

Design of Reversing Open Belt Transmission System for Salt-Crushing Machine with Roller-Type

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ARTICLE HISTORY

Received: 20 Juni 2024

Revised: 5 September 2024

Accepted: 20 September 2024

KEYWORDS

Design
Power
Roller
Salt
Transmission

ABSTRACT– The raw salt should be reduced the size to convert it into consumption salt. Salt crushing machine generally was designed to reduce salt grain size using rollers for crushing. The small-capacity salt-crushing machine should be designed to meet the needs of small businesses. This study aims to design a salt-crushing machine in a small capacity with a proper power transmission system that will be applied to a roller-type salt crusher. The transmission system is designed to upgrade the performance of roller-type salt crushers through V-belt and pulley transmission mechanisms and obtain the appropriate size or type of V-belt and pulley based on the capacity of the drive motor. The results show power required to crush salt by this system is 299.46 W. The motor used is a single-phase AC motor that has a power size of 1/2 HP, and the corresponding v belt is type A with a size of 51 inches, the rpm needed is 360 rpm, and the distance between rollers is 0,7 mm. Then the pulley needed is with a ratio of 1: 4. The pulleys used are type A1 which has a diameter of 3 inches and 12 inches. The average salt weight loss after the crushing process was 14.27%.

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Introduction

The total national salt requirement in 2021 is 4,671,700 tons which local salt contributes 1,593,799 tons and the import allocation is 3,077,901 tons [1]. It is currently felt that the productivity of the Indonesian local production is still low, and has not made a significant contribution to meeting domestic salt needs. In fact, many salt ponds have changed their function, resulting in an increasing area of salt fields becoming idle land. This is because the price of salt was low with low quality of local salt [2]. Increasing the economic value of salt products will also increase income which can improve the welfare of coastal communities. This is one of the efforts to empower coastal communities in a sustainable manner through product innovation based on coastal products, such as raw salt [3]. Several efforts to increase the added value of Indonesian salt are by carrying out salt washing processes and processing of consumption salt. Several studies have been carried out to improve the quality of salt by washing [4][5][6][7].

One attempt to optimize the use of raw salt into a product with high selling value is by processing it into consumption salt. The use of sea salt, one of which is raw salt, can increase

added value through the utilization as consuming salt [8]. Consuming salt is generally served in the form of coarse salt and fine salt. Salt in the form of small granules usually called fine salt is obtained by reducing the size using a salt crusher.

There are several important components in the salt crusher: bearing, electric motor, pulley, roll, adjuster, and V-belt [9]. This study focuses on the design of the power transmission system for a salt-crushing machine. The design must accommodate the objectives and be in accordance with the physical and mechanical properties of salt, which generally contains water. For moist salt, the crushing method used is the roller type. Several roller-type transmission system designs have been researched for various agricultural commodities [10][11][12]. To produce good quality salt with a specific particle size, the roller rotation speed and roller distance must be considered [13].

Salt-crushing machines with roller type have been designed previously with several power transmission systems. Salt crushing machines generally have large capacity with a 2-roller crushing mechanism and high rpm [14]. Salt-crushing machines had also been designed with one roller and on a small scale [15]. However, the distance

between rollers and power transmission must be considered to produce uniform salt size and a good crushing process suitable for small capacities. Further design of the roller and its power transmission system is needed which is suitable for small capacity salt crushing machines so that it can produce salt with a uniform particle size and a good crushing process. To design a salt-crushing machine with a roller-type capacity of 50 kg/hour, a power transmission design is needed to accommodate the opposite direction of the roller. This research aimed to design a salt-crushing machine with a roller-type capacity of 50 kg/hour with a reversing open belt drive transmission system.

Material and Methods

The steps in this research generally include design and calculations, implementation of the design in the form of design drawings, manufacturing and assembling the transmission and testing the transmission power. The raw material used was raw salt produced by conventional farmers from Indramayu, West Java.

A. Design of Power Transmission Mechanism in Roller Type Salt Crushing Machine

Design and calculations were aimed at obtaining an effective transmission mechanism. The power transmission system in the salt crusher is one of the driving components of the salt crusher. The salt was moist, so the crushing method used was the roller type. The roller method of crushing salt will be more efficient compared to other methods because there will be less salt sticking to the surface of the roller reducing the risk of jamming. The transmission design used in this tool was a reversing open belt drive transmission system. The results of the design are in the form of transmission specifications, transmission mechanisms, and material specifications. The power transmission mechanism of the roller-type salt crusher was built according to a capacity of 50 kg. The design of the reversing open belt drive transmission system is shown in Figure 1.

In Figure 1, two horizontal parallel pulleys are connected to another pulley shaft function to move the crushing roller, where the pulleys are connected to the drive source on the motor. This design aims to connect pulleys to move the crushing roller to rotate in the opposite direction. This is so that the salt can be pushed into the grinding roller.

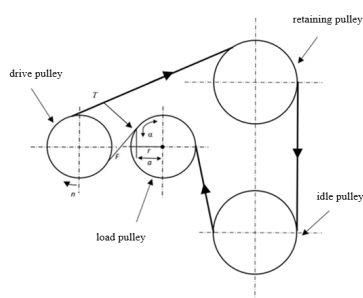


Figure 1. Design of a reversing open belt drive transmission

B. Calculation of Power and Force on the Crankshaft

The crankshaft is one of the main components used in the roller-type crushing process. The crankshaft is driven by a belt connected to an electric motor. The roller is the main component in the salt-crushing process, where the roller is rotated by a belt connected to an electric motor. So, it is necessary to calculate the power required for a roller-type salt crusher with a capacity of 50 kg/hour. It was assumed that the speed required for this tool is 360 rpm.

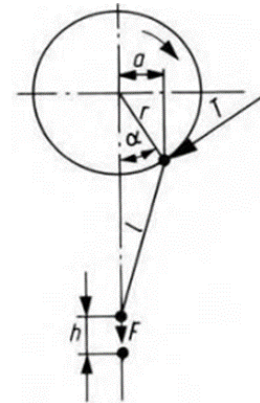


Figure 2. Free Body Diagram

A free diagram of the calculation of power requirements can be seen in Figure 2. The calculation of power requirements begins with calculating the tensile force using Equation 1 and Equation 2, then motor power requirements using Equation 3.

Dynamic tangential force:

$$\frac{T_{fd}}{F} = \sin \alpha \quad (1)$$

T_{fd} = Tangential Force (N)

F = Force (N)

Moment power when power was stored in the pulley:

$$P_{def} = \frac{T_{fd} \times r_c \times 2\pi \times n}{60} \quad (2)$$

T_{fd} = Tangential Force (N)

r_c = radius (mm)

n = rotation (rad/minute)

Motor Power :

$$P_{def} = P \left(\frac{360^\circ - \alpha}{\alpha} \right) \quad (3)$$

P_{def} = Moment Power (Nm/s)

P = Power (Watt)

Equation 3 was used to determine the pulley size ratio. The pulley size is then used for the pulley ratio and determining the belt length and distance between pulleys using Equations 4, 5, and 6.

Pulley Ratio:

$$\frac{N_2}{N_1} = \frac{D_1}{D_2} \quad (4)$$

N_2 = speed of the driven pulley (rpm)
 N_1 = speed of motor pulley (rpm)
 D_1 = Diameter of motor pulley (inch)
 D_2 = Diameter of the driven pulley (inch)

Belt length:

$$L = 2C + \frac{\pi}{2}(D_2 + D_1) + \frac{(D_2 - D_1)^2}{4C} \quad (5)$$

L = V-belt length (mm)
 D = Diameter of pulley (mm)
 C = Distance between D_1 dan D_2 (mm)
 Distance between pulley:

$$C = \frac{L_S - \left(\frac{\pi}{2}(D_1 + D_2) + \frac{(D_2 - D_1)^2}{L_S} \right)}{2} \quad (6)$$

C = Distance between pulley (mm)
 L = Belt length (mm)
 D = Diameter of pulley (mm)

Calculations on the shaft include calculating shear stress, torque, and shaft diameter using Equations 7, 8, and 9.

$$\tau = \frac{\tau_u}{F_s} \quad (7)$$

τ = Shear stress (N/mm²)
 τ_u = ultimate shear stress (MPa)
 F_s = safety factor

The torque transmitted by the shaft :

$$T = \frac{P \times 60}{2\pi N} \quad (8)$$

T = Torque (Nmm)
 P = Power (Watt)
 N = Shaft rotation (Rpm)

Relation to shaft diameter:

$$T = \frac{\pi}{16} \times \tau \times d^3$$

Results and Discussion

A. Salt Crushing Machine with Reversing Open Belt Drive Transmission System

The salt-crushing machine that has been built can be seen in Figure 3. The salt crushing machine with roller type capacity of 50 kg/hour has overall dimensions of 300 × 250 × 890 mm. The main material of the frame was made of hollow iron and the hopper and rollers use 316 stainless steel plates. The reversing open belt drive transmission system was applied to drive 2 rollers that rotate in opposite directions to crush the salt. The transmission system circuit used 2 horizontal parallel pulleys that rotate in opposite directions with a diameter of 60 mm and 2 vertical parallel pulleys with a size of 85 mm to produce opposite directions. One of the pulleys functions as an idle to adjust belt tension. The

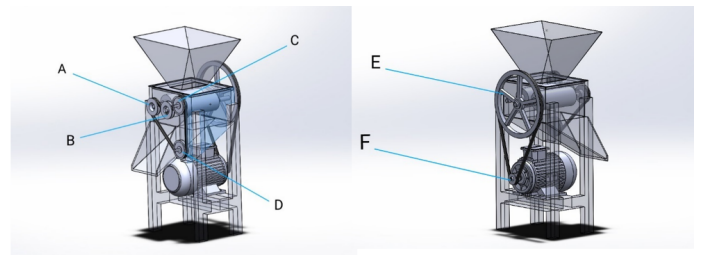
distance between the two rotating rollers was 0.7 mm and the rotation speed was 360 rpm.



Figure 3. Reversing open belt drive pulleys on a salt crusher machine

B. Transmission System

This machine used a mechanism of 2 rollers that rotate in opposite directions to grind the salt. In Figure 4, pulley A which is connected to pulley shaft E functions to drive the crushing roller, where pulley E is connected to pulley F as a driving source for the motor. Pulley D functions to regulate the tension of the belt and pulley C aims to connect pulley B to move the crushing roller so that it can rotate in the opposite direction to pulley A. This mechanism pushes the salt that enters through the hopper towards the grinding roller. From the results of this study, the mechanism was successful in moving the roller in the opposite direction and crushing the salt that passed through it.



(A) Front View

(B) Back View

Figure 4. Salt crushing machine (A) Front View (B) Back View

C. Specification Power Calculation

The roller is the main component in the salt grinding process, where the roller is rotated by a belt connected to an electric motor. For this reason, it was necessary to calculate the power required for a roller-type salt crusher with a capacity of 50 kg/hour.

$$\alpha = 45^\circ$$

$$r_c = 30 \text{ mm}$$

$n = 360 \text{ rpm} = 2261.94 \text{ rad/minute}$

$F = 21 \text{ kg} = 206.01 \text{ N}$

Dynamic Tangential Force :

$$\frac{T_{fd}}{f} = \sin \alpha$$

$$T_{fd} = 206.01 \times \sin 45^\circ = 145.67 \text{ N}$$

Moment power when power was stored in the pulley:

$$P_{def} = \frac{T_{fd} \times r_c \times 2\pi \times n}{60}$$

$$P_{def} = \frac{145.67 \times 0.06 \times 6.28 \times 2261.94}{60}$$

$$P_{def} = 2069.23 \text{ Nm/s}$$

Motor Power requirement :

$$P_{def} = P \left(\frac{360^\circ - \alpha}{\alpha} \right)$$

$$P = \frac{2069.23 \frac{\text{Nm}}{\text{s}}}{\left(\frac{360^\circ - 45^\circ}{45^\circ} \right)}$$

$$P = 299.46 \text{ Nm/s} = 299.46 \text{ W}$$

The motor power required was 299.46 W, while the motor specification available on the market has a ½ HP specification of 372.85 W. So the motor used for this machine was a motor with ½ HP power.

D. Calculation Calculation of pulley transmission and belt

The rotation speed of the motor used (N_1) was 1430 rpm while the pulley attached to the motor had a diameter of (d_1) 3 inches and the desired rotation speed of the driven pulley (N_2) was 360 rpm. So the diameter of the driven pulley (d_2) was obtained:

$$\frac{N_1}{N_2} = \frac{d_2}{d_1}$$

$$d_2 = 12 \text{ inch}$$

Distance between pulley :

$L_s = 51 \text{ inch}$

$D_1 = 76 \text{ mm}$

$D_2 = 300 \text{ mm}$

$$C = \frac{L_s - \left(\frac{\pi}{2}(D_1 + D_2) + \frac{(D_2 - D_1)^2}{4L_s} \right)}{2}$$

$$C = \frac{1295.4 - \left(\frac{\pi}{2}(76 + 300) + \frac{(300 - 76)^2}{4 \times 1295.4} \right)}{2}$$

$$C = 333.17 \text{ mm}$$

Belt length :

$$L = 2C + \frac{\pi}{2}(D_2 + D_1) + \frac{(D_2 - D_1)^2}{4C}$$

$$L = 2 \times 333.17 + \frac{\pi}{2}(300 + 76) + \frac{(300 - 76)^2}{4 \times 333.17}$$

$$L = 1362.74 \text{ mm}$$

The selected belt with a size of 51 inch = 1295.4 mm stretches to 1362.74 mm after determining the axis distance between the pulleys.

The design of the power transmission mechanism for the roller-type salt crusher, the selected shaft was made from stainless steel 316. The allowable shear stress was:

$$\tau = \frac{\tau_u}{F_s} = \frac{40}{1} = 40 \text{ N/mm}^2$$

Torque that transmitted to the shaft :

$$T = \frac{P \times 60}{2\pi N} = \frac{372.83 \times 60}{2\pi \times 360} = 9.87 \text{ Nm} = 9.87 \times 10^3 \text{ Nmm}$$

Shaft diameter :

$$T = \frac{\pi}{16} \times \tau \times d^3$$

$$= 9.87 \times 10^3$$

$$= \frac{\pi}{16} \times 40 \times d^3$$

$$= 7.85 d^3$$

$$d = 11 \text{ mm}$$

E. Performance Test

The result from machine performance testing can be seen in Table 1. The data showed that this machine can crush the raw salt into fine salt with a capacity according to the plan 50 kg/hour and can operate well. The data in Table 1 shows that the amount of salt after going through the crushing process decreases. The average reduction that occurred was 14.27%. The main factor causing the reduction in the amount of salt after crushing was the presence of salt sticking to the surface of the roller because the salt still contains water. During the crushing process of 50 kg salt, no roller jam occurred.

Table 1. Machine Performance in Crushing Salt

Salt Before crushing	Salt After crushing	Yield (%)	Water Content (%)	Time (s)
		88,2	3,52	3300
		82,8	3,57	3180
		86,2	3,51	3240

Conclusion

The power transmission system for the salt crusher with a roller-type capacity of 50 kg/hour has been designed using the reversing open belt drive transmission. The power transmission system used a v-belt and pulleys with 2 rollers

that moved in opposite directions using the reversing open belt drive method. This mechanism used 2 pulleys coupled to a roller to produce movement in the opposite direction. The power required to crush salt using the roller method was 299.46 W. The motor used was a single-phase AC motor which had a power of ½ HP. The V-belt required was type A with a size of 51 inches, and the rpm required was 360 rpm with the original rotation being 1430 rpm. The pulleys ratio was 1:4. The pulleys used were type A1 which has a diameter of 3-inch mm and 12 inches. The shaft diameter required from the calculation results was 11 mm. To adjust the diameter of the selected shaft pulley hole, it has a diameter of 20 mm. The average reduction in salt weight after the crushing process was 14.27%.

Acknowledgment

Thank you to the Kedaireka Matching Fund Program from the Ministry of Education, Culture, Research and Technology Indonesia and PT. Matra Kreasi Mandiri for supporting this research.

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