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Design Calculations of Turmeric Polishing Machine

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***Abstract*: The post processing of turmeric rhizome is done many days after the harvesting. In post processing maintaining the curcumin content in turmeric is important and which is depends upon the methods used for processing the turmeric. This process deals with machine which work efficiently to clean the turmeric rhizomes without boiling and steaming as the process of boiling and steaming lots of important chemical get lost which decrease the quality of the turmeric.**

***Keywords*: Hopper, Turmeric rhizome, Belt conveyor, Water sprayer, Rotary brushes.**

1. Design and Calculations

A. Belt and Pulley

Required structural specification
Total weight of belt and work, m1 =30.
Friction coefficient of sliding surface μ = 3.0
Drum radius d = 4 inch
Belt speed v = 7 inch/s ± 10%
Motor power supply = 115 v ac, 60 Hz.
Weight of drum m_2 = 35.2702

B. Determine the Gear Ratio

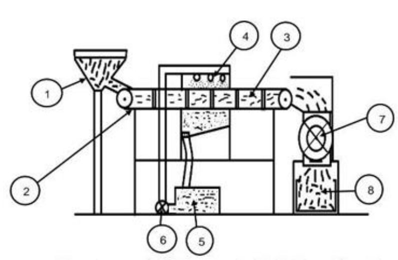
Speed at the gearhead output shaft,

$$N_g = \frac{v.60}{r.D} = \frac{(7\pm0.7)\times60}{r\times4} = 33.4\pm3.3 \text{ r/min}$$

Because the rated speed for a 4 pole motor at 60 Hz is 1450~1550 r/min. The gear ratio (i) is calculated as follows.

$$i = \frac{1450\sim1550}{NG} = 39.5\sim51.5$$

From this range a gear ratio of i =50 is selected.



1. Hopper
2. Belt Conveyor
3. Turmeric Rhizomes
4. Water Sprayer
5. Water tank reservoir
6. Pump
7. Rotary Brush
8. Polished Turmeric Rhizomes Collector

C. Calculate the required torque

On a belt conveyor the greatest torque is needed when starting the belt conveyor. To calculate the torque needed for start up the friction coefficient of the sliding surface is first determined.

$$f = \mu\times m_1 = 0.3 \times 30 = 9\text{lb} = 144 \text{ oz}$$

Torque load (t_l) is,

$$t_l = \frac{F.D}{2.\,n} = \frac{144\times4}{2\times0.9} = 320 \text{ oz-in.}$$

The load torque obtained is actually the load torque at the Gearhead drive shaft, so this value must be converted into load torque at the motor output shaft. If the required torque at the motor output shaft is t_m. Then

$$t_m = \frac{TL}{i.\,n\,G} = \frac{320}{50\times0.66} = 9.7 \text{ oz-in.}$$

(Gearhead transmission efficiency n_g = 0.66)

Look for a margin of safety of 2 times, taking into consideration commercial power voltage fluctuation. 9.7 × 2 = 19.4 oz-in or more. Therefore, motor 51k40gn-awu is the best choice. Since a gear ratio of 50:1 is required,

Select the gearhead 5gn50ka which may be connected to the 51k40gn-awu motor.

D. Load Inertia

Roller moment of inertia

$$J_1 = 1/8 \times m_2 \times d_2 \times 2$$

$$= 1/8\times 35.27\times 4^2 \times 2$$

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$= 141$ oz-in^2

Belt and work moment of inertia,

$J_2 = m_1 \left(\frac{r \times D}{2r}\right)^2 = 30 \times 16 \times \left(\frac{r \times 4}{2r}\right)^2$
$= 1920$ oz-in^2

Gearhead shaft load,

$J = j_1 + j_2 = 141 + 1920 = 2061$ oz-in^2

Here, the 5gn50ka permitted load inertia is,

$j_g = 4 \times 50^2 = 10000$ oz-in^2

Therefore, $j < j_g$ the load inertia is less than the permitted inertia, so there is no problem.

Since the motor selected has a rated torque of 36.1 oz-in. Which is somewhat larger than the actual load torque, the motor will run at a higher speed than the rated speed. Therefore, the speed is used under no load conditions to calculate belt speed and thus determine whether the selected product meets the required specifications.

$v = \frac{Nm \times r \times D}{60 \times i} = \frac{1740 \times r \times 4}{60 \times 50} = 7.3$ in/s

(where n_m is the motor speed)

The motor meets the specifications.

E. Conveyor

Here is an example of how to select a speed control motor to drive a belt conveyor. Performance,

Belt speed v_l is 0.6 in/s ~40 in/s

Specifications for belt and work condition, motor power supply = single phase 115v ac.

Roller diameter, d= 4inch

Mass roller, $m_1 = 2.2$lb

Total mass of belt and work, $m_2 = 33$lb.

Friction coefficient of sliding surface, $\mu = 0.3$.

Belt roller efficiency, ή = 0.9.

F. Find the required speed range

For the gear ratio select 15:1 from the permissible torque table for combination type. So, that the minimum / maximum speed fall within the speed range.

$n_g = \frac{60 \times VL}{r \times D}$

Belt speed,

0.6in /s …… $\frac{60 \times 0.6}{r \times 4} = 2.87$ r/min

40in/s …….. $\frac{60 \times 40}{r \times 4} = 191$ r/min

G. Calculate the load inertia j_g

Load inertia of roller (j_{m1})

$= 1/8 \times m_1 \times d^2$

$= 1/8 \times 2.2 \times 16 \times 4^2 = 70.4$ oz-in^2

Load inertia of belt and work: j_{m2}

$J_{m2} = m_2 \left(\frac{r.D}{2r}\right)^2 = 33 \times \left(\frac{r \times 4}{2r}\right)^2 = 132$ oz-in^2

The load inertia j_g is calculated as follows

$J_g = j_{m1} \times 2 + j_{m2}$

$= 270.4 \times 2 + 132$

$= 273$ oz -in^2.

From the specification, the permissible load inertia for bx5120a-15 is 2300 oz-in^2 (4.2×10^{-2} kg-m^2).

H. Calculate the load torque t_L

Friction coefficient of the sliding surface $f = \mu . m_2 = 0.3 \times 33 = 9.9$lb

Load torque, $t_l = \frac{F \,.\, D}{2ή} = \frac{9.9 \times 4}{2 \times 0.9} = 22$lb-in

Since the permissible torque is 47 lb-in (5.4 n-m) the safety margin is $t_m / t_l = 50 / 22 = 2.3$

Visually, a motor can be operated at the safety margin 1.5~2 or more.

I. Index table

Geared stepping motors are suitable for systems with high inertia, such as index table.

Determine the drive mechanism:

Diameter of index table, $d_t = 11.8$ inch (300mm)

Index table thickness, $l_t = 0.39$ inch (10mm)

Thickness of work, $l_w = 1.18$ inch (30mm)

Diameter of work, $d_w = 1.57$ inch (40mm)

Material of table and load,

= iron (density = 4.64 oz/in^2)

(7.9×10^{-3} kg/cm^3)

Number of load =12

Distance from center of index table to center of load, l = 4.92 inch (125 mm)

Polishing angle, $\emptyset = 30°$

Positioning period, $t_o = 0.3$ sec

The step pn geared (gear ratio 7:2:2:1 can used

Gear ratio, i = 7.2

Resolution, $\theta_s = 0.05°$

Speed range is 0~416 r/min.

Determine the operating pattern:

1) Find the number of operating pulses (a) [pulses]

Operating pulses (a)

$= \frac{\text{Angle rotated per movement } (\theta)}{\text{Gear output shaft step angle } (\theta s)} = \frac{30°}{0.05°}$

= 600 pulses

2) Determine the acceleration period t_1 (sec)

An acceleration period of 25% of the positioning period is appropriate.

Acceleration period,

$t_2 = t_o \times 0.25 = 0.3 \times 0.25 = 0.075$ sec

3) Calculate the operation speed

$N = \frac{60}{360} \times \frac{\Theta}{to-t1} = \frac{60}{360} \times \frac{30}{0.3-0.075} = 22.2$ r/min

4) Determine the operating pulses speed f_2 (Hz)

Operating pulse speed f_2

$= \frac{a-g1\times t1}{to-t1} = \frac{600-0}{0.3-0.075} = 2667Hz$

Where,

a = number of operating pulses

g_1 = starting pulses speed

t_1 = acceleration period

T_0 = positioning period

Calculate the required torque t_m,

1) Calculate the load torque, t_l (oz.-in)

Frictional load is omitted because it is negligible load torque i.e. considered as 0.

2) Calculate the acceleration torque, t_a (oz.-in)

a) Calculate the total inertia j_l

Inertia of table $j_1 = \pi/32 .p .l_t. D_t^4$

$= \pi/32 \times 4.64 \times 0.39 \times 11.8^4 = 3442$ oz-in^3

Inertia of work, $j_c = \pi/32.p.l_w.d_w{}^4$

$= \pi/32 \times 4.64 \times 1.18 \times 1.57^4 = 3.3$ oz-in^2

Weight of work $m = \pi (d_w/2)^2.l_w.p$

$= \pi (1.57/2)^2 \times 1.18 \times 4.64 = 10.6$ oz.

The center of the load is not on the center of rotation, so since there are 12 pieces of work:

Inertia of work $j_w = 12\times (j_c + m \times l^2)$

$= 12\times (3.3 + 10.6 \times 4.92°)$

$=3118$ oz-in^2

Total inertia $j_l = j_t + j_w$

$=3442+3118$

$=6560$ oz-in^2

b) Calculate the acceleration torque, t_a

Acceleration torque, t_a

$= \frac{(Jo.i2+Jl)}{g} . \frac{\pi.\theta s}{180} . \frac{f2-f1}{t1}$

$= \frac{(J0\times 7.2\times 7.2+6560}{386} \times \frac{\pi\times 0.05}{180} \times \frac{2667-0}{0.075}$

$= 4.16j_o + 527$ (oz.-in).

c) Calculate the required torque, t_m

Safety factor = 2

Required torque = $(t_l + t_a) \times 2$

$T_m = \{0+ (4.16j_o + 527)\} \times 2$

$= 8.32j_o + 1054$ oz.-in

Select a motor:

1) Provisional motor selection

Motor	Rotor inertia	Required torque	
		lb-in	N-m
As66aa-n7.2	$J_o = 2.2$	67	7.6

2) Determine the motor from the speed torque characteristics.

As66aa-nt.2

Select a motor for which the required torque falls within the pull out torque of the speed torque characteristics.PN geared type can operate inertia load up to acceleration torque less than maximum torque.

2. Conclusion

The proposed polisher was capable of polishing 4 kg dried turmeric fingers in 10minutes. The polisher saved 81% and 87% polishing time over paddle-operated device beating and hand beating, respectively. The turmeric polisher saved 77.60% and 72.27% cost of polishing compared to hand beating and paddle-operated device beating, respectively. Considering custom hiring service as the same as hand beating (6.34 Tk/kg).

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