

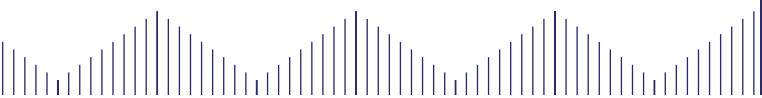


Institute  
Of Continuing  
Education &  
Professional Studies

# *INTERNATIONAL JOURNAL ON* **E-LEARNING** *AND* **HIGHER EDUCATION**



**VOLUME 13**  
**JUNE 2020**  
**ISSN 2229-8223**



## **Design and Develop STEM Education in Malaysia: A Downdraft Gasifier Model**

**Mohd Mahadzir Muhammad, Noor Iswadi Ismail, Nor Azirah Mohd Fohimi, Hazim Sharudin, Theophanny Paula Theresia Rampisela**

*Faculty of Mechanical Engineering, Universiti Teknologi MARA Cawangan Pulau Pinang, Kampus Permatang Pauh,*

*Jalan Permatang Pauh, 13500 Permatang Pauh, Pulau Pinang, Malaysia mahadzir399@ppinang.uitm.edu.my, noraz330@uitm.edu.my*

*Automotive Research and Testing Center (ARTeC), Universiti Teknologi MARA Cawangan Pulau Pinang, Kampus Permatang Pauh, Jalan Permatang Pauh, 13500 Permatang Pauh, Pulau Pinang, Malaysia iswadi558@uitm.edu.my, hazim@uitm.edu.my*

*Fakultas Keguruan dan Ilmu Pendidikan, Universitas Pattimura, Jl. Ir. M. Putuhena, Kampus Poka,*

*Kota Ambon, Maluku, Indonesia rampisela83@gmail.com*

*\*Corresponding Author*

*Abstract: Design and development of a downdraft gasifier model can be used as a basis to foster STEM (science, technology, engineering and mathematics) education for young generation. Teaching and learning process through model can bridge the gap between STEM disciplines through actual practices, models should be used as a means to promote STEM literacy and the transfer of knowledge and skills between contexts, both in and out of the STEM disciplines. It is therefore imperative that intended model-based pedagogies for STEM education classrooms are further researched, in order to contribute in producing a creative thinking students in STEM educators. Downdraft gasifier used to produce renewable energy. This knowledge is important to young generation. It has been introduced to the secondary school and university. In this paper, a model of downdraft gasifier was designed, developed and tested for the visibility of producer gas output. This model was constructed at lab scaled to decrease the low temperature zone that appear in the actual size. The various parts of the gasifier like the throat, combustion zone, grate, reduction zone, fuel hopper, gas outlet and air inlet were designed. Biomass material source such as rubber wood was selected based on its properties as fuel. Later, the gasifier was ignited by a lighter to prove that the gas produced was a combustible gas. Results showed flares occurred on the gas output. It is proven that the gas ignited when flame is applied to the gas. This proves*

*that the producer gas produced is flammable. The yellow colour of flame was also observed.*

***Keywords:*** *Downdraft Gasifier, STEM Education, Producer Gas, Creative Thinking*

## **INTRODUCTION**

STEM Education is derived from the SMET stands for Science, Mathematics, Engineering and Technology. In Malaysia, STEM (Science, Technology, Engineering and Mathematics) refers to education policies and school curriculum options to enhance competitiveness in science and technology to students. This is reflected in the Malaysia Education Blueprint 2013-2025 (Ministry of Education, 2013) which emphasizes STEM education at school level through curriculum and co-curricular activities with support through various stakeholders. STEM education was a priority for schools and universities to uphold and strengthen the field of engagement to the younger generation. It emphasized the concept of 4C components, namely communication, collaboration, creativity and critical thinking as contained in the 21st century learning (PAK-21) and high-level thinking skills (KBAT). The development of these components is seen as producing young people with high skills in solving complex problems (Kerka, 1992; Lopez & Whittington, 2001; Chinedu et al., 2015). Today the implementation of STEM is seen in the second wave when governments, statutory bodies, associations, non- governmental organizations (NGOs) and external agencies work together to promote STEM to the community. STEM education is seen to give birth to young people who have high intellectuals in science and technology. It is also capable of driving the country's economy and making Malaysia a high-income nation. Efforts to empower STEM culture among the younger generation, the media and technology must be fully utilized. Moreover, now the younger generation is so close to technology.

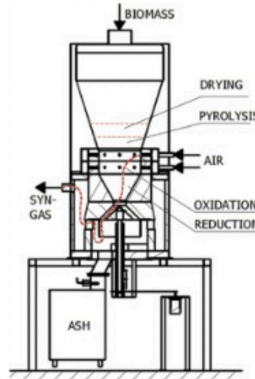
Bioenergy is the largest source of growth in renewable consumption over the period 2018 to 2023 (International Energy Agency, 2019). Bioenergy as solid, liquid or gaseous fuels will account for 30% of the growth in renewable consumption in this period. This is a result of the considerable use

of bioenergy in heat and transport. Other renewables have less penetration in these two sectors, which account for 80% of total final energy consumption.

Renewable energy knowledges are important to young generation. It has been introduced to young people in secondary school and also the university. For example, through the Design and Technology (RBT) subjects and a subject such as Thermodynamics are specifically taught about it. To produce young students who can think creatively, the appropriate learning model is needed. In this paper, a model of downdraft gasifier was designed, developed and tested. The objective is to design, fabricate, develop, test and obtain the flame visibility on the producer gas output. This model is built on a laboratory scale to reduce the low temperature zone that appears when it is in real condition. The various parts of the gasifier like the throat, combustion zone, grate, reduction zone, fuel hopper, gas outlet and air inlet were designed. The sources of biomass used in this study are rubberwood based on its nature as a fuel. This is based on research conducted by (Corella, 2001), (Lapuerta, 2008), and (Warnecke, 2000) that used rubber wood, wood chip and hazelnut shells respectively as their gasifier's fuel. The composition of gas for three type of biomass are then compared to select the best type of biomass material. The percentage of carbon monoxide for rubber wood is obtained to be highest. High percentage in carbon monoxide will help during combustion in the combustion zone. Apart from this, rubber wood is chosen as biomass fuel because of its availability in this country.

## **DOWNDRAFT GASIFIER**

This gasifier was developed to convert high volatile fuels such as wood. It is proven to be most successful design for power generation (Reed & Das, 1988) because producing low tar gas. This type of gasifier has four distinct zones which is drying zone, pyrolysis zone, oxidation zone and reduction zone. Both biomass and air move in the downward direction in the lower section of the gasifier unit. The producer gases leave a point just below the grate of the gasifier, which enables partial cracking of the formed tars and hence a gas with low tar content is produced (Patra & Sheth, 2015). Fig. 1 show the big scale of downdraft gasifier design.



**Fig. 1 Downdraft Gasifier Design (Jankes et al. 2012)**

## **METHODOLOGY**

### **3.1 Design and Drawing**

SolidWorks 2014 software is used to draw and design the model laboratory scaled downdraft gasifier. The parts needed to build is hopper, throat, combustion zone, reduction zone, grate and gas outlet. These parts were studied and analysed based on the other reserachers (Reed & Das, 1988; Patra & Sheth, 2015 and Jankes et al. 2012).

### **3.2 Fabrication Process**

The process of fabrication of the gasifier involve cutting, turning and welding as the joining process. Material selected for gasifier's body is mild steel because of its thermal conductivity and high melting point which is 1600 °C. The fabricated parts, rubber hose, air blower and galvanized pipe were assembled at FKM's welding workshop.

### **3.3 Experiment Setup**

A downdraft gasifier model was designed for 3 kilogrammes capacity. Rubber wood size used as biomass fuel ranging between 30 mm to 35 mm. The amount of small rubber wood is burned in the reactor first

to get small combustion and flame. The remaining rubber wood was weighed using weighing scale before being filled into the gasifier and left to burn at full capacity. Air is supplied with air blower at highest speed. Air velocity was measured with anemometer and recorded. The gases produced left the reactor through the upper section, and a thermocouple was installed near the gas outlet to monitor the temperature of the exit gas. The temperature was taken for every 20 minutes. Fig. 2 shows the full setup for this experiment. At the end of experiment, the gasifier was cleaned to remove tar, ashes and unburnt wood inside the reactor. A size 30 spanner was used to loosen all the bolts located around the lower lid and tighten it all back after cleaning process was completed. The following equipment such as thermocouple, air blower, anemometer, spanner, weighing scale and a lighter during the proceses of gasification.

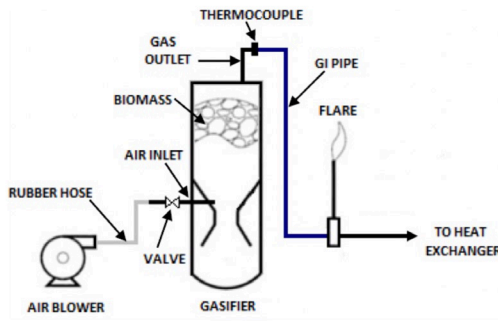


Fig. 2 Experiment Set up

## RESULTS AND DISCUSSION

### 4.1 Drawing Result

Downdraft gasifier's model have internal and outer diameter of 0.2 m and 0.21 m. The height of the fuel hopper was 0.25 m and can be filled with 3 kilograms of rubber woodchip at full capacity. Reduction zone was designed with height of 0.05 m and the diameter of 0.1 m. The combustion zone on the other hand has the height of 0.04 m and diameter of 0.08 m. Air inlet and gas outlet have the diameter of 0.03

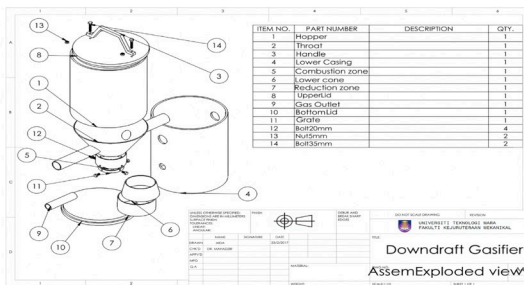
m and 0.02 m respectively.

Having high throat angle will decrease temperature, conversion efficiency and reaction rate. Therefore, smaller angles are appropriate but the downdraft gasifier model also needs longer gasification zone length to react efficiently. So in this design, the height of the throat was 0.1 m, the upper throat diameter was 0.2 m and the lower throat diameter was 0.08343 m. The throat angle was inclined 59.04°. These dimensions were chosen according to Reed and Das, 1988.

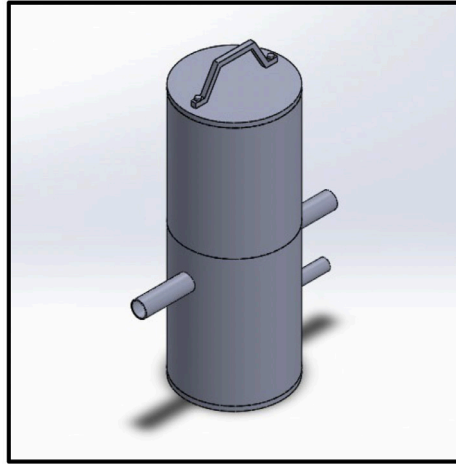
Grate height also need to be considered so that it will not block char in downdraft gasifier because blocked grate will block the flow of air and reducing the temperature area of the throat. 0.01 m height grate was positioned

0.03 m below the lower throat section and 0.140 m from the lower lid. The ash from reaction chamber could fall down freely through the grate, therefore, the char in downdraft gasifier will not be blocked.

Overall, this gasifier design is approximately 0.5 metre height with 0.21 metre diameter. The size of gasifier was reduced to reduce some low temperature zone that appear in the throat zone that will result in a rise of tar content in producer gas. The drawing of all parts are shown in Fig. 3. The isometric view of the gasifier are shown in Fig. 4.



**Fig. 3 Downdraft Gasifier Exploded View**



**Fig. 4 Isometric View**

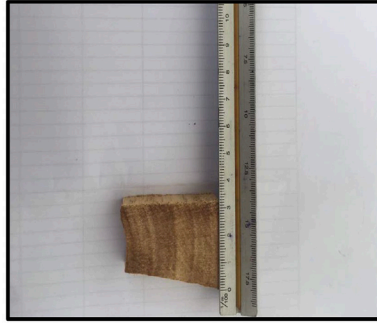
## 4.2 Experiment

In these experiments, rubber wood is used as a feedstock for the gasification. It is a renewable source of energy and easily available at large scale in Malaysia. The wood is in block sized and it has to be cut into smaller pieces ranging between 0.030 m to 0.035 m as can be seen in Fig. 5. Small amount of rubber wood was added into the gasifier to start a small combustion before the gasifier was filled with the rest of the biomass and left to burn with full capacity. It was observed that the average lab-scaled gasification process duration is approximately 2 hours for a batch-load of 3 kilograms of rubber wood. The gasifier is sealed tightly and the gasifier is let to run for about 15 minutes to make sure that the combustion of wood inside the reactor is stable. The composition of producer gas derive from a downdraft gasification process which was determined by Gas Chromatograph is presented in Table 1. It was found that the result obtained was approximately similar to producer gas result published by Mahadzir, 2012.

An initial indication of suitability of producer gas to be used was determined by flare test. Fig. 6 is photographs of the flare test showing during operation of the gasifier. It was observed that producer gas flared



with a blue flame without any smoke. This proves that the producer gas produced is flammable.



**Fig. 5 A piece of rubber wood**

**Table 1. Producer gas Composition**

	Producer gas composition (% vol) at 30 min					LHV (MJ/Nm <sup>3</sup> )
	H <sub>2</sub>	N <sub>2</sub>	CO	CO <sub>2</sub>	CH <sub>4</sub>	
Authors	12.57	51.73	21.89	12.52	1.3	4.58
Mohd Mahadzir Muhammad, 2012	13.11	52.98	20.36	12.08	1.47	4.51



**Fig. 6 Flare Test**

## CONCLUSION

The design and develop of the model scaled downdraft gasifier has been carried out. The lab model scaled based on the design, drawing and actual test were managed to be produced. Overall height is 0.58 m and the outer diameter 0.21 m. The hopper was designed to have the maximum capacity of 3 kilograms of feedstock. Throat was considered into this gasifier because it allowed maximum mixing of gases in high temperature region which aids

in tar cracking. Throat angle is designed to be  $59.04^\circ$  and have the length of 0.11662 m because smaller angles required a longer gasification zone length to reach optimum efficiency. The grate height is increased so that it does not block with char in downdraft gasifier. This model can be used as a laboratory teaching and learning tools for STEM education where the younger generation can understand more about renewable energy especially the field of biomass and producer gas.

## **ACKNOWLEDGEMENTS**

Authors would like to express our gratitude to Universiti Teknologi MARA for supported by giving the grant 600-IRMI/DANA 5/3/ARAS (0138/2016) and also to Fakultas Keguruan dan Ilmu Pendidikan, Universitas Pattimura, Indonesia for the short collaboration, thanks you.

## REFERENCES

- Chawdhury, M. A. (2011). Development of a Small Downdraft Biomass Gasifier for Developing Countries. *Journal of Scientific Research*, 3.
- Chinedu, C.C.; Kamin, Y. and Olabiyi O. S. (2015). Strategies for Improving Higher Order Thinking Skills in Teaching and Learning of Design and Technology Education. *Journal of Technical Education and Training (JTET)*, 7(2), 35-43.
- Corella J, Herguido J, Toledo JM, Gomez-Cívicos JI. Modelling fluidized bed biomass gasifiers: Part II. Gasification with steam in a bubbling fluidized bed. In: Kyritsis S, et al., editors. 1st World Conference on biomass for energy and industry, vol. 2. London, UK: James and James (Science Publishers), p.1971-5, 2001
- International Energy Agency (2019). Renewables 2018: Market analysis and forecast to 2023. IEA Publications Jankes G. G. et al.(2012). Biomass Gasification with CHP Production. A Review of the State-of-the-Art Technology and Near Future Perspectives. *Thermal Science*, 16, S115-S130.
- Kerka, S. (1992). Higher order thinking skills in vocational education: ERIC Clearinghouse.
- Lapuerta M, Hernández JJ, Pazo A, López J. Gasification and co-gasification of biomass wastes: effect of the biomass origin and the gasifier operating conditions. *Fuel Processing Technology*, 89:8 28 – 37.
- Lopez, J., & Whittington, M. S. (2001). Higher-order thinking in a college course: A case study. *NACTA JOURNAL*, 45(4), 22-29.
- Ministry of Education of Malaysia (2013). Malaysia Education Blueprint 2013-2025 (Pre-School to Post- Secondary Education). Putrajaya: Ministry of Education.

Patra, T. K. and Sheth, P. N. (2015). Biomass gasification models for downdraft gasifier: A state-of-the-art review.

Renewable and Sustainable Energy Reviews, Elsevier, 50(C), 583-593.

Rajendran, N., & Idris, P. U. P. S. (2008). Teaching & Acquiring Higher-Order Thinking Skills: Theory & Practice: Penerbit Universiti Pendidikan Sultan Idris.

Reed, T B, and Das, A. (1988). Handbook of biomass downdraft gasifier engine systems. United States. doi:10.2172/5206099.

Warnecke R (2000). Gasification of biomass: comparison of fixed bed and fluidized bed gasifier. Biomass and Bioenergy, 18(4) 89–97.

Mohd Mahadzir Muhammad (2012). Enhancement of producer gas quality through CO<sub>2</sub> absorption using CaO- sand mixture in a fluidized bed reactor. Ph.D Dissertation, Universiti Sains Malaysia.