DESIGN AND DEVELOPMENT OF A MANUALLY-OPERATED HYDRAULIC HOT-PRESSING MACHINE FOR AGRICULTURAL WASTES-BASED PARTICLEBOARD APPLICATION

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ABSTRACT: *Agricultural wastes are residues produced as a result of various agricultural operations. The use of these materials offers potential benefits both environmentally and socio-economically. One of the most successful approaches to the management of agricultural waste is the production of particleboards from it. Particleboard is a wood-based panel product manufactured under pressure and temperature from the particles of wood, or its alternative resources as substitutes, such as agricultural wastes, or other lignocellulose fibrous materials and a binder. Hence, a hot pressing machine is very important in producing particle boards from agricultural and industrial wastes for evaluation purposes. In this study, the design, development and evaluation of a manually-operated, hydraulic hot-pressing machine for producing particleboard from alternative resources have been conducted. A simulation study of the hot-press machine based on the design shows that it can withstand stress and heat brought about in producing the particleboards. Further, the fabrication of the hot-pressing machine is successful as it can produce the composite board based on the design parameters.*

Keywords: agricultural wastes. hot-pressing machine, particleboard, design, and development, manually-operated

1. INTRODUCTION

Agricultural wastes are residues from the growing and processing of raw agricultural products such as fruits, vegetables, meat, poultry, dairy products, and crops. They are the non-product outputs of the production and processing of agricultural products that may contain material that can benefit man but whose economic values are less than the cost of collection, transportation, and processing for beneficial use[1]. Poor management and improper disposal of agricultural wastes may lead to many negative environmental consequences and may constitute a nuisance to global health and a threat to food security [2]. More specifically, burning these wastes leads to increased levels of carbon dioxide in the atmosphere, which contributes to global warming. These wastes can also cause blockage of drains and canals which consequently results in flooding. Moreover, accumulated wastes release offensive odors, thereby contributing to air pollution, and also serve as a breeding ground for mosquitoes and flies which spread several diseases. Waste products also add to space problems in landfills, as they remain in landfills until they are biodegraded. The use of these materials offers potential benefits both environmentally and socio-economically. They are cheap, abundantly available, and resource-oriented when handled appropriately and the environmental problems associated with inappropriate disposal are eliminated. Moreover, recycling these agricultural solid wastes will result in the reduction of greenhouse gas emissions and use as fossil fuel as well as contribute significantly to the development of new green markets, creation of jobs, production of bio-energy, and bio-conversion of agricultural solid wastes to animal feed [2]. Also, agro-industrial wastes pave the way for some other important research fields, such as the production of new and alternative fuels and energy generation[3] .

One of the most successful approaches to the management of agricultural waste is the production of particleboards from it. Recently, the use of alternative resources as a substitute for wood raw materials has increased in the particleboard industry because of the depletion of forest resources [4]. Studies of particleboard using wood residues and agricultural by-products have examined crop wastes [5], maize cob [6], rice husks [7], a combination of rice husk and wood sawdust [8, 9, 10], wheat straw [11], tree leaves [12], sunflower stalks [12], maize husks [13], coconut [14], banana bunch [15], and palm kernel shell [16]. Particleboard is a wood-based panel product manufactured under pressure and temperature from the particles of wood or other any lignocellulose fibrous materials and a binder. Hence, a hot pressing machine is very important in producing particle boards from agricultural and industrial wastes for evaluation purposes.

In this study, the design, development, and evaluation of a manually-operated, hydraulic hot-pressing machine for producing particleboards from alternative resources have been conducted. The machine has been tested successfully as it can produce composite boards from agri-industrial wastes based on the design parameters considered in the study.

2. MATERIALS AND METHODS

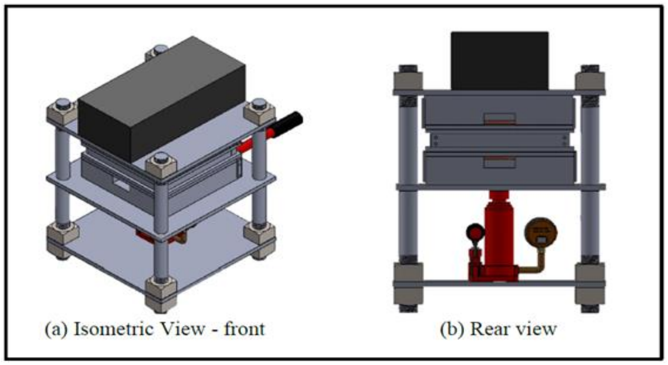
This study is focused on the design and fabrication of a hydraulic hot-pressing machine that can produce one particleboard for a single press. The particleboard has a maximum width of 250mm, a length of 250mm, and a thickness of 10mm. The machine is manually operated by a hydraulic bottle jack located at the bottom plate support.

2.1. Concept Design

Figure 1 shows the concept design of the hydraulic hot-pressing machine. It is based on an existing bench top press with heated platens used in laboratory testing. The heating element is designed based on commercially available materials.

2.2. Design Parameters

Parameters are identified and defined during the designing process. The pressing operation is an extremely important step in the production of particleboard considering that it determines the quality of the board produced. The design parameters identified are pressure application, heat application and time of pressing. During pressing operation, the pressure applied can affect the smoothness of the surface of the particleboard. Surface roughness affects the porosity of the particleboard as well as the water absorption capacity of the material. In [10],the pressure used was 2-4 MPa or 290-580 psi in producing rice hull-sawdust particle board. In the present



study, the design pressure is slightly increased to 750 psi and

Figure 1. Concept design of hydraulic hot-pressing machine

is held constant during the pressing operation. The common operating temperature for particleboard press generally ranges from 149^{0}C to 182^{0}C. Press temperature and time vary in keeping with the products that are being produced [17]. In this study, the designed temperature used is 120 ^{0}C and was based on the spontaneous combustion risk of sawdust. The designed time for pressing the particleboard is 10 minutes based on [18]. A stopwatch was used to limit the pressing time of the mixture.

2.3. Heat Source

The study utilized the 8" coil of an electric stove as a heat source for the machine. The power rating of one coil is 1,500W, and so the total power rating of the machine is 3,000W. The heating coil and its guide comprised the heated plate. The upper and lower heated platens are almost identical, which differ only with their orientation in the machine, as shown in Figure 2.

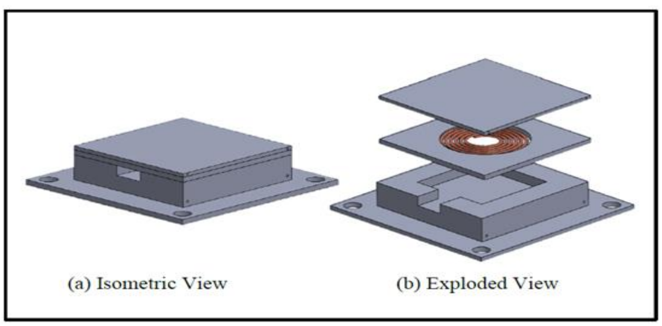


Figure 2. Lower and Upper Heated Platens of the Machine

2.4. Heat Analysis

The proposed design has been simulated through *SolidWorks* software for the critical and heated parts of the machine. The heating element/ heat source is also simulated to test the thermal expansion of the material but the temperature must not be high enough for the part to warp. Also, the heat analysis is done to determine the heat distribution from the heat source if it is uniform.

2.5. Fabrication of the Hot-Press Machine

The machine has five major components: upper plate support, middle plate, bottom plate support, round bar post, and hydraulic jack. These have been fabricated in a machine shop with engineering services.

2.6. Production of Particleboard

The process of producing particle board is shown in Figure 3. The manufacturing process involved hot pressing the mold of mixed composite materials with applied temperature, pressure, and time to attain.

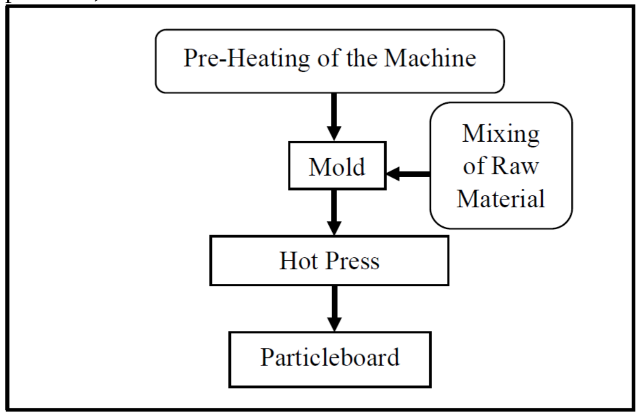
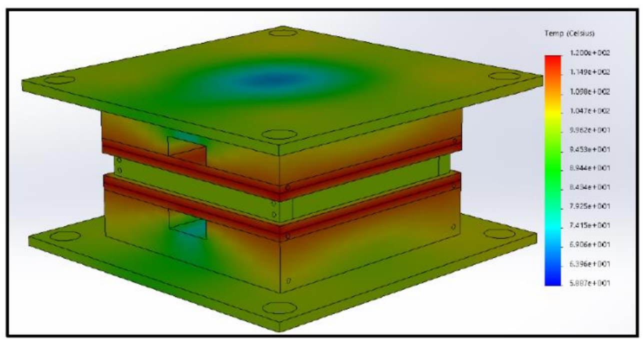


Figure 3. Process of Particle Board Production

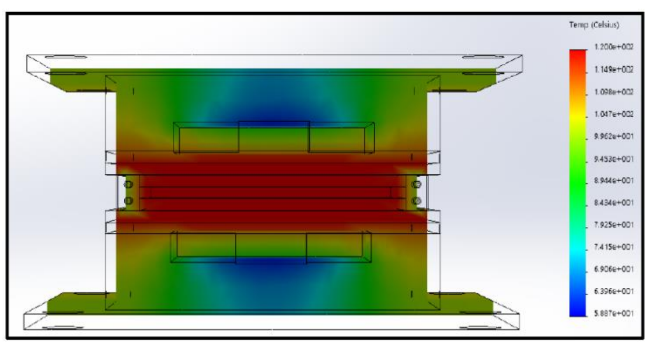
3. RESULTS AND DISCUSSION

3.1. Simulation Results of the Molder

Figure 4 shows the thermal simulation of the molder. As shown in Figure 4a (isometric view), the maximum temperature at 120^{0}C from the heat source shows that it was not conducted through the center part of the molder. However, the simulation result of the cut view of the molder (Figure 4b) shows that the heat was conducted through the materials used. The temperature of the heating element was approximated at 120^{0}C from the heating element powered at 1,500W.



(a) Isometric View



(b) Cut View

Figure 4. Thermal Simulation of the Molder

The temperature input was the maximum temperature that was constant throughout the pressing procedure. The heat source and molding unit of the machine have undergone heat analysis simulations. The design of this part of the machine was based on the availability of materials.

In Figure 5, the stress analysis of the molder is presented. It shows that the molder will not fail even with the maximum pressure that the hydraulic jack can apply which is 2,500 psi (10 MPa). The design is safe and the material will not fail since the maximum stress of 10MPa (red) did not exceed the allowable bending stress of 166 MPa considering that the ultimate tensile strength of the material is approximately 415MPa at 120ºC [19] and a factor of safety of 2.5.

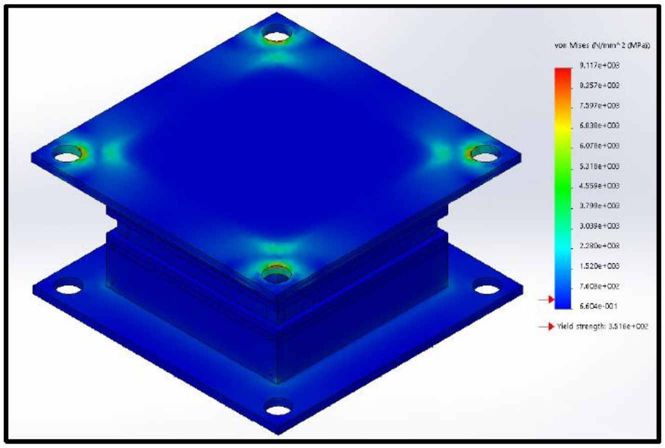


Figure 5. Von Mises Stress Result of Molder

3.2. Fabricated Hot-Pressing Machine

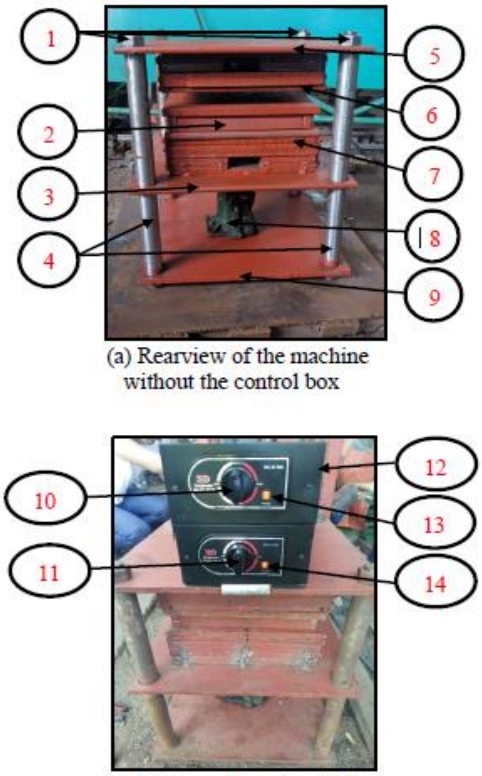
Figure 6 shows the fabricated hot-pressing machine with its various parts. It is equipped with two safety features; a circuit breaker for the main circuit and a thermal fuse for every heating element which trips when the temperature of the wire exceeds 200C.

3.3. Sample Particle Board Product

During testing, the machine was able to produce a different mixture of particle boards based on the design parameters considered in the study. Some of these products are shown in Figure 7.

4.0 CONCLUSION

A simulation study of the hot-pressing machine based on the design shows that it can withstand stress and heat brought about by producing particle boards. Further, the fabrication of the hot-pressing machine is successful as it can produce the composite board based on the design parameters.



(a) Rearview of the machine without the control box

(b) Control box installed

Legend:

(1) Nut	(8) Hydraulic Jack
(2) Molder	(9) Bottom Plate Support
(3) Middle Plate	(10) Upper Heated Platen Thermostat
(4) Round Bar Post	(11) Lower Heated Platen Thermostat
(5) Upper Plate Support	(12) Control Box
(6) Upper Heated Platen	(13) Upper Thermostat Indicator Light
(7) Lower Heated Platen	(14) Lower Thermostat Indicator Light

Figure 6. Fabricated Hot-Pressing Machine for Particle Board

(a) 30:55:15 *(Sawdust: Rice husk: Cassava starch) ratio*

(b) 30:55:15 *(Sawdust: Rice husk: Corn starch) ratio*

Figure 7. Samples of Particleboard produced

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