Preface: 4th International Conference and Exhibition on Sustainable Energy and Advanced Materials 2015 (ICE-SEAM 2015)

Dear Distinguished Delegates and Guests,

On behalf of the Organizing Committees, I warmly welcome you to the 4th International Conference and Exhibition on Sustainable Energy and Advanced Materials 2015 (ICE-SEAM 2015), held on November 11, 2015 in Solo, Indonesia. This conference is hosted by Sebelas Maret University (UNS), Indonesia and jointly organized by Universiti Teknikal Malaysia Melaka (UTeM), Malaysia, Brawijaya University, Indonesia and Diponegoro University, Indonesia. The theme of the ICE-SEAM 2015 conference is **"Energy Efficient and Advanced Material for Sustainable Development"**.

The aims of this joint conference are to increase internationalization activities and enhance collaborative relationships between universities, disseminate information, technology, engineering, performance and the latest scientific discoveries in the field of engineering at the international level and provide information and exposure to the industry and other institutions on the progress and opportunities for collaboration in research and consultancy hence strengthen networking between academicians, scientists, engineers and technologists at regional and international levels.

More than 85 papers were submitted to ICE-SEAM 2015 and around 69 papers are accepted for the conference after peer reviewed by reviewers drawn from the scientific committee, external reviewers and editorial board depending on the subject matter of the paper. Reviewing and initial selection were undertaken electronically. After the peer-review process, the submitted papers were selected on the basis of originality, significance, and clarity for the purpose of the conference.

We would like to thank the Rector of UNS for financial supporting, the keynote speakers, the program chairs, organization staff, the members of the committees and our sponsors for their work. Thanks also go to all those who have contributed to the success of ICE-SEAM 2015.

Hopefully, all participants and other interested readers benefit scientifically from the conference.
We hope all of you have a unique, rewarding and enjoyable week at ICE-SEAM 2015 in Solo.

With our warmest regards,
Dr. Triyono
Solo, Indonesia
November 11, 2015

Sustainable Energy and Advanced Materials
AIP Conf. Proc. 1717, 010001-1–010001-1; doi: 10.1063/1.4943422

Design of drying chamber and biomass furnace for sun-biomass hybrid rice-drying machine

Dhimas Satria, Haryadi, Ruben Austin, and Bobby Kurniawan

Citation: AIP Conference Proceedings **1717**, 050015 (2016); doi: 10.1063/1.4943490
View online: http://dx.doi.org/10.1063/1.4943490
View Table of Contents: http://scitation.aip.org/content/aip/proceeding/aipcp/1717?ver=pdfcov
Published by the AIP Publishing

Design of Drying Chamber and Biomass Furnace for Sun-Biomass Hybrid Rice-Drying Machine

Dhimas Satria[1, a)], Haryadi[2, b)], Ruben Austin[3, c)] and Bobby Kurniawan[4, d)]

[1]*Mechanical Engineering Department, University of Sultan Ageng Tirtayasa, Indonesia*
[2]*Industrial Engineering Department, University of Sultan Ageng Tirtayasa, Indonesia*
[3]*Mechanical Engineering Center, University of Sultan Ageng Tirtayasa, Indonesia*
[4]*Laboratory of Production System, University of Sultan Ageng Tirtayasa, Indonesia*

[a)]*Corresponding author: dhimas@untirta.ac.id*
[b)] *haryadi@untirta.ac.id*
[c)]*rubenaustinhart@gmail.com*
[d)]*b.kurniawan@untirta.ac.id*

Abstract. In most Asian countries, rice drying is carried out manually by exposing rice to sunlight. However, problem occurs when rain season comes. Lack of sunlight deters the drying process. This paper proposes a design of mechanical rice drying machine with hybrid sun-biomass energy source. Pahl & Beitz method, which consists of four steps process: function planning and clarification, design concept, design prototype, and design details; are used as design methodology. Based on design result and calculation, in this paper propose specifications for drying machine and biomass furnace. Drying chamber is a continuous flow system with pneumatic-conveyor as blower. This hybrid utilizes two types of energy sources, sun and biomass. The proposed machine has capacity of 500 kilograms per cycle using 455 Watt of energy, which is more efficient than ordinary heater. Biomass furnace utilizes heat transfer by means of arranging 64 pieces of stainless steel pipes of 0.65 diameters in parallel.

INTRODUCTION

Indonesia is one of agrarian country in Asia. Most of its people work as farmers or land hard harvesters. Rice is a commodity that commons as staple food. To anticipate populations grow, it is required to increase food stock by enhancing its production capacity and quality. Most farmers dry the rice manually by exposing it to sunlight. One of the problems commonly faced by this method is lack of sunlight when rain season comes. Moisture level of rice must below 20 % in order high quality of rice is produced. As a result, farmers must sell rice at lower price because of its quality is undesired [4]. Other consequences caused by imperfection of drying process are: unremoved germ, the color of the rice changes from white to yellow, sprout can thrive in rice, and even rice decay as an unavoidable post-harvest loss [10].

In order to tackle the problems mentioned above, this paper proposes a design of hybrid drying machine for rice drying process, which constitutes of drying chamber as a location to place rice in drying process and biomass furnace that serves as heater. The design of chamber and furnace is developed using Pahl & Beitz method [7]. Moreover, material transfer is conducted by pneumatic conveyor as an improved version of tube dryer [10]. Hybrid in our design is a combination of two energy sources, i.e. sun and biomass energy. In dry season, the machine can be powered by sun or biomass to produce heat whereas in rain season drying process still can be processed by biomass energy only. Pneumatic conveyor is designed to make recirculation happen in material transfer process so that drying process can be uniform. The proposed drying machine uses cross counter flow model. In this model, rice and air heater move concurrently in order rice can be dried uniformly [9]. The results of this paper are expected this machine can help farmers to tackle drying process problem in rain season.

Sustainable Energy and Advanced Materials
AIP Conf. Proc. 1717, 050015-1–050015-7; doi: 10.1063/1.4943490

A BRIEF DESCRIPTION ABOUT DRYING MACHINE

Drying is preservation method by mean of reducing water content from rice so that rice can be preserved last longer. Improving shelf life of rice by drying could prevent micro-organism activity because it needs much water in its environment to support its activity [6]. As in [5], drying also can be viewed as an operation where heat and mass transfer occurs.

Drying decreases water content of rice and prevents the growth of microbe, fungi, and other harmful miro-organism. In addition, drying also lessens rice volume hence less storage and distribution cost can be made more efficient. The combination of time and temperature during drying process on cereal products mostly conducted in order to avoid husk decay. Temperature, humidity, air flow, and initial water content are several factors that affect drying time [1].

Cross counter flow drying mechanism is used in this proposed design. This mechanism allows greater flexibility in process automation operations, such as loading, drying, cooling and unloading. All operations from loading rice to chamber until drying is completed can be done efficiently in terms of number of workers involved in drying process [8].

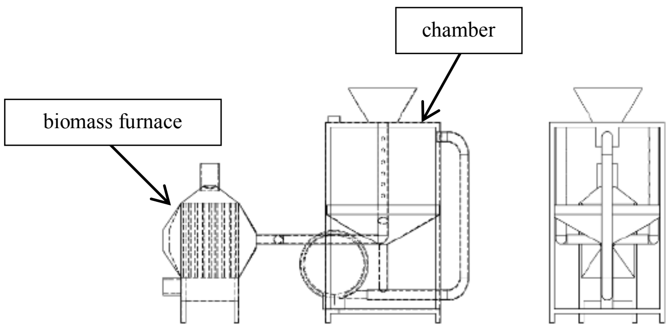
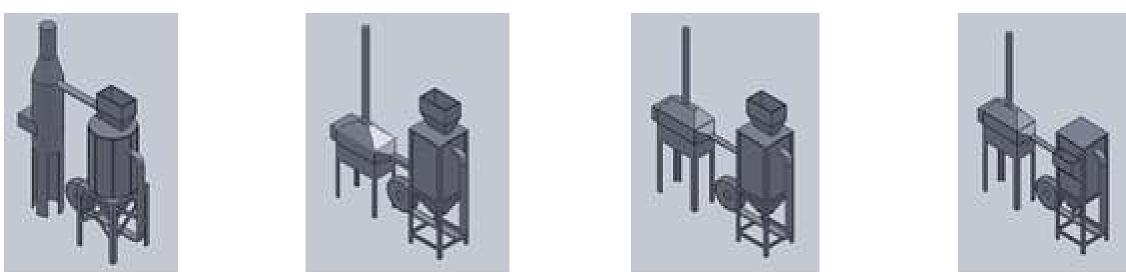


FIGURE 1. Sun-biomass hybrid machine for drying process.

DESIGN AND CALCULATION OF HYBRID DRYING MACHINE

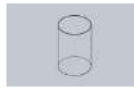
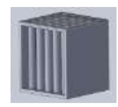
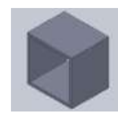
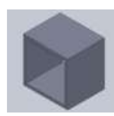
Figure 1 shows the design drawing of drying machine. It consists of drying chamber and biomass furnace. Pahl & Beitz method, which consists of four steps process: function planning and clarification, design concept, design prototype, and design details; are used as design methodology. The first step is to define and determine the shape and functions of parts composing the drying chamber and biomass furnace. Two alternatives of parts are presented in column A and B.



(a) Variant 1 (b) Variant 2 (c) Variant 3 (d) Variant 4

FIGURE 2. Several alternatives of drying machine design.

TABLE 1. Solution and principle of parts

No	Solutions \ Priciple	A	B
1.	Chamber shape		
2.	In Hopper	 Top hopper	 Side Hopper
3.	Out Hopper	 Hopper centered in the middle	 Hopper tilted to the side
4.	Heat Exchanger	 Horizontal line pipe	 Vertical line pipe
5.	Furnace	 Cylindrical	 Box
6.	Air Duct	 Box-shaped Ducting Inlet	 Cylindrical Ducting Inlet
7.	Gas Exhausting	1 chimney	2 chimney
8.	Ventilation Fan Shape	 Axial Fan	 Centrifugal Fan
9.	Exhausting Fan Shape	 Axial Fan	 Ventilator Turbine
10.	Manual Handling	 Ball roller	No ball roller

From the combination of solution and function in Table 1 this paper proposed four variants of drying namely Variant 1, Variant 2, Variant 3, and Variant 4, with easy for manufacturing considerations. The four variants solutions along with their respective functions can be seen in Table 2. This paper discusses briefly those variants below.

TABLE 2. Combinations of solutions and functions

Variant Name	Solution-function combination
1	1A – 2A – 3A - 4B – 5B – 6B – 7A – 8A – 9A – 10A
2	1B – 2A – 3A – 4A – 5B – 6A – 7A – 8A – 9A – 10A
3	1B – 2A – 3A – 4B – 5B – 6B – 7A – 8A – 9A – 10A
4	1B – 2B – 3B – 4B – 5B – 6B – 7A – 8A – 9B – 10A

Variants

Variant 1 has a concurrent flow model. Its furnace is cylindrical with cylindrical pipe heat exchanger vertically arranged. The deficiency of this variant is it is not easy to manufacture cylindrical shape of furnace because the wall is easy to break if bent. Moreover, heat would not spread uniformly in this design.

Variant 2 has a cross flow model. Its furnace is prism shaped with cylindrical pipe heat exchanger horizontally arranged. Ducting inlet has cubic shape. The deficiency of this variant is it generates less heat because heat air follow through horizontal pipe. Furthermore, heat would not spread uniformly in this design.

Variant 3 has a cross counter flow model. Its furnace is prism shaped with cylindrical pipe heat exchanger horizontally arranged. Ducting inlet has cubic shape. The advantage of this variant is it is not hard to manufacture than those of cylindrical ones. In addition, heat would spread uniformly in this design.

Variant 4 has a counter flow model. Its furnace is box shaped with cylindrical pipe heat exchanger horizontally arranged. Ducting inlet has cubic shape. The deficiency of this variant is heat produced would not spread uniformly in this design because air flow which moves from opposite direction will expose enormous pile of rice. In effect, pile of rice is not uniformly heated. Furthermore, unloading process more difficult to do because it has only one side sloping.

TABLE 3. Decision matrix

Criteria	Variant 1	Variant 2	Variant 3	Variant 4
Power (900 Watt)	REFERENCE DESIGN	S	S	S
Temperature generated (40 - 60^{o} C)		S	S	S
Capacity per cycle (500 kg)		S	S	S
Machine weight*		S	S	S
Polluted substances emitted*		S	S	S
Number of process*		S	S	S
Manufacturing time*		S	S	S
Assembly time*		S	S	S
Assembly operations*		S	S	S
Disassembly operations*		S	S	S
Disassembly time*		S	S	S
Number of components*		S	S	S
Non-standard tools*		S	S	-
Standard tools*		S	S	S
Temperature of electronic devices		S	S	S
Input and output system		+	+	-
%Reliability**		-	+	-
TOTAL (+)		1	2	0
TOTAL (-)		1	0	3
Total Score		0	2	-3

The next process in process design is to select the best variant using decision matrix in Table 3. The criteria used in the selection process are: power consumption, production capacity, machine weight, ease of manufacturing, ease of assembly, and reliability among others. In this selection process, Variant 3 is the best alternative design.

Technical Calculations of Drying Chamber and Biomass Furnace

In this section, this paper calculates technical specifications of drying chamber and biomass furnace for the selected Variant 3 design in previous section. The technical specifications are humidity level, air dryer capacity, mass and heat transfer, and total energy consumed.

Humidity Level

Humidity level (HL) is the difference of rice mass before and after drying process. It is also can be called water content distracted from rice. The data from experiment are as follow:

- Initial rice mass m_i is 500 kg.
- Initial water content before drying process (MC_{wb1}) is 25% (wb).
- Water content after drying process (MC_{wb2}) is 12% (wb).

Then calculate the ratio of water content before drying process to dry rice as

$$MC_{db1} = \frac{MC_{wb1}}{1 - MC_{wb1}} = \frac{0.25}{1 - 0.25} = 0.333 = 33{,}33\% \tag{1}$$

Calculate the ratio of water content before drying process to dry rice as

$$MC_{db2} = \frac{MC_{wb2}}{1 - MC_{wb2}} = \frac{0.12}{1 - 0.12} = 0.1364 = 13.64\% \tag{2}$$

Mass of rice without water content (m_{nw}) can be calculated as

$$MC_{db2} = \frac{m_i}{1 + MC_{wd1}} = \frac{500}{1 + 33.3\%} = 375.009\,\text{kg} \tag{3}$$

And mass of rice after drying process (m_f) is calculated by

$$m_f = m_{nw}\left(1 + MC_{db2}\right) = (1 + 13.64\%) * 375.009 = 426.16\,\text{kg} \tag{4}$$

Humidity level (HL) or water content distracted from rice by hybrid pneumatic-conveyor drying machine can be determined by

$$m_f = m_i - m_f = 500 - 426.16 = 73.84\,\text{kg} \tag{5}$$

Air Dryer Capacity

In order to make the drying machine be capable to hot the chamber uniformly, air dryer capacity (Q) is determined by

$$Q = vA = 0.09\left(0.8x1\right) = 0.07\,m^3/s = 4.32\,m^3/\min = 259.2\,\text{CMH} \tag{6}$$

where v is the speed of fan or blower and A is area of chamber. Note that v can be chosen arbitrarily and in this experiment the value of v is 0.09 m/s. Hence based on the calculation of air dryer capacity as in (6), the axial fan with capacity of 270 CMH is used in this machine.

Mass Transfer of Air Dryer

Mass transfer of air dryer in chamber is calculated at temperature 43^0. Hence the mass transfer occurs can be calculated as follow

$$m = Q\rho = 0.072\, m^3/s\, x 1.116\, kg/m^3 = 0.08 kg/s \tag{7}$$

Material Base for Chamber's Wall

Acrylic is chosen as material base for chamber's wall because it has several favorable properties for drying chamber, such as the following:

- High strength and durability.
- Easy to manufacture
- Low assembly cost
- Low material cost

Heat Exchange of Biomass Furnace

Technical design and specifications of biomass furnace are as follow:

- Material for furnace is stainless steel 201 pipes with dimensions 1 inch length and 1.5 mm thickness.
- Outer diameter of pipe is 0.0254 m.
- Inner diameter of pipe is 0.0239 m.
- Number of pipes is 64.

In heat exchanger process occurs in furnace, gas from environment, i.e. from outside furnace, is heated and compressed with axial fan using temperature data as follow:

- Environment temperature ($T_{c,i}$) is (24^0 C + 34^0 C)/2 = 29^0 C = 320 K
- $T_{c,o}$ is 60^0 C = 333 K
- $T_{h,i}$ is ranging from 200^0 C – 200^0 C (in this design 200^0 C or 473 K is used)
- Inner diameter of pipe is 0.0239 m.
- Fan speed (Vh) is designed at 1 m/s.

Based on calculation, the length of the pipe is 0.65 m and this design can endure against heat process because $Q_{transmission}$ (938.983 W) is less than $Q_{heat\ exchanger}$ (2,497.36) during process.

Total Energy Consumption

Energy used by this drying machine is to rotate blower (E_b), to rotate fan pushing heat air (E_{f1}), to rotate fan of biomass furnace (E_{f2}), and to rotate exhausting fan in chamber (E_x). Then, total energy consumed (E_t) by the drying machine is

$$E_t = E_b + E_{f1} + E_{f2} + E_x = 370 + 25 + 38 + 21 = 454 \text{ Watt} \tag{8}$$

CONCLUSIONS

Based on calculation results of hybrid pneumatic-conveyor drying machine, recommended specifications are as follow:

Drying Chamber Specifications:

- Design of drying chamber using cross counter flow.
- Biomass furnace is constructed box-shaped with cylindrical vertical-line pipe heat exchanger.
- Chamber dimension is 1,000 mm x 1,000 mm x 2,300 mm.
- Hopper, made from ST 37 steel plate and 2 mm thickness, has 30^0 inclined.
- Acrylic with transmissivity 83% and dimensions of 800 mm height and 1,000 mm width is used as chamber's wall.
- Machine frame is made from ST 37 steel elbow with 40 mm length, 40 mm width, and 4 mm height.
- Blower power is 370 Watt.

Biomass Furnace Specifications:

- Biomass furnace is design from arrangement of straight pipe heat exchanger in-line.
- Furnace dimension is 800 mm x 500 mm x 1,200 mm.
- Heat transfer mechanism is design by arranging 64 pieces of stainless steel 201 pipes 650 mm of diameter in parallel.
- A 270 CMH fan is used to blow hot air.

ACKNOWLEDGMENTS

The authors wish to thank LPPM Untirta for partially funding this project.

REFERENCES

1. Brooker and B. Donald, *Drying Cereal Grains* (The AVI Publishing Company, Inc., Wesport, 1974).
2. Y. A. Cangel, *Heat Transfer* (Mc Graw-Hill Book Company, NY, 2006).
3. E. Cao, *Heat Transfer in Process Engineering* (Mc Graw-Hill Book Company, New York, 2010).
4. S. B. Daulay, *Pengeringan Padi* : *Metode dan Peralatan* (Universitas Sumatera Utara, Medan, 2005).
5. N.W. Desrosier, *Teknologi Pengawetan Pangan* (UI Press, Jakarta, 1998).
6. T. Estiasih, *Teknologi Pengolahan Pangan* (Bumi Aksara, Malang, 2009).
7. G. Pahl, W. Beitz, J. Feldhusen, K. H. Grote, *Engineering Design A Systematic Approach* (Springer Publishing, New York, 2007).
8. A. S. Siregar, "Pengaruh suhu dan lama pengeringan gabah yang disimpan selama 4 bulan terhadap mutu beras," Thesis, Universitas Sumatera Utara, Medan, 2002.
9. S. Yasuyuki, *Pengeringan Bahan Olahan dan Hasil Pertanian* (IPB, Bogor, 1992).
10. Wardi, "Prototipe alat pengering padi dengan kapasitas 10 kg skala laboratorium menggunakan bahan bakar batok kelapa," Thesis, Universitas Sultan Ageng Tirtayasa, Serang, 2013.