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ANALYTICAL CALCULATION OF PULLEY AND V-BELT FOR RICE THRESHER POWERED BY MATARI MGX-390 GASOLINE ENGINE

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Abstract

In the agricultural industry today, a lot of tools with automatic transmission have become primary needs for many people. To be able to operate a rice threshing machine, one that can support the running of the tool is the pulley and V-belt on the driving machine. Therefore, this research aims to analyze the pulley and V-belt on the rice thresher with the Matari MGX-390 gasoline engine so that it meets the required criteria and applicable standards. Due to the important role of the V-belt and pulley components, this study will discuss calculations in the design of V-belt and pulley components for a rice thresher with a Matari MGX-390 gasoline engine. The method used is direct observation, to see directly the shape and specifications of the rice thresher machine as well as the Matari MGX-390 gasoline engine used, also to record the dimensions of the pulley and V-belt so that further analysis is carried out on these components, and it can be seen whether the pulley and the V-belt used can be declared safe. Then calculations are carried out to determine the type of V-belt used, V-belt length, maximum voltage, demand voltage, and service life on the V-belt used. Based on the results of the research and calculations that have been carried out, it shows that the V-belt used by the rice thresher with the Matari MGX-390 machine can be declared safe with the type of V-belt used as type A, with a length of 1,649.74 mm, a maximum tension of 138.8 N, voltage requirement 121 N, service life 14,055 working hours.

Keywords: Matari MGX-390, Rice Threshing, V-belt, Pulley, Gasoline Engine

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1. Introduction

Paddy or rice is the staple food for the Indonesian people. BPS data shows that rice production in Indonesia in 2021 will reach 54.42 million tonnes[1], and data from the Ministry of Trade shows that Indonesia occupies the third position in the country that produces the most rice in the world[2]. This indicates that rice production in Indonesia must be better in terms of quality and quantity.

In the world of food and agriculture today, many tools have been used as primary needs by a company or individual, so the supporting factors that can improve these tools must be prepared. One way to increase effectiveness and efficiency in agricultural production is to innovate appropriate and low-cost technologies, especially in handling yields, namely the rice thresher. Rice threshing can be done traditionally (manually) or using a machine. Manual handling of rice yields will result in relatively large scattered yield losses and poor grain quality and requires more human resources[3].

A rice thresher is a mechanical device that functions to separate rice from its stalks and increase productivity and clean quality of rice. A gasoline engine drives the rice thresher. Gasoline propulsion engines are power-generating machines that convert gasoline fuel into heat energy, eventually transformed into mechanical power[4].

Based on previous research from Haris[5], he performed an analysis of calculating the dimensions of the pulley and V-belt on the counter machine that had been developed to determine the required motor power, the dimensions of the pulley and V-belt used the tensile and slack side forces and the V-belt type. Belts used. In addition, research from Wandhika et al.[6] also stated that apart from knowing the dimensions, maximum tension, and tension requirements, by analyzing the calculations on the V-belt and pulley, one can also find out how the pulley and V-belt components should be safe to use for the tool or machine used. In the research of David et al.[7] who analyzed the belt calculation on the 2014 Toyota Fortuner found that the type of V-belt used, and obtained good results for operating a 3400 rpm engine compressor with a design power of 112.53 kW, with a maximum tension of 14.9 N. It is also known that the service life of the V-belt used is 721,000 working hours.

Vol.4 (No.3). 2022. pp. 92-96
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Based on this description, in this study, calculations were carried out for designing V-belts and pulleys to obtain quality and accountable V-belt design results because errors in pulley and V-belt design calculations can cause component damage earlier than has been calculated so that it has the potential to endanger operation or losses in maintenance costs.

2. Experimental and Procedures

The method used in this research is to make direct observations to find data in the form of specifications for the Matari MGX-390 branded driving machine and rice threshing equipment. Besides that, a literature study is also needed to obtain other supporting data. Furthermore, calculations determine the type of V-belt used, the length of the V-belt, maximum voltage, voltage requirement, lifetime or service life.

2.1 Material Samples

The initial analysis was carried out by direct observation of one of the farmers in Cicinde Selatan Village, Karawang-West Java, who has a rice thresher, to find out the shape and specifications of the rice thresher and its driving machine. Then the data will be recorded as a reference for the next stage. The rice thresher is shown in Fig. 1 while its specifications can be seen in Table 1.

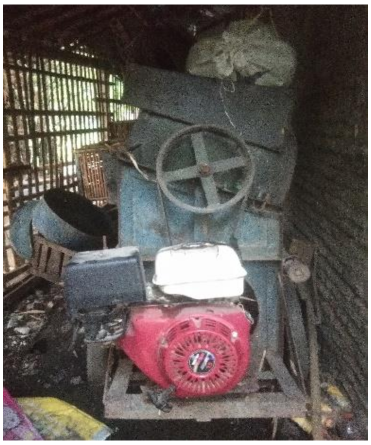


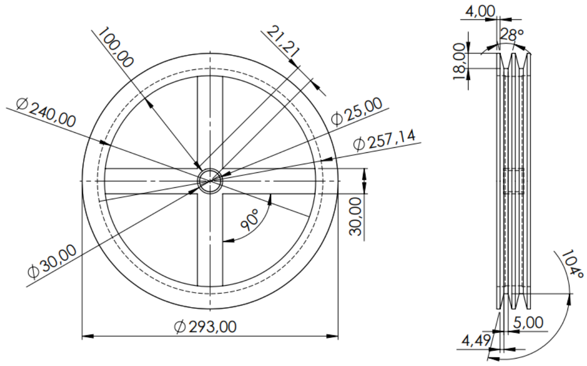
Fig. 1. Rice thresher and Matari drive machine MGX-390

Table 1. Specifications of rice thresher and driving machines

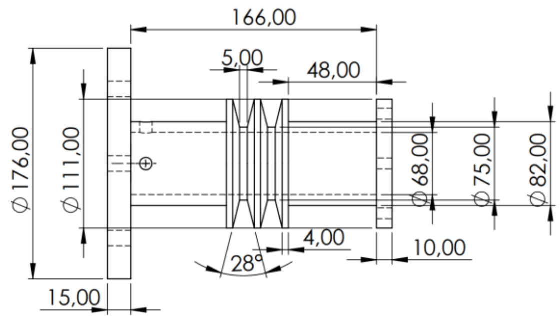
Parts	Spesification
Propulsion machine type	Matari MGX-390
Engine power	15 HP (11,18 kW)
Fuel	gasoline
Engine rpm	3600 rpm
Oil capacity	1,1 l
Fuel tank capacity	6,5 l
Rice thresher cycle	1050 rpm

2.2 Design Calculation

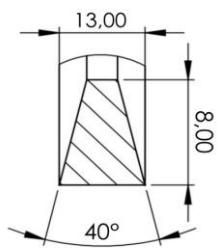
In this study, calculations are made to determine the type of V-belt used, the V-belt's length, the V-belt's maximum voltage, the required V-belt voltage, and the service life of the V-belt. With reference to previously recorded data, namely the dimensions and specifications of the pulley and V-belt on the rice thresher with the MGX-390 gasoline engine. and calculation formulas from journal article literacy studies in previous studies that can support success in this study.



(a)



(b)



(c)

(d)

Fig. 2. Matari MGX-390 components machine (a) big pulley, (b) small pulley, (c) V-belt, (d) V-belt assembly

Vol.4 (No.3). 2022. pp. 92-96
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After knowing the dimensions of the pulley and V-belt, then the drawings are made in CAD software as an illustration of the object of this study. Fig. 2 is the result of a CAD drawing that refers to data that has been recorded in previous observations.

3. Results and Discussion

3.1 Result of Planned Power Calculation

This calculation determines the correction factor based on Table 2, where the normal power required is the design power with a correction factor of 1.5.

Table 2. Types of correction factors based on the transmitted force [3].

Transmitted Power	Correction Factor
Required Average Power	1.2 – 2.0
Maximum Required Power	0.8 – 1.2
Normal Power	1.0 – 1.5

This value is taken with the consideration that the shaft will not experience a shock when transmitting power. Equation (1) is used for power calculation.

$$P_d = N \cdot F_c \quad (1)$$

where N is the engine power of 11.18 kW and F_c is the correction of factor 1.5. Based on the calculation above, it can be concluded that the planned power on the shaft is 16.77 kW.

3.2 Result of Belt Type Selection

This type of V-belt is chosen from the power to be transmitted and the rotation that occurs on the pulley. With the planned power obtained from the calculation, namely 16.77 kW and the planned rotation of 3600 rpm, the appropriate type of V-belt is obtained according to the diagram in Fig. 3[8]:

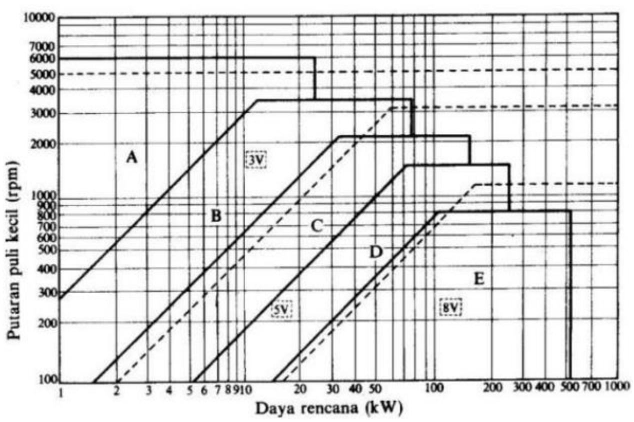

Fig. 3. V-belt selection diagram

Based on the diagram above, in this study, the type A V-belt was used with the dimensions of the V-belt according to IS: 2494-1974. The dimensions of the A V-belt are as follows, width (b): 13 mm, thickness (t): 8 mm, groove angle (c): 40°, and rubber density: 1140 kg/cm^3. The maximum tensile stress ($T_{s\ max}$) is 1.72 MPa. After obtaining the data of the belt, the calculation is carried out for the cross-sectional area of the belt.

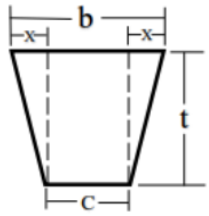

Fig. 4. V-belt cross-sectional area [8].

3.3 Result of Pulley Diameters and V-Belt Length Calculation

In this study, the V-belt used as a driving machine for the rice thresher uses a type A V-belt, which according to the dimensions of the standard V-belt type in Table 3, the minimum diameter of the pulley is determined based on the V-belt type.

Table 3. Standard V-Belt Dimensions according to IS: 2494-1974.

Type of belt	Power ranges kW	Pulley min. dia. (mm)	Top width (mm)	Thick-ness (mm)	Weight /meter length (N)
A	0,7 – 3,5	75	13	8	1.06
B	2 – 15	125	17	11	1.89
C	7,5 – 75	200	22	14	3.43
D	20 – 150	355	32	19	5.96
E	30 – 350	500	38	23	-

The minimum diameter of the pulley used is 75 mm. Then the diameter of the driven pulley can be found using the following Equation (2)[9].

$$\frac{N_1}{N_2} = \frac{d_2}{d_1} \quad (2)$$

$$\frac{3600\ rpm}{1050\ rpm} = \frac{d_2}{75\ mm}$$

$$d_2 = \frac{3600\ rpm \cdot 75\ mm}{1050\ rpm} = 257.14\ \text{mm}$$

Therefore, based on the diameter of the drive pulley (d_1) = 75 mm, the pulley driven by the rice thresher (d_2) is 257.14 mm. So that these results can be used to perform further calculation, namely the calculation of the V-belt length.

Vol.4 (No.3). 2022. pp. 92-96
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To find out the planned length of the V-belt, Equation (3) is used[7]:

$$L = \pi(r_1 + r_2) + 2.x + \left(\frac{r_1+r_2}{x}\right) \quad (3)$$

where r_1 = 37.5mm, r_2 = 128.57 mm, and distance between design axles (x) = 564 mm. So that the length of the V-belt is obtained as L = 1649.74 mm.

Then it is known that the drive pulley diameter (d_1) = 75 mm, the driven pulley diameter (d_2) = 257.14 mm, and the length of the V-belt (L) = 1649.74 mm. After knowing the diameter of the driving pulley and the driven pulley, as well as the length of the belt used, it can proceed to the next calculation, namely calculating the contact angle of the V-belt.

3.4 Result of Calculating V-Belt Contact Angle

The V-belt cross section scheme can be seen as follows:

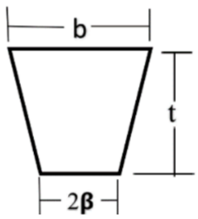

Fig. 5. Schematic of V-belt section

The angle is sought using Equation (4)[10]:

$$\sin\alpha = \left(\frac{r_2-r_1}{x}\right) \quad (4)$$

$$\sin\alpha = \left(\frac{d_2-d_1}{2\times x}\right)$$

where is d_2 257.14 mm, d_1 75 mm, and x 564 mm.

From these calculations, the contact angle of the V-belt used is (α) 10°. So that the next step of analysis can be continued, namely calculating the speed of the V-belt.

3.5 Result of Calculating V-Belt Speed

The calculation of the V-belt circumferential speed is influenced by the diameter of the pulley and its rotation. Then the calculation can be done using Equation (5):

$$v = \frac{\pi\times d_1\times N_1}{60} \quad (5)$$

where d_1 = 75 mm, N_1 = 3600 rpm, so that the speed of the V-belt is obtained (v) = 14.13 m/s. The angle of rotation small pulley on the machine can be found using Equation (6):

$$\theta = (180 - 2\alpha)\frac{\pi}{180} \quad (6)$$

Then based on these calculations, it is obtained that the small angle of rotation of the pulley is θ = 2.79 rad.

3.6 Result of Cross-sectional Area the V-Belt Calculation

To find the cross-sectional area of the V-belt (A), you can first calculate the cross-sectional areas of the X and C sides using Equation(7) and (8)[7]:

$$X = \tan 20° \times t \quad (7)$$

$$C = b - 2.x \quad (8)$$

where t = 8 and b = 13 mm, So that the values for x = 2.91 mm and C = 7.18 mm.

After obtaining the results of the cross-sectional area of the V-belt on sides x and c, the cross-sectional area of the V-belt can be calculated using Equation (9):

$$A = \frac{1}{2}\times(C + b)\times t \quad (9)$$

So that the cross-sectional area (A)= 80.72 mm^2.

3.7 Result of Maximum Stress of V-Belt and Centrifugal Force Calculation

The maximum stress that occurs in the V-belt can be known systematically by calculating the maximum tensile stress of type V-belt A ($T_{s\ max}$) to the cross-sectional area of the V-belt (A) using Equation (10)[7]:

$$T_{max} = T_{s\ max} \times A \quad (10)$$

where $T_{s\ max}$ = 1.72 MPa, and cross-sectional area of the V-belt A = 80.72 mm^2. The value of T_{max} = 138.8 N.

Centrifugal force can be found using Equation (11):

$$T_c = m \times v \quad (11)$$

where m = 1.14 kg, v = 14.13 m⁄s. Therefore, we get a centrifugal force (T_c) value of 16.10 N.

3.8 Result of V-Belt Tension Calculation

The V-belt material is made of rubber and has a trapezium cross-section. The V-belt is attached around a V-shaped pulley groove as well. To calculate the tension on the tight and loose sides of the V-belt, you can use Equation (12):

Vol.4 (No.3). 2022. pp. 92-96
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$$T_1 = T_{max} - T_c \tag{12}$$

The slack side tension of the V-belt can be found using Equation (13):

$$2{,}31 log \frac{T_1}{T_2} = \frac{\mu \times \theta}{\sin \beta} \tag{13}$$

$$2{,}31 log \frac{T_1}{T_2} = \frac{0{,}3 \times 2{,}79}{\sin 20°}$$

So, we get the values for T_1 = 122.7 N and T_2 = 1.7 N.

3.9 *Result of V-Belt Stress Requirements and Lifetime Calculation*

To find out that the selected V-belt is safe to use, it can be calculated the need for the V-belt tension to move the pulley on the rice thresher using Equation (14)[11]:

$$T = T_1 - T_2 \tag{14}$$

With a value of 121 N, it can be concluded that the V-belt used is declared safe because the maximum tension of the type A V-belt is 138.8 N. To find out or predict the lifetime of the V-belt, Equation (15) can be used [12]:

$$H = \frac{N_{base}}{3600 \times U \times x} \left[\frac{\sigma_{fat}}{\sigma_{max}}\right]^m \tag{15}$$

Where H = lifetime of the V-belt (working hours), N_{base} = the basis of the fatigue test 10^7 cycles, σ_{fat} = fatigue limit (for V-belts = 90 Kg/cm^2), σ_{max} = maximum stress arising from V-belt operation (53.47 kg/cm^2), x = the number of rotating pulleys, m = 8 for V-belt type belts, and U = number of belt rotations per second (6.27 revolutions/second).

$$H = \frac{10^7}{3600 \times 6.27\, rad/s \times 2} \left[\frac{90\, kg/cm^2}{53.47\, kg/cm^2}\right]^8$$

So that the lifetime value of the V-belt is H = 14,055 working hours.

4. Conclusions

Based on the results of the various explanations and calculations that have been done, the results obtained are the rice thresher machine with the Matari MGX-390 gasoline engine used by farmers in Cicinde Selatan village using the V-belt A type with a length of 1649.74 mm, contact angle of 10°, cross-section area of 80.72 mm2, and maximum stress of 138.8 N. The rice thresher with Matari MGX-390 motor uses a small pulley with a diameter of 75 mm and a large pulley of 257.14 mm. The V-belt used in the rice thresher machine driven by the Matari MGX-390 brand has a service life of 14055 working hours and can be declared safe with the pulley used.

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