

# Design and analysis of biomass pyrolysis briquette molding machine

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**Abstract.** The increasing population and industry in the world have increased the energy demand. Fossil fuel still dominates the current energy consumption in Indonesia, although renewable energy sources are widely available in the country. One of the sources that can be used as a renewable energy source is solid waste as biomass from palm oil processing. The biomass can be converted to solid fuel by using the pyrolysis technique prior molded into a briquette. This study aims to analyze the biomass briquette molding machine in the simulation environment. The solid work simulation is used to analyze the machine regarding the material strength, static test, displacement, strain, and safety factor. The strength test of von mises stresses achieves a maximum value of  $3.713 \times 10^5$  psi with node 43,485. It is known that the frame is still safe to use because the Yield Strage value is below the Von miss Stress value. Meanwhile, with a maximum displacement of 0.748 cm at node 62,816, a maximum strain of 0.00104 at element 43,485, and a safety factor of  $3.278 \times 10^8$ , it shows this briquette's design molding machine is safe to use.

## 1 Introduction

Increasing population growth and industry globally then increasing energy demand by 80% leads to increased energy use in fuels, resulting in the depletion of petroleum reserves. The phenomenon makes people put effort into increasing alternative renewable energy sources. Biomass energy can be considered a renewable energy source [1, 2, 3, 4]. The Oil Palm Empty Fruit Bunches (EFB) from palm oil mill activity serve as solid biomass [4, 5, 6, 7].

The oil palm mill produces 60% crude palm oil, 20% fiber, and 20-23% EFB. The EFB is a solid waste that can be used as alternative energy besides shells and fiber [8-9]. Indonesia has abundant availability of EFB [10-11]. The fibers and shells have been used extensively for fuel boilers to generate steam for processing palm oil and generate electricity for other parts activities during processing. Meanwhile, the EFBs are usually used as fertilizer for oil palm plantations [12].

A thermochemical process can convert the EFBs into renewable energy solid fuel as charcoal [13]. Charcoal from EFB can be processed using a pyrolysis process at a temperature of 350 – 500 °C [14-15]. The pyrolysis process produces syngas, bio-oil, and solid [16-17].

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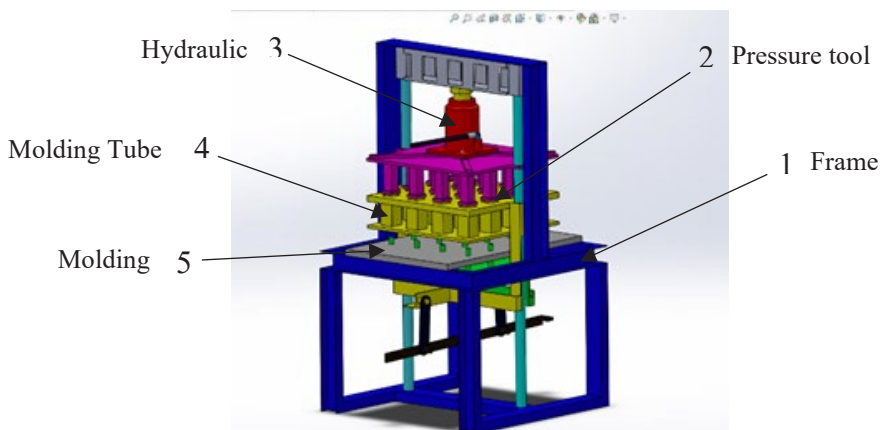
The percentage yield of pyrolysis products depends on several conditions working during the process [18-19].

The charcoal produced from pyrolysis has a high calorific value. It can be served as fuel and processed into solid fuels in the form of briquettes [14]. The briquettes compose charcoal powder and adhesive mixed before entering the pressing process to get the desired solids [20-21]. Making solid briquettes requires a compaction process of about  $25 - 125 \text{ N cm}^{-1}$  according to the Indonesian National Standard (SNI) number 01-6235-2000 [22-23]. Therefore it is necessary to design a suitable machine for briquette molding. The machine design process needs to be carried out with material selection and strength analysis, especially the machine frame, to support the pressing load requirement [24]. A reasonable molding machine frame must be able to withstand the workload and not experience banding. In designing the molding machine frame, it is necessary to pay attention to materials, material properties, and yield strength to avoid failure in the production process [25]. The analysis process can be done using Solidworks software. The use of this software can show the points that experience the smallest loading, medium loading, and largest loading [26]. The analysis results also present a comparison of the threshold values so that the value of the safety factor can be known. They also compare the safety value of the material before it is used and has been given a load [27]. Then from the simulation analysis, test results show whether the material used for the machine frame is resistant to loading or not in the briquette production process.

This study analyzes the design of the briquette molding machine, especially the machine frame, in terms of the strength of the material using ASTM A 36. This briquette molding machine's design and analysis process use SolidWorks software to analyze the material characteristics, stress, strain, displacement, safety factors and find the material's durability on the briquette molding machine frame.

## 2 Methodology

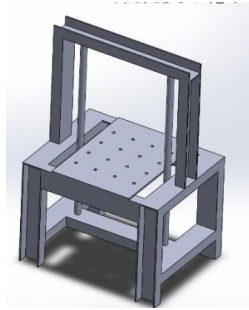
Briquette production requires charcoal machines, adhesives, and molding machines. The charcoal as a pyrolysis product is used as raw material for the briquette. EFB is treated as raw material with a working temperature of  $400 \text{ }^\circ\text{C} - 500 \text{ }^\circ\text{C}$  for 180 minutes in the pyrolysis processes. Charcoal from the pyrolysis process is then mashed into 40 mesh to get a uniform size, mix with the tapioca glue adhesive of 10% of the weight of the charcoal. The mixture is then brought to the molding process before entering the drying process at the oven with a temperature of  $100 \text{ }^\circ\text{C}$  for 60 minutes to reduce water content.



**Fig. 1.** Design of a Briquette Molding Machine.

Figure 1 is a briquette molding machine designed to produce 16 briquettes in 1 time of production. The briquettes are rectangular in size with a size of 40 mm x 40 mm. There is a middle cavity of 5 mm. For 1-time molding, production takes 10 minutes because the molding process has several stages: the entry of molding materials, the compaction process, and removing the briquettes to the dryer. The selection of a square briquette shape facilitates the packaging and is expected to enhance the briquette's complete burning process.

Things to be considered first in the machine's design are the specifications of pressure and material used. The briquette machine frame design is shown in Figure 2. The material specification used for the molding machine is shown in Table 1. This briquette machine frame has 500 mm x 400 mm x 1,100 mm in size.



**Fig. 2.** Briquette Machine Frame Design.

**Table 1.** Specification for the molding machine.

No	Name	Size
1	Frame	UNP
2	Pressure	ASTM A36
3	Tube molding	ASTM A36 (thick = 0.5mm, Long = 40 mm, Wide = 40 mm, Hige = 60 mm)
4	Molding	ASTM A36 (size 400 mm x 500 mm x 3 mm)
5	Drawer	Stainless steel
6	Compressor	Maximum pressure: 8 bars
7	Pneumatic	Bore = 50 mm; Stroke = 70 mm

The machine frame will be analyzed to get the information on structural strength using SolidWorks software when pressurized by 8 bar (116.03 psi). The analysis will also be carried out to get information on the proposed design's stress, displacement, strain, and safety factor.

### 3 Results and discussion

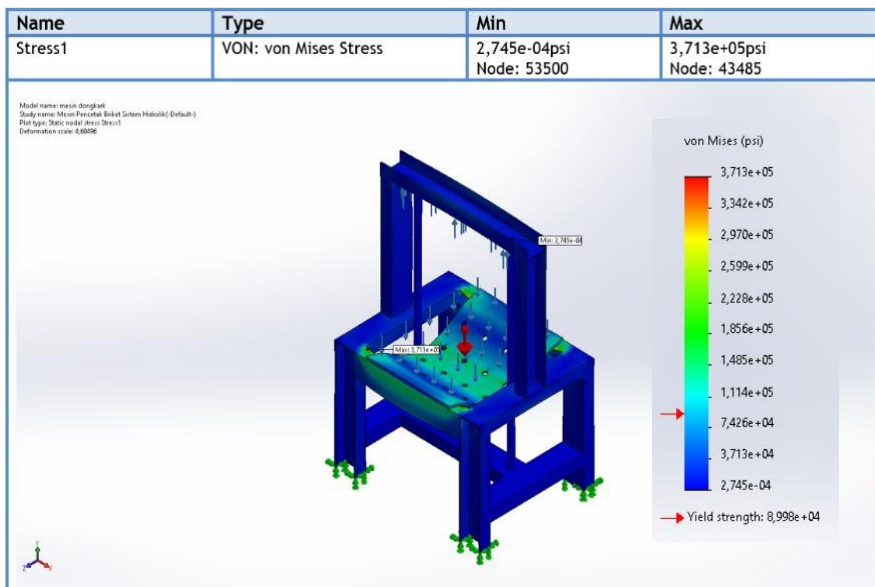
The value of ASTM A36 material characteristics in yield strength, tensile strength, modulus of elasticity, Poisson's ratio, shear modulus, nodes, elements, and aspect ratio are shown in Table 2.

**Table 2.** Value of material characteristics.

Name	Property	Unit
material	ASTM A36	
Yield Power	6.20422 x 10 <sup>8</sup>	N m <sup>-2</sup>
Attractiveness	7.23826 x 10 <sup>8</sup>	N m <sup>-2</sup>
Elastic Modulus	2.1 x 10 <sup>11</sup>	N m <sup>-2</sup>
Poisson's Ratio	0.28	
Shear Modulus	7.9 x 10 <sup>10</sup>	N m <sup>-2</sup>
Element Size	1.84521	cm
Total Nodes	64,621	
Total Element	30,950	
% elements with an aspect ratio < 3	38.4% of	
elements with Aspect Ratio > 10	52	

From the analysis, the yield strength of ASTM A36 material is 6.20422 x 10<sup>8</sup>, tensile strength is 7.23826 x 10<sup>8</sup>, and elastic modulus is 2.1 x 10<sup>11</sup>. The values obtained are the highest point of the material in receiving static loading. Based on the simulation, the maximum yield strength material is 6.20422 x 10<sup>8</sup> N m<sup>-2</sup>. The minimum stress value at a compressive load of 8 bar (116.03Psi) for the briquette molding process should not be above the value of the yield strength of the material due to the yield point is the limit point for the strength of the material.

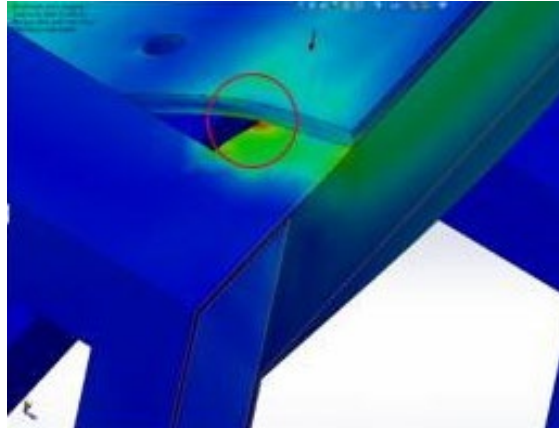
The stress analysis simulation obtained a maximum value of 3.713 x 10<sup>5</sup> Psi on the node of 43,485, showing by a red bar chart. In comparison, the minimum value is 2.745 x 10<sup>-4</sup> Psi on the node of 53,500 (blue bar charts).



**Fig 3.** Stress Analysis (Von Mises Stress).

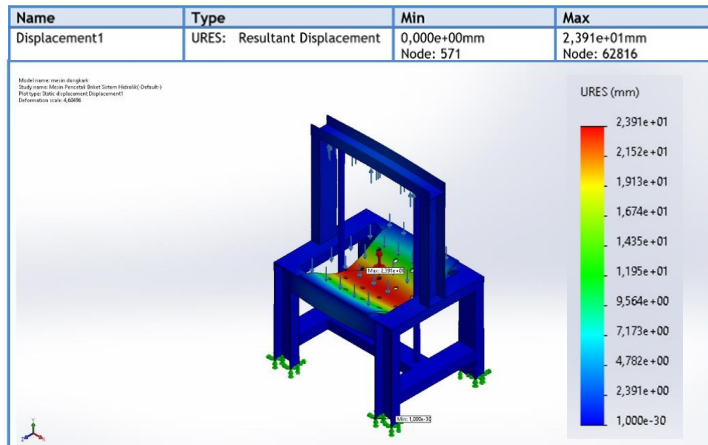
Figure 3 shows the lowest and highest value of stress based on simulation analysis with the indicated yield strength of 8.998 x 10<sup>4</sup>. This value is the point where the occurrence of

strains and displacement on the machine frame. It can be stated that the machine frame is still safe to use, where the yield strength is still above the minimum value of stress analysis. The highest stress point occurs at the connection, marked with a red circle and a red dot, as shown in Figure 4.

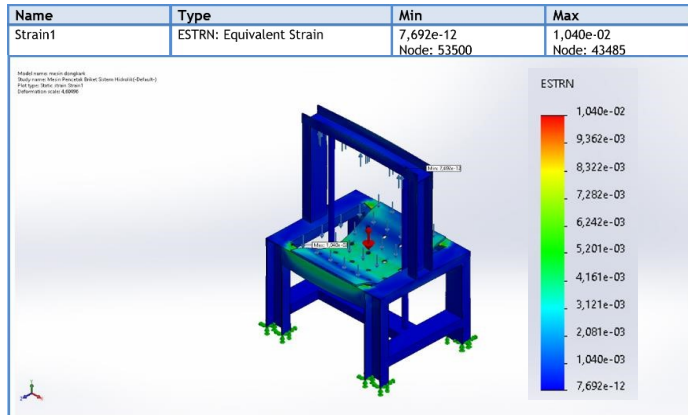


**Fig 4.** Highest Stress Point.

Displacement occurs on the mold base around 0.748 mm, with the maximum transfer analysis of  $2.391 \times 10$  mm, as shown in Figure 5. In addition to the simulation, the strain value obtained indicates that the machine can handle the working pressure up to 8 bar. The strain of 0.00142 occurs at the molding plate base, as shown in Figure 6. The stress and displacement analysis above found that ASTM A36 material can withstand the workload experienced during the molding briquette processes. Thus it has good durability.

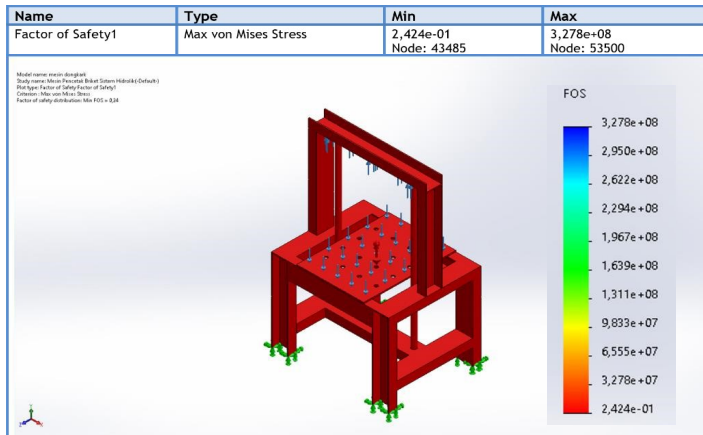


**Fig 5.** Displacement Analysis.



**Fig 6.** Strain analysis

The safety factor analysis on the molding frame obtained a maximum value of  $3.278 \times 10^8$  at node 53,500 and a minimum point of  $2.424 \times 10^{-1}$  at node 43,485. The simulation analysis results in Figure 7 show that the lowest security value is on the red graph, and the highest security value is on the blue graph. The minimum value of the safety factor is obtained at a pressure of 8 bar (116.03Psi) with a value of  $2.424 \times 10^{-1}$ , where value of safety factor still below yield strength of the molding frame with a value of  $8.998 \times 10^4$ . Therefore, the value of the safety factor obtained is still below the value of yield strength, thus the molding machine designed can be declared safe to use in the production process using a pressure of 8 bar (116.03 Psi).



**Fig 7.** Analysis of Safety Factors.

## 4 Conclusion

This study focuses on design, simulate, and analyzing the briquette molding machine utilizing biochar from EFB. The proposed design of a briquette molding machine using ASTM A36 with a working pressure of 8 bar shows that frame stress simulation results, including stress, strain, and displacement, are safely used. In addition, the proposed design has good durability, indicated by the ability to withstand pressure against damage during the briquette molding process.

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