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Design and Performance Analysis of Potato Slicing Machine (Shaft Design and Rectangular Cutting Blade)

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Abstract-* This research presents the design and performance analysis of potato slicing machine (shaft design and rectangular cutting blade). The main purposes of this research are to construct the potato slicing machine and does performance test. And then, the static structural analysis of the shaft is done by using ANSYS 14.5 software. Then, the theoretical and analytical results of von-Mises stresses and effective strain are compared. In this research, shaft diameter is calculated by using ASME code equation. Mild steel shaft is selected for design to obtain high strength. The length of shaft is 600mm and the calculated diameter of rotating shaft is 20mm. Single-row deep groove ball bearings 6804 and 6904 are selected. The stress analysis for shaft is conducted using ANSYS14.5 by numerical approach and also the von-Mises stresses and effective strain are calculated theoretically. From the comparison, theoretical and numerical equivalent von-Mises stresses and effective strains are nearly the same. By observing the analysis results, the stress values obtained are less than the yield strength 247MPa of mild steel. So, the design is safe under working condition. The performance of the machine is tested and the efficiency of the machine is 85% with capacity 3.8 kg/min.

Indexed Terms -- Design, Performance, Shaft, Rectangular Cutting Blade, Slicing Machine

I. INTRODUCTION

Slicing equipment consists of rotating or reciprocating blades which cut the food material as it passes beneath. The food is held against the blades by centrifugal force while for slicing meat, the food is held on a carriage as it travels across the blade.

The automated potato slicing machine is a fast method commonly used in medium scale industries. The use of motorized slicer will facilitate mass production of the chips. The potato is pressed and moved across the sharp blades of the machine. Potato slicing machine is used for slicing potatoes that are fed across the inlet hopper and sliced chips are guides through the outlet hopper. The machine is a single pulley driven shape of slices with different shapes. It requires low maintenance and easy handling. Rotary cutting knives are usually employed to cut the potato being presented on them, often on a vibrating belt in to parallel sliced of the thickness.

The shaft is vital part of automatic potato slicing machine and the shaft design is very important for the whole machine. In this research, the design calculation of shaft is mainly included and static strength of this shaft is analyzed for safety. Various types of cutting blades can be used in one automatic potato slicing machine and in this research, rectangular cutting blade is designed and with this blade, and the performance of the potato slicing machine is also tested. And then, the static structural analysis of shaft is calculated theoretically and also numerically by using ANSYS 14.5 software.

There are mainly two types of potato slicing machines. They are manual potato slicing machine and automatic potato slicing machine.

Figure 1. Manual and Automatic potato slicing machines

Automatic potato slicing machine usually has the following components. The components of automatic potato slicing machine are as follows: (i)Slicing wheel (ii) V-belt mechanism (iii) Motor (iv) Frame (v) Inlet hopper (vi) outlet hopper There are various types of cutting discs. They are circular disc, dice-shape disc and rectangular discs. Figure 2 shows circular and rectangular discs.

Figure 2 Circular and Rectangular Discs

II. DESIGN CONSIDERATION AND STRESS ANALYSIS OF SHAFT

A. Pulley Diameter of Input Shaft

It is important to know the diameter of pulley fitted on input shaft. A shaft that rotates gives torque or moment to cutting disc and cutting disc slices the potatoes into chips. The diameter of pulley on input shaft is obtained from the equation of velocity ratio between the driver pulley and driven pulleys and, the diameters and rotating speeds of motor pulley are known The velocity ratio is as follow.

$$\frac{N1}{N2} = \frac{D2}{D1} \quad (1)$$

B. Diameter of the Shaft

Design of shafts of ductile material based on strength is controlled by maximum shear theory. Shafting is usually subjected to torsion, bending and axial loads. For a solid shaft having little or no axial loading, the ASME code equation is given as:

$$d^3 = \frac{16}{\pi S_s}\sqrt{\left(K_b M_b\right)^2 + \left(K_t M_t\right)^2} \quad (2)$$

C. Bearing Selection

Many types of bearings with various shapes of rollers are available, such as ball, cylindrical roller, long cylindrical roller, needle roller, tapered roller, convex roller bearing.

Figure 3. Deep Groove Ball and Tapper Roller Bearing

Figure 4. Thrust Ball Bearing

The equivalent bearing load

$$P = X\ V\ F_r + Y\ F_a \quad (3)$$

Nominal life in working hr

$$L = \frac{60nL_h}{1000000} \quad (4)$$

Nominal life in million of revolution

$$L = \left(\frac{C_r}{P}\right)^p \quad (5)$$

D. Stresses in Shaft

Axial loads are usually comparatively very small at critical locations where bending and torsion dominate, so they will be left out of the following equations. The fluctuating stresses due to bending and torsion are given by

Bending stress

$$\sigma_b = \frac{32M}{\pi D^3} \quad (6)$$

Centrifugal stress

$$\sigma_y = \sigma_c = \left(\frac{3+\nu}{8}\right)\rho\omega^2 r^2 \quad (7)$$

Shear stress

$$\tau_{xy} = \frac{16M_t}{\pi D^3} \quad (8)$$

Principal stresses

$$\sigma_{1,2} = \frac{1}{2}\left(\sigma_x + \sigma_y\right) \pm \frac{1}{2}\sqrt{\left(\sigma_x + \sigma_y\right)^2 + 4\tau_{xy}^2} \quad (9)$$

Effective Stress

$$\bar{\sigma} = \frac{1}{\sqrt{2}}\left[\left(\sigma_1 - \sigma_2\right)^2 + \left(\sigma_2 - \sigma_3\right)^2 + \left(\sigma_3 - \sigma_1\right)^2\right]^{1/2} \quad (10)$$

Principal strains $\varepsilon_1 = \frac{1}{E}\left[\sigma_1 - \nu\left(\sigma_2 + \sigma_3\right)\right]$ (11)

$$\varepsilon_2 = \frac{1}{E}\left[\sigma_2 - \nu\left(\sigma_3 + \sigma_1\right)\right] \quad (12)$$

$$\varepsilon_3 = \frac{1}{E}\left[\sigma_3 - \nu\left(\sigma_1 + \sigma_2\right)\right] \quad (13)$$

Eff ective strain

$$\bar{\varepsilon} = \left[\frac{2}{3}\left(\varepsilon_1^2 + \varepsilon_2^2 + \varepsilon_3^2\right)\right]^{1/2} \quad (14)$$

III. DESIGN CALCULATION AND STRESS ANALYSIS OF SHAFT

Table 1describes known data for design calculation of shaft such as speed of cutting disc, speed of motor pulley, diameter of motor pulley, power of motor, tensions at tight and slack side.

Table 1. Specification Data

Parameter	Symbol	Value	Unit
Capacity	c	7	Kg/min
Speed of Cutting Disc	N	467	Rev/min
Speed of Motor Pulley	N	1400	Rev/min
Diameter of Motor Pulley	D	75	mm
Motor Power	P_m	1.1	kW
Tight side tension	T_1	271.9	N
Slack side tension	T_2	21.7	N

Table 1 shows specification data for design calculation of shaft.

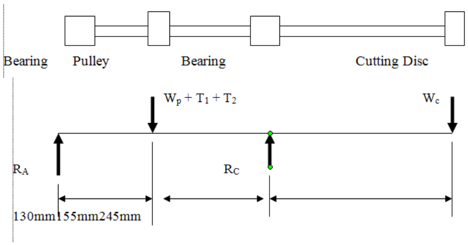

Figure 5 Free Body Diagram of Shaft

Table 2. Result data of shaft

Sr. No	Parameter	Symbol	Value	Unit
1	Standard shaft diameter	d	20	mm
2	Inner diameter of bearing at point A	d_A	20	mm
3	Outer diameter of bearing at point A	D_A	32	mm
4	Inner diameter of bearing at point C	d_C	20	mm
5	Outer diameter of bearing at point C	D_C	37	mm
6	Bending Stress	σ_b	31.20	MPa
7	Centrifugal Stress	σ_C	775	MPa
8	Shear Stress	τ_{xy}	19.22	MPa
9	First Principal Stress	σ_1	40.35	MPa
10	Second Principal Stress	σ_2	9.16	MPa
11	Effective Stress	$\bar{\sigma}$	45.61	MPa
12	First Principal Strain	ε_1	2.0934×10^{-4}	-
13	Second Principal Strain	ε_2	-4.588×10^{-4}	-
14	Effective Strain	$\bar{\varepsilon}$	1.944×10^{-4}	-

IV. STATIC STRUCTURAL ANALYSIS OF SHAFT

ANSYS is a finite element analysis tool, which include static/dynamic structural analysis (both linear and non-linear). This computer simulation product provides the finite elements to model behavior, and supports material models and equation solvers for a wide range of mechanical design problems. Rotating shaft design is drawn by SolidWorks software as shown in Figure 6.

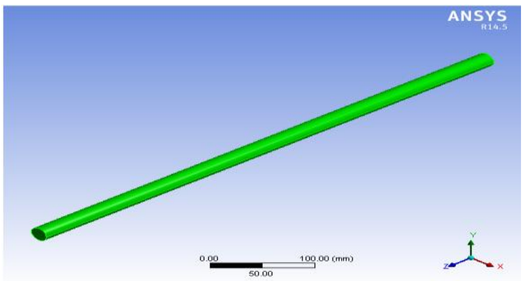

Figure 6. Geometry of Shaft

The static structural shaft SolidWorks model was added to the geometry in ANSYS Workbench. This geometry model was meshed as shown in Figure 7. This meshed model was imported to static structural for static structural analysis of the shaft.

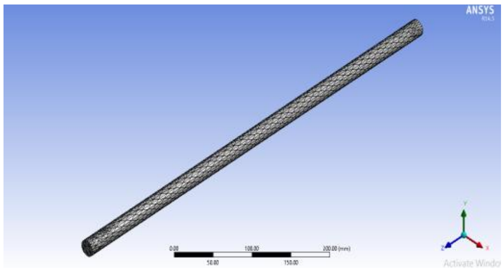

Figure 7. Meshing of Rotating Shaft

Firstly, give the input conditions to the model, which applied the resultant force of 9800.3 N along the shaft or Z-axis and torsional moment of 30.19 Nm is applied to the shaft as shown in Figure 8. The engineering data for type of material uses the mild steel for testing material.

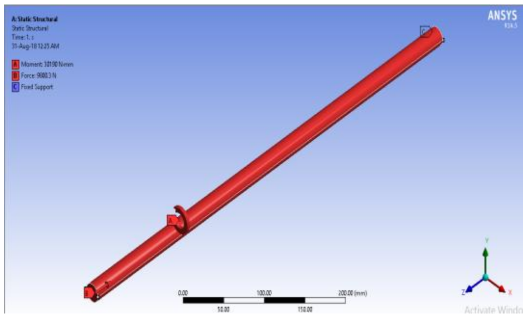

Figure 8. Loading Condition of Rotating Shaft Using Mild Steel

After finishing set up the boundary conditions on rotating shaft, run the solution and get equivalent(von-Mises) stress and equivalent elastic strain. According to the Figure 9, the maximum equivalent (von-Mises) stress on the shaft is 46.177MPa and minimum equivalent (von-Mises) stress is 0.44246MPa.

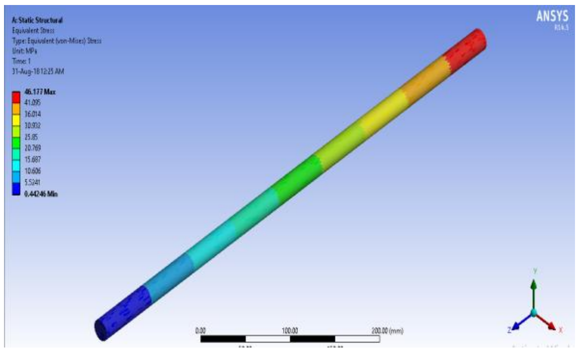

Figure 9. Effective Stress in Rotating Shaft Using Mild Steel

According to the Figure 10, the maximum equivalent elastic strain on the shaft is $2.2506e^{-4}$ and minimum equivalent elastic strain is $2.3238e^{-6}$.

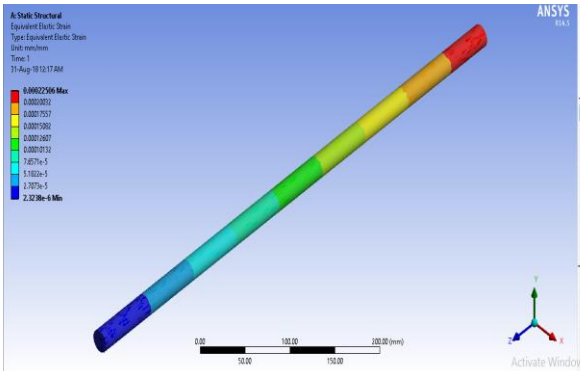

Figure 10. Effective strain in Rotating Shaft Using Mild Steel

Table 3. Comparison Data of Effective Stress

Material	Von-Mises Stress (Theoretical)	Von-Mises Stress (Numerical)	Percentage error
Mild Steel	45.61MPa	46.17MPa	2%

Table 4. Comparison data of Effective Strain

Material	Effective Strain (Theoretical)	Effective Strain (Numerical)	Percentage Error
Mild Steel	1.944×10^{-4}	2.2506×10^{-6}	13%

V. CONSTRUCTION AND PERFORMANCE TESTING

Construction

Before starting the construction of potato slicing machine, the required raw materials for design are as followed

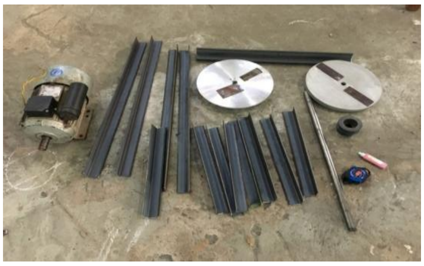
Figure11. Raw Materials

(i)Shaping

Because they are raw materials, they cannot use immediately for research and some shaping processes are to be done as follows;


Figure 12. Shaping of Cutting Disc

Figure 12 shows the shaping of cutting disc which is used for slicing of potatoes.

(ii)Main Frame

After the shaping process, the next is the construction of main frame for research and it is as followed:


Figure 13. Main Frame

Figure 13 shows the main frame of automatic potato slicing machine.

(iii) Motor and Bearing Placing in Main Frame

After the main frame for machine have been constructed, the placing of Motor and Bearing in the main frame is to be done as followed:


Figure 14. Setting of Motor and Bearing

Figure 14 shows the placing of motor and bearing into the main frame of automatic potato slicing machine.


Figure 15. Belt and Pulley Placing

Figures 15 shows the belt and pulley placing into the main frame of automatic potato slicing machine.

(iv) Rectangular Cutting Blade


Figure16. Rectangular Cutting Blade

Figure 16 shows rectangular cutting blades.

(v) Potato Slicing Machine (Complete Assembly)


Figure 17. Front View with Cutting Disc and Inlet Hopper

Figure 17 shows view of automatic potato slicing machine.

Performance Test
Table 4 describes results data of five performance tests of automatic potato slicing machine.

Table 4. Result Data of Performance Test

No	Total Weight (kg)	Time Taken (sec)	Capacity (kg/min)	Efficiency (%)
1	330	7	2.8	85
2	345	5	4.1	79
3	350	6	3.5	82
4	360	5	4.3	88
5	390	6	3.9	83

VI. CONCLUSION AND DISCUSSION

This research has been studied the shaft used in the potato slicing machine. In this thesis, shaft is designed for 1.1kW potato slicing machine. Potato slicing machine shaft design is calculated by using ASME principle. After the design calculations, the shaft diameter is chosen as 20mm. For safety, theoretical and numerical analysis of this shaft is done and from the theoretical results the von-Mises stress is 45.612MPa and effective strain is 1.944×10^{-4}. And from numerical results of ANSYS software, the von-Mises stress is 46.177MPa and effective strain is 2.2506×10^{-4}. The percent deviation between theoretical and numerical results of von-Mises stress is 2% and that of effective strain is 13%. So, it is in 0-20% and it is safe. Performance of the machine is tested and the average capacity is 3.72kg/min and average efficiency is 83.4%.

This research is attempted to design rotating shaft for potato slicing machine. The design data in this thesis are as well as length of shaft (L) is 600mm, diameters of the shaft is 20mm, motor power is 1.1 kW, tension at the tight side is 271.9 N, tension at the slack side is 21.7N, speed of cutting disc is 467 revolutions per minute. Single-row deep groove ball bearings 6804 and 6904 are selected after calculated. The total cost of the whole machine is about 3.5 lakhs and it is very economical if compared with the local market because the price is 29 lakhs. The performance of the machine is tested by doing five tests and taking the average values of capacity and efficiency. The average capacity and efficiency of the machine from five tests are 3.72kg/min and 83.4%. The capacity and efficiency of the machine is good.

In the theoretical results, the von-Mises stress is 45.612MPa and effective strain is 1.944×10^{-4}. According to the simulation results, the maximum von-Mises stress is 46.177MPa and effective strain is 2.2506×10^{-4} . The percent deviation ofvon-Mises stress in comparison of theoretical and numerical results is 2% and that of effective strain is 13%.

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REFERENCES

[1] F. H. C. A. Silva, D. N. Javatissa, et al Manpreet Singh, "Design and Development of a Ginger Slicer for Small Scale Spice Processors,2017.

[2] S.S. Singh and B. D. Shukla, "Abrasive Peeling of Potatoes", 2017.

[3] V. P. Talodhikar et al," Mechanization and Development of Potato Peeling Machine", 2017.

[4] Tony Thomas et al," Design and Development of Automated Vegetable Cutting Machine", 2017.

[5] American Scientific Research Journal for Technology, 2016.

[6] Ukatu A. C, et al, "Machine for Slicing Vegetables, erials", 2015.

[7] Aremu D.O. Akinola et al, "Construction and Performance Evaluation of a Potato Slicing Machine" , 2014.

[8] Chung Yee Look et al," Development of an integrated Grating and Slicing Machine for Starchy Vegetables", 2013.

[9] O.O.A woluy. "Design and Construction of Plantain Slicer "2011.

[10] J. Chatthong, W. Boonchouytan et al, "Design and Construction of Semi-automated Slicer Ginger Machine", 2011.

[11] Leo, Balogun A, et al "Design and Performance Evaluation of a Multi-Crop Slicing Machine", 2009.