

PAPER • OPEN ACCESS

Influence of Different Materials on the Mechanical Aspects in the Design of Cyclone Gasifier

To cite this article: C. Y. Khor *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **743** 012008

View the [article online](#) for updates and enhancements.

You may also like

- [A user-centered, iterative engineering approach for advanced biomass cookstove design and development](#)
Ming Shan, Ellison Carter, Jill Baumgartner et al.
- [Modelling and simulation of a Single Cyclone for Optimal Efficiency for a Batch-Type Fixed-Bed Down-Draft Gasifier using CFD](#)
S. J. Aliyu, E. L. Kucha and S. J. Ibrahim
- [Design and implementation of a laser-based absorption spectroscopy sensor for in situ monitoring of biomass gasification](#)
David Viveros Salazar, Christopher S Goldenstein, Jay B Jeffries et al.



The Electrochemical Society
Advancing solid state & electrochemical science & technology



249th
ECS Meeting
May 24-28, 2026
Seattle, WA, US
Washington State
Convention Center

Spotlight Your Science

**Submission deadline:
December 5, 2025**

SUBMIT YOUR ABSTRACT

Influence of Different Materials on the Mechanical Aspects in the Design of Cyclone Gasifier

C. Y. Khor¹, M. A. M. Nawi¹, Muhammad Ikman Ishak¹, Z. X. Wei¹ and M. U. Rosli¹

¹Simulation and Modelling Research Group (SimMReG), Faculty of Engineering Technology, Universiti Malaysia Perlis (UniMAP), Kampus UniCITI Alam, Sungai Chuchuh, Padang Besar, 02100 Perlis Indera Kayangan, Malaysia.

Email: cykhor@unimap.edu.my

Abstract. Cyclone gasifier is used as the energy conversion system for the biomass. The design and material selection for the cyclone gasifier is important, which affect the strength of the gasifier during the operation. This research aims to investigate the effect of the various materials to the mechanical aspects (i.e., stress, strain and displacement) of the cyclone gasifier. The mechanical aspects analysis is carried out by using the finite element (FE) based software. The stress, strain and displacement of the cyclone gasifier's structure was analyzed for various stainless steel materials (i.e., ferritic (FSS), AISI 316, 1023 CSS, 201 ASS and AISI 4130). The finite element analysis revealed the use of 201 ASS experienced highest stress (221 MPa). Lowest strain and displacement were found on 201 ASS and 1023 CSS, respectively. These research findings are expected to be used as the reference for the engineer in the material selection process for the design and fabrication of cyclone gasifier.

1. Introduction

The gasification system is an alternative way to convert the biomass or organic matter to the renewable energy. At the same time, it's also beneficial to the environment sustainable. In the energy conversion process, the gasifier may experience high temperature, mechanical and thermal stress on the gasifier's structure. Prior to the fabrication of the cyclone gasifier, the design and material selection are crucial to ensure the safety and functionality during the operation. A conventional trial-and error method is costly and time consuming in the design analysis process. Thus, simulation technique is an alternative way to tackle these problems. In the simulation modelling, various techniques like computational fluid dynamics [1,2], finite element analysis [3,4] and coupling of both finite element and finite volume method [5] can be applied to various engineering problems.

Recent years, the simulation techniques are widely applied in solving various engineering problems such as conventional and molded underfill process [6,7], integrated circuit (IC) encapsulation process [8], reflow soldering process [9,10], airflow analysis in the reflow oven [11] and fluid-structure interaction problems [12,13]. Besides, the simulation analysis also applicable to predict the structural problems in of the cyclone gasifier [14]. During the gasification process, the pressurized airflow enters the compartment and the structure may impose with a specific pressure. Cyclone gasifier is classified as the entrained-flow bed gasifier, which could produce low CH₄ syngas and free of tar [15]. The unburned particles are separated from the syngas when passing through the cyclone gasifier. Thus, the cyclone gasifier saves the operating cost for the cleaning of the syngas. Moreover,



the air flow characteristics in the gasifier were investigated via computational fluid dynamics on various types of gasifier [16-18].

The understanding of the mechanical aspect is crucial in the design process of the cyclone gasifier before the fabrication process. Many factors such as material selection, operating condition and physical design [14] may influence the reliability and functionality of the cyclone gasifier. Besides, the cyclone geometry is one of the significant factors to affect the internal airflow performance [19]. In the design process, the engineer needs the preliminary information as the input to design the cyclone gasifier. The preliminary information of the cyclone gasifier provides the reference to the engineer to select the most suitable material for the structure of cyclone gasifier. The current study is the extension of our previous work [14]. The finite element based [20-22] simulation is applied to explore the mechanical aspects [23] of the structure of cyclone gasifier when using different materials for its structure. The mechanical aspects which are stress, strain and displacement of each material are compared.

2. Methodology

This study was focused on the study of different materials towards the mechanical aspects of the cyclone gasifier. A similar cyclone gasifier model and finite element method were adapted from our previous work [14]. The 3D cyclone gasifier model was simulated in the finite element based software to study the stress, strain and displacement of the structure when different materials are applied. The cyclone's dimension and design are depicted in Figure 1.

- i. Cyclone inlet height, D_i (0.210 m)
- ii. Inlet width, D_i (0.210 m)
- iii. Gas outlet (vortex finder) diameter, D_e (0.18 m)
- iv. Length, S (1.90 m)
- v. Barrel height, h (1.50 m)
- vi. Total height, H (5.00 m)
- vii. Cone-tip diameter, B (0.18 m)
- viii. Body diameter, D (0.445 m)

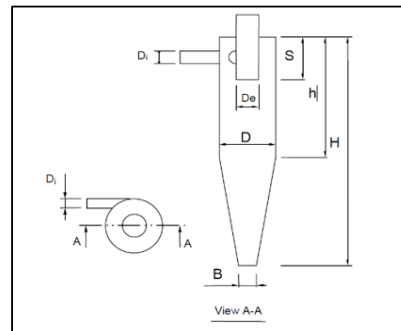


Figure 1. Dimension of the cyclone gasifier [19].

Five different materials were considered for the analysis, which are ferritic stainless steel (FSS), AISI 316 stainless steel (AISI 316), 1023 carbon stainless steel (CSS 1023), 201 annealed stainless steel (ASS 201) and AISI 4130 stainless steel (AISI 4130). The materials are applied to the structure of the cyclone gasifier as shown in Figure 1. During the simulation, the internal pressure was applied on the compartment of the cyclone (Figure 2), which mimic the internal pressure during the operation. The stress, strain and displacement will be analyzed on the critical location for five different materials.

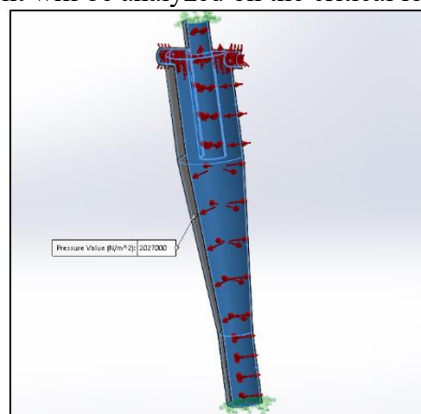


Figure 2. Pressure distribution in the cyclone gasifier [14].

3. Results and Discussion

Figures 3-5 depict the results from the mechanical aspects, which are maximum stress, strain and displacement of the cyclone's structure using various materials. The results demonstrate the variation of the mechanical aspects when different materials were applied to the cyclone structure. The use of CSS 1023 and AISI 4130 yields lowest stress that imposed to the cyclone, with only 217 MPa compared to other materials. However, 201 annealed stainless steel shows the highest stress (221 MPa) amongst the five types of material. In terms of strain, ASS201 has the lowest value of strain and AISI 4130 shows the highest strain during the operation. Moreover, the results revealed CSS1023 yields the lowest displacement, which means the cyclone's structure has better rigidity and resist to the deformation compared with AISI4130.

From the results, CSS1023 demonstrates the good mechanical aspects amongst the materials with lower stress and displacement. In addition, CSS1023 has the excellent machinability with reasonable strength. CSS1023 is easy to form and it is cheaper compared to the other steels. Thus, it is suitable for the fabrication of the cyclone gasifier. From the consideration of the mechanical aspects, CSS1023 is recommended for the fabrication of the cyclone gasifier. On the other hand, other approaches such as Analytical Hierarchy Process (AHP) [24, 25] and ELETRE methods can be also applied to select the material and process for the fabrication of the gasifier.

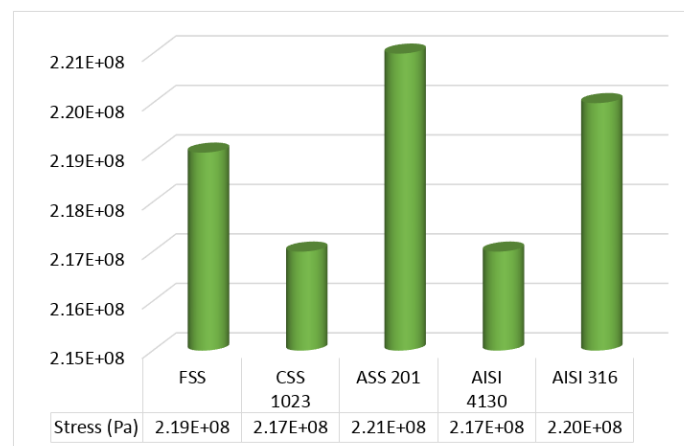


Figure 3. Maximum stress versus different materials.

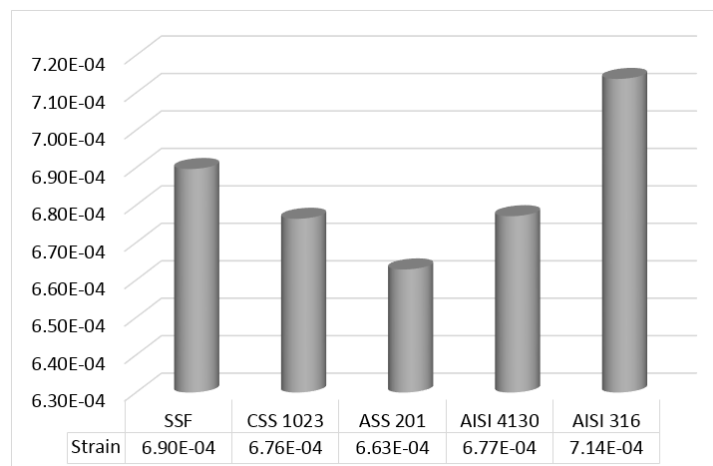


Figure 4. Maximum strain versus different materials.

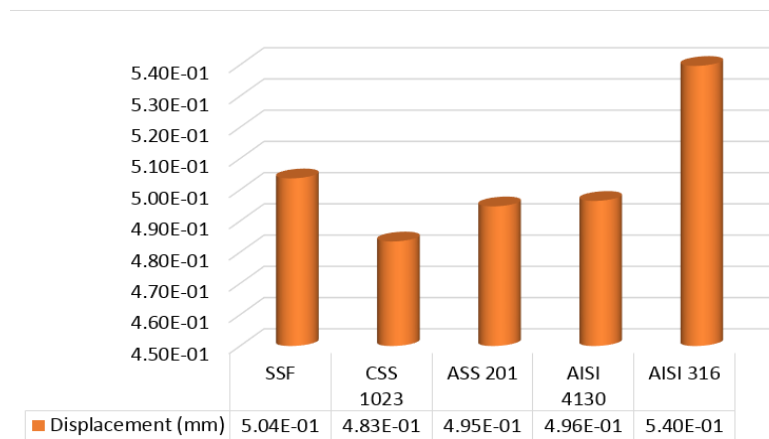


Figure 5. Maximum displacement versus different materials.

4. Conclusion

The study of mechanical aspects of cyclone gasifier with different materials has been carried out in a FE based simulation. The results indicated that the selection of material significantly affects the mechanical aspects of the cyclone gasifier. Improper material selection will result in the higher stress concentration, strain and deformation, which lead to the safety issue when the gasifier operates. The top of the cyclone was a critical region and it can be minimized by increasing the physical design parameter of the cyclone. The simulation results revealed the use of CSS1023 resulted in low stress (217 MPa) and displacement (0.483 mm) and it is also machinability. With these characteristics, CSS1023 is suitable for the fabrication process of cyclone gasifier. The current results are expected to be used as the reference for the material selection and design of cyclone gasifier. Moreover, the application of simulation modelling technique provides better understanding of fundamental knowledge and also effectively reduces the time to market and cost in the fabrication process.

References

- [1] Abdul Aziz M S, Abdullah M Z, Khor C Y, Iqbal A M and Che Ani F 2014 *International Journal of Heat and Mass Transfer* **72** 400-410.
- [2] Khor C Y, Abdullah M Z, Majid M F M A, Mujeebu M A, Abdullallah M K and Ariff Z M 2010 *Heat and Mass Transfer* **46** 1315-1325.
- [3] Khor C Y and Abdullah M Z 2012 *Simulation Modelling Practice and Theory* **29**, 109-122.
- [4] Ramdan D, Abdullah M Z, Khor C Y, Leong W C, Loh W K, Ooi C K and Ooi R C 2012 *IEEE Transactions on Components Packaging and Manufacturing Technology* **2**(11) 1786-1795.
- [5] Ong E E S, Abdullah M Z, Khor C Y, Loh W K, Ooi C K and Chan R 2014 *Microelectronic Engineering* **113**(1) 40-49.
- [6] Khor C Y and Abdullah M Z 2013 *Microelectronics Reliability* **53** 334-347.
- [7] Khor C Y, Abdullah M Z, Lau C-S, Leong W C and Abdul Aziz M S 2014 *Microelectronics Reliability* **54** 796-807.
- [8] Ong E E S, Abdullah M Z, Khor C Y, Loh W K, Ooi C K and Ooi R C 2012 *International Communications in Heat and Mass Transfer* **29**(10) 1616-1623.
- [9] Lau C-S, Abdullah M Z and Khor C Y 2013 *Microelectronics International* **30**(3) 151-168.
- [10] Lau C-S, Khor C Y, Soares D, Teixeira J C and Abdullah M Z 2016 *Soldering & Surface Mount Technology* **28** 41-62.
- [11] Najib A M, Abdullah M Z, Khor C Y and Saad A A 2015 *International Journal of Heat and Mass Transfer* **87**, 49-58.
- [12] Leong W C, Abdullah M Z and Khor C Y 2012 *Microelectronics Reliability* **52** 744-756.
- [13] Abdul Aziz M S, Abdullah M Z, Khor C Y, Fairuz Z M, Iqbal A M, Mazlan M and Rasat M S M 2014 *Advances in Mechanical Engineering* **2014** 275735.

- [14] Wei Z X, Khor C Y, Rahim W M F W A, Razak N A, Ishak M I, Rosli M U, Jamalludin M R, Nawi M A M and Zakaria M S 2018 *AIP Conference Proceedings* **2030** 020047.
- [15] Henrich E, Dahmen N and Niebel A 2015 *BioBoost Report* 1-38.
- [16] Kumar U and Paul M C 2019 *Chemical Engineering Science* **195** 413-422.
- [17] González W A and Pérez J F 2019 *Energy* **186** 115904.
- [18] Luo H, Lin W, Song W, Li S, Dam-Johansen K and Wu H 2019 *Fuel Processing Technology* **195** 106146.
- [19] Singh P, Couckuyt I, Elsayed K, Deschrijver D and Dhaene T 2016 *Applied Mathematical Modelling* **40** 4248-4259.
- [20] Jizat N M, Mohamad S N and Ishak M I 2017 *AIP Conference Proceedings* **1885** 020126
- [21] Ishak M I, Ahmad Shafi A, Abdul Kadir M R and Sulaiman E 2017 *Journal of Medical and Biological Engineering* **37**(3) 336-344
- [22] Ishak M I, et al. 2017 *MATEC Web of Conferences* **97** 01040
- [23] Tan J S, Khor C Y, Rahim W M F W A, Ishak M I, Rosli M U, Jamalludin M R, Zakaria M S, Nawi M A M, Abdul Aziz M S and Che Ani F 2017 *AIP Conference Proceedings* **1885**, 020063.
- [24] Rosli M U, Jamalludin M R, Khor C Y, Ishak M I, Jahidi H, Wasir N Y, Faizal W M, Wan Draman W N A, Lailina N M, Ismail R I 2017 *MATEC Web Conf.* **97**, 01039.
- [25] Luqman M, Rosli M U, Khor C Y, Zambree S, Jahidi H 2018 *IOP Conf. Series: Materials Science and Engineering*, **318**, 2018, 012058.