A Numerical Study on Thermal Performance of Biomass and Its Impact Due to Moisture for Direct Combustion Based Electricity Generation

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***Abstract*-Moisture content of fuel in a thermal power plant plays a significant role in determining its efficiency, as the performance increases with decrease in moisture. In recent years techniques for drying the biomass based fuel have become predominant in order to make it a sustainable source of renewable energy. In this paper the parameter of moisture is developed and tested in the user interface based computer model and database management system. This program shall compute the thermal output of biomass composition as heat of combustion on conditions of 30%, 20% and 10% moisture content in the samples. It is observed that there is substantial change in the heat of combustion with change in the content of moisture which is presented in this work. Also there is no combustion if the moisture content in the sample exceeds 30% resulting in shut down of the boiler. The results are more compatible with practical possibilities and will be useful in configuring the computer model to process and produce more accurate outcomes to achieve the optimum composition with high efficiency, greater calorie and low cost of power generation. The outcome shall be verified by using commercial simulation software and later by physical experiment which would enable in fixing the errors of the computer model developed by ourselves in the laboratory.**

Keywords- Biomass; Combustion; Moisture; Database System; Numerical Simulation

I. INTRODUCTION

In the combustion system of thermal power plant it is essential to remove the water content of fuel before the first stage of combustion to avoid reduction in combustion temperature below optimum level and the overall system efficiency. Also there are issues concerning storage of seasonal biomass where the presence of moisture can catalyze bacterial activity in turn altering the material properties.

Reduction in boiler temperature generally leads to incomplete combustion of fuel which leads to emission of unwanted flue gasses. Biomass can be added to the reactor in either a wet or dry state with constant reaction conditions and minimum extra heating time. The modern combustion systems are designed to operate within the specified range of moisture content in the fuel. Biomass is a derivative of waste materials from various natural sources that exists in different forms depending upon its composition in content.

However the choice of biomass type based on its availability alters the values of the calorie and thermal efficiency. The use of information technology with more essential features can aid in developing the renewable fuel by increasing the thermal performance and reducing the cost.

II. MATERIAL AND METHODS

Biomass samples are configured into the database management system using the user interface system of the computer model which is self developed by us in the laboratory. In the previous work the same samples were tested but without considering the moisture content. In this paper the computer model is coded with moisture content feature that would influence the thermal output significantly. The user can enter the value of moisture content in terms of percentage in each sample of biomass while entering the composition parameters itself.

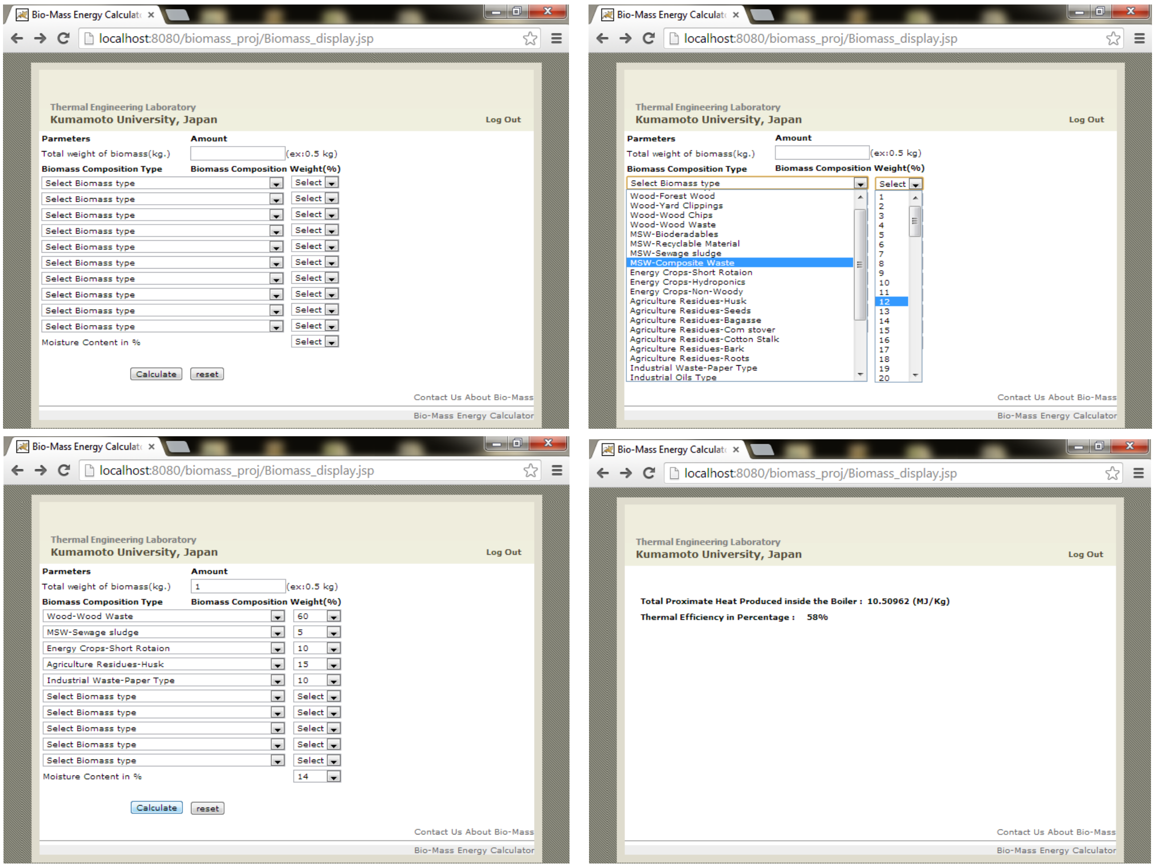

Fig. 1 User interface based computer model and database management system

III. RESULTS AND DISCUSSIONS

In this experiment the computer model is coded with moisture content feature in terms of percentage. The samples 1-5 are biomass composition with 0.5 kg weight while the samples 6-10 are 1 kg weight. The numerical simulation is performed individually considering 10%, 20% and 30% moisture for each sample. These parameters are entered by user while configuring the biomass composition and numerical simulation is performed accordingly.

It is observed that the performance of these samples during the combustion was extremely poor at 30% moisture content in biomass and the combustion halted when moisture percentage exceeded beyond 30%. The samples cannot be experimented if the moisture content is high and needs pre-treatment so that the percentage falls below 30%.

However for 20% and 10% of moisture content in biomass, the samples exhibited significant change in the heat of combustion values. But no similar characteristics were found in 0.5 kg weight samples 1-5 and 1 kg samples 6-10 when compared with each other. Individually if the characteristics of each sample is considered observation was made where there is similarity in the rate of change of heat of combustion with respect to the change in the moisture content.

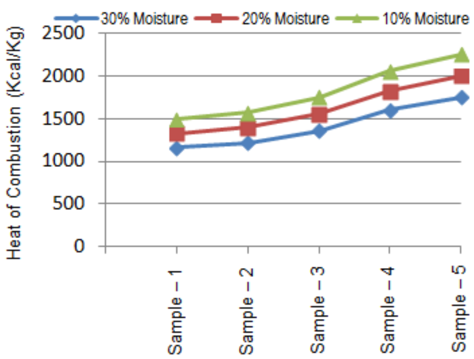

Fig. 2 Graph showing the Heat of combustion for the 0.5 Kg weight biomass samples for 30%, 20% and 10% of moisture content

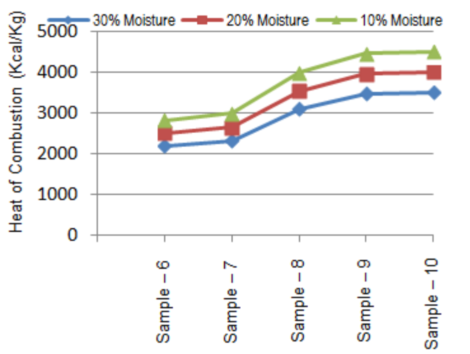

Fig. 3 Graph showing the Heat of combustion for the 1.0 Kg weight biomass samples for 30%, 20% and 10% of moisture content

TABLE 1 NUMERICAL RESULT OF 0.5 KG WEIGHT BIOMASS SAMPLES TESTED USING THE DEVELOPED COMPUTER MODEL AND DATABASE MANAGEMENT SYSTEM AT 30%, 20% AND 10% OF MOISTURE LEVEL

Sample No.	Composition Weight in Kg	Biomass Composition	Composition Weight in %	Actual Weight of each Composition	Heat of Combustion in Kcal/Kg for 30% moisture content	Heat of Combustion in Kcal/Kg for 20% moisture content	Heat of Combustion in Kcal/Kg for 10% moisture content
Sample -1	0.5	Wood - Forest Wood	40	0.2	1163.028	1329.175	1495.321
		MSW - Recyclable Material	5	0.025			
		Industrial Waste - Food and Fiber processing waste	5	0.025			
		Agricultural Residues - Husk	15	0.075			
		Energy Crops - Short Rotation	10	0.05			
		Plantation - Forestry	25	0.125			
Sample -2	0.5	Energy Crops - Hydroponics	10	0.05	1220.704	1395.091	1569.477
		Agricultural Residues-Corn stover	25	0.125			
		Plantation - Forestry	25	0.125			
		Plantation - Algae	20	0.1			
		Plantation - Aquatics	20	0.1			
Sample -3	0.5	Wood - Yard Clippings	10	0.05	1362.089	1556.674	1751.258
		Wood - Wood Chips	10	0.05			
		Energy Crops - Short Rotation	5	0.025			
		Energy Crops - Hydroponics	10	0.05			
		Energy Crops - Non-Woody	10	0.05			
		Agricultural Residues - Bagasse	15	0.075			
		Agricultural Residues-Corn stover	10	0.05			
		Agricultural Residues-Cotton stalk	10	0.05			
		Plantation - Forestry	10	0.05			
		Plantation - Algae	5	0.025			
		Plantation - Aquatics	5	0.025			
Sample -4	0.5	Wood - Wood Waste	60	0.3	1598.417	1826.763	2055.108
		MSW - Sewage Sludge	5	0.025			
		Short Rotation Energy Crops	10	0.05			
		Agricultural Residues - Husk	15	0.075			
		Industrial - Paper Waste	10	0.05			
Sample -5	0.5	Agricultural Residues - Husk	60	0.3	1753.170	2003.623	2254.076
		Agricultural Residues - Seeds	5	0.025			
		Agricultural Residues - Bark	10	0.05			
		Wood -Wood Waste	15	0.075			
		Industrial - Paper Waste	10	0.05			

TABLE 2 NUMERICAL RESULT OF 1.0 KG WEIGHT BIOMASS SAMPLES TESTED USING THE DEVELOPED COMPUTER MODEL AND DATABASE MANAGEMENT SYSTEM AT 30%, 20% AND 10% OF MOISTURE LEVEL

Sample No.	Composition Weight in Kg	Biomass Composition	Composition Weight in %	Actual Weight of each Composition	Heat of Combustion in Kcal/Kg for 30% moisture content	Heat of Combustion in Kcal/Kg for 20% moisture content	Heat of Combustion in Kcal/Kg for 10% moisture content
Sample-6	1	Agricultural Residues - Bagasse	15	0.15	2192.216	2505.389	2818.563
		Agricultural Residues-Corn stover	20	0.2			
		MSW - Sewage sludge	10	0.1			
		MSW - Composite Waste	15	0.15			
		Animal Waste - Feces	20	0.2			
Sample-7	1	Wood - Forest Wood	40	0.4	2326.056	2658.349	2990.643
		MSW - Recyclable Material	5	0.05			
		Industrial Waste - Food and Fiber processing waste	5	0.05			
		Agricultural Residues - Husk	15	0.15			
		Energy Crops - Short Rotation	10	0.1			
		Plantation - Forestry	25	0.25			
Sample-8	1	MSW - Sewage sludge	15	0.15	3107.129	3551.005	3994.880
		MSW-Composite Waste	20	0.2			
		Animal Waste-Feces	35	0.35			
		Animal Waste-Slaughter Waste	20	0.2			
		Plantation - Cultivated Crops	10	0.1			
Sample-9	1	Animal Waste-Feces	6	0.06	3478.809	3975.782	4472.755
		MSW-Sewage sludge	8	0.08			
		Animal Waste-Slaughter Waste	12	0.12			
		MSW-Composite Waste	38	0.38			

		Agricultural Residues-Husk	16	0.16			
		Agricultural Residues-Bagasse	5	0.05			
		Plantation - Herbaceous	5	0.05			
		Plantation - Algae	5	0.05			
		Plantation - Cultivated Crops	5	0.05			
Sample-10	1	Agricultural Residues-Husk	60	0.6	3506.341	4007.246	4508.152
		Agricultural Residues-Seeds	5	0.05			
		Agricultural Residues-Bark	10	0.1			
		Wood-Wood Waste	15	0.15			
		Industrial Waste-Paper Type	10	0.1			

IV. CONCLUSIONS

The moisture content feature is a key parameter in the database management system that enables the computer model to simulate more accurate numerical results. This model will be useful in determining the optimum composition of biomass and preparing its sample accordingly. This method shall reduce the dependency on pre-treatment methods to increase the calorie of fuel when used in place of coal in the thermal power plants. However reduction in percentage of moisture content is considered critical in order to get better performance and avoid wastage of fuel. Natural drying techniques are still suitable for most users while preparing the biomass composition, however if the user desires to get better efficiency some of the forced drying techniques also need to be considered.

In the further work the database system shall be coded with additional features to improvise the computer model. The results shall however be verified by performing numerical simulations using commercial software and in later stages by physical experimentation.

REFERENCES

[1] R. H. BASHA and S. c. TORII, “Use of information technology and numerical methods to increase the thermal performance of Biomass based renewable fuel,” International Journal of Renewable Energy and Environmental Engineering, ISSN 2348-0157, vol. 02, no. 02, , pp. 117-120, April 2014.

[2] R. H. Basha and S. c. Torii, “Design of a computer model for simulation of combustion parameters of Biomass using J2SE 5.0 program,” International Journal of Earth Sciences and Engineering, vol. 7, no. 01, pp. 172-176, 2014.

[3] A.-peng Chen, R. H. Basha, and S. c. Torii, “Classification of biomass based on its role in combustion for sustainable and renewable source of energy using proximate and ultimate analysis,” International Journal of Earth Sciences and Engineering, vol. 7, no. 01, pp. 136-142, 2014.

[4] R.anipet H. Basha and S. c. Torii, “Composition analysis of Biomass utilization in combustion to increase the thermal performance by using computer methods,” BIOINFO Renewable & Sustainable Energy, vol. 03, no. 01, pp. 29-32, 2013.

[5] S. Watanabe and S. Torii, “Development study of a biomass fueled furnace and impact of the moisture content on the combustion condition,” International Journal of Advanced Transport Phenomena, vol. 01, no. 01, pp. 1-5, Jan.-Dec. 2012.

[6] S. Ewanick and R. Bura, “Effect of biomass moisture content on bioethanol yields from steam pretreated switch grass and sugarcane bagasse,” Bioresource Technology (Elsevier), pp. 2651-2658, 2011.

[7] C. Rhen, M. Ohman, R.Gref, and I. Wasterlund, “Effect of raw material composition in woody biomass pellets on combustion characteristics,” Biomass and Bioenergy (Elsevier), pp. 66-72, 2007.

[8] T. Minowa, “Creating a Data Base (DB) to promote the utilization of Biomass,” AIST Today International Edition, National Institute of Advanced Industrial Science and Technology, no. 21, pp. 8-9, 2006

[9] I. Obernbergera and G. Thek, “Physical characterisation and chemical composition of densified biomass fuels with regard to their combustion behaviour,” Biomass and Bioenergy (Elsevier), pp. 653-669, 2004.

[10] A. P. C. Faaij, “Biomass Combustion,” Encyclopaedia of Energy (Elsevier), vol. 01, pp. 175-179, 2004.

[11] J. Werthera, M. Saengera, E.-U. Hartgea, T. Ogadab, and Z. Siagib, “Combustion of agricultural residues,” Progress in Energy and Combustion Science (Elsevier), pp. 1-27, 2000.

[12] B. M. Jenkins and J. M. Ebeling “Thermo chemical properties of biomass fuels,” California Agriculture, pp. 14-16, May-June,1985.

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Ranipet Hafeez BASHA was born at Hyderabad, India on 29-December 1985. He did his Master of Technology (M. Tech) in Computer Science and Engineering from Acharya Nagarjuna University (2008-2010) and Bachelor of Technology (B. Tech) in Electrical and Electronics Engineering from Jawaharlal Nehru Technological University (2003-2007). He is presently pursuing his Doctor of Philosophy (Ph. D) in Renewable Energy at Graduate School of Science & Technology, Kumamoto University, Japan.

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