in kerosene.
2. Flame height of metallic wick depends on fuel level and tip exposure.
3. Flame height is enhanced with increase in diameter of metallic wick.
4. Metallic wick is made to operate for a longer duration using water cooling system.
5. Fuel consumption is found to be much less in metallic wick stove as utilization efficiency of metallic wick stove is greater than that of conventional cotton wick stove.

REFERENCES