Design and Structural Analysis of Shelling Cylinder for Maize Sheller

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Abstract - The objective of this paper is to design the shelling cylinder for maize sheller and to analyze the structural behaviors on the shelling cylinder due to applied impact load and toque on it. This paper discusses about the shelling cylinder of maize sheller as axial flow type produced in Aung-Paddy and Maize Sheller Industrial Zone at Mandalay. The shelling cylinder consists of spike teeth to shell the corn, which are constructed with gray cast iron. The shelling cylinder's diameter is 184mm and length of cylinder is 460mm. The speed of shelling cylinder is 302rpm at power supplied 1.1kW. Weight of shelling cylinder, power, shelling torque are estimated in this paper. SolidWorks software is used for modeling and analysis of the shelling cylinder of maize sheller. The stress distribution on shelling cylinder is expressed by theoretically and numerically approach. The theoretical and numerical result data of maximum von-Mises stresses are 23.111MPa and 20.588MPa for gray cast iron. The percentage error is 11%. The yield strength of gray cast iron is 276MPa. The theoretical and numerical results of maximum von-Mises stresses are not exceed the yield strength. Therefore, this design is satisfied.

Indexed Terms – Axial flow, Maize Sheller, Structural Analysis of Shelling Cylinder, Shelling Cylinder

I. INTRODUCTION

Maize is one of the most important cereal crops in the world agricultural economy. Myanmar is an agricultural country; the important bone of its economy is the agriculture field. Maize is originated from Mexico several thousand years back, even before Columbus landed in South America. It can be called as "Queen of cereals" and "King of fodder" due to its great importance in human and animal diet. It is also a rich source of starch (60-80%), protein (8-12%), fat (3-5%) and minerals (1-2%). Maize has become a staple food in many parts of the world. For thousands of years, corn was shelled by hand and was very laborious and time consuming. Therefore, the use of maize shellers is becoming more and more popular and is the most suitable method for local farmers. In order to accomplish this process, there are four main types of maize sheller such as hand-held sheller, rotary sheller, manually operated sheller and motorized sheller [3].

The main components of maize sheller include shelling, separation and cleaning units. The shelling unit which consists of a rotating cylinder and concave jointly shell the maize seeds from the corn. The shelling teeth are bolted by screws axially. In the separation unit, the shelled maize seeds fall through the lower concave openings and then the seeds are fell with an inclined outlet. For the cleaning system, the corn-cob together with shuck and other matters are thrown by fan blade. The separated maize seeds are discharged using a discharge chute as shown in Figure-1 [10].

Desta K and Mishra, T.N. developed and started performance evaluation of a sorghum sheller. A combination of different feed rates (6, 8, 10 kg/min), cylinder-concave clearance at 2 different levels (7mm and 11 mm) and cylinder speed at different levels (300, 400 and 500 rpm) were investigated. The results of the performance analysis showed that shelling efficiency was increased with an increase in cylinder speed for all feed rates and cylinder concave clearances. The shelling efficiency was found in the range of 98.3 to 99.9% [2].


Figure 1 . Constructed Maize Sheller

II. METHODOLOGY

In this research, the design parameter is collected from maize sheller with motor power of 1.1kW, measuring the data of the shelling cylinder at Aung-Paddy Thresher Industrial Zone, (Mandalay), Myanmar, and then, calculated the weight of shelling cylinder, angular velocity, shelling power, and shelling torque for the shelling cylinder design. The theoretical and numerical analysis of shelling cylinder are expressed in this paper.

In this paper, it includes of three main parts, which are;
A: *Design Consideration of Shelling Cylinder*
B: *Theoretical Analysis of Shelling Cylinder*
C: *Numerical Analysis of Shelling Cylinder*

A. Design Consideration of Shelling Cylinder for Maize Sheller

(1). Weight of Shelling Cylinder:

Weight of shelling cylinder,

$$W_{cylinder} = \rho V_{cylinder} g \quad (1)$$

where,

$W_{cylinder}$ - weight of shelling cylinder (N)
$V_{cylinder}$ - volume of cylinder (m^3)
g - acceleration due to gravity (m/s^2)

$$V_{cylinder} = \frac{\pi D^2_{cylinder}}{4} \times L_2 \quad (2)$$

where,
$V_{cylinder}$ - volume of cylinder (m^3)
$D_{cylinder}$ - diameter of cylinder (mm)
L_2 - length of cylinder (mm)

(2). Weight of Pulley:
Weight of pulley:

$$W_{pulley} = \rho V_{pulley} g \quad (3)$$

$$Vpulley = \pi r^2 w_2 \quad (4)$$

where,
V_{pulley} - volume of pulley (m^3)
r - radius of pulley (mm)
w_2 - width of pulley (mm)
ρ - density of gray cast iron pulley (kg/m^3)

(3). Weight of Blower:
Weight of Blower:

$$W_{blower} = \rho V_{blower} g \quad (5)$$

$$V_{blower} = A \times L_1 \times n_{blade} \quad (6)$$

where,
V_{blower} - volume of blower (m^3)
A - area of blower (m^2)
L_1 - length of blower (mm)
ρ - density of gray cast iron (kg/m^3)
n_{blade} - no of blades on blower

(4). Power Transmission System:

$$Power = (work\ done)/time = F\omega r \quad (7)$$

where,
F - weight of shelling cylinder(N)
ω - angular velocity (rad/sec)
r - radius of shelling cylinder (m)

(5). Determination of Shelling Torque:

Shelling torque,

$$T = F \times r \quad (8)$$

where,
F - weight of shelling cylinder (N)
r - radius of shelling cylinder (m)

(6). Required Force for Maize Sheller:
The spike teeth which are attached to the shelling cylinder, rotate with the shaft due to centrifugal force.

Centrifugal force at shelling cylinder:

$$F = m \times \omega^2 \times r \quad (9)$$

Angular velocity of shelling cylinder:

$$\omega = \frac{2\pi \times N_{cylinder}}{60} \quad (10)$$

where,
F - centrifugal force (N)
m - mass of shelling cylinder (kg)
ω - angular velocity (rad/sec)
r - radius of shelling cylinder (m)
$N_{cylinder}$ - speed of shelling cylinder (rpm)

Table 1. Result Data of Shelling Cylinder

Parameters	**Symbol**	**Value**	**Unit**
Weight of shelling cylinder	$W_{cylinder}$	864	N
Weight of pulley	W_{pulley}	652	N
Weight of blower	W_{blower}	69.22	N
Angular Velocity	ω	31.62	rad/sec
Shelling Power	P	0.733	kW
Shelling Torque	T	23.18	N-m
Centrifugal force	F	8.095	kN

Table 1 shows the calculated weight, required power, torque and centrifugal force of shelling cylinder design used in maize sheller.

B. *Theoretical Analysis of Shelling Cylinder*
Structural behaviour (von-Mises stress, effective strain) of shelling cylinder are calculated by theoretical approach. The threshing drum is made of gray cast iron ASTM40.

(1) Bending stress for shelling cylinder:

$$\sigma_x = \sigma_b = \frac{F}{A_{drum}} = \frac{m\omega^2 r}{\pi D t} \quad (11)$$

(2) Shear stress for shelling cylinder:

$$\tau_{xy} = \frac{T \times R}{J} \qquad (12)$$

The Principle stresses for shelling cylinder can be calculated in von-Mises criteria.

$$\sigma_{1,2}=\frac{1}{2}\left(\sigma_x+\sigma_y\right)\pm\frac{1}{2}\left[\left(\sigma_x-\sigma_y\right)^2+4\tau_{xy}^{2}\right]^{\frac{1}{2}} \qquad (13)$$

The von-Mises stress,

$$\bar{\sigma} = \frac{1}{\sqrt{2}}\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right]^{\frac{1}{2}} \qquad (14)$$

The constitutive equations are called the relation between stress and strain. Hooke's law would be show that;

Principle strains:

$$\varepsilon_1 = \frac{1}{E}\left[\sigma_1 - \upsilon(\sigma_2 + \sigma_3)\right] \qquad (15)$$

$$\varepsilon_2 = \frac{1}{E}\left[\sigma_2 - \upsilon(\sigma_1 + \sigma_3)\right] \qquad (16)$$

$$\varepsilon_3 = \frac{1}{E}\left[\sigma_3 - \upsilon\left(\sigma_1 + \sigma_2\right)\right] \qquad (17)$$

The effective strain for shelling cylinder:

$$\bar{\varepsilon} = \left[\frac{2}{3}\left(\varepsilon_1{}^2 + \varepsilon_2{}^2 + \varepsilon_3{}^2\right)\right]^{\frac{1}{2}} \qquad (18)$$

Table 2. Properties of ASTM 40 Gray Cast Iron

Material Properties	Values	Units
Young Modulus, E	124	GPa
Poisson Ratio,ν	0.27	-
Yield Strength, S_y	276	MPa
Density, ρ	7200	kg/m^3

Table 2 shows the material properties of ASTM40 gray cast iron for design calculation of the shelling cylinder.

Table 3 Theoretical Result Shelling Cylinder

Von-Mises Stresses, (MPa)	Effective Strain, $\bar{\varepsilon}$ ($\times10^4$)	Shear Stress, τ (MPa)	Centrifugal Force, F (kN)	Bending Stress, σ_b (MPa)
23.111	1.874	0.056	8.095	3.04

Table 3 shows the theoretical results of the shelling cylinder design. The von-Mises stress, the effective strain, shear stress, centrifugal force and bending stress are calculated by theoretically in the shelling cylinder design.

C. Numerical Analysis of Shelling Cylinder;

To estimate the following stresses and strains distribution of shelling cylinder, ANSYS software has been used. The design of shelling cylinder was analysed with gray cast iron ASTM40.

(1). Model of Shelling Cylinder for Maize Sheller:

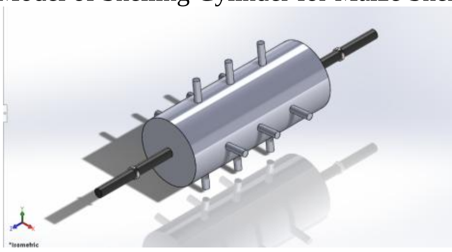

Figure 2. 3D Model of Shelling Cylinder

Figure 2 shows the model of shelling cylinder for maize sheller which is drawn by SolidWorks Software 2016.

(2) Boundary Conditions of Shelling Cylinder:

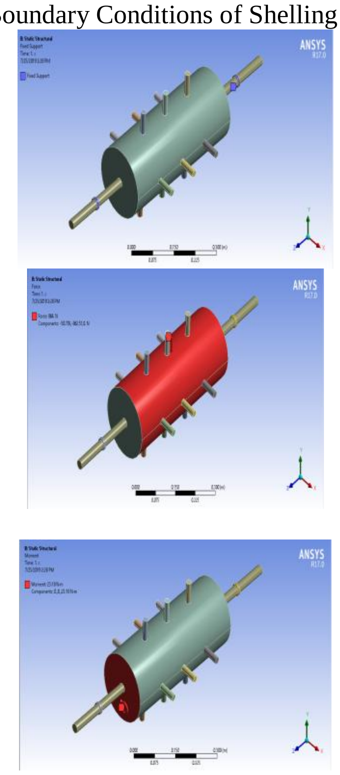

Figure 3. Boundary Conditions of Shelling Cylinder

Figure 3 shows the boundary conditions of shelling cylinder. Fixed supports are provided at the bearings on the shelling cylinder shaft. The simulation is carried out by choosing the static condition. The centrifugal force and torque are acting on the shaft of shelling cylinder. The centrifugal force acting on this shaft is the direction of shelling cylinder rotation.

(3). Meshing of Shelling Cylinder:

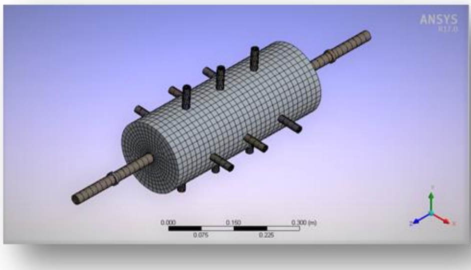

Figure 4. Meshing of Shelling Cylinder

Figure 4 shows meshing of shelling cylinder by using ANSYS software. To generate the mesh model of shelling cylinder, with curvature-based mesh, element size is default and the generated mesh is done by fine position to obtain the good quality of mesh. In the meshing process, the number of nodes are 93007 and elements are 19883.

(4). Stresses and Strains Analysis of Shelling Cylinder:

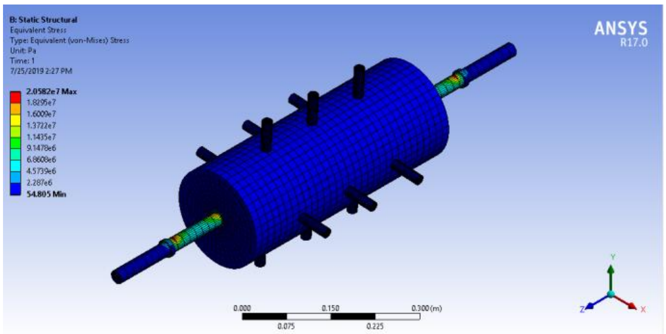

Figure 5. Von-Mises Stress Distribution of Shelling Cylinder

Figure 5: Shows the shelling cylinder's stress distribution after applying centrifugal force and torque at cylinder. It can be seen that the von-Mises stress is generated at the shelling support of the cylinder is 20.588MPa. And the minimum von-Mises stress is 54.085 Pa at the spike teeth of the cylinder.

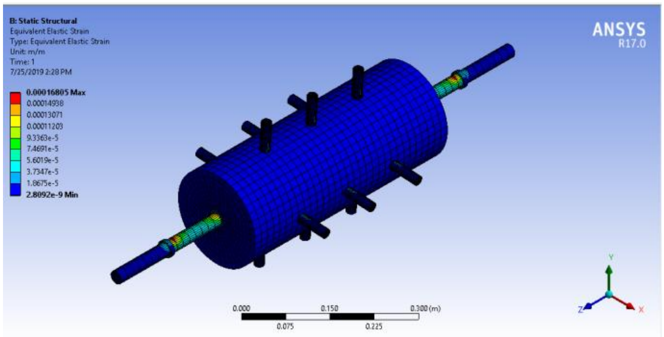

Figure 6 . Effective Strain Distribution of Shelling Cylinder

Figure 6 shows the effective strain distribution of shelling cylinder. The maximum and minimum effective strains are 1.681×10^{-4} and 2.809×10^{-9} which occur due to Von-Mises stresses on the shelling cylinder.

Table 4. Comparison of Theoretical and Numerical Result of Shelling cylinder

Results	**Theoretical**	**Numerical**	**(%)Deviation**
Von-Mises Stress, σ(MPa)	23.111	20.588	11
Effective Strain, $\bar{\varepsilon}$ ($\times10^{-4}$)	1.874	1.681	10

Table 4 shows the comparison of theoretical and simulation results for gray cast iron ASTM40. The error percent of Von-Mises stresses and effective strains are 11% and 10% respectively.

III. RESULT AND DISCUSSION

In this research paper, weight of shelling cylinder, the angular velocity, shelling power and shelling torque, cylinder's speed were calculated in the shelling cylinder design. The calculated weight, required power, torque and centrifugal force of shelling cylinder are 864N, 0.733kW, and 23.18N-m and 8.095kN design used in maize sheller. The von-Mises stress, the effective strain, shear stress, centrifugal force and bending stress are calculated by theoretically in the shelling cylinder design. The theoretical result of maximum von-Mises stress is 23.111MPa; the numerical result of maximum von-Mises is 20.588MPa. After checking the results, the theory and simulation results are nearly the same. Therefore, these values are not exceeding the yield strength of gray cast iron 276MPa. So this design is satisfied. The model of shelling cylinder design is drawn by SolidWorks software and structural analysis is simulated by ANSYS software.

IV. COCLUSION

In this paper, the shelling cylinder is designed with 184mm diameter and length of 460mm are calculated theoretically. The model of shelling cylinder for maize sheller is drawn by using SolidWorks software and analyzed by ANSYS software. The performance of shelling cylinder is to shell the maize seeds from the corn. The shelling cylinder is rotating with 302rpm and it can apply centrifugal force and torque which are calculated. The maximum von-Mises stress is affected at the shelling supports and the minimum value of von-Mises stress is applied at the spike teeth of the cylinder. While the maximum von-Mises stress is 23.111MPa, the maximum effective strain value is 1.874×10^{-4}. The theoretical result is between the ranges of the numerical result which are not exceeding the yield strength of gray cast iron 276MPa. So, this design is satisfactory.

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