Fabrication and Performance Evaluation of Inclined Screw Feeder for Feedstock Feeding in Downdraft Gasifier System

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Abstract - **In recent years, biomass gasifier based power plant is got increasing attention worldwide. Biomass feedstock is fed into the gasifier manually via the hopper. This feeding method is ineffective when the gasifier is operated continuously. Thus, it is important to develop automatic feeding system to feed the feedstock into the gasifier. The present work aims to design and develop an inclined screw type feeder for small scale downdraft gasifier system. The screw feeder is tested using a feedstock of rice husk. The screw feeder has a design capacity of 40 kg/h, feedstock velocity of 0.025 m/s, screw diameter of 139.8 mm, and total length of 2995 mm. The screw feeder is driven by 2 HP electric motor. From performance test, it can be figured out that the screw has an actual capacity of 30 kg/h with feedstock velocity of 0.005 m/s. In overall, it can be stated that the screw feeder can be used successfully to feed the rice husk feedstock into the downdraft gasifier during 8 hours continuous operation.**

Keywords: Feeder; gasifier; inclined; rice husk; screw

I. INTRODUCTION

Development of biomass gasification based power plant is got more attention in recent years. Biomass energy is still a primary world's energy source, biomass energy supplied about 1/7 of the world energy demands [1]. Indonesia itself has biomass energy potential about 33 GW [2]. Biomass gasification is a thermochemical process that converting solid biomass energy into producer gas fuel by means sequence processes in the gasifier reactor [3]. Combustion of producer gas is cleaner than direct combustion of solid biomass [4]. According to flow direction between producer gas and feedstock in the reactor, gasifier is divided into downdraft gasifier, updraft gasifier, and cross-draft gasifier [5, 6].

In developing biomass gasifier based power plant, feeding system has to be taken into account in designing the system. The feeding system feeds the feedstock into gasifier during the process. The feeding system has to be able to operate continously, since the power plant operates continously. Common feeding system used was hopper at the top of the gasifier's reactor [7-10]. The continous operating time of this system is limited by size of the hopper. The bigger the hopper's size, the longer the continous operating time. Other feeding systems have been reported sor far are pneumatic conveyor [11, 12]. This system is only suitable for grain size feedstock. However, there is no feeding system which able operate continously as well as suitable for larger size feeedstock, such as rice husk.

Thus, the present works aims to design and fabricate an inclined screw feeder for feeding system of downdraft gasifier. The work also investigate the performance of the screw in term of efficiency and slip. No proevious work regarding screw feeder for downdraft gasifier has been reported so far.

II. METHODOLOGY

The present work is divided into three parts, such as design, fabrication, and evaluation. Design and calculation of an inclined screw is performed based on the gasifier capacity and its continuous operation time. Fabrication is performed in local workshop in Yogyakarta. Meanwhile, the performance evaluation of the screw feeder is conducted at Laboratory of Manufacturer Institut Sains dan Teknologi AKPRIND.

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A. Design

In order to obtain proper design of the inclined screw feeder which suitable for the requirement, following primary design calculations are performed.

Feeding rate

$$Q = 60 \times \frac{\pi D^2}{4} \times S\, n\, \psi\, \gamma\, C \quad (1)$$

where D is the screw diameter, S is the screw pitch, n is rotation speed of the screw, ψ is the loading efficiency, γ is the bulk density of a feedstock, and C is the correction factor for inclined screw. ψ = 0.4 for non-abrasive material and C = 0.65 for inclination angle higher than 20º [13].

Input power

$$N_o = \frac{Q\, L\, \omega_0}{367}\left(\omega_0 + \sin\beta\right) \quad (2)$$

where Q is feeding rate, L is the screw length, ω_0 is the friction factor, and β is the inclination angle of the screw. For granular material, such as rice husk and sawdust, the ω_0 = 1.2 [13]

Feedstock velocity

$$V = \frac{S\, n}{60} \quad (3)$$

where S is the screw pitch and n is the rotation speed of the screw

Shaft diameter

$$d_s = \left[\frac{5.1}{\tau_a} \times K_t \times C_b \times T\right]^{\frac{1}{3}} \quad (4)$$

where τ_a is the shear stress of the shaft material, K_t is the twist correction factor, C_b is the bending correction factor, and T is the torque of the shaft.

Fig. 1 presents exploded view of the inclined screw feeder and the downdraft gasifier in the present work. The main components of the screw feeder are stand, electric motor, transmission, control panel, screw conveyor, hopper, and barrel. Downdraft gasifier consists of upper reactor and lower reactor. Meanwhile, detail drawing of the screw feeder and the gasifier are given in Fig. 2.

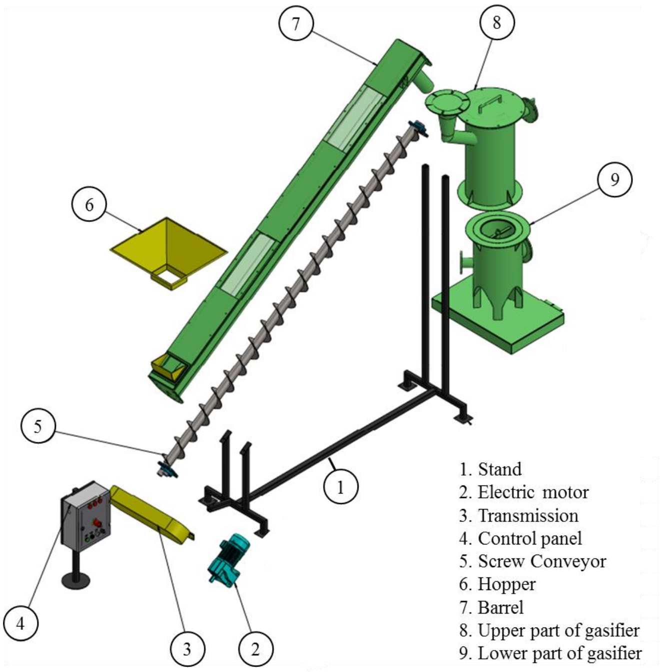

Fig. 1. Inclined screw feeder and downdraft gasifier

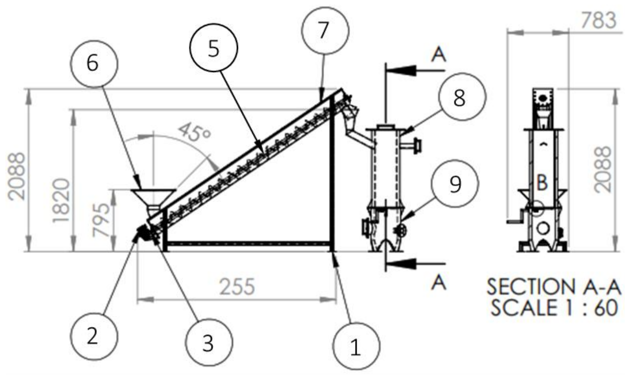

Fig. 2. Technical drawing (unit: mm)

B. Fabrication

The screw feeder is fabricated in local workshop in Yogyakarta. Fig. 3(a) and Fig 3(b) display the photographs during fabrication work.

Fig. 3(a). Photograph of fabrication work

Fig. 3(b). Photograph of fabrication work

C. Performance evaluation

Performance of the screw feeder is tested in Manufacturer Laboratory of Mechanical Engineering Department Institut Sains dan Teknologi AKPRIND. The test is conducted using feedstock of rice husk. The experimental setup for evaluating performance of the screw feeder is shown in Fig. 4. The test aims to figure out actual feeding rate, efficiency, actual feedstock velocity, and slip. Efficiency and slip of the screw are calculated using Eq. (5) and Eq. (6).

$$\eta = \frac{Q_{Actual}}{Q_{Design}} \times 100\% \qquad (5)$$

$$Slip = \left(\frac{v_{Design} - v_{Actual}}{v_{Design}}\right) \times 100\% \qquad (6)$$

Fig. 4. Experimental setup

III. RESULT AND DISCUSSION

Fig. 5 shows a comparison between design feeding rate and actual feeding rate. The design feeding rate is 40 kg/h and actual feeding rate investigated is 30 kg/h. By using Eq. (5), the efficiency of the screw feeder is found to be 83%. The efficiency of the screw indicates that some amount of the feedstock transferred flows back to the bottom part of the barrel and remain there during the transfer. This causes an efficiency of the screw. However, the performance of the screw is good since the efficiency is higher than 50%.

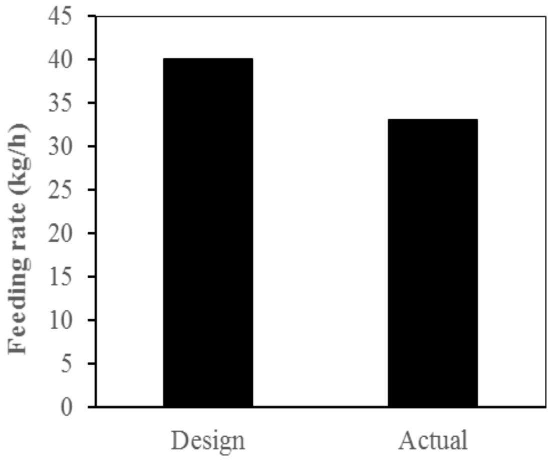

Fig. 5. Feeding rate

Meanwhile, Fig. 6 displays a comparison between design feedstock velocity and actual feedstock velocity. The design feedstock velocity is 0.025 m/s and actual velocity is found to be 0.005 m/s. Using Eq. (6), the slip of 0.8% occurs during the feeding of the rice husk from the hopper to the gasifier. However, the value is still under the design limit.

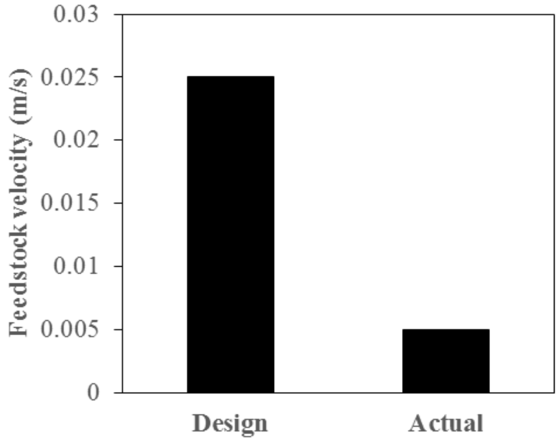

Fig. 6. Feedstock velocity

IV. CONCLUSSION

The inclined screw feeder for rice husk feeding into the downdraft gasifier has been design, fabricated, and tested in the present work. It can be concluded that the inclined screw feeder can operate properly to handling the rice husk feedstock during 8 hours continuous operation of the gasifier. The screw feeder has an efficiency of 83% and slip of 0.8%.

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REFERENCES

[1] T. Jain and P.N. Sheth, “Design of energy utilization test for a biomass cook stove: Formulation of an optimum air flow recipe”, Energy. 166, 2019, pp.1097-1105

[2] Perpres 22, "*Peraturan Presiden Republik Indonesia Nomor 22 Tahun 2017 tentang Rencana Umum Energi Nasional"* (Regulation of President of Republic of Indonesia Number 22 Year 2017 about National Energy Outlook), 2017

[3] P. Basu, "Biomass Gasification and Pyrolysis: Practical Design and Theory". Elsevier Inc, 2010

[4] J.J. Hernández, G. Aranda-Almansa, and A. Bul, "Gasification of Biomass Wastes in an Entrained Flow Gasifier: Effect of the Particle Size and the Residence Time". Fuel Processing Technology 91 (6), 2010, pp. 681–92

[5] F.M. Guangul, S.A. Sulaiman, R. Ramli, "Gasifier selection, design and gasification of oil palm fronds with preheated and unheated gasifying air," *Bioresour. Technol.*, vol. 126, 2012, pp. 224–232

[6] F. Vyarawalla, P.P. Parikh, H.C. Dak, B.C. Jain, "Utilisation of Biomass for Motive Power Generation - Gasifier Engine System," vol. 5, 1984, pp. 227–242

[7] P. N. Sheth and B. V. Babu, "Experimental studies on producer gas generation from wood waste in a downdraft biomass gasifier," *Bioresour. Technol.*, vol. 100, no. 12, 2009, pp. 3127–3133

[8] A. L. Galindo, E. S. Lora, R. V. Andrade, S. Y. Giraldo, R. L. Jaén, and V. M. Cobas, "Biomass gasification in a downdraft gasifier with a two-stage air supply: Effect of operating conditions on gas quality," *Biomass and Bioenergy*, vol. 61, 2014, pp. 236–244.

[9] J. D. Martínez, E. E. Silva Lora, R. V. Andrade, and R. L. Jaén, "Experimental study on biomass gasification in a double air stage downdraft reactor," *Biomass and Bioenergy*, vol. 35, no. 8, 2011, pp. 3465–3480.

[10] Z. A. Zainal, A. Rifau, G. A. Quadir, and K. N. Seetharamu, "Experimental investigation of a downdraft biomass gasiÿer," vol. 23, 2002, pp. 283–289.

[11] S. J. Yoon, Y.-I. Son, Y.-K. Kim, and J.-G. Lee, "Gasification and power generation characteristics of rice husk and rice husk pellet using a downdraft fixed-bed gasifier," *Renew. Energy*, vol. 42, 2012, pp. 163–167

[12] G. Teixeira, L. Van De Steene, E. Martin, F. Gelix, and S. Salvador, "Gasification of char from wood pellets and from wood chips : Textural properties and thermochemical conversion along a continuous fixed bed," *Fuel*, vol. 102, 2012, pp. 514–524.

[13] Prameswari, "*Perencanaan Ulang Mesin Pembersih Pasir Menggunakan Screw Conveyor Dengan Kapasitas 17 Ton/Jam",* (Design of Sand Cleaner Machine Using Screw Conveyor with Capacity of 17 ton/h), 2018, pp. 1–88.