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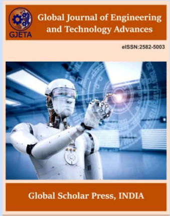

(RESEARCH ARTICLE)

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Verification Of ballistic machine performance against load and capacity at TPST Samtaku Jimbaran Bali

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Abstract

Waste is the result of a shift in people's consumption habits that are not proportional to the level of their activity. Waste has no use value because it is dirty and smelly, but if it can be processed properly, it can become something valuable and boost the use value of society. Every day, 4,281 tons of waste are created on the island of Bali, according to waste data. Only 52 percent of the waste has been managed, while the rest has been controlled. This ballistic machine that can plan 10 tons per hour is already used in Jimbaran, Bali. The shaft in the study is 2350 mm in diameter and has three parts: screw conveyor input, cutting blades and supports, and screw conveyor outlets. The axial force of the screw conveyor is 513,685 N with a threaded knife cutting force of 1; 73,138 N, thread 2; 76.59 N, thread 3; 75.28 N, thread 4; 73.64 N, thread 5; 71.64 N, thread 6; 69.41N, and thread 7; 66.83 N. Highest moment load on the horizontal part is at x = 2200 mm and the vertical part is at x = 1220 mm in the calculation of the bending moment of 107,099 N/mm2. The engine ballistic produces 16.9 horsepower. The capacity of the machine is 281.7 kg of garbage, and it can produce 1.46 tons per hour after being confirmed in one hour.

Keywords: Verification; Load; Capacity; Performance; Power; Ballistic Machine; TPST Samtaku

1. Introduction

The the number of inhabitants, types of activities, and consumption habits within a community all affect the amount of waste created, resulting in a new type, volume, and characteristics of waste. Waste, in general, has no use value due to its dirty and smelly nature, but if it can be properly processed, then it can be turned into something useful, increasing the use value of society. Waste processing in Indonesia is still quite limited, according to the source. Waste processing in 514 cities/regencies in go.id is still relatively low, with an average value of less than 50%. As a result, having a garbage shredder is very important. In Indonesia, one form of waste chopper is Ballistics which has been used in Jimbaran, Bali. This machine is demonstrated to look like a missile on a cutting tube, and the material used is a hardox plate, which can withstand abrasion. The purpose of this ballistic machine is to cut organic and inorganic waste during the waste sorting process. Screw conveyors are used in this machine to help push waste into the cutting chamber and out of the cutting tube. The threads on the knives used in this ballistic machine have varying angles of inclination, and each thread has three blades.

This ballistic machine that can plan 10 tons per hour is already operating in Jimbaran, Bali. The resulting capacity of this ballistic machine is less than 10 tons per hour, so the problem that can be lifted from this difficulty is to confirm the actual capacity of the ballistic machine at TPST Samtaku Jimbaran Bali.

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2. Research description

2.1. Garbage

Garbage is a part of something that can no longer be utilized, that is not liked, or that must be thrown away, and that generally comes from human and solid activities.

Indonesia's population is changing rapidly, especially in metropolitan areas, resulting in high levels of urbanization that require large and dense communities. According to Indonesia's population projections for 2020, 56.7 percent of Indonesia's population will live in urban areas, and this number will continue to increase. As a result, the pattern of community activity in the metropolitan area changed, resulting in an increase in waste production. Minimum waste management systems, regional geographical locations, high socioeconomic levels, and waste decomposition technology are re-all elements that can contribute to the increase in waste.

2.2. Couples

The shaft is a component of the engine element that is responsible for transferring power or rotation from the source to the engine. Other engine components, such as pulleys and gears, are needed to aid in power transfer or rotation. The shaft will bend as a result of pressure and weight. The rotating and pulling shaft consist of circular steel. Loads are divided into five categories, as follows:

- Transmission on Shaft
- Shaft Axle
- Shaft Spindle
- Couples
- Flexible Shaft

2.3. Shaft Material

Table 1 Material Properties of AISI 1045

Do not.	Property	Value
Physical Properties		
1.	Density	7.85 g/cm^3
Mechanical Properties		
2.	Tensile Strength, Ultimate	569 N
3.	The Power of Results	343 MPa
4.	Elongation	20%
5.	Modulus of Elasticity	IPK 205
6.	Fish Ratio	0.29
7.	Shear Modulus	IPK 80,0
Component Element Properties		
8.	Carbon, C	0.42 – 0.48%
9.	Copper, Cu	≤ 0,30%
10.	Iron, Fe	97.6 – 98.8 %
11.	Mangan, Mn	0.60 – 0.90 %
12.	Phosphorus, P	≤ 0,03%
13.	Silicone, Si	0.15 - 0.35%
14.	Sulphur, S	≤ 0,035%

The shaft of the machine is usually made of pulled and finished steel. The material S-C (carbon steel construction machine) is made of kiln ingots (ferrosilicon oxidized and casted steel). AISI 1045 is the material used. AISI 1045 is a medium carbon steel with a carbon content of 0.4730 percent. Medium steel has a carbon content of 0.25 percent to 0.55 percent, while AISI 1045 has a carbon content of 0.4730 percent.

2.4. Gravity Calculation

The weight of the mass, the density of the substance used, and its gravity are used to calculate gravity. Blades, blade supports, and screws were all found on the shaft of the ballistic machine. The following is the gravity equation:

$$m = \rho \ x \ v \qquad \text{.........} \ (1)$$

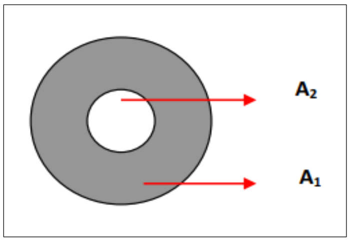
$$W = m \ x \ g \qquad \text{.........} \ (2)$$

Where:

m = Mass (kg)
p = AISI density of 1045 (g/cm^3)
v = Volume (mm^3)
g = Gravity (m/s^2)
W = Gravitational Mass (N)

2.5. Screw Weight Calculation

The gravity of the screw is calculated using the surface area of the screw and the density of the material used, with the following equation:



$$A = \frac{\pi}{4}(D^2 - d^2) \qquad \text{..............} \ (3)$$

$$V = A \ x \ p \qquad \text{..............} \ (4)$$

$$m = \rho \ x \ v \qquad \text{..............} \ (5)$$

$$W = m \ x \ g \qquad \text{..............} \ (6)$$

Where:

V = Volume (mm^3/min)
D_2 = Screw conveyor diameter (mm)
d_1 = Shaft Diameter (mm)
P = Nothing (mm)
p = AISI density of 1045 (g/cm^3)
g = Gravity (m/s^2)
W = Screw Gravity (N)

2.6. Axial Force Screw Conveyor

The friction factor of the material against the walls of the conveyor is used to calculate the axial force along the plane (f). The axial force (P) of the screw conveyor can be calculated using the formula:

$$P = qLf \qquad \text{..........} \ (7)$$

Where:

P = Axial Force of Screw Conveyor (kg)
q = Meter Load (tons/hour)
L = Long Screw Conveyor (m)
f = Friction Factor

2.7. Shaft Rotation Calculation

The rotation of the shaft can be calculated by comparing the rotation of the drive and the diameter of the pulley, and the rotation of the drive can be determined by comparing the rotation of the drive and the diameter of the pulley.

$$\frac{n_1}{n_2} = \frac{D_2}{D_1} \qquad \text{............} (8)$$

Where:

D_1 = Drive Pulley Diameter (mm)
D_2 = Driven Pulley Diameter (mm)
n_1 = Shaft Rotation (rpm)
n_2 = Transmission Motor Shaft (mm)

2.8. Screw Conveyor Capacity

Screws are used in ballistic machines to force waste down from the hopper to the cutting area, where it is cut.

$$Q = 60\ \frac{\pi D^2}{4}\ S\ x\ n\ x\ \psi\ x\ \gamma\ x\ C\ (\frac{ton}{h}) \qquad \text{......} (9)$$

Where:

Q = Screw Conveyor Capacity (ton/h)
V = Material Flow Rate (m3/h)
S = Pitch Screw (m)
D = Thread Diameter (m)
n = Thread Rotation (rpm)
γ = Material Density (3 tons/hour)
C = Correction Factor
β = 0 yang 5o 10o 15o 20o
ψ = Efficiency of Vertical Screw Conveyor

2.9. Torque Moments

The shaft will be loaded in the form of a torsional moment as a result of power and rotation.

$$T = 9{,}74\ \times 10^5 \frac{p_d}{n} \qquad \text{..........} (10)$$

Where:

T = Plan a Rotating Moment (kg.mm)
Pd = Plan Power (kW)
N = Rotation (rpm)

2.10. Shaft Subjected to Torsional Pressure and Bending

The shaft distributes power through belts, gears, chains and other mechanisms. As a result, the shaft is subjected to torsional and pliable loads.

$$\sigma_{max} = \frac{5{,}1}{{d_s}^3} x \sqrt{K_m {M_b}^2 + K_t {M_t}^2} \qquad \text{.........} (11)$$

Where:

K_m = Correctipada Supple Stress Factor
M_b = Stress Bending
K_t = Torque Correction Factor
M_t = Moment of Torque

2.11. Shaft Rotation

The rotation of the shaft can be determined by knowing the rotation of the motor used:

$$\frac{D_2}{D_1} = \frac{n_1}{n_2} \quad \text{………… (12)}$$

Where:

D_2 = Driven Pulley Diameter (mm)
D_1 = Drive Pulley Diameter (mm)
n_1 = Rotation (rpm)

2.12. The Power to Cut Waste

This is the cutting speed of the blades in units of time during cutting.

$$v_p = \frac{\pi\left(l_p + d_{pp}\right)n_2}{60x100} \quad \text{……… (13)}$$

Where:

v_p = Blade Speed (m/s)
d_{pp} = Shaft Blade Diameter (m/s)
I_p = Knife Inertia ($kg.mm^2$)

2.13. Inertial Axis Moment

The equation for calculating the moment of the inertial about the shaft is:

$$I = \frac{1}{2}MR^2 \quad \text{…….. (14)}$$

Where:

I = Moment of Inertia ($kg.mm^2$)
R = Shaft Diameter (mm)
M = Mass (kg)
Blade Inertial Moments and Support

This equation can be used to calculate the moment of inertia about the shaft:

$$I = \frac{1}{3}ML^2 \quad \text{…….. (15)}$$

Where:

I = Moment of Inertia ($kg.mm^2$)
L = Blade Length/stand (mm)
M = Mass (kg)

2.14. Angular Velocity

The angular quantity created by a circular path is called angular velocity. The following is the angular velocity equation:

$$\omega = \frac{\pi . n_2}{30} \quad \text{………….. (16)}$$

Where:

ω = Angular Velocity (rad/s)
n_2 = Shaft Rotation (rpm)

2.15. Angular Acceleration

After obtaining the value of the angular velocity, the resulting angular acceleration can be calculated as follows:

$$\alpha = \frac{\omega_1 - \omega_2}{\Delta t} \quad \text{……….. (17)}$$

$$\omega = \frac{d\theta}{dt} = \frac{2\pi}{t} \quad \text{……….. (18)}$$

Where:

α = Angular Acceleration (rad/s^2)
t = Time(s)

2.16. Inertial Torque Shaft, Blade and Support

The inertial torque is calculated after the angular acceleration is calculated, and it is as follows:

$$T_{po} = \frac{l_{po}\ x\ \alpha}{g} \quad \text{…………… (19)}$$

$$T_{pi} = \frac{l_{pi}\ x\ \alpha}{g} \quad \text{…………… (20)}$$

$$T_{pe} = \frac{l_{pe}\ x\ \alpha}{g} \quad \text{…………… (21)}$$

Where:

T_{po} = Shaft Inertial Torque (rad/s^2)
T_{pi} = Blade Inertial Torque (rad/s^2)
T_{pe} = Knife Supporting Inertial Torque (rad/s^2)

2.17. The Power of Inertia

The strength of inertia can be estimated using the following equation after knowing the inertial torque:

$$P_{po} = \frac{T_{po}\ x\ n_2}{9{,}74\ x\ 10^5} \quad \text{………… (22)}$$

$$P_{pi} = \frac{T_{pi}\ x\ n_2}{9{,}74\ x\ 10^5} \quad \text{………… (23)}$$

$$P_{pe} = \frac{T_{pe}\ x\ n_2}{9{,}74\ x\ 10^5} \quad \text{………… (24)}$$

Where:

P_{po} = Shaft Inertial Power (Kw)
T_{po} = Shaft Inertial Torque (rad/s^2)
P_{pi} = Inertial Force of the Knife (Kw)
T_{pi} = Torque Inertial blade (rad/s^2)
P_{pe} = Knife Supporting Inertial Force (Kw)
T_{pe} = Knife Supporting Inertial Torque (rad/s^2)

n_2 = Shaft Rotation (rpm)

2.18. Ballistic Thrust Machine

The transmission and power system on the shaft provide the necessary power for the ballistic engine, therefore the power equation is:

$$Pt = P + P_1 + P_2 + P_3 \qquad \text{.........} \ (25)$$

$$P = P_t + P_a + P_p + P_f \qquad \text{..........} \ (26)$$

Where:

Pt = Shaft Power (kW)
P = Knife Cutting Strength (kW)
P_1 = Blade Inertial Force (kW)
P_2 = Knife Supporting Inertial Force (kW)
P_3 = Shaft Inertial Power (kW)
1 kW = 1.34 HP

3. Reusable Methodology

3.1. Literary Studies & Observation

There are four parts to the ballistic engine pivot: a hopper, a booster chamber, a counting chamber, and an outboard thruster. The hopper is a temporary storage area for garbage before it is stored in a helicopter tube. The Screw Conveyor Inlet in the driver's chamber serves as a tr ash pusher, allowing the garbage to be moved to the enumeration chamber. Enumeration, which occurs in the enumeration chamber with a knife, is the following step. The last procedure takes place in the pusher chamber, where there is a Screw Conveyor Outlet, whether here the garbage is pushed to the end and out of the ballistic machine. The shaft of the ballistic machine measures 2350 mm long and is supported by two bearings. The shaft of the ballistic machine in this investigation was made of AISI 1045 steel.

3.2. Issue Detection

A problem that can be solved after conducting observational research is the capacity of the ballistic machine, which is expected to be 10 tons per hour as planned. However, the capacity of the machine has not met the planning objectives, according to data and information obtained from TPST Samtaku Jimbaran Bali.

3.3. Drawing with a Machine

The next step in this investigation is to make a drawing of the machine based on observations. Solidworks 2018 is a software used to create machine drawings. It can be used to build a Free Body Diagram for modeling and computational purposes, as well as to explain explanatory points, such as loading locations and the use of illustrative images as descriptions. Perform the following parts/components:

Table 2 Blade Dimensions

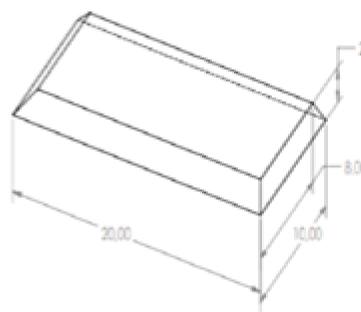
Length	200 mm	
Thickness	20 mm	
High	100 mm	
Total Number	21	

Table 3 Dimensions of Screw Conveyor Inlet

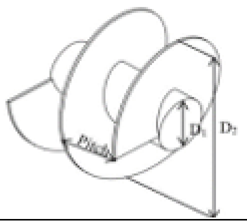
D_1	200 mm	
D2	600 mm	
Length	500 mm	
Pitch	200 mm	

Table 4 Dimensions of Screw Conveyor Outlet

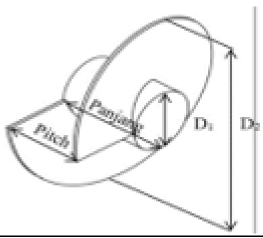
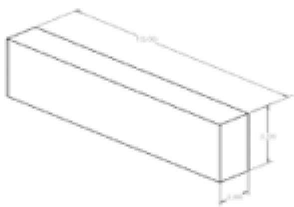
D_1	200 mm	
D2	600 mm	
Length	260 mm	
Pitch	200 mm	

Table 5 Knife Support Dimensions

Length	150 mm	
Thickness	20 mm	
High	50 mm	
Total Number	18	

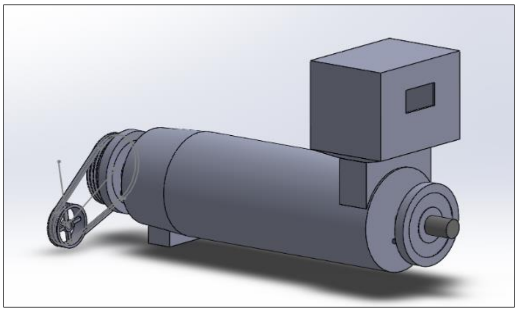


Figure 1 Ballistic Machine

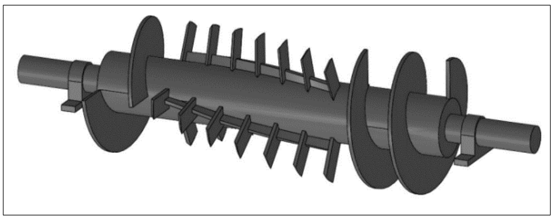


Figure 2 Shaft Ballistic Machine

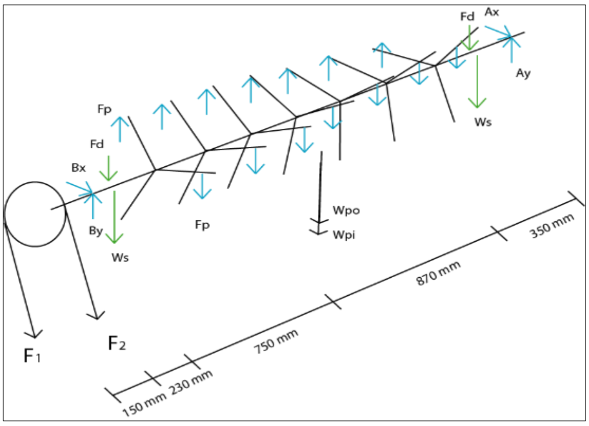


Figure 3 Shaft Free Body Diagram

Where:

W_s	= Weight of Screw Conveyor Inlet (N)
W_{po}	= Shaft Weight (N)
W_{pi}	= Knife Weight (N)
W_s	= Weight of Screw Conveyor Outlet (N)
F_d	= Axial Force of The Screw Conveyor (N)
W	= Weight (kg)
g	= Gravity Accrolation (m/s^2)
A	= Reaction on the base (n)
B	= Reaction on the base (n)
F_p	= Cutting Force Knife (N)
F_1	= Belt Reaction Force (N)
F_2	= Belt Action Force (N)

3.4. Motor Specifications, Shaft Rotation

Figure 4 Motor Specifications

The transmission obtained from the calculation of the diameter of the shaft pulley and the motor pulley with an average motor rotation load of 1480 rpm can be used to calculate the shaft design power.

3.5. Calculation of Stress and Moments

At this stage, a diagram of the free body is made vertically and horizontally. For the vertical direction there are 11 pieces of force and for the horizontal direction there are 4 pieces.

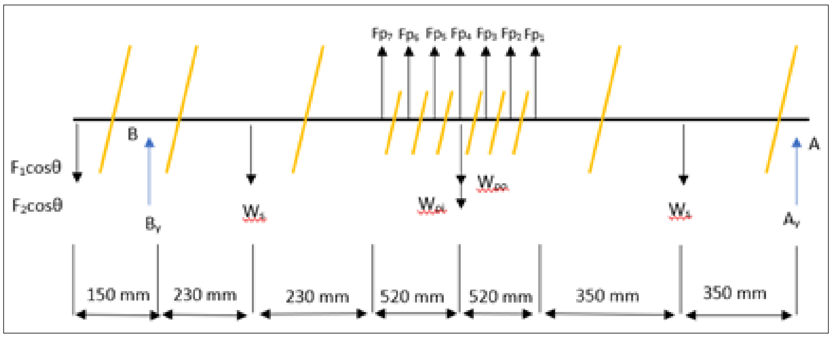


Figure 5 Free Body Diagram of Vertical Axis Style

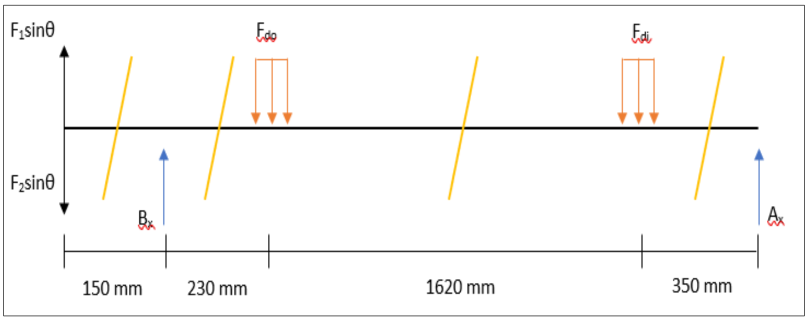


Figure 6 Free Body Diagram of Horizontal Axis Style

3.6. Capacity Verification

The verification process is currently being carried out using the input of waste data into the Samtaku Jimbaran Bali TPST on November 1-5, 2021, as part of the experiment.

4. Results and Discussion

4.1. Weight Calculation Screws

The density of AISI 1045 is 7.85 g/cm³, so the mass of the screw is as follows:

$$m = \rho \; x \; v$$

$$= 7{,}85 \; x \; 6280 \; x \; 10^3 \frac{g}{cm^3} \; x \frac{cm^3}{1000} \; x \frac{kg}{1000},$$

$$= 49{,}29 \; kg$$

$$W = m \; x \; g$$

$$= 49{,}29 \; kg \; x \; 9{,}81 \; m/s^2$$

$$= 483{,}61 \; N$$

4.2. Blade Weight Calculation

On ballistic machines, there are 21 blades and 7 threads. As a result, calculate the weight of the blades as follows:

$$LP = \frac{1}{2}(upperside + lowerside) x\ high$$

$$= \frac{1}{2}\left(100\ mm + 80\ mm\right) x\ 20\ mm$$

$$= 1800\ \ mm^2$$

$$V_1 = 1800\ mm^2\ x\ 200\ mm$$

$$= 360000\ mm^3$$

$$LP = \frac{1}{2}\ lowerside\ x\ high$$

$$= \frac{1}{2}\ (20\ mm\ x\ 20\ mm)$$

$$= 200\ mm^2$$

$$V_{2'} = 200\ mm^2\ x\ 100\ mm$$

$$= 20000\ mm^3$$

$$V_2 = \left(360000\ mm^3 - \ 20000\ mm^3\right)$$

$$V_2 = 340000\ mm^3$$

$$m = \rho\ x\ v$$

$$= 7{,}85\ x\ 340000\ \frac{g}{cm^3} x\ \frac{cm^3}{1000}\ x\ \frac{kg}{1000\ g}$$

$$= 2{,}669\ kg$$

$$m_{total} = 2{,}669\ kg\ x\ 21$$

$$= 56{,}049\ kg$$

$$W = m\ x\ g$$

$$= 56{,}049\ kg\ x\ 9{,}81\ \frac{m}{s^2}$$

$$= 549{,}84\ N$$

4.3. Weight Calculation of Knife Support

Knife supports are used to hold the blades in place, and there are 18 of them, so the weight of the supports is as follows:

$$m = \rho\ x\ v$$

$$= 7{,}85\ x\ 150000\ \frac{g}{cm^3}\ x\ \frac{cm^3}{1000}\ x\ \frac{kg}{1000}$$

$$= 1{,}1775\ kg$$

$$m_{total} = 1{,}1775\ kg\ x\ 18$$

$$= 21{,}195\ kg$$

$$W = m\ x\ g$$

$$= 21{,}195\ kg\ x\ 9{,}81\ m/s^2$$

$$= 207{,}922\ N$$

4.4. Cutting Strength and Torque

The cutting force in the experimental sample comes from the waste load. Garbage is divided into organic and inorganic waste by its characteristics:

Table 6 Cutting Experiments

Test Materials	Test Material (kgf)
Wrap Noodles	41,2
Plastic Bottle	22,56
Mango Leaves	18

The average experimental power is 26.58 kilograms per square meter. As a result, the cutting torque is:

$$T = F_p\ x\ r$$

$$T = 26{,}58\ x\ 254$$

$$T = 6725{,}86\ kgf.mm$$

Where:

F_p = 26,58 *kgf*
R*pulley* = 254 mm

4.5. Shaft Rotation Calculation

The diameter ratio of the pulley used can be used to find the rotation received by the shaft, as shown below:

$$\frac{D_2}{D_1} = \frac{n_1}{n_2}$$

$$\frac{508}{304{,}8} = \frac{1250}{n_2}$$

$$n_2 = \frac{1480\ x\ 304{,}8}{508}$$

$$n_2 = 750\ rpm$$

$P_d = f_c \times N$

$= 1.3 \times 36.75\ kW$

$= 47.775\ kW$

4.6. Perhitungan Torsional Moment

The diameter ratio of the pulley used can be used to find the rotation received by the shaft, as shown below:

$$T = 9{,}74\ x\ 10^5\ \frac{P_d}{n}$$

$$T = 9{,}74\ x\ 10^5\ \frac{47{,}7}{750}$$

$$= 60926{,}8\ kg.mm$$

4.7. Shear Stress Calculation

Since the shaft material is AISI 1045 or S 45C, with a tensile strength of 58 kg/mm2, the shear stress is as follows:

$$\sigma_a = \frac{\sigma_b}{sf_a x\ sf_2}$$

$$\sigma_a = \frac{58}{6\ x\ 1{,}5}$$

$$= 6{,}444\ kg/mm^2$$

4.8. Screw Material Rate and Axial Force

The following equation can be used to calculate the flow rate of screw materials:

$$v = \frac{\pi ds}{1000\ x\ 60}$$

$$= \frac{\pi.600.20}{1000\ x\ 60}$$

$$= 6{,}28\ x\ 10^{-4}\ m/s$$

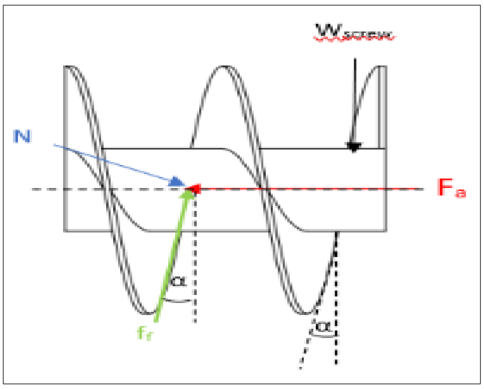
$$F = m\ x 58$$

$$= 985{,}96\ \ kg\ x\ 0{,}52$$

= 513.685 N

4.9. Axial Force Screws

To determine the force exerted on the screw, an analysis of the direction of the working force is performed, and Newton's law is applied as follows:



$$F_t = m\ x\ g$$

$$F_t = 300\ kg\ x\ 9{,}81\ m/s^2$$

= 2943 N

$\sum F_x = 0$

F_a = N (cos 58 + μs (sin 58)) – Screw W (sin 58)

$\sum F_y = 0$

N = $\frac{f_t coscos\ 58 + W_{screw} coscos\ 58}{\mu_s coscos\ \alpha - sinsin\ \alpha}$

N = $\frac{2943\ (0{,}521) + 9672{,}27\ (0{,}521)}{8{,}33\ (0{,}521) - 0{,}853}$

N = 1884.91

F_a = 1884.91 (cos 58 + μ_s (without 58)) $-_{Screw}$ W (without 58)

= 1884,91 (0.521 + 8,33 (0.853)) – 9672,27 (0.853)

= 6124.8 N

Where:

F_t = 1884.91 N

μ_s = 8,33

a = Angle (58°)

F_a = Axial Force (N)

4.10. Knife Cutting Power

The blades of the ballistic machine contained 21 blades and were separated into seven threads, each with a different 4.2 slope. As a result, the cutting strength of the knife for each thread is as follows:

$$F = m\ x\ g$$

$$= 2{,}669\ (3)\ x\ 9{,}81\ m/s^2$$

$$= 78{,}54\ N$$

$$F_{p1} = m\,x\,sin\,sin\,90$$
$$= 78{,}54\,N$$
$$F_{p2} = 78{,}54\,x\,sin\,sin\,85{,}8$$
$$= 76{,}59\,N$$
$$F_{p3} = 78{,}54\,x\,sin\,sin\,81{,}6$$
$$= 75{,}28\,N$$
$$F_{p4} = 78{,}54\,x\,sin\,sin\,77{,}4$$
$$= 73{,}64\,N$$
$$F_{p5} = 78{,}54\,x\,sin\,sin\,73{,}2$$
$$= 71{,}68\,N$$
$$F_{p6} = 78{,}54\,x\,sin\,sin\,69$$
$$= 69{,}41\,N$$
$$F_{p7} = 78{,}54\,x\,sin\,sin\,64{,}8$$
$$= 66{,}83\,N$$
$$\sum F_p = \frac{511{,}97}{7} = 73{,}138\text{ N}$$

The cutting power of the knife for each thread is 73.138 N.

4.11. External Load Shaft

There are two bearings on the shaft of the ballistic machine, A and B. Horizontal direction has the following reactions in the free body diagram:

$$\sum M_B = 0$$

$$A_x (2200) - F_{di} (1850) - F_{do} (230) + F_1 sin (70) (150) - F_2 sin (70) (150) = 0$$

$$A_x (2200) = 513.685 (1850) + 513.685(230) - 250065{,}58 + 87744.195$$

$$An_x (2200) = 906143{,}415 = 411.883 \text{ N}$$

$$\sum F_x = 0$$

$$Axe + Bx + F_1 (sin70) - F_{di} - F_{do} - F_2(sin70) = 0$$

$$= -466.65 \text{ N}$$

Each of the four parts of the moment in the horizontal free body diagram has the following values:

Table 7 Horizontal Bending Moment

Cut	Cutting Area Length	Bending Moment of the Cutting Area	Max Value
Cutting 1	$0 \le x_1 \le 350$	x = 350; 144159,05 N.mm	
Cutting 2	$0 \le x_2 \le 1970$	x = 350; 144159,05 N.mm	
Cut 3	$0 \le x_3 \le 2200$	x = 2200; 162322,2 N.mm	Max
Cut 4	$0 \le x_3 \le 2350$	x = 2200; 0 N.mm	

The vertical direction in the diagram of the free body has the following support reactions:

$$\sum M_B \quad = 0$$

W s.1850 + W po.980 + W pi.980 + W s.230 + F_1cosθ.150 + F_2cosθ.150 – Fp 1.1650 – Fp 2.1477 – Fp_3. 1304 – Fp 4.1130 – Fp 5.956 – Fp 6.783 – Fp 7.610 - Ay.2200 = 0

A_y(2200) = 9672,27 N (1850) + ((757,76 N + 15459,611 N)980) + 5029,579 N (230) - 2165,07 N (cos70)(150) - 759,69 N (cos70)(150) – 78,54 N (1650) – 76,59 N (1477) – 75,28 N (1304) – 73,64 N (1130) – 71,68 N (956) – 69,41 N (783) – 66.83(610)

$$A_y \quad = \frac{34079443{,}3}{2200}\ \text{N}$$

$$A_y \quad = 15490{,}6\ \text{N}$$

$$\sum F_y \quad = 0$$

$A_y + B_y + Fp_1 + Fp_2 + Fp_3 + Fp_4 + Fp_5 + Fp_6 + Fp_7 - W_s - W_{po} - W_{pi} - W_s$ - W s - F_1(cos70) - F $_2$(cos70) = 0

B_y = -15725.26 – 78.54 – 76.59 – 75.28 – 73.64 – 71.68 – 69.41 – 66.83 + 5029.57 + 15459,611 + 757.76 + 5029.57 + 1363.9 + 478.6

$$B_y \quad = 16911.35\ \text{N}$$

The free body chart for the vertical direction has a component of 11 moments, with the following values for each moment:

Table 8 Vertical Bending Moment

Cut	Cutting Area Length	Bending Moment of the Cutting Area	Max Value
Cutting 1	$0 \le x_1 \le 350$ X = 350	5503820 N.mm	
Cutting 2	$0 \le x_2 \le 700$ X = 700	7458122 N.mm	
Cut 3	$0 \le x_3 \le 873$ X = 873	8478278,78 N.mm	
Cut 4	$0 \le x_4 \le 1046$	9511685,63 N.mm	
Cut 5	$0 \le x_5 \le 1220$	10564164,65 N.mm	Max
Cut 6	$0 \le x_6 \le 1393$	10564164,65 N.mm	
Cut 7	$0 \le x_7 \le 1566$	8817730,87 N.mm	
Cut 8	$0 \le x_8 \le 1739$	7083696,51 N.mm	
Cut 9	$0 \le x_9 \le 1970$	5361670,08 N.mm	
Cut 10	$0 \le x_{10} \le 2200$	3077754,6 N.mm	
Cut 11	$0 \le x_{11} \le 2350$	2029873,8 N.mm	

4.12. Biggest Bending Moment

The moment resulting from the horizontal bending moment and the vertical bending moment is the biggest moment.

$$M_b = \sqrt{{M_{Bx}}^2 + {M_{By}}^2}$$

$$M_b = \sqrt{(162322{,}2)^2 + (10564164{,}65\ )^2}$$

$$M_b = 10565411{,}65\ N.mm$$

4.13. Pony Max

The following equation can be used to calculate the maximum voltage that occurs:

$$\sigma_{max} = \frac{5{,}1}{{d_s}^3} x \sqrt{K_m {M_b}^2 + K_t {M_t}^2}$$

$$\sigma_{max} = \sqrt{\left(\frac{1{,}5x\ 32(10565411{,}65)}{\pi(200)^3}\right)^2 + \left(\frac{1\ x\ 16(60926{,}8)}{\pi(200)^3}\right)^2}$$

$$\sigma_{max} = 107.099\ \text{N/mm}^2$$

4.14. Cutting speed and strength of the blade

The following calculations can be used to calculate the circular velocity of the blade:

$$v_p = \frac{\pi\,(L_p) + (d_{pp})n_2}{60\ .\ 100}$$

$$v_p = \frac{\pi\ (200) + (200)\ 750}{60\ .\ 100}$$

$$v_p = 29{,}7\ mm/s$$

$$P = F_p\ x\ v_p$$

$$P = 73{,}138\ N\ x\ 29{,}7\ mm/s$$

$$P = 2172{,}19\ Nmm/s$$

$$P = 2{,}170\ \frac{Nm}{s} = 2{,}172\ watt$$

4.15. Inertia of the Pivot Al Moment

The shaft of the ballistic machine is made of 7.85 g/cm3 (S 45C) material with a shaft radius of 50 mm. As a result, the moment of inertia is:

$$I = \frac{1}{2} MR^2$$

$$\text{I} = \frac{147{,}89\ x\ 250\ mm^2}{2}$$

$$= 36972{,}5\ kg.mm^2$$

4.16. Knife and Knife Support Moments in Case of Inertia

The moment of inertia of the blade and support can be calculated as follows:

$$I_{pi} = \frac{1}{3} M a^2$$

$$I_{pi} = \frac{1}{3} 2{,}669 \; x \; 200^2$$

$$I_{pi} = 53380 \; kg.mm^2$$

$$I_{pe} = \frac{1}{3} M a^2$$

$$I_{pe} = \frac{1}{3} 1{,}1775 \; x \; 150^2$$

$$I_{pe} = 13246{,}87 \; kg.mm^2$$

4.17. Angular velocity and angular acceleration

The angular velocity can be determined using the following equation after obtaining the moment of inertia of the shaft and blades:

$$\omega = \frac{\pi \; x \; n_2}{30}$$

$$\omega = \frac{\pi \; x \; 750 \; rpm}{30}$$

$$\omega = 78{,}5 \; rad/s$$

$$t = \frac{2\pi}{\omega}$$

$$t = \frac{2\pi}{78{,}5 \;\; rad/s}$$

$$t = 0{,}08 \; s$$

$$\alpha = \frac{d\omega}{\Delta t}$$

$$\alpha = \frac{78{,}5 \; rad/s}{0{,}08 \; s}$$

$$\alpha = 981{,}25 \; rad/s^2$$

4.18. Torque Inertia Shaft, Blade and Knife Support

The inertial torque can be determined using the following equation after acquiring the angular acceleration:

$$T = \frac{lpi \; x \; a}{g}$$

$$T_{pi} = \frac{53380 \; kg.mm^2 \; x \; 981{,}25 \; rad/s^2}{9{,}81 \; m/s^2}$$

$$T_{pi} = 5339{,}36\ kgmm$$

$$T_{po} = \frac{36792{,}5\ kg.mm^2\ x\ 981{,}25\ rad/s^2}{9{,}81\ m/s^2}$$

$$T_{po} = 3680{,}18\ kgmm$$

$$T_{pe} = \frac{13246{,}87\ kg.mm^2\ x\ 981{,}25\ rad/s^2}{9{,}81\ m/s^2}$$

$$T_{pe} = 1325{,}02\ kgmm$$

4.19. Supporting Inertial Forces of Shafts, Blades, and Blades

Inertial power can be estimated using the following equation after the torque is calculated:

$$P = \frac{\tau\ x\ n_2}{9{,}74\ x\ 10^5}$$

$$P_{pi} = \frac{5339{,}36\ kg.mm\ x\ 750\ rpm}{9{,}74\ x\ 10^5}$$

$$P_{pi} = 4{,}1\ Kw$$

$$P_{pe} = \frac{1325{,}02\ kg.mm\ x\ 750\ rpm}{9{,}74\ x\ 10^5}$$

$$P_{pe} = 1\ Kw$$

$$P_{po} = \frac{3680{,}18\ kg.mm\ x\ 750\ rpm}{9{,}74\ x\ 10^5}$$

$$P_{po} = 2{,}8\ Kw$$

As a result, the entire power requirement of the ballistic machine is:

$$Pt = P + P_1 + P_2 + P_3$$

$$Pt = 0{,}002\ Kw + 4{,}1\ Kw + 1\ Kw + 2{,}8\ Kw$$

$$Pt = 7{,}902\ Kw$$

When converted to 10.6 HP House Power (1 kW = 1.34 HP)

4.20. Hopper Capacity

To calculate the capacity of the hopper, multiply the volume of the hopper by the volume of space filled with garbage:

$$v_t = v_2 + v_1$$

$$v_1 = 850\ mm\ x\ 600\ mm\ x\ 650\ mm$$

$$v_1 = 0{,}3315\ m^3$$

$$v_2 = \frac{1}{2}(850\ mm + 693\ mm) x\ 53\ mm\ x\ 693\ mm$$

$$v_2 = 0{,}0283\ m^3$$

$$v_t = 0{,}3598\ m^3$$

If 1 m3 = 300 kg of litter is converted, the total amount of litter that can be filled is 107.94 kg.

4.21. Chopper Tube Capacity

The shaft, screw conveyor, blades, and knife support are all contained inside the helicopter tube. The volume of the remaining space of the shaft components determines the capacity of the cutting tube. The volume of the counter tube can then be estimated using the formula:

$$Q = v_1 + v_2$$

$$v_1 = 3{,}14x0{,}38^2x1{,}73$$

$$v_1 = 0{,}78\,m^3$$

$$v_2 = \frac{1}{3}\,3{,}14x0{,}38\,m(0{,}38^2 + 0{,}38x0{,}35 + 0{,}35^2)$$

$$v_2 = 0{,}16\,m^3$$

$$Q = 0{,}94\,m^3$$

$$q = v_1 + v_2 + v_3$$

$$q = 10091200\,mm^3 = 0{,}01\,m^3$$

$$Q_t = 0{,}94\,m^3 - q$$

$$Q_t = 0{,}93\,m^3$$

The garbage that can fill the space in the counting tube is 281.7 kg if 1 m3 = 300 kg is converted.

Where:

v_1 = Blade Volume
v_2 = Knife Support Volume
v_3 = Shaft Volume
Q_t = Capacity (kg)
q = Full Capacity Chopper Tube

4.22. Screw Conveyor Capacity

Garbage is pushed into the enumeration chamber of the screw conveyor section of the ballistic machine. The following information is available:

Roll rotation (n) = 750 rpm

S = Pitch screw = 200 mm = 0,2 m

Ψ = Friction Factor Load Efficiency = 0.25

(non-absorbent free flow)

γ = Material Weight = 0.3 tons / m^3

D = Screw Diameter = 400 mm = 0.4 m

C = Friction Factor = 0.65

$$Q = 60\,\frac{\pi D^2}{4}\,S\,x\,n\,x\,\psi\,x\,\gamma\,x\,C\,(\frac{ton}{jam})$$

$$Q = 60\ \frac{3{,}14x0{,}32^2\ m}{4}\ 0{,}2\ m\ x\ 750\ x\ 0{,}25\ x\ 0{,}3\ x\ 0{,}65\ (\frac{ton}{jam})$$

$$Q = 45{,}14\ (\frac{ton}{jam})$$

4.23. Machine Production Capacity

Within 8 hours, the ballistic machine was in operation. The average daily waste that enters the TPST is 26162 kg on November 1-5, 2021, and it is still a combination of organic and inorganic waste. Sorting out organic and inorganic waste is the next step.

$$Q = \frac{Z}{t}$$

$$Q = \frac{26162\ kg}{8\ h}$$

$$Q = 3270{,}3\ kg/h$$

Garbage capacity on ballistic machines:

$$Q_b = v\ x\ rpm$$

$$Q_b = 281{,}7\ kg\ x\ 750\ rpm$$

$$Q_b = 211275\ kg/m$$

$$Q_b = 12{,}676\ \frac{ton}{h}$$

As a result, the capacity of the machine can produce 101,412 tons of garbage every hour in one day. The capacity of the machine has exceeded the intended capacity, according to the plan.

To eliminate the machine's production capacity terminal, apply the following screw conveyor calculations used to transport waste to the outside of the ballistic tube:

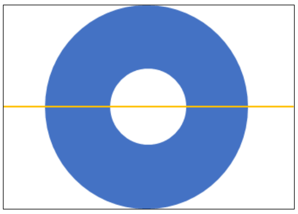


Figure 7 Screw Conveyor

$$V = A\ x\ p$$

$$V = \frac{\pi}{4}\ (D^2 - d^2)\ x\ p$$

$$V = \frac{\pi}{4}\ (600^2 - 200^2)\ x\ 200$$

$$V = 50240000\ mm^3 = \frac{0{,}05}{2}\ m^3 = 0{,}025\ m^3$$

The screw conveyor part that pushes the waste out of the ballistic tube will only push half of it. To determine the capacity of the screw conveyor, do the following:

$$Q = 60\ x\ n\ x\ v\ x\ p$$
$$Q = 60\ x\ 750\ x\ 0{,}025\ m^3\ x\ 1{,}3\ kg/m^3$$
$$Q = 1{,}46\ ton/h$$

Where:

V = Volume of Screw Conveyor (m^2)
D = Screw Conveyor Diameter (m)
d = Shaft Diameter (m)
p = Pitch (m)
Q = Capacity(tons/h)
P = Density of Garbage (kg/m^3)

The machine uses the capacity of the screw conveyor placed in the part after enumeration, which will further become the output of waste after the enumeration process is completed, according to the calculation. A machine capable of producing chopped yields at the rate of 1.46 tons / hour produces the resulting capacity in a matter of hours. And the capacity of the ballistic machine, which is 243 kg for 10 minutes, is converted to 24.3 kg/min if the capacity is converted in a matter of minutes. Where this has been met, the results obtained from the enumeration of waste are 1.5-2.4 mm in size, and the results are ideal.

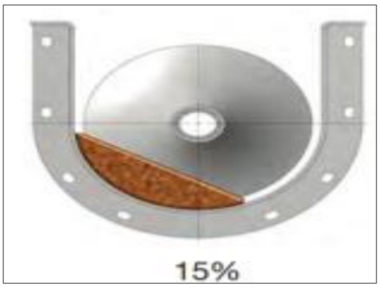


Figure 8 Garbage Filled 15% In Ballistic Tubes

Figure 9 Size of Waste Counting Results

5. Conclusion

The following results were achieved after studying the calculations and simulations on the shaft of a ballistic machine with a capacity of 10 tons per hour:

The greatest bending moment is 10565411.65 N.mm, and the maximum voltage occurring is 107.099 N / mm2, according to the load analysis of ballistic machines. The shaft requires 4.5 kW of electricity, 1.6 kW of support, 6.5 kW of blades, and the entire power load of the ballistic engine is 37.3 HP.

The calculation of capacity is based on incoming waste from November 1 to 5, 2021, with an average of 26162 kg per day. Incoming garbage is moving at a speed of 1.62 m/s. The tube capacity of the ballistic machine is 281.7 kg, with a production rate of 1.46 tons per hour.

Compliance with ethical standards

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Disclosure of conflict of interest

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