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DESIGN OF NATURAL FIBER POWDER MACHINE

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Abstract

Natural fiber processing is the type of fiber as raw materials for textile or other industries that can be obtained directly from nature. In the Indonesian automotive industry, the manufacture of parts in vehicles is Polypropylene high impact (PPHI). An example of an existing part is a CVT slide piece made with a mixed polymer composite material from PPHI and pineapple leaf fiber. Pineapple leaf fibers with small sizes are needed so that the mixing of polymer composites is good. Therefore modern technology is required to process pineapple leaf fibers. This final project makes a natural fiber powder *machine for processing natural fiber, namely scavenging. The research methodology used is a prescriptive design method. The design results produce a natural fiber powder machine (pineapple leaf fiber) for polymer composite materials with long size specifications of 420 mm long, 300 mm wide, and 582 mm high. The production capacity of the natural fiber storage machine is 5 kg/h. The source of the engine drive is a 1 HP AC electric motor with a rev of 2800 rpm. The transmission system uses a V-belt with a drive shaft 30 mm in diameter. The frame construction is made of a 35x35x5 mm profile with ST42 material and knives using S45C material (AISI 1045) with a thickness of 10 mm. It uses nine dynamic blades and six sharp plane fixed blades in a 30-degree active blade and a 60-degree fixed blade.*

Keywords: *Natural Fiber, Pineapple Leaf Fiber, Prescriptive Design, Machine*.

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1. INTRODUCTION

The growth of technology makes composite materials widely used in the automotive field, and the needs of the automotive industry are again competing to make vehicle spare parts and composite materials made from under polymers [1]. Biofiber-reinforced polymer composites are often used in automotive applications, especially interior applications [2]. A unique versatile use in the Indonesian automotive industry is polypropylene high impact (PPHI) [3]. Propylene high impact (PPHI) is one of the polymers commonly used in the Indonesian automotive industry. Studies on using PPHI as a binder in natural fiber-reinforced polymer composites have yet to be studied much. Therefore, a study of the tensile preimpact properties of PPHI composites reinforced with flax fiber and pineapple leaf fiber was carried out. PPHI was used as a binding agent, and hemp fiber, and pineapple leaf fiber, functioned as a strengthening material [3], [4]. Textile products are generally made from natural fibers, and artificial fibers Natural fibers are obtained from plants and animals, such as cotton, wool, linen, and silk. In comparison, human fibers are referred to as artificial or synthetic fibers [5].

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Natural fibers are more convenient to use, but the low production availability and demand, and extremely high needs, make natural fibers very expensive (such as silk). While artificial fibers have a low price, high production, and are more durable than natural fibers [5], [6]. Because the durability of large impact loads makes PPHI incredibly good to be used as a binder for natural fiber-reinforced polymer composites, one of the spare part components that can be made of this material is a CVT slide piece. To produce CVT slide pieces, slide pieces are components of the continuously variable transmission, one of the energy transfers that play a role in protecting the position of the roller housing that moves translationally [1], [7]. Natural fibers derived from plants can be grouped again according to the origin of the fiber. Fiber is taken from seeds (seed fibers), for example, cotton fiber, and kapok. Fibers are taken from leaves (leaf fibers), such as abaca, henequen, sisal, pineapple, and tongue-in-law [3].

There are several powder machines, such as Hammer Mills, Disc Mills, Cylinder Mill, and Cutter Mills, with Mills with different working principles for each type they want to use. The machine to be designed uses a Cutter Mill where the working principle is tried by cutting on natural fibers [8]-[10].

The design of this natural fiber powder machine is the equipment used to replace natural fibers with powder. This equipment is driven using an electric motor or diesel engine. This equipment uses a knife-type enduring machine (Cutter Mill), where this type is used for clay or fibrous materials [8], [11], [12]. This urges the author to design a particular machine that is used so that the natural fiber powder pineapple leaf fiber be produced with a shorter creation time and does not consume much human la. The result is also smoother (120, 170, and 200 mesh) [13]-[15].

2. METHODOLOGY

This stage of research requires some of the literature that can be done. A flow chart is needed to make this research activity easier to see in figure 1.

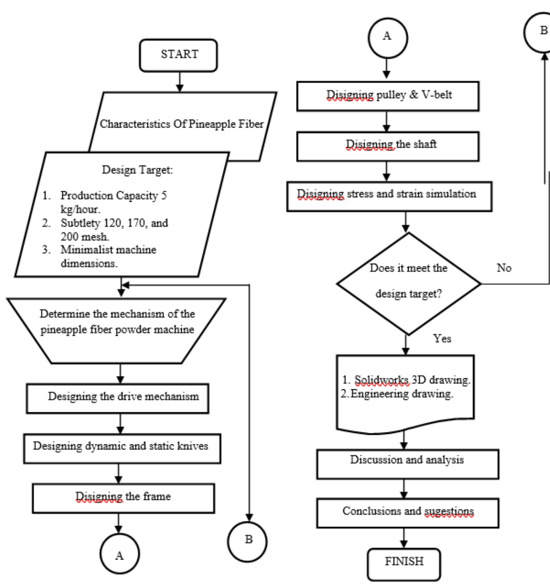


Figure 1. Design Of Natural Fiber Powder Machine Flow Diagram.

2.1. Design Concept

Of the various variations of machine components that can be used against this natural fiber powder machine, the selected components are as follows. [11]

Table 1. Example of table creation.

VARIABLE	VARIAN		
	A	B	C
Engine Drive	Electric Motor AC	Torque Motor	Manual
Frame Profil	Profil L	Profil C	Profil I
Transmission System	V-belt and *pulley*	Gears	Gear and chain
Shaft	Carbon Steel	stainless steel Coated steel	
Knife Mechanism	Hammer Mill	Cutter Mill	Disk Mill
Knife Material	AISI 1045 (S45C)	JIS SUP 9	Baja HSS

Of the various variations of machine components that can be used in this natural fiber powder machine, the selected components are as follows:

1. Engine Drive: AC Electric Motor 1 Phase
2. Frame Profile: L Elbow Profile (35x35x5 mm)
3. Transmission System: V-belt and pulley
4. Shaft: Carbon Steel
5. Knife Mechanism: Cutter Mill
6. Knife Material: AISI 1045 (S45C).

2.2. Design Drawing

After designing the machine's concept, the next step is to make design drawings. The design drawings are created with the Solidworks application, as shown in figure 2.

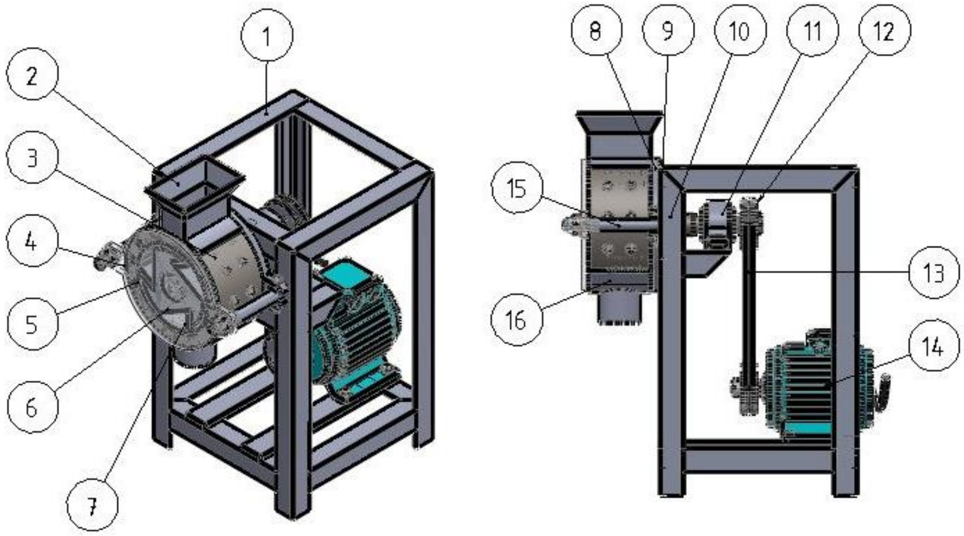


Figure 2. Solidworks Design Drawing

Image caption:

1. Frame	6. Knife Mount	11. Pillow Block	16. Output
2. Hopper	7. Mesh	12. Pulley	
3. Knife House	8. Back Cover	13. V-belt	
4. Front Cover	9. Bearing	14. Electric Motor	
5. Static and Dynamic Knives	10. Shaft	15. Locking Shaft	

3. RESULTS AND DISCUSSION

To be able to meet the target of the natural fiber powder machine design, several calculation parameters are needed to be able to obtain the specifications of the machine [16]. The calculation is done by theoretical method using data that has been obtained previosly. Here are the parameters needed in the planning of a natural fiber powder machine with a capacity of 5 kg/h:

3.1. Theoretical Capacity

Theoretical capacity is the machine's capacity, which includes the results of variable calculations and the dimensions of the sieve on the natural fiber powder machine [17]. The theoretical capacity of the natural fibre powder machine (preferably pineapple leaf fiber) is calculated using an approach with the equation of the mass flow rate of the particles from the scavenging on the sieve [17].

$$\dot{m} = \rho \, . \, A \, . \, v \tag{1}$$

where:
$\dot{m}$ = Mass Flow Rate (kg/s)
ρ = Density 0,42 (kg/m^3)
A = Area of holes in the sieve 0,00125 (m^2)
v = The speed at which particles fall through the sieve is 2,93 (m/s)

3.2. Pineapple Leaf Fiber Cut Style

It was found that the cutting force of natural fibers (pineapple leaf fibers) was carried out by a static method from an experiment using 2 knives, namely a stationary knife and a motion knife with the same sharpness[15]. Here is the data obtained in figure 3:

Figure 3. Pineapple Leaf Fiber Cutting Style Testing

In the test of the minimum cutting force of the pineapple leaf fibers, the knife used has an angle on the short side (α) 30^0. The method used against the test is the static method [11].

Table 2. Pineapple Leaf Fiber Cutting Style Static Testing

EXPERIMENT	MINIMUM CUTTING MILL (Kg)
I	1,6
II	3
III	2
IV	2,5
V	2,4
AVERAGE	2,3 kg

In this test method, the minimum cutting force value is 2,3 kg, in the static cutting method, so this value is used in the subsequent design process.

3.3. Engine Rotation Planning

By deciphering the case through a machine capacity of 5 kg/h, the number of stationary blades is 6 blades, the motion blades are 9 blades, and the mesh used is 120 mesh, 170 mesh, and 200 mesh. The size of the incoming material per chip is 2.5 mm [17].

$$n = \frac{Rotation}{m} \, x \, Q \tag{2}$$

where:
n = Motor rotation (rpm)
Rotation = Requird rounds (rotation)
m = Pineapple leaf fiber weight 0,015 (gram)
Q = Capacity 5 kg/h (gram/minute)

3.4. Propulsion Planning

To determine what works on natural fiber powder [11], [19]:

$$F = m \, . \, g \tag{3}$$

where:

F = Force (N)

m = Minimum cut mass 2,3 (Kg)

To determine torsi acting on natural fiber powder [19]:

$$T_3 = F \, . \, r \tag{4}$$

where:
T_3 = Torsi (N.m)
F = Force (N)
r = The long radius of the knife (m)

The cutting power of this pineapple leaf fiber is [19]:

$$P = T_3 \, . \, \omega \tag{5}$$

where:
P = Cutting power (watt)
ω = Angular velocity 313,37 (rad/s)

3.5. Transmission Planning

For ample torque in the motor is [19]:

$$T_1 = \frac{T_2 . n_2}{n_1} \tag{6}$$

where:
T_1 = Motor torque (N.m)
T_2 = Shaft torque (N.m)
$n_{1,2}$ = Motor rotation (rpm)

The amount of motor power is [19]:

$$L = 2C + \frac{\pi}{2}\left(d_p + D_p\right) + \frac{1}{4C}(D_P - d_P)^2 \tag{7}$$

where:
L = Belt circumference length (mm)
C = Shaft axis distance (mm)
d_p = Small pulley diameter (mm)
D_p = Large pulley diameter (mm)

3.6. Shaft Planning

To search for transmitted power, with equations [19]:

$$P_d = f_c \,. P \tag{8}$$

where:

P_d = Planned power (kW)

f_c = Correction Factors

P = Motor Power (kW)

To look for moments that happen in the mover [19]:

$$T = 9{,}74 \; x \; 10^5 \frac{P_d}{n_2} \tag{9}$$

where:

T = Twisting moment (kg. mm)

P_d = Power plan (kW)

n = Shaft rotation (rpm)

To search for allowable voltage [19]:

$$\tau_a = \frac{\sigma_B}{(Sf_1 x Sf_2)} \tag{10}$$

where:

τ_a = Shear permit (kg/mm^2)

σ_B = Tensile strength of the material S45C 58 (kg/mm^2)

Sf_1 = Safety factor 6

Sf_2 = Safety factor 2

To search for shaft diameter calculations [19]:

$$Ds = \left[(\frac{5{,}1}{\tau_a}) \sqrt{(K_m M)^2 + \; (K_t T)^2} \right]^{\frac{1}{3}} \tag{11}$$

where:

Ds = Minimum Shaft Diameter (mm)

τ_a = Shear Tension Shaft ($\frac{kg}{mm^2}$)

M = Bending Moments (kg.mm)

T = Twisting Moment (kg.mm)

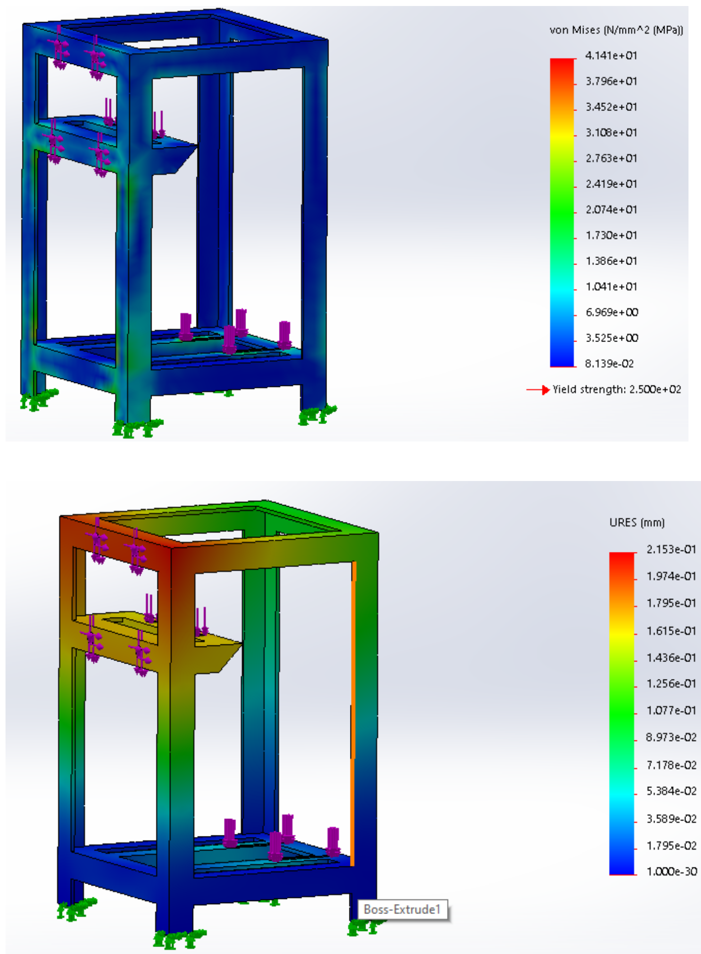
K_t = Torsion Moment Correction Factor

K_m = Bending Moment Correction Factor

3.7. Solidworks Simulation

In the Solidworks simulation, you can see the voltage that occurs, displacement, and safety factors in the components carried out by the simulation. Among them are the following:

- Strain, displacement, and safety factors on the frame
  The engine frame uses iron elbow material ASTM A36 with a size of 35 x 35 x 5 mm. the cutting force of the fibres (direction x = 474.72 N and direction y = 8.258 N), as well as the load of the electric motor of 186.39 N. From **Figure 4.** the maximum shear is 41.41 MPa, and there is a yield strength of 250 MPa. The maximum frame displacement is 0.2153 mm, and the safety factor obtained is 6. Still safe to use [9].



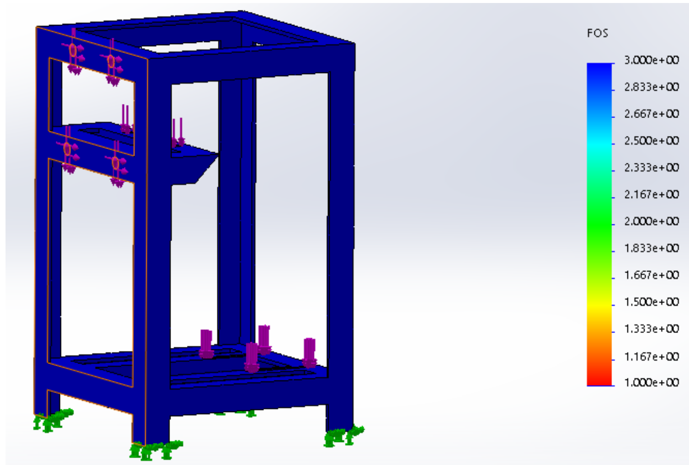
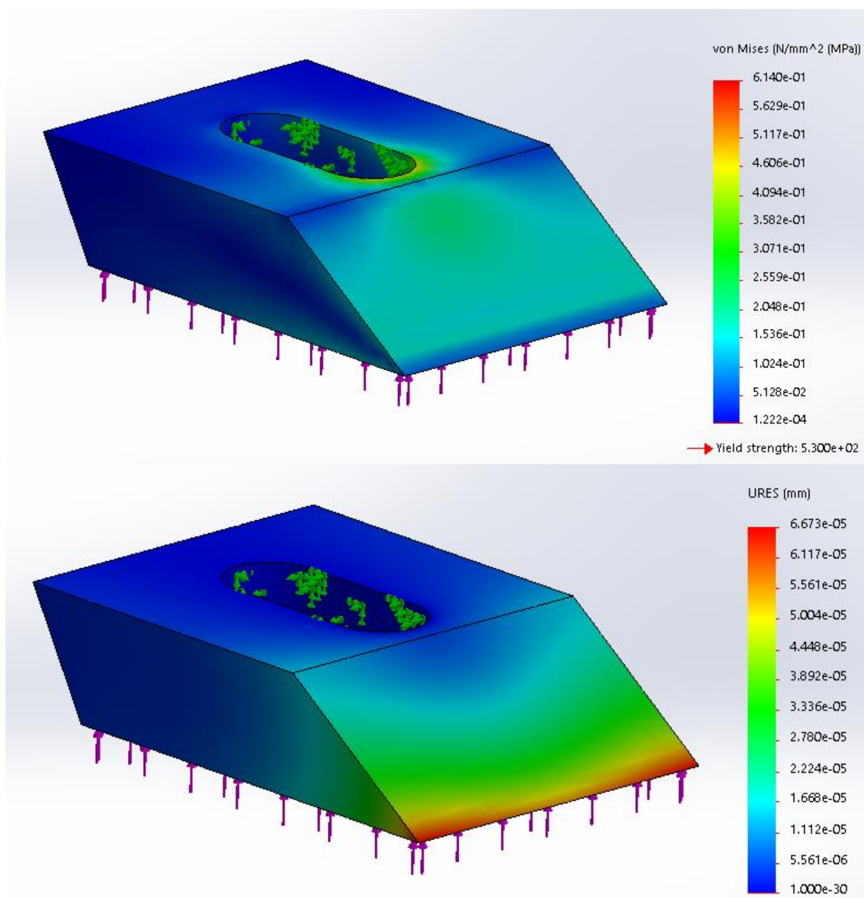


Figure 4. Frame Simulation

- Strain, displacement, safety factor on dynamic knives

  Viewed from **Figure 5.** below, the simulation of the shear on the dynamic blade simulated using AISI 1045 material has a maximum strain of 0.6140 MPa. Where the yield strength is 530 MPa. The maximum frame displacement is 6,673 x 10^{-5} mm, the safety factor obtained is 8.6 x 10^{2}. Still safe to use [9].



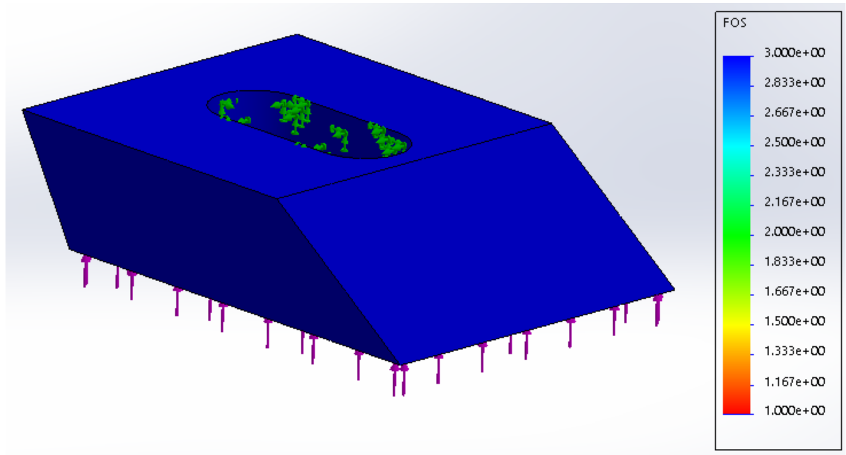
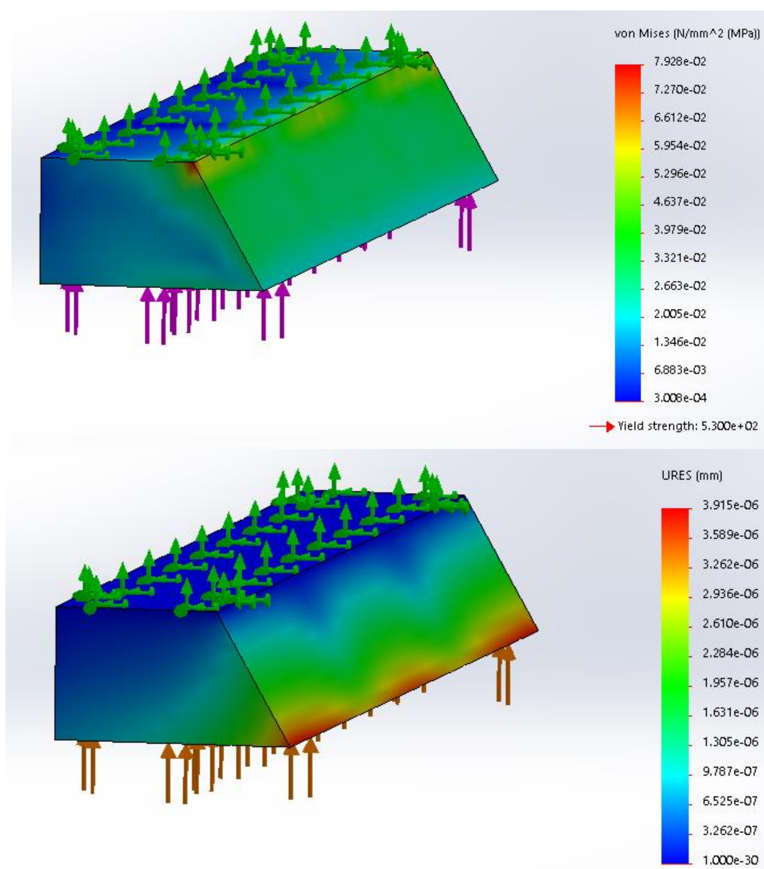


Figure 5. Dynamic Blade Simulation

- Strain, displacement, safety factor on static knives

  Viewed from **Figure 6.** below, the simulation of the shear on the static blade simulated using AISI 1045 material has a maximum voltage of 0.079 MPa, there is a yield strength obtained from the material of 530 MPa. The maximum frame displacement is 3.915×10^{-6} mm, and the safety factor obtained is 6.7×10^{3}. Still safe to use [9].



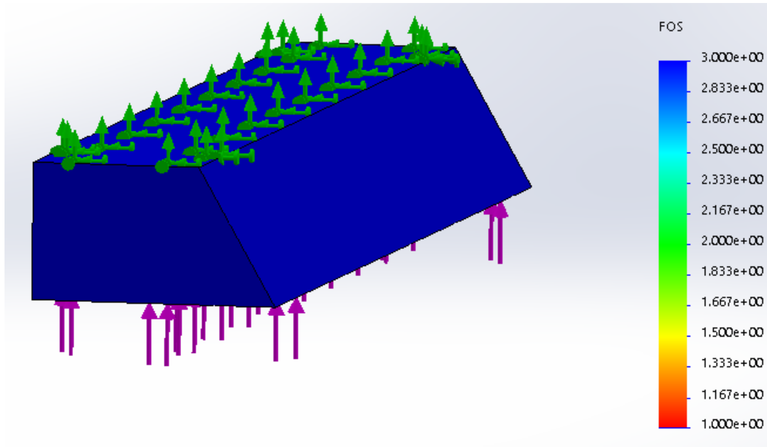


Figure 6. Static Knife Simulation

4. CONCLUSION

The design results of the natural fibre powder machine, as shown in Table 3.

Table 3. Design Results

Experiment		Results Obtained
Knife	Knife Material	AISI 1045
	Number of knives	Knive Static (6 pcs) Dynamic (9 pcs)
	Dynamic & static blade angle	60^0 dan 30^0
Transmission System	Diameter Pulley	Ø 3,5inch Pulley mover
		Ø 3inch Pulley driven
	Belt Type	A-28 (L = 740 mm)
Shaft	Shaft Diameter	Ø 28 mm Drive blade shaft
		Ø 26 mm Driven pulley shaft
		Ø 30 mm Bearing
	Shaft Material	S45C atau AISI 1045 (58 kg/mm^2)
Stake	Stake Dimensions (bxhxl)	Knife dinamis 8 x 7 x 82 mm
		Pulley 8 x 7 x 30 mm
	Stake Material	ST 42 (42 kg/mm^2)
Drive Motor	Drive Motor Power	1 Hp
	Drive Motor Rotation	1 Phase 2800 rpm
Frame	Frame Type	35 x 35 x 5 mm (Angel iron)
	Frame Material	Material ST42 (ASTM A36)

Based on the design made, six static knives are obtained, and nine dynamic knives with the sharpness obtained are static 60^0 and dynamic 30^0. The material used by the knife is AISI 1045 (S45C) where, the transmission obtained in the design of the diameter of the drive pulley is 3-inches, and the diameter of the driven 3.5-inch V-belt length is obtained with type A-28 length of 740 mm. In the calculation, the diameter of the shaft is also obtained, namely the diameter of 26, 28, and 30 mm, the material used on the shaft is S45C. The electric motor obtained motor power is 1 Hp and the rotation of the electric motor is 2800 rpm. The frame used is angle iron with a size of 35 x 35 x 5 mm with the material used ST42.

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