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Thermal Performance and Emission Analysis Of Available Metal And Non Metal ICS In Bangladesh

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ABSTRACT : *Low thermal efficiency and primitive design of cook stove causes natural biomass resources degradation and environmental pollution. The solution to this problem is to introduce improved cook stove (ICS). In this article metal and non-metal type cook stoves, which are made in Bangladesh have been tested according to international test protocol. It has observed, a substantial thermal efficiency found in metal cook stoves, which is between 35 to 40%, whereas the non-metal has only 20 to 30% efficiency. Despite the fact that the non-metal cook stoves have lower thermal efficiency but better emission performance from these has found when a chimney is attached. So, less toxic or hazardous elements exhaust from this type of stoves during practical operation. The metal type cook stoves have also possessed the low emission characteristics if there is an external arrangement of draught control, which reduces the Carbon mono-oxide (CO) concentration about 2 ppm.*

KEYWORDS: *Improved Cook Stove, Water Boiling Test, Parts Per Millions.*

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I. INTRODUCTION

For cooking purpose, more than 3 billion people are relying on solid fuel [1]. Every year about 1.3 billion people died by becoming exposed to smoke and other pollutants released from burning biomass fuel [2]. Solid fuels used in open fired stove are considered to be potential motive to hazardous health problems. The low grade fuel and inadequate ventilated cook stoves used by users cause incomplete combustion and indoor air pollution. Thus, cause maximum possibility of disability, premature deaths, and severe diseases [3]. A stove has the characteristic of higher efficiency and cleaner combustion is termed as improved cook stove (ICS). It also emits less greenhouse gas to air as well as improve the health condition of the user. An Improved Cook Stove (ICS) could alleviate the entire problem concerned with efficiency and health hazard. Conventional cook stoves have very low efficiency. Moreover, large amount of charcoal produced from the given fuel remains unused. These types of cook stoves also produce substantial amount of Carbon Monoxide which is also an indication of incomplete fuel combustion. The objective of this research is to assess the thermal performance of the cook stove.Thermal efficiency is substantially affected by cook stove structure and insulation properties. Here different reason of heat leakage properties of cook stove is identified. Both metal and mud type improved cook stove were adopted to complete this research experiment. Water boiling test has been taken among the three popular test methods i.e for Kitchen Performance Test (KPT), Controlled Cooking Test (CCT) to measure the thermal performance. Portable air sampler, CO monitor and aerosol particle sampler have been used during test to measure emission.

II. REVIEW ON PERFORMANCE ANALYSIS ON ICS

In order to make the cook stove marketable continuous and extensive experimental testing is required. It helps to identify the necessary steps to take to keep the production cost as low as possible. In accordance to test result, the cook stove is behind cook stove testing, one of them is customer satisfaction. The primary concern is savings of fuel's consumption and its influence on customer lifestyle. Without the proper test, it is impossible to know the drawbacks of cook stove project. The drawbacks of cook stove help to understand the performance parameters, which need to be accurately determined, because it causes the decrement of cook stove performance.

III. LITERATURE REVIEW

Mukunda et al. [6] designed and commercialized cook stoves which required prepared, small-sized fuel, something that Verhaart [7] had strongly recommended. This class of stoves called Swosthee and modified Swosthee (each with more than one versions), were found to have thermal efficiencies of more than 40% which is much higher than the typical 20-30% observed in most improved cook stoves of that time [8]

Mukunda et al. [9] carried out an extensive work on design and performance of a powdery biomass stove, an improved version of a traditional sawdust stove. This cook stove can be operated with a mixture of up to 50% non-powdery biomass in powdery biomass, and was found to have very low CO emissions, of the order of 10-20 ppm. Dixit et al. [10] developed a single pot as well as multi-pot pulverized fuel stove using a fuel block.

IV. TEST PROTOCOL OF ICS

Intermediate Technology Development Group (ITDG), was the first to introduce the idea about the cook stove testing. They proposed a technique to test cook stove both in laboratory and on field [4]. The laboratory assessment of cook stove is mostly involved in WBT (water boiling test. Two year after first outcome by ITDG in 1982, another organization VITA (Volunteers in Technical Assistance) modified the draft of ITDG according to international standard [5], which was accepted 3 years later in 1985 by several stove testing groups. The document was consisted of exhaustive action of test method such as, WBT, Controlled Cooking Test (CCT) and Kitchen Performance Test (KPT). The WBT test was also described the emission measurement, which was in brief, because it was proposed by other protocols. However, the thermal performance version of protocols that was modified according to country prospective, was widely accepted such as India, China and Bangladesh [11], [12]. From the definition of water boiling test it is clear that it is used to compare the performance of different cook stove. Through the boiling process, it estimates the fuel consumption. This protocols involved with two phases, which is high power and low power phase that is still adopted by many protocols except the BIS protocols. The high power phase, a fixed amount of water is heated till boiling. Another phase, the low power involved with boiling water for 45 minutes at below 3 degree of boiling point. For statistical analysis, the test must conduct repeatedly at least three times.

A specified cook task is performed under CCT protocol, which estimates the fuel consumption. This test is rely on the food to be cooked, cook stove design and operation of cook stove. A trained cook is compulsory to operating the test. This test could either conducted in laboratory confinement or in the field.

The cook stove which actual effects on household and overall energy consumption is studied in KPT or Kitchen Performance Test protocol. Under this protocol, a cook stove is operate in a cycle to measure the fuel consumption. This test is solely field based so appropriate that is equal economic group of households are selected for this test. The test is conducted for 5 to 7 days. The household are allowed to consume 90% of fuel during the test. It is recommended that KPT should conduct after several CCT test, since it involves large effort.

V. WATER BOILONG OF (WBT) OF ICS

Water Boiling Test (WBT) is a simulation of the cooking process that can be performed on most stoves in use throughout the world. There are three phases of WBT test which are, high power (cold start) phase-1, high power (hot start) phase-2 and low power (simmering) phase-3. The first stage assess the capability of stove to retain heat. On the other hand, during the low power phase the temperature is kept below 3 degree Celsius of local boiling point for 45 minutes. Among various parameters that the WBT calculate, thermal efficiency (TE), specific energy consumption (SEC), firepower (FP)/power input and boiling time (BT). The emission factors are measured by exhaust flow method, which is taken in every 30s interval. The equivalent wood consumption is calculated by normalizing the moisture and charcoal content. All test are performed on three trials.

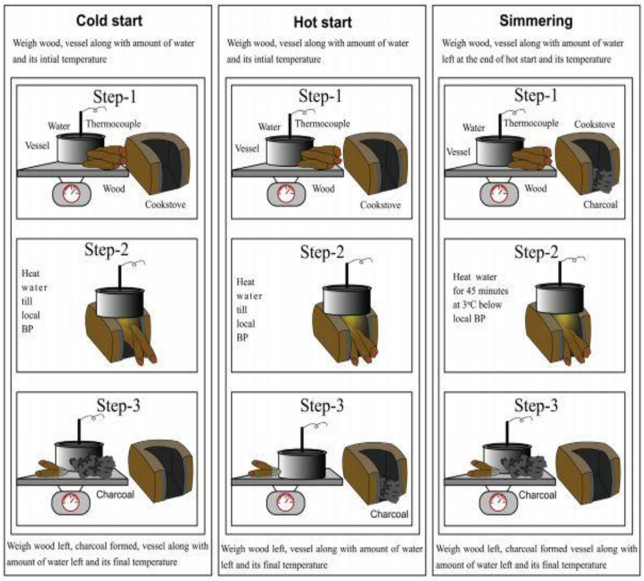

Fig. 1: Steps of Water Boiling Test [13]

High power (cold start) phase-1:

❖ First fill up a family size pot with 3 kg of water. Note down, pot + weight of water. Stove must be at room temperature. Measure the room temperature of water.

Fig. 2: Cold start phase of cook stove experiment

❖ A perforated wooden fixture is used to form thermometer such as its head is above 5 cm from the base of the pot.
❖ Note both the weight & type of fuel used to fire the stove for the first time.
❖ Make fire with fuel wood and start the stop watch after fire start
❖ The pot above the stove must bring to boiling point rapidly. Noted that no fuel is wasted. When the water temperature reaches to the boiling point (As shown in digital thermometer) following task to be done quickly. The time needed to reach the water to boiling point. Bring out the wood from the stove. Atthat end of the wood, charcoal is stored, accumulate those on the charcoal tray.

Measure the weight of remaining fuel and the weight of pot with water.

High Power (Hot start) phase-2

❖ Do not keep the stove cold.
❖ 3 liter water is filled for family based stove and for institutional or commercial based stove, 10 liter water is filled. After that, pot is placed at the top of stove. Combined weight of pot and water is noted to the data sheet.
❖ Note the room temperature of water

Fig. 3: Hot start phase of cook stove experiment

While water reached to the boiling point then the following tasks to be done immediately.

- ❖ The time has been spent to reach boiling point of first pot to be noted
- ❖ Note the water temperature of second pot
- ❖ Bring out of all fuel from stove and turn off fire. Measure the weight of rest of the fuel and note it to the data sheet.
- ❖ In this stage no need to measure the weight of charcoal.
- ❖ Measure the both pot including water quickly and put again to the mouth of stove

Low power (Simmering) phase-3

- ❖ This experiment is applicable for the water of first pot.
- ❖ Reset the stopwatch and Place the thermometer into the pot. Charge the fuel in to the stove in such a way that water temperature of first pot remains 3 degree less from boiling point that is 97 degree(if the temperature falls, 6 degree from boiling point the test would be canceled)
- ❖ Charge the fuel into the stove till 45 minutes in such a way that water temperature remains 3 degree below from boiling point.

Fig. 4: Simmering phase of cook stove experiment

After 45 minutes, the following tasks should be done immediately

- ❖ Bring out unused fuel wood from stove. If there is any charcoal attached to the fuel wood end, keep them to the charcoal tray. Measure the unused fuel wood and note to the data sheet.
- ❖ Note the water temperature of first pot and measure weight of first pot including water and note it to the data sheet. There is no need to measure weight or temperature of second pot because simmering

In this period, WBT (test) is end. This test is done 3 times for each stove.

VI. THERMAL PERFORMANCE OF COOK STOVE

Three cook stove of individual characteristic were selected to measure the thermal parameter. Several parameter such as water boil time, firepower, burning rate of fuel etc. were measured by using the WBT Excel sheet. Distinct differences were observed between these types of cook stove. In this section, Burning rate of fuel during cook stoves operation were compared with each other. As a result, specific fuel consumption and firepower originated by this consumption were also compared. Three types of cook stove were used to conduct the experiment. The first one is single mouth concrete type cook stove (Sample 1), then the second one is Double mouth concrete type cook stove with chimney (Sample 2) and the last one is metal type single mouth cook stove developed by Prakti (Sample 3).

Fig. 5: Sample of cook stove for thermal performance test.

VII. COMPARISON OF BURNING RATE OF COOK STOVE

The burning rate was compared between these 3 samples of cook stove. The average boiling time required individual samples of cook stove to finish the cold start phase of WBT were 15, 19 and 15 minutes. So it is apparent that on an average the concrete type and single type cook stove require less time to boil water during operation. The average burning rate of sample 1 cook stove is 26.46 g/min, where the sample 2 cook stove has 111.84 g/min, which is made of same material concrete, but in this case, it is double mouth. The metal type (sample 3) cook stove has the lowest burning rate, which is 16.4 g/min. The average boiling time required for individual samples of cook stove to finish the hot start phase of WBT were 12, 18 and 11 minutes. So it is apparent that on an average the concrete type and single type cook stove require less time to boil water during operation. The average burning rate of sample 1 cook stove was 27.7 g/min, where the sample 2 cook stove was 111.8 g/min, which is made of same material concrete, but in this case, it is double mouth. The metal type (sample 3) cook stove has the lowest burning rate, which is 16.4 g/min. It is quite seen that because of high power test, the two stage of WBT, which is cold and hot start stage, have similar trend of experimental burning rate.

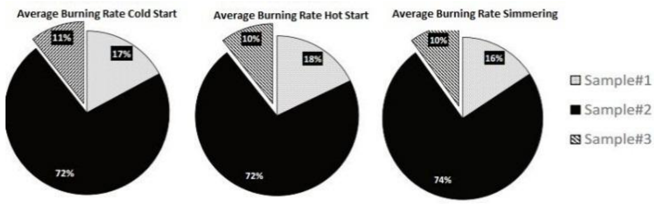

Fig. 6: Burning rate pie charts

The simmering stage of WBT comprised of 45 minutes. In this test the three sample of cook stove showed different result than other two stage of WBT. This stage is low power phase, so the burning rate value was found comparatively less than cold and hot start stages. The average burning rate of sample 1 cook stove was 9.2 g/min, where the sample 2 cook stove has 43.1 g/min, which is made of same material concrete, but in this case, it is double mouth. The metal type (sample 3) cook stove has the lowest burning rate, which is 5.8 g/min.

VIII. COMPARISON OF SPECIFIC FUEL CONSUMPTION

The specific fuel consumption during cold start phase was illustrated in the figure 7. For sample 1 stove, the fuel consumption was 146 g/liter, which is about 12% higher than sample 2 stove having 105 g/liter fuel during this stage of WBT. The lowest fuel consumption was observed in metal type cook stove, i.e. 26%.During the hot start phase of WBT test, there was an equal portion of fuel consumed by sample 2 cook stove, which is 95.5 g/liter, as compared to cold start phase. Single mouth metal type cook stove has consumed 29 %of fuel, which is 10 % less than the concrete type of cook stove. The concrete type sample 1 cook stove cook stove consumed 120.3 g/liter fuel, which is the highest among cook stoves.

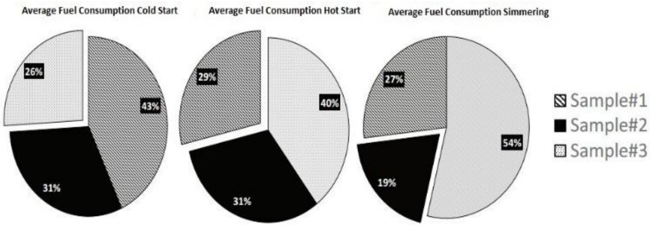

Fig. 7: Specific fuel consumption pie charts

IX. COMPARISON OFFIRE POWER OF COOK STOVES

The fire power of cook stove is most essential parameter as it expressed the equivalent dry fuel energy consumed by the stove per unit time. The average fire power during the high power cold start phase was maximum found in double mouth (sample 2) concrete type cook stove, which is 32521 watts. Compared to that single mouth (sample 1) cook stove was found less than the double mouth one, in percentage which is 17 % (fig. 8), a variance of about 50 %. Metal type cook stove has the least amount of fire power (4770 watts), recorded in this phase about 11% of total.

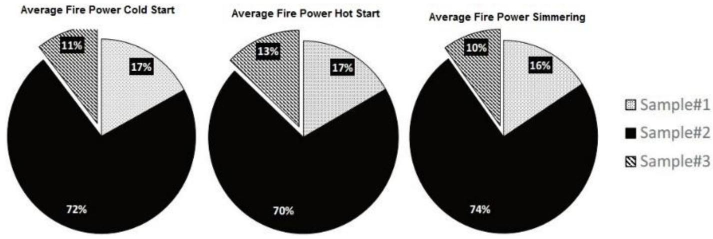

Fig. 8: Pie charts of fire power cook stove

The high power hot start phase shows similar trend like cold start phase on fire power issue of all types of cook stove. However, there was a substantial amount fire power raise in that stage. The double mouth (sample 2) stove fire power raised about 200 watts compared to cold start phase, which is 34015 watts. Despite shares the least portion about 13%, in this stage (sample 2) metal type cook stove fire power also increased to about 150 watts, which is 6243 watts. Single mouth concrete type cook stove covers 17 % fire power among all three cook stove during high power hot start phase.

At simmering stage, the fire power of metal type cook stove (sample 3) is lowest among all three phases about 10 %. In this particular stage double mouth, (sample 2) cook stove fire power was found maximum compared to other two stage, 74 %. Also, among all there stage the average fire power percentage of single mouth concrete (sample 1) cook stove was observed maximum, about 16 %.

X. ENERGY BUDGET OF COOK STOVES

In order to estimate the energy flow budget, some physical characteristics cook stove should consider with reference to fig 9. At the combustion stage of fuel, a partial amount of energy goes to the stove. Part of this energy absorbed by the stove body and the remaining dissipated through the body to atmosphere. There was a significant contribution of stove material to the absorbed energy of cook- stove. The stove which made out of heavy material absorbs the maximum portion of energy compare to the lighter one. The lighter construction material dissipates lost energy to the surroundings.

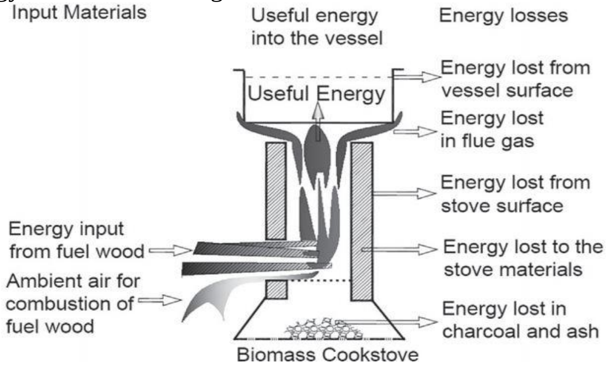

Fig. 9: Various components of input materials and energy flow of cook stove [14].

5.1 Comparison of Energy utilization: Metal and concrete type

Energy is created and dispersed differently depending on the stove used and how it is operated. The energy needed to sustain combustion is a function of combustion rate and ambient conditions but typically will be quite small when compared to overall heat transfer [15]. Heat transfer to or from a cooking pot or stove, body depends on their relation to the combustion process, temperature, material, surface area and mass. The energy absorbed by the body of the stove increases as the specific heat, the surface area, and the mass increase. As the stove and pot temperatures change the amount of energy being transferred also changes.

In an ideal case, no energy leaves the water in the form of steam, and heat transfer to the pot can be calculated using Eq. (1)

We know,

Useful Energy, $Q = ms\Delta T$……………….. (1)

Where, m=Mass, S= Specific heat, ΔT= Temperature difference

5.1.1 Double mouth concrete cook stove

Below is the experimental data of double mouth concrete type cook stove. Here the energy utilization of both pot during stove operation is analyzed. Here the initial temperature of water on both pot is 31 degree Celsius or 305.15 kelvin.

The graph (fig 10}) is obtained by using experiment data. Here the energy utilization or heat flux form stove to the pot 1 and pot 2 water is illustrated. The value in the table 1 obtained by using Eq.1

Q_w (P1) = Specific Heat of Water (4200 J/Kg/K)× Mass (4kg)× (Final Temperature (315.65 K) - Initial Temperature (305.15 K)

=176400 J

Similar method was followed during the calculation of pot 2 energy utilization.

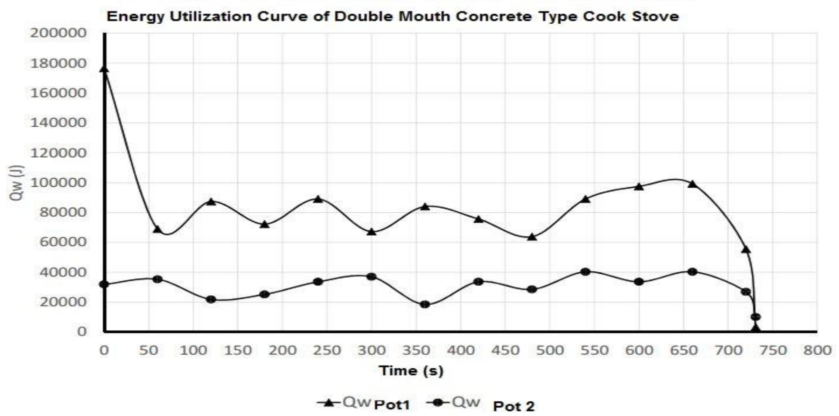

Fig. 10: Energy utilization curve of (9-8”) concrete double mouth cook stove.

The figure 10, shows the stages of energy utilization of double mouth cook stove. It is clear that initially, this cook stove use lots of energy during the starting phase. Compare to pot 1, pot 2 use less energy as the pot 1 is not directly heated by the flame. During the middle period of stove operation pot 1 energy fluctuated. The second peak energy was found during the end phase of stove operation when the energy usage reaches close to hundred thousand joules.

After starting at 176400 J, pot 1 energy usage fall sharply to 68880 joules, a drop of 107 thousand in one minute. The heat flux fluctuated constantly until 6 minutes of test time. There was a sharp increase of heat flux for next two minutes then it continues to rise and reached the value 100 thousands joules. There was a substantial fall in heat flux during 11 minute of test time, which remain constant approximately 5.5 thousand joules before it drops again to 3360 joules at the end of the test. Pot 2 heat flux pattern is similar to pot except the fluctuation was observed during the second half of experiment that is form 5 minutes to 10 where it reaches lowest to 2 thousand joules.

Fig. 11: (9-8") Concrete double mouth with chimney.

5.1.2 Concrete type single mouth cook stove

Concrete type cook stove is made from the mix of cement, sand and other materials. So there is heat loss occur during the operation of cook stove. Below is the experimental data of single mouth concrete type cook stove useful energy curve. Here the energy utilization of single pot during stove operation is analyzed. Here the initial temperature of water of the pot is 31 degree Celsius or 305.15 kelvin. Mass of the water was 4 liter or 4 Kg.

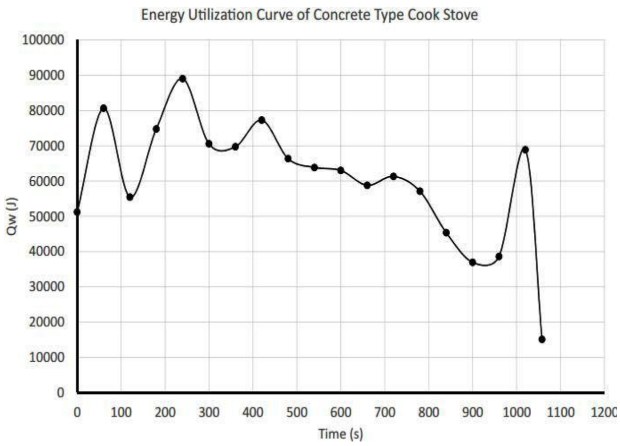

Fig12: Energy utilization curve of concrete type cook stove (single mouth)

The figure 12, shows the stages of energy utilization of single mouth cook stove. It is clear that initially, this cook stove use comparatively less energy during the starting phase. As the experimental time span the stove begin to apply more energy to heat the water of the pot. The peak energy use is close to 90 thousand joules. After that the energy usage falls gradually as the temperature of pot water increase before again rose to achieve boiling temperature at the end.

Fig. 13: Single mouth concrete cook stove during operation.

XI. COMPARISON OF COMBUSTION HEAT TRANSFER

Increased flame temperature and fire bed temperatures are indicators of clean combustion of biomass. The temperature of the flame and the fire-bed of the cook-stove are at their maximum when the air-supply for combustion is adequate and distributed uniformly. Thus, the temperature of the flame and fire-bed directly influences combustion, efficiency and emission factors of the cook-stoves. The difference between the flame temperature, fire-bed temperature, material and thickness of the cooking pot influences the heat transfer rate. When the convection heat transfer rate is obtained by a linear function of the temperature difference, the heat transfer rate of radiation is obtained by fourth order exponential function of the temperature difference.

The heat transferred from the combustion chamber to the vessel by convection can be estimated by the standard equation as given in Eq. 2.

$Q = h \times A \times (T_{flame}\} - T_{vessel})$………….... (2)

Where, h = Heat Transfer Coefficient = 10; Area A = 0.159 m^2

The heat transferred from the combustion chamber to the vessel by radiation can be estimated by the standard equation as given in Eq.3.

$Q = \epsilon \times h \times A \times (T^4_{flame}\} - T^4_{vessel})$……..(3)

Where Є = Emissivity of Black body = 1

It is clear from the graph (fig.14) below that heat transfer by convection is the least way to transfer heat form metal cook stove. There was a similar pattern of heat transfer observed from

The superimposed curve, radiative and convective respectively.

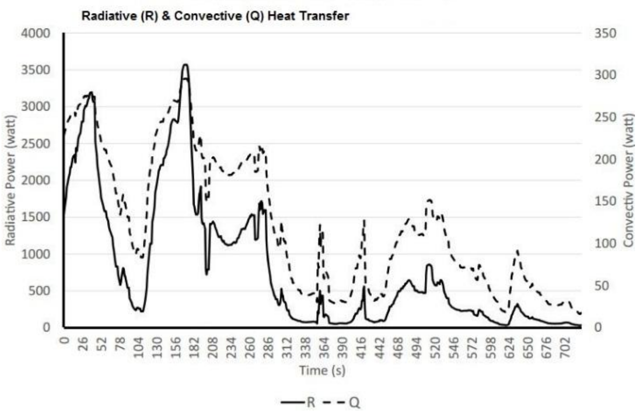

Fig. 14: Radiative and conductive heat transfer of metal cook stove during combustion.

From 200 and 1500 respectively, both convective and radiative energy rose gradually. After that, there were sudden falls after 2 minutes. They continue to rise and reached at peak at 300 and 3500 respectively. The heat transfer fall again sharply at 3rd minute but recover again at initial value after few seconds. After one further decrease in transfer amount radiative and convective heat transfer maintain a range (150 and 1000) respectively, before end.

In comparison to metal cook stove, concrete cook (fig. 15) stove has different pattern of heat transfer. Heat transfer was fluctuated wildly in between test time. Radiative heat transfer is maximum between two types of heat transfer way. The peak values are 900 and 6000 watt respectively. Both heat transfer had risen toward the end of the test period. The radiative heat transfer of concrete type cook stove begins at 500 watt. The radiative heat transfer drops sharply to the beginning phase of experiment at 7th minute. Then the vale keep fluctuating for 5 minutes before reaching the peak value to 6000 watt. There was a similar trend observed in case of convective heat transfer. The radiative heat transfer again achieve the highest value at 22th minute of experimental time. Both convective and radiative heat transfer sharply increases during the end period of experiment.

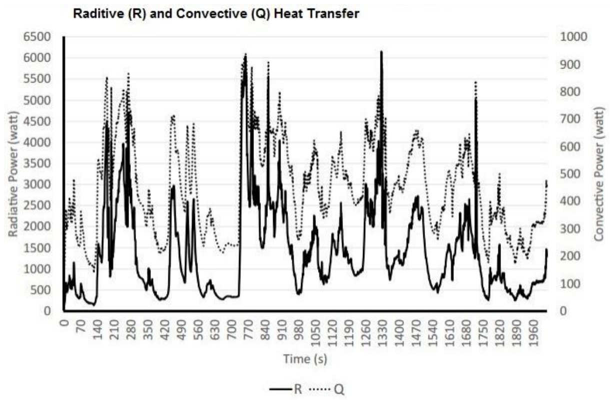

Fig. 15: Radiative and conductive heat transfer

XII. EXPERIMENTAL RESULTS OF EMISSION TEST

The ICS research facility at Institute of Energy, University of Dhaka was used to study the emission measurement. A total of 22 single mouth metal portable improved cook stoves including a traditional cook stove was experimented. The lab facility was a kitchen of 11 ft length, 7 ft. width and 8 ft. height with two windows of 3 sq. ft. and a door of 11 sq. ft. The particulate matter (PM) was carried out in this facility. There were two filter based Air Matrix Samplers (AMS), to measure distinct level of air particle. Although a digital air sampler, Anderson PDRM was used in parallel with AMS. The digital air sampler is capable of measuring in real time (2min interval) during the operation of cook stove. Another emission parameter, BC (Black Carbon, was measured in Atomic Energy chemistry laboratory using reflectance measurement of PM2.5 filer sample [16]. Finally, carbon monoxide (CO) from cook stove was monitored by an electrochemical based gas sensor (Drager PAC III).

For the experiment, two cook stoves were selected. Shabuj Chula, which is single mouth metal ICS and another is traditional cook stove made out of mud. The emission data of Shabuj Chula is given in table.

Table 1: Single mouth (Shabujchula) metal ICS

Parameter	Unit	Cold Start phase	Hot Start phase	Simmering phase
CO	ppm	11±0.4	9±0.4	8±0.9
PM10		748±113	589±87	327±8
PM2.5	μg/m^3	515±78	406±60	225±6
BC in PM2.5	μg/m^3	176±1	138±1	78±13

From the table it is apparent that, among the particle that emit from cook stove the concentration of PM10 is relatively more than other the maximum was found 748 μg/m^3 with an error limit of 113, during the cold start phase of cook stove operation.

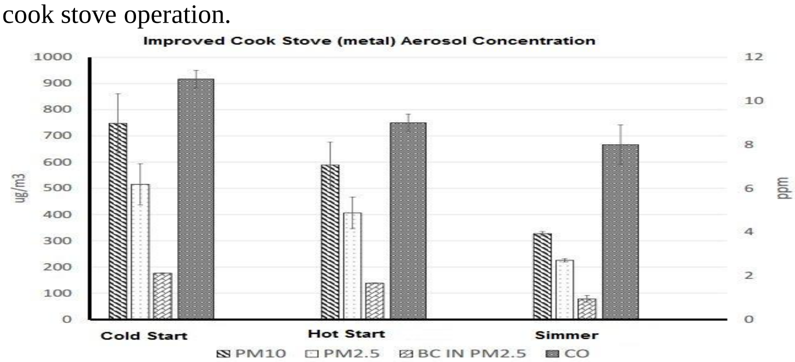

Fig. 16: Aerosol concentration graph of ICS with error bar.

From the figure 16, it is clear that, there is a gradual decrease in concentration of particle as the cook stove froward the experiment phase. The concentration of CO was peak at about 11 ppm during cold start phase and nadir at close to 8 ppm during simmer phase of stove operation.

The emission data of traditional cook stove (TCS) is given in table.

Table 2 : Traditional stove fixed mud (local)

Parameter	Unit	Cold Start phase	Hot Start phase	Simmering phase
CO	ppm	13.8±0.6	12.7±0.8	11.9±0.4
PM10		1520±27	1146±222	945±20
PM2.5	µg/m^3	998±54	757±190	621±52
BC in PM2.5	µg/m^3	376±27	285±72	234±23

From the table it is apparent that, among the particle that emit from cook stove, the concentration of PM10 is relatively more than other the maximum was found 1520 µg/m^3 with an error limit of 27, during the cold start phase of cook stove operation. Comparatively, TCS concentration is more than that of ICS in all section of aerosol component.

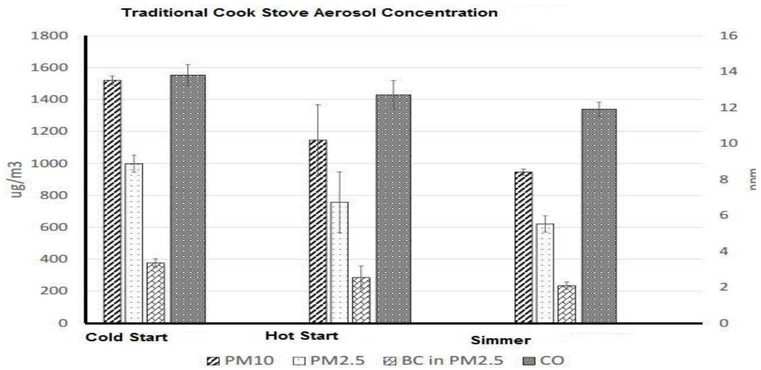

Fig. 17: Aerosol concentration graph of TCS with error bar.

From the figure 17, it is clear that, there is a gradual decrease in concentration of particle as the cook stove froward the experiment phase. The concentration of CO was peak at about 14 ppm during cold start phase and lowest at close to 12 ppm during simmer phase of stove operation. The CO concentration pattern remain similar at all phase of stove operation.

The emission test is conducted during the each three phase of WBT test. The fuel is required to heat the water until it reaches it local boiling point. The stoking for entire WBT was carried by a several years experienced person and experimental data was monitor and recorded by lab researcher, since stoking rate is highly person dependent.

The traditional cook stove exhausts substantial quantity of pollutant substance which hazardous for environment and human. Moreover, improved cook stove has high efficiency which outweighs the cheap traditional cook stove. The portable characteristic of ICS made it more popular and dynamic compared to traditional cook stove. It is immediately apparent from experimental result that substantially less air is polluted with pollutant parameter such as, particulate matter, black carbon and carbon monoxide from ICS (Improved Cook Stove).

XIII. CONCLUSION

The purpose of this study was to assess the thermal and emission performance of different types of improved cook stoves available in Bangladesh. Metal and concrete type improved cook stoves performance parameter whether it is thermal, energy transfer and emission pattern were discussed. Thermal performance data revealed that metal type cook stoves have higher thermal efficiency. Metal cook stove results 15\% more thermal efficiency, which is in between the range of 35 to 45\%, compared to concrete type cook stoves. However, metal and concrete type of cook stoves also was used to examine the heat gain or useful energy profile. In case of single mouth cook stove, metal use peak twelve thousands joule energy, whereas concrete one energy utilization only about nine thousand. This characteristics of energy utilization substantially influence their respective boiling time. The convective and radiative heat transfer from the flame to the pot illustrated that concrete type cook stove's heat flux is greater than the metal one. The emission analysis between ICS and TCS (Traditional Cook Stove) provides a clear picture of aerosol component and its concentration from both type of stove. The traditional cook stoves emit 1520 mg/m3 of PM10 and 998 mg/m3 of PM2.5. These two particle scale matter affect the human health.

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