# Design, Structural Analysis and Prototype Testing of Spike Tooth Cylinder for Rice Thresher Machine

Name: Rebira Wirtu Aga

MSc in Mechanical Design System Engineering

Team Leader of Agricultural Machinery and Farm Power and Co-ordination of metal and wood workshop @ JAERC

Oromia Agricultural Research Institute (OARI), Oromia, Ethiopia

Email: rebiraaga@gmail.com

## Summary

*Cereals, including wheat, barley, oats, rice, maize, sorghum, and millets, are major grain crops globally. Post-harvest grain loss is a significant issue in developing countries, in Ethiopia. Post-harvest grain management practices are crucial for food security. Thus, the threshing of rice by traditional and poor machine threshing units has its own problems on the quality and loss of the product. As the result, rice producers (farmers and investors are often unable to obtain competitive quality products from their farms and supply them to the market.*

*Threshing operations involve removing husks and straw from grains or seeds, either manually or with animals or machinery. A study aims to design, analyse, and performance of a spike tooth rice threshing unit in Ethiopia, focusing on drum speed and feeding rate.*

*The thesis study successfully designed, performance test, manufactured, and tested a spike-tooth cylinder for a rice thresher machine, focusing on local materials suitable for low and medium agricultural farmers. The model was created using SOLIDWORK software and imported to ANSYS software for structural analysis. The study found that the maximum shear stress (360.87Mpa) occurred at 1280 rpm of the spike tooth cylinder. The maximum equivalent stress was generated at disc supports by nine levels of forces, while the torsional moments range from 97.89 to 681 4.741 MPa. Bending stress was highest at the highest speed of the spike tooth cylinder, causing the threshing machine decreased performance. The study also assessed the performance of the* performance *thresher at different drum speeds and feeding rate levels using R-STAT software. Results showed that the maximum capacity was 458.3 g/min at 1280 rpm, and the maximum threshing efficiency* 98.16% *was achieved at 5000 g/min and 7000 g/min. The interaction of drum speed and feed rate significantly affected threshing efficiency*

*The interaction of drum speed and feed rate significantly affected threshing efficiency. The maximum cleaning efficiency was achieved at 900 kg/hr feed rate and 1280 rpm, and the interaction of drum speed and feed rate significantly affected cleaning efficiency. Higher speeds resulted in greater grain breakage, while lower speeds had a moderate amount.*

## INTRODUCTION

### Background

Cereals are the first cultivated grasses belonging to the Poaceae family. The popular cereal crops of the world include wheat, barley, oats, rice, maize, sorghum, and millets, but the major cereals of the developing countries are maize, rice, orghum, and millet(Olugboji OA, 2004). Rice and wheat are major grain crops in the world. The planting area of rice in China is about 30 million ha and its annual yield is more than 200 million. Almost half of the world population feed on rice. Consequently, grain harvester is an important agriculture machinery that improves harvesting efficiency and reduces labor costs. The typical kind of grain harvester is a combine which integrates the harvesting processes such as gathering, cutting, threshing, separation and cleaning, etc., especially threshing is its most important function(Fu et al., 2018a). More than 40 percent of the rice consumption in West Africa is imported, which represents 2.75 million tons per year(Thanthirige et al., 2016).

Post-harvest grain loss is the loss of grains (quality and/or quantity) between the moments of harvest and consumption. Reduction in food losses is sometimes considered as the 'third dimension' to the world food supply equation, i.e., in addition to increase in food production and increases in population(Befikadu Dubale, 2014). This figure is quite large especially for Ethiopia where a great majority of people are food insecure. It is ironic that the immediate victims of food insecurity have traditionally been farmers, i.e., the very producers of food. Each year, despite weather conditions, hundreds of thousands of rural households suffer food insecurity; literally depending on food-aid for their survival(Teferi et al., 2022). Hence, it is important to recognize that post-harvest grain management (PHGM) practices and capacities (and not just production and marketing) are important for many reasons including the achievement of food security objectives(Ayalew et al., 2013). Clearly a better PHGM capacity and practice would minimize the magnitude of loss. This is in addition to the potential employment and income linkage effects and gains from the activities. Unfortunately, this crucial area has not received the attention it deserves among researchers and policy makers(Economics & Library, n.d.).

## Statement of problems

Inappropriate threshing conditions in a manual threshing process reduces the grain output with respect to excessive and high energy input. Estimates suggest that the magnitude of post-harvest loss in Ethiopia was tremendous ranging from 5% to 26% for different crops(Debebe, 2022). The rice threshing in Ethiopia especially areas of Jimma and Illubabor were done by stick, under the foot of animals and by the traditional threshing machine. Thus, the threshing of rice by traditional and poor machine threshing units has its own problems on the quality and loss of the product. As the result, rice producers (farmers and investors are often unable to obtain competitive quality products from their farms and supply them to the market.

Different researchers have reported that they were focused on threshing machine factors like moisture content, drum speed, concave clearance, and peripheral speed rather than spike tooth cylinder structural design and FEA of spike tooth structure.

However, researchers studied the rice thresher machine, but none of them studied the spike tooth cylinder of the rice thresher machine, and else they did not study the spike tooth structure analyzed with FEA and statistically analyze this threshing unit.

Further, few researchers have considered the influence of other inputs during threshing such as energy on threshing performance). The present Design, Structural analysis, and performance evaluation test of rice spike tooth cylinder will optimize will be proposed.

Finally, designed, modelled by solid work, structurally analyzed, and the imported 3D model of spike tooth imported to ANSYS software and simulated, because of analysis, a spike tooth cylinder which used to thresh a rice with light weight, low postharvest loss, highly efficient, high threshing capacity will be manufactured.

## Objectives

### General objective

The general objective of this study is to design, structural analysis, and performance evaluation of a prototype of spike tooth rice threshing unit in terms of different feed rate, different drum speed level.

### Specific objectives

a) To determine the influence of drum speed and feeding rate on the threshing performance of a spike tooth rice threshing unit.

b) To design, structural analysis and manufacture the prototype of a rice thresher machine.

c) To collect data on fields for optimizing the threshing capacity, cleaning efficiency and threshing efficiency of the rice thresher using spike tooth cylinder threshing unit

d) Analysis the data collected during prototype test using R-stat software.

e) To model the rice spike tooth SOLIDWORK and force and torsional moment analysis on structural of spike tooth using ANSYS commercial software

f) Comparing the design analysis results of theoretical solution with ANSYS solution

## RESULT AND DISCUSSION

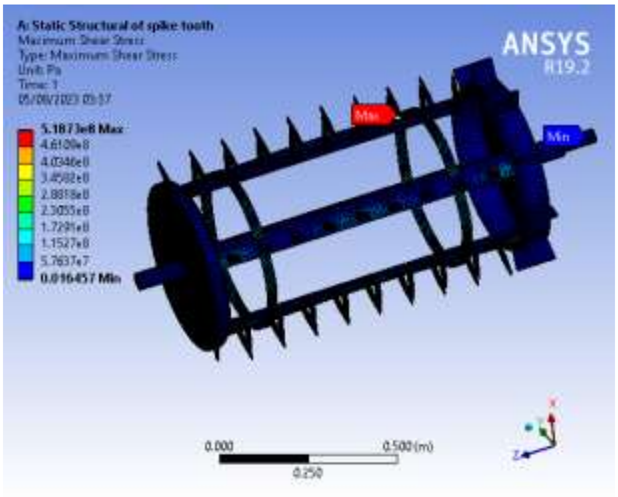
### Structural analysis of spike tooth cylinder using ANSYS 19.2

The FEA results of structural analysis are obtained by ANSYS workbench 19.2 software. This results for obtained by calculation of threshing cylinder design, calculating total cylinder weight, threshing power, speed, torque, and moment. The design calculations assumed mass of spike tooth and rotation speed for calculation of torsion moment, forces, principal stress, equivalent (von-mises) stress, and bending stress. The spike tooth cylinder for rice thresher model was created using Solid Work software and imported to ANSYS software.

Table 1: Structural Steel Mechanical properties

| Properties | Value | Unit |
|---|---|---|
| Density | 7850 | Kg/m$^3$ |
| Young Modulus | 2,07E+11 | Pa |
| Poison’s ratio | 0.3 | |
| Shear Modulus | 7.9615E+10 | Pa |
| Tensile yield strength | 2.5E+08 | Pa |
| Tensile ultimate strength | 2.5E+08 | Pa |
| Limit rupture in traction | 4.6E+08 | Pa |
| Bulk Modulus | 1.725E+11 | Pa |

### Shear Stress at different spike tooth cylinder speed(rpm)



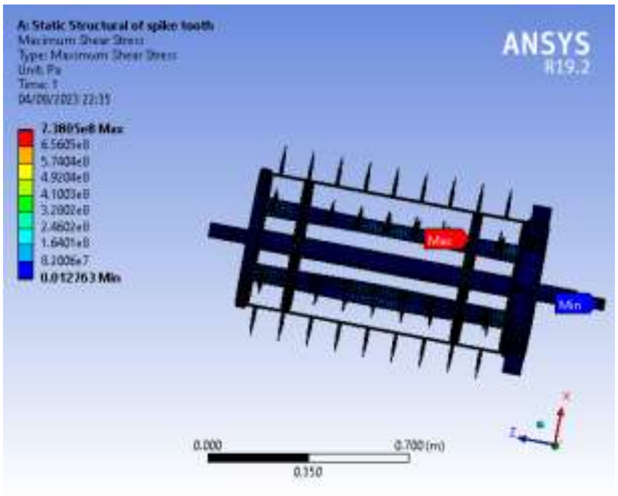
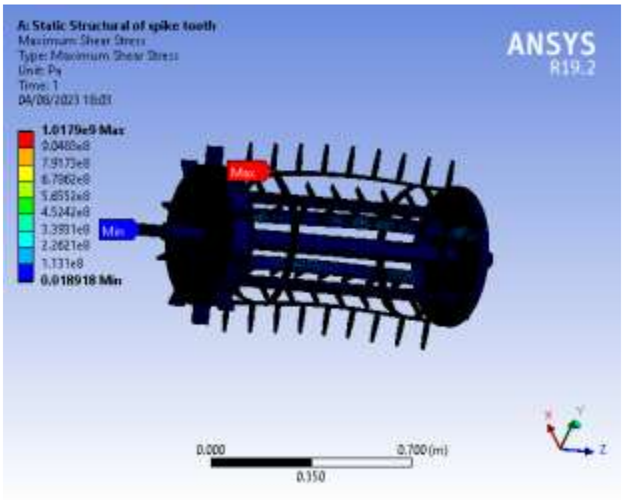


Figure 1: max. Shear stress at speed of 480 rpm Figure 1 : max. Shear stress at speed of 580 rpm



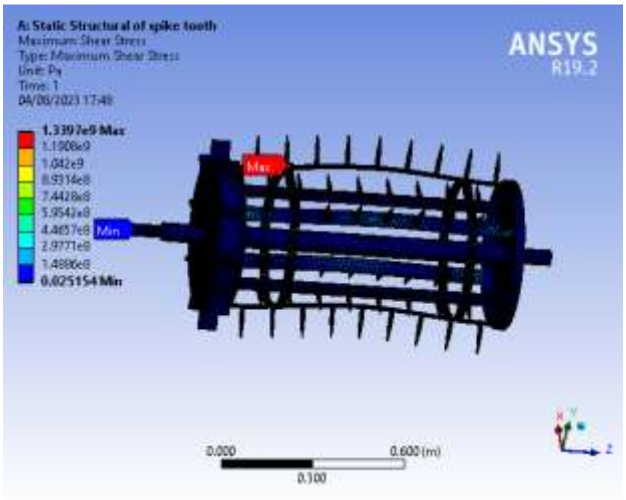
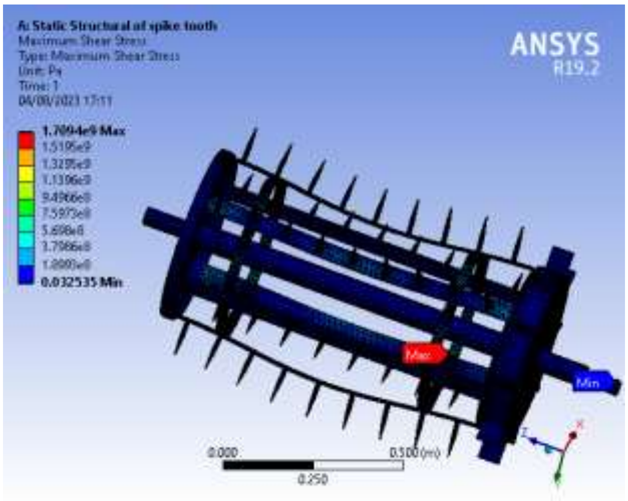


Figure 2: max. Shear stress at speed of 680 rpm Figure 3: max. Shear stress at speed of 780 rpm



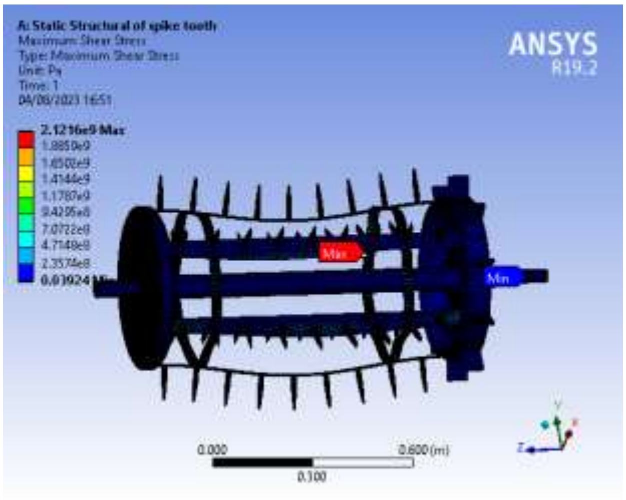
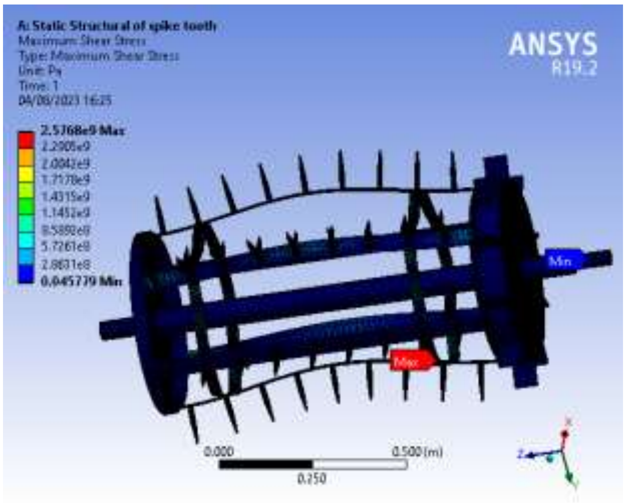


Figure 4: max. Shear stress at speed of 880 rpm Figure 5 : max. Shear stress at speed of 980 rpm



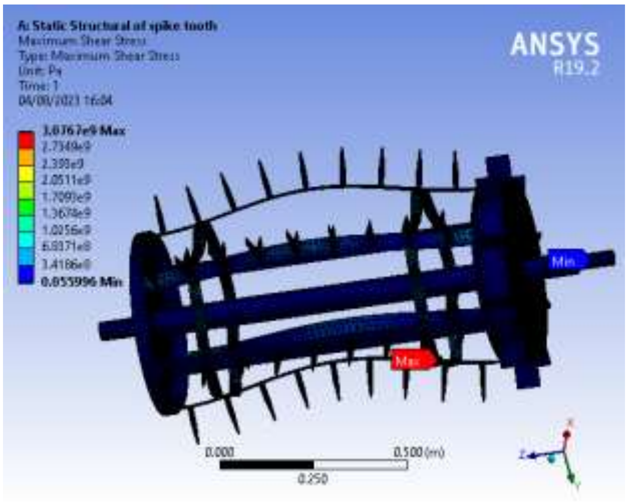


Figure 6: max. Shear stress at speed of 1080 rpm Figure 7: max. Shear stress at speed of 1180 rpm

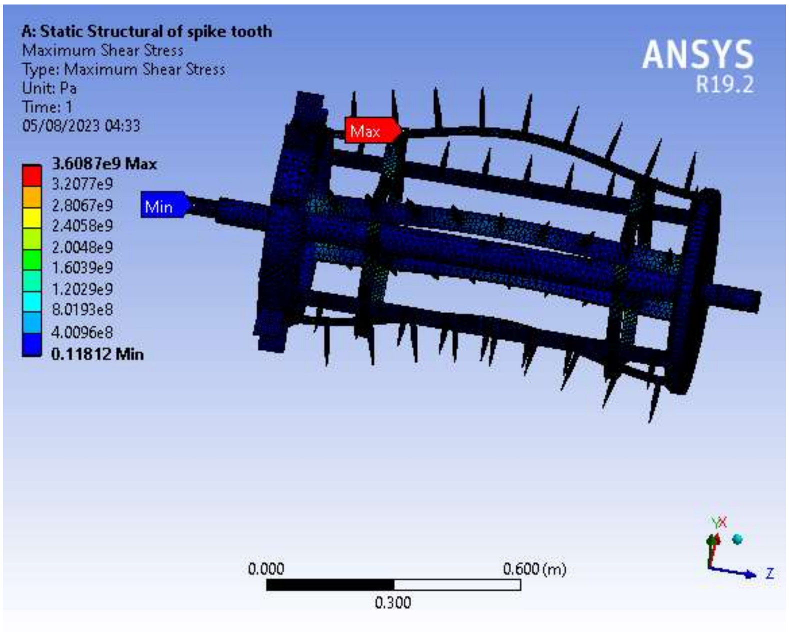


Figure 8: max. Shear stress at speed of 1280rpm

Table 1: Comparison of theoretical and ANSYS solution for maximum shear stress

| | **Maximum shear stresses** | |
|---|---|---|
| **Spike tooth speed** | **Numerical solution** | **Analytical Solution** |
| 480 | 91.98 | 51.87 |
| 580 | 133.25 | 73.805 |
| 680 | 184.85 | 101.79 |
| 780 | 240.85 | 133.97 |
| 880 | 310 | 170.94 |

| | | |
|---|---|---|
| 980 | 382.7 | 212.16 |
| 1080 | 464.7 | 257.68 |
| 1180 | 554.8 | 307.67 |
| 1280 | 653.5 | 360.87 |

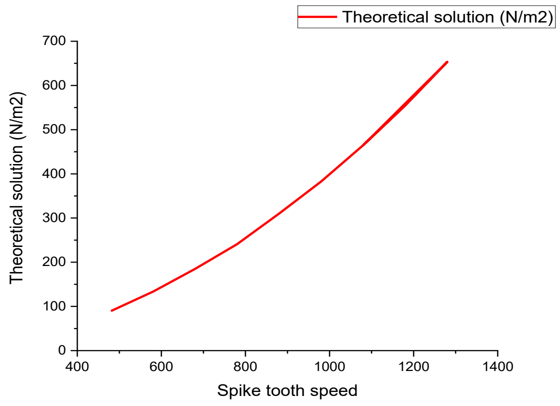


Figure 9: Theoretical solution vs spike tooth cylinder speed

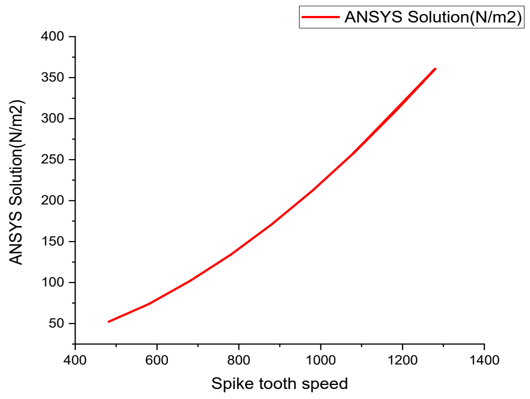


Figure 10: ANSYS solution vs spike tooth cylinder speed

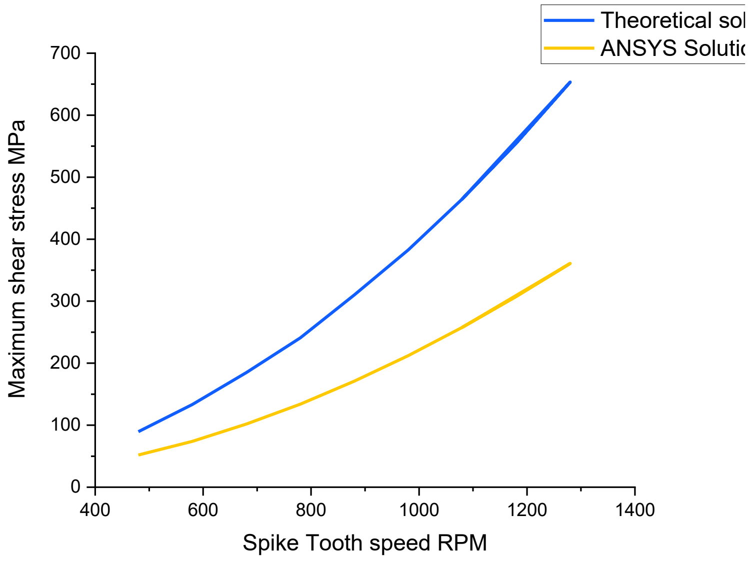


Figure 11: maximum shear stress vs spike tooth cylinder speed

The different axial loads depending on spike tooth speed were applied to the spike tooth cylinders of the thresher in the y-axis, as the torsional moments caused by the different torques applied to the spike tooth cylinders of the thresher in the z-axis. By varying the rotational speed level of the spike-tooth cylinder, different forces and torques were calculated. As shown in the above result (Table 2, different maximum shears were recorded because different forces and torsional moments were applied to the spike tooth cylinder. As the spike tooth speed increased from minimum (480 rpm) to maximum (1280 rpm), different maximum shear stresses were recorded (51.87, 73.805, 101.79, 133.97, 170.94, 212.16, 257.68, 307.67, and 360.87), respectively. But the maximum of all shear stresses (360.87) is recorded at the high-speed of 1280 rpm of the spike tooth cylinder.

Figure 1 – 9 show that, as a result of the ANSYS simulation, shear stress effects vary from the minimum level speed to the maximum level speed of spike tooth speed. Shear stress was often used to describe the strength of a material. Because of maximum force (66kN), applied to spike tooth, the shear strength of a material can withstands without failing. The evidence of this withstands was, when a maximum force of this design applied to the spike tooth, only the shape of spike tooth cylinder deformed.

Figure 12 show that when speed of spike tooth increased, the solution of theoretic and solution of ANSYS also increased, as both theoretical solution and ANSYS solution increased, the shear stress of material were increased with.

### Maximum principal stress at different spike tooth cylinder speed (rpm)

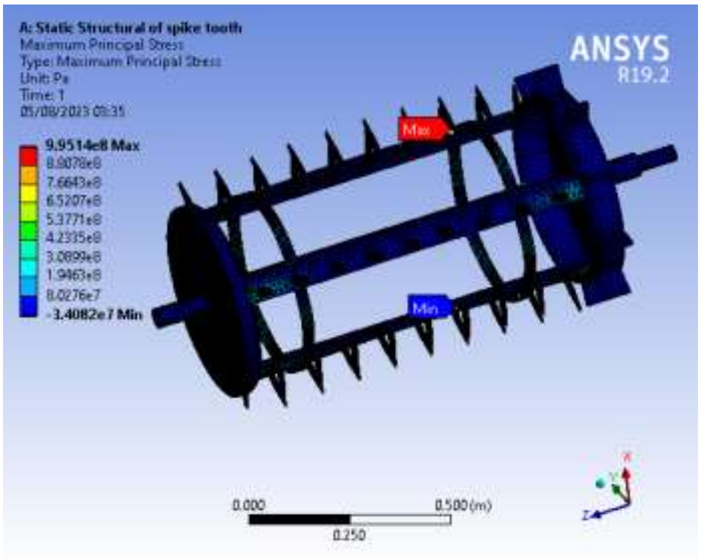
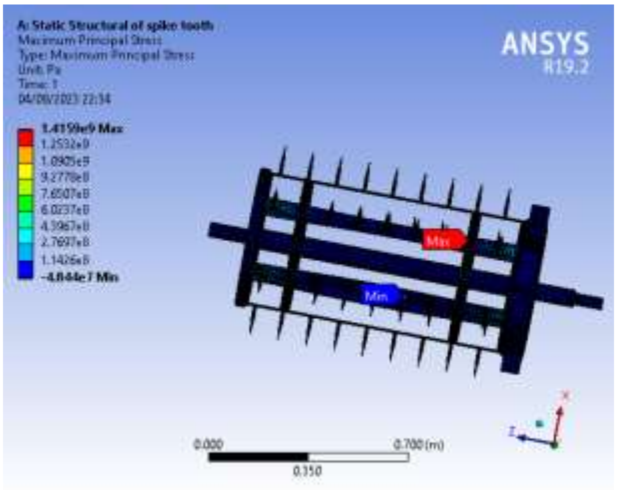


Figure 12: principal stress at speed of 480 rpm



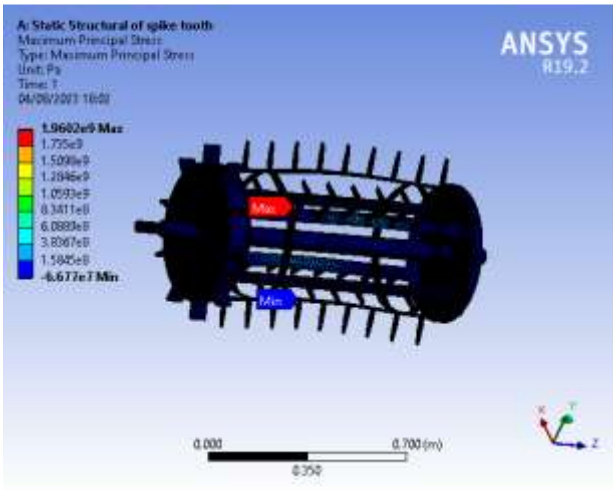
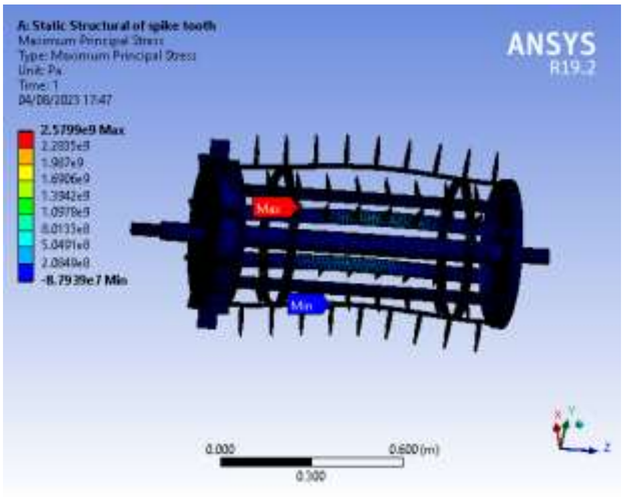


Figure 13: principal stress at speed of 580 rpm Figure 14: principal stress at speed of 680 rpm



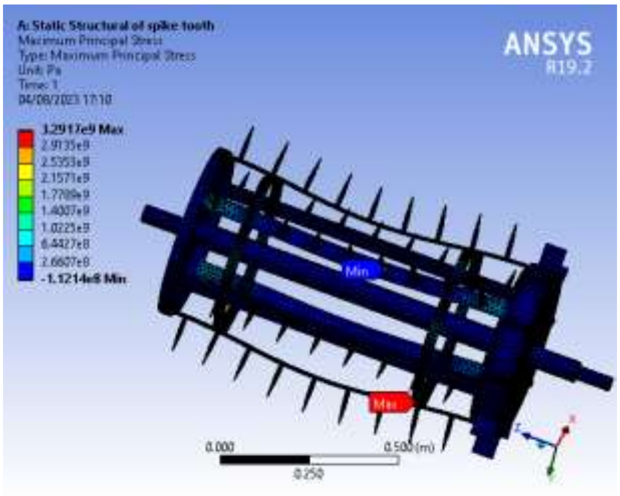
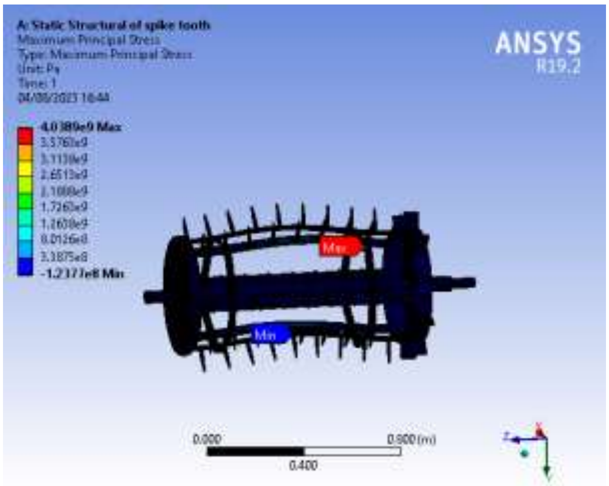


Figure 15: principal stress at speed of 780 rpm   Figure 16: principal stress at speed of 880 rpm



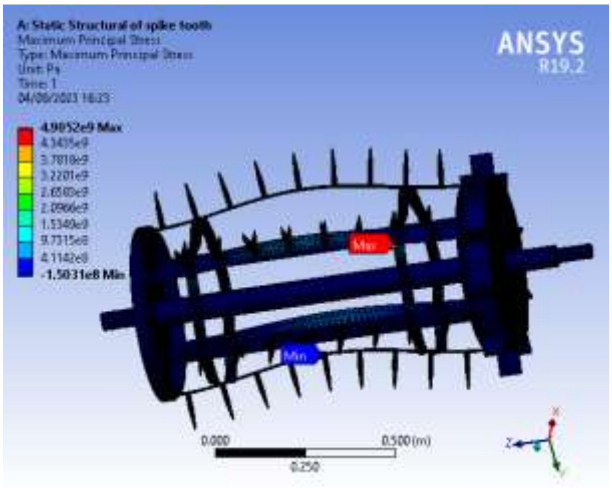
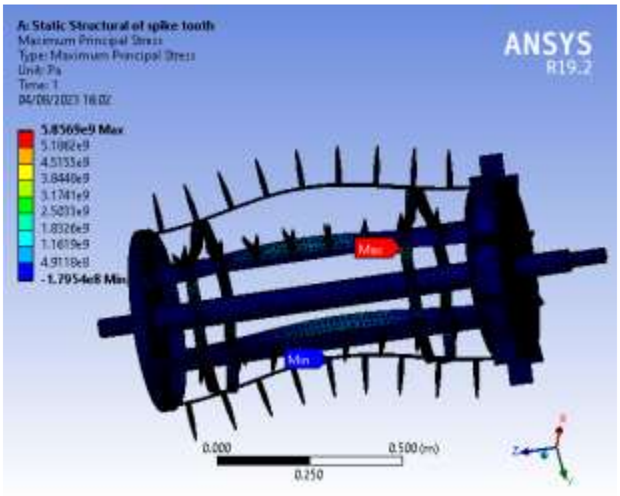


Figure 17: principal stress at speed of 980 rpm   Figure 18:  principal stress at speed of 1080rpm



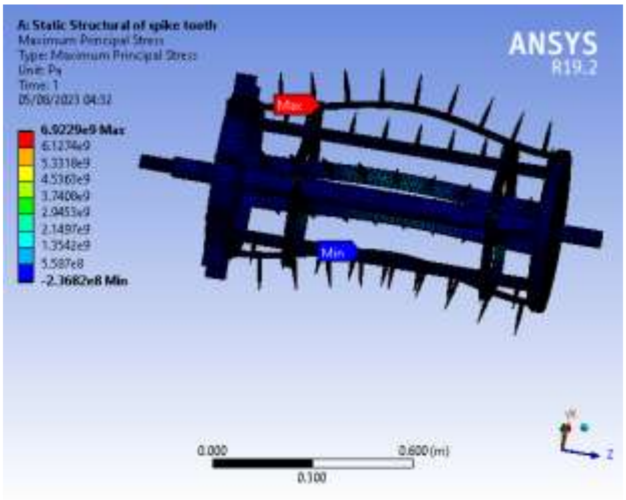


Figure 19: principal stress at speed of 1180rpm Figure 20: principal stress at speed of 1280rpm

Table 2: comparison results of theoretical and ANSYS solution for maximum principal stress

| **Spike tooth speed** | **Maximum Principal stress** | |
|---|---|---|
| | **Numerical solution** | **Analytical Solution** |
| 480 | 94.64 | 99.514 |
| 580 | 136.85 | 141.59 |
| 680 | 190 | 196.02 |
| 780 | 247.7 | 257.99 |
| 880 | 318.8 | 329.17 |
| 980 | 393.6 | 4038.9 |
| 1080 | 477.6 | 490.52 |
| 1180 | 570.6 | 585.69 |
| 1280 | 672.02 | 692.29 |

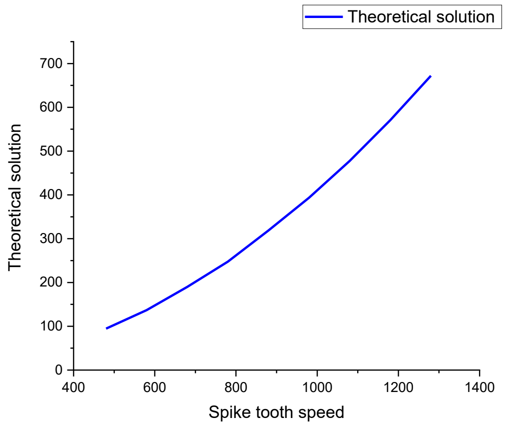


Figure 21: Theoretical solution vs spike tooth cylinder speed

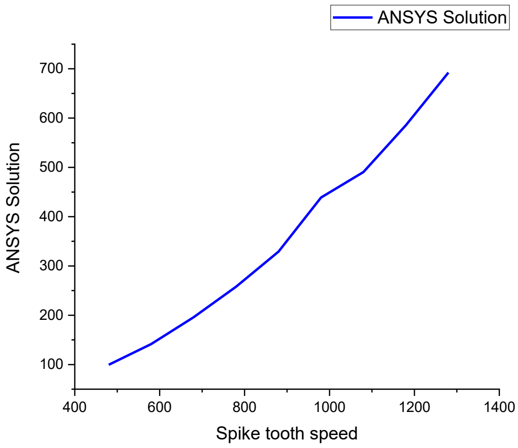


Figure 22: ANSYS solution vs spike tooth cylinder speed

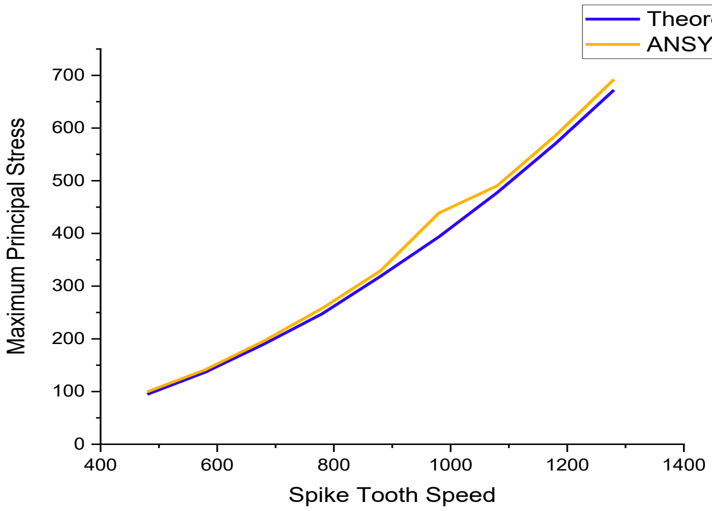
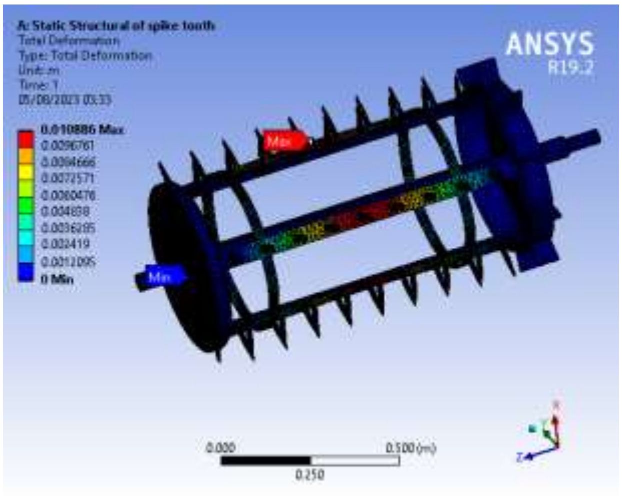


Figure 23: maximum principal stress vs Spike tooth speed

## Total deformation at different spike tooth cylinder speed (rpm)



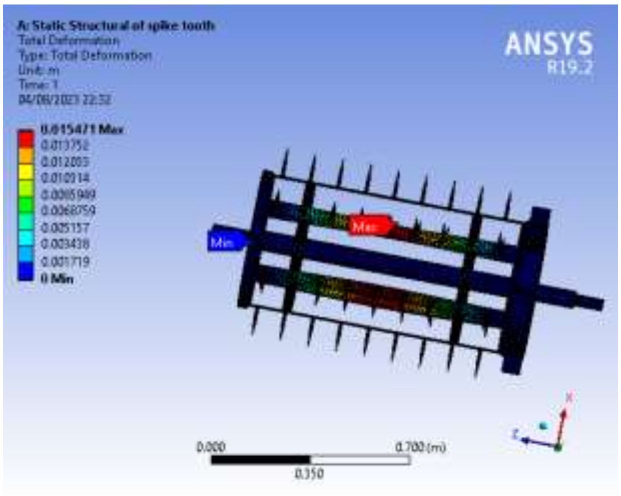
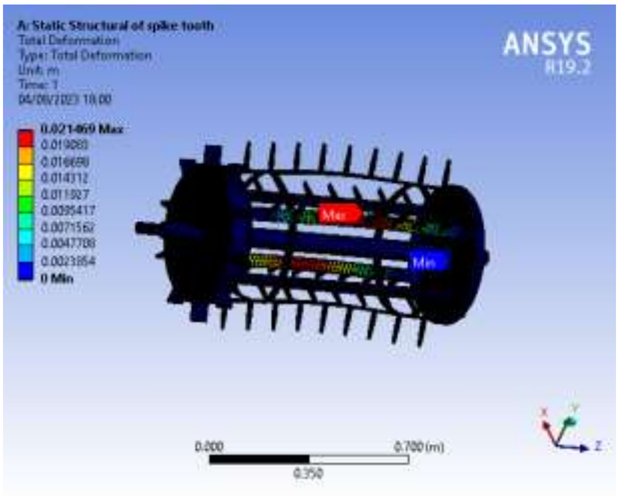


Figure 24: Deformation at speed of 480 rpm Figure 25: Deformation at speed of 580 rpm



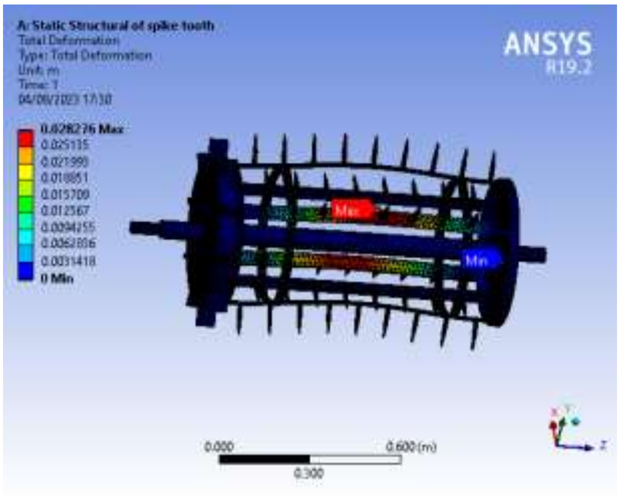
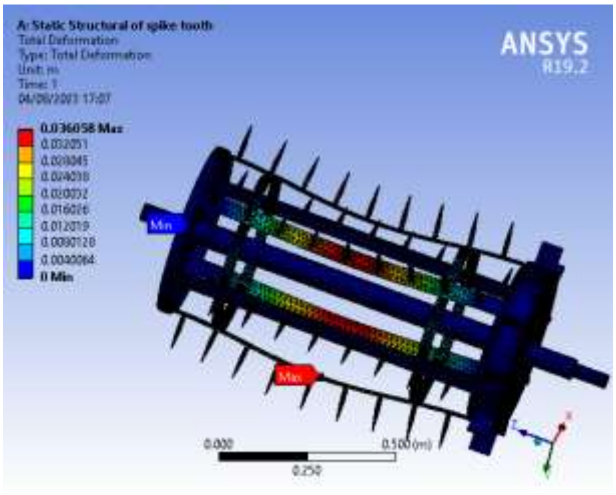


Figure 26: Deformation at speed of 680 rpm Figure 27: Deformation at speed of 780 rpm



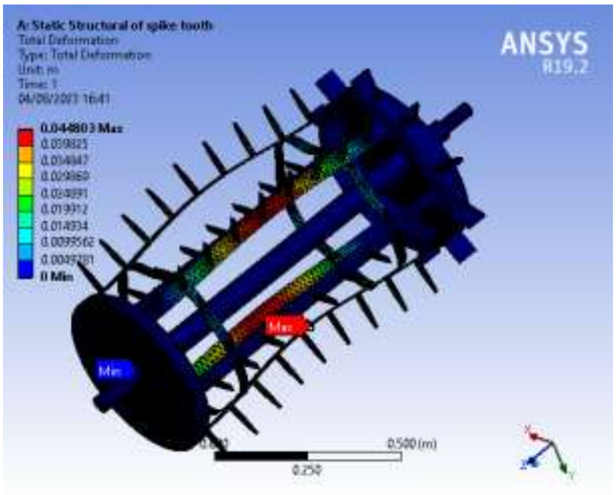
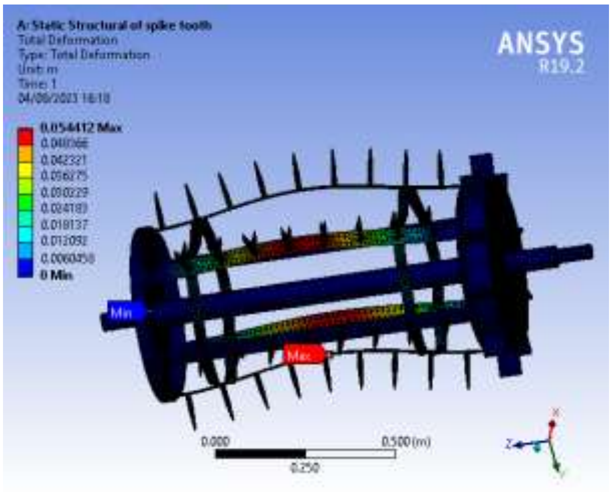


Figure 28: Deformation at speed of 880 rpm Figure 29: Deformation at speed of 980 rpm



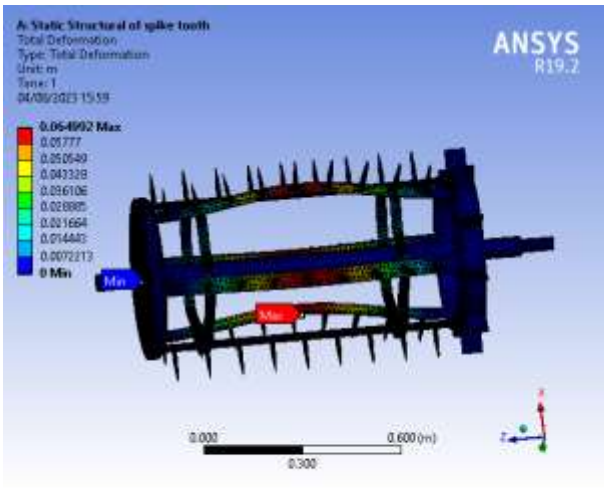


Figure 30: Deformation at speed of 1080 rpm Figure 31: Deformation at speed of 1180 rpm

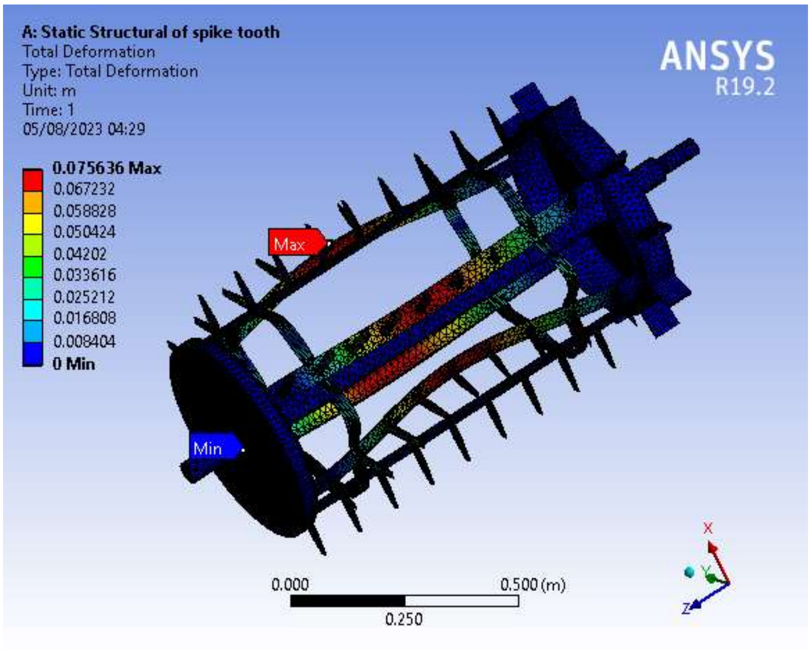
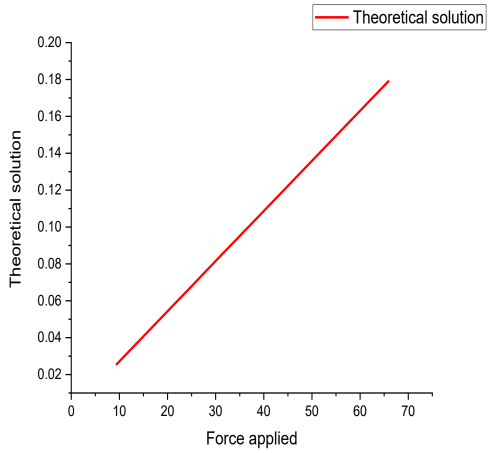


Figure 32: Deformation at speed of 1280 rpm

Table 3: comparison results of theoretical and ANSYS solution for total deformation

### Maximum Total deformation

| Force applied(kN) | Numerical solution | Analytical Solution |
|---|---|---|
| 9.3 | 2.52755036e-02 | 0.010886 |
| 13.5 | 3.669024724e-02 | 0.015471 |
| 18.6 | 5.05510072e-02 | 0.021469 |
| 24.5 | 6.65860041e-02 | 0.028276 |
| 31.2 | 8.490666753e-02 | 0.036056 |
| 38.7 | 1.05178709e-01 | 0.044803 |
| 47 | 1.27736416e-01 | 0.054412 |
| 56.14 | 1.52577072e-01 | 0.064992 |
| 66 | 1.793745417e-01 | 0.075636 |



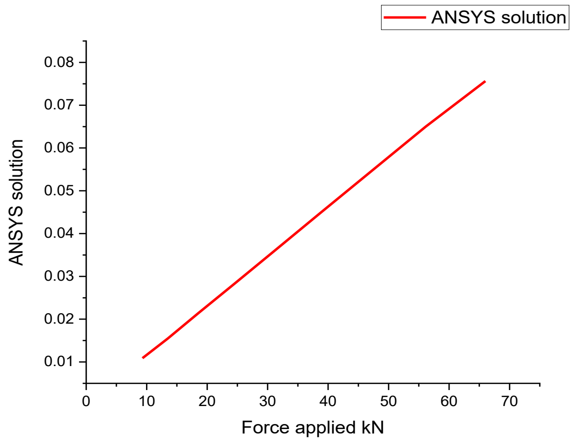


Figure 33: Theoretical solution vs applied force

Figure 34: ANSYS solution vs applied force

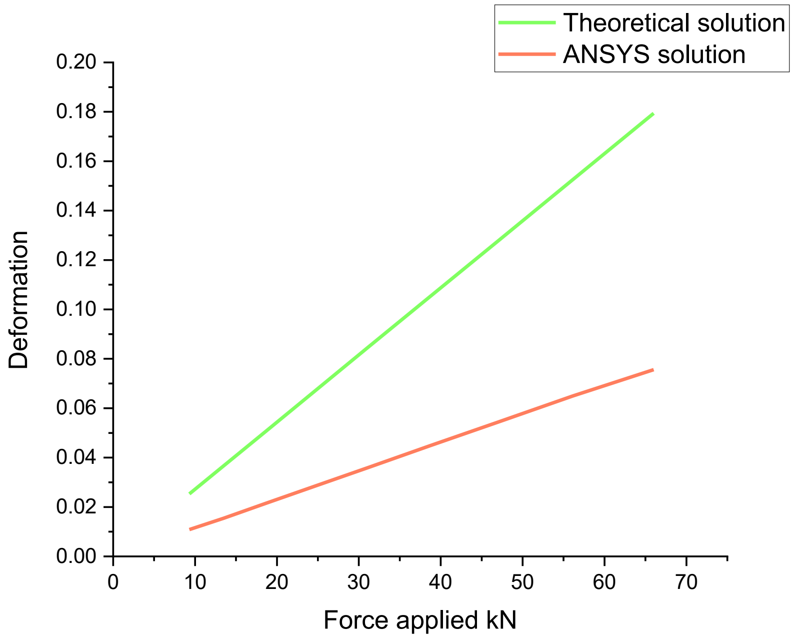


Figure 35: Deformation vs Force applied

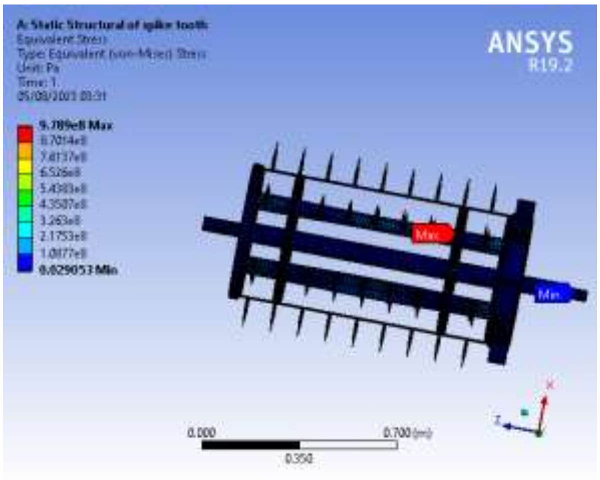
The deformation of the spike tooth is a very important part of this study. The deformation shape changes according to the force applied across the body on the y-axis of the spike-tooth cylinder. The steel structure's overall amount of deformation from the applied load zone to the fixed support region is depicted by the contour simulation in figure 25 - 33.

All the ANSYS solution results are recorded under a combination of axial loading and torsional moments in a rotating body. The maximum total deformation (0.075636 m) is generated at the high speed of the spike tooth (1280 rpm, or 134.04 rad/sec), vertical load of 66kN and the minimum total deformation (0.010886 m) is recorded at the low speed (480 rpm or 50.3 rad/sec) of the spike tooth cylinder and at minimum force of 9.3kN the threshing machine.

As shown in graph (figure 34-35), as forces applied to spike tooth increases, the ANSYS solution also increase and theoretical solution (figure 36) increase as.

Generally, as theoretical and ANSYS solutions are increases, the deformation of imported spike tooth cylinder also gradually increases.

### Equivalent (Von-Mises) stress at different spike tooth cylinder speed(rpm)



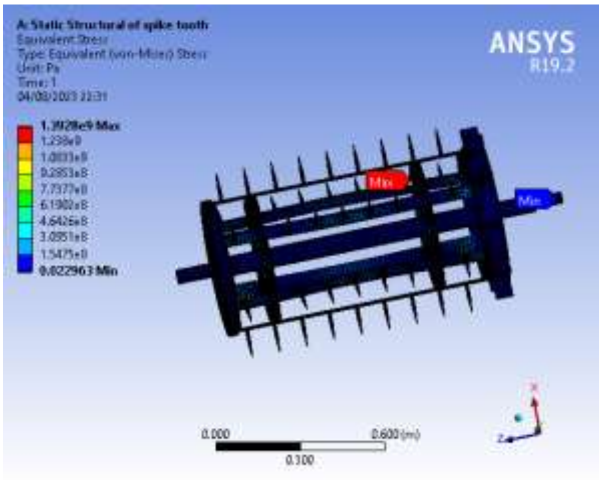
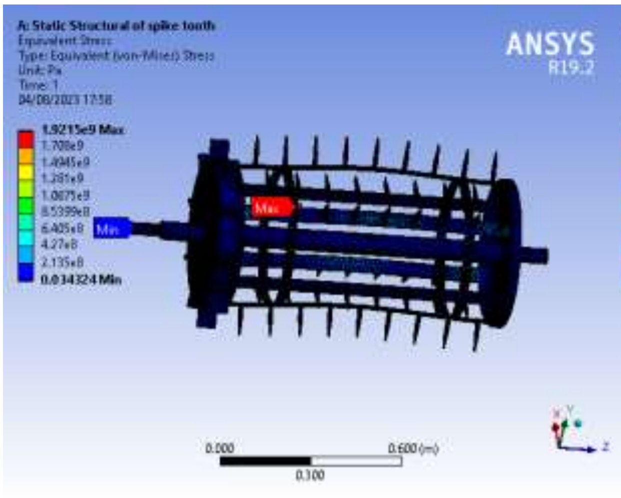


Figure 36: Equiv.(von-Mises) stress at speed of 480rpm Figure 37: Equiv.(von-Mises) stress at speed of 580rpm

Researches



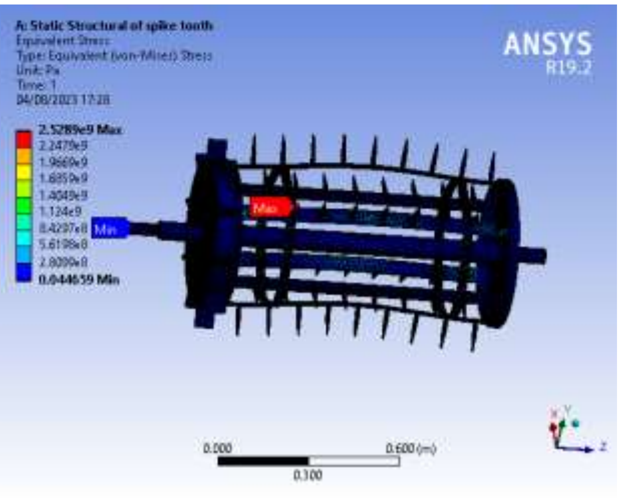
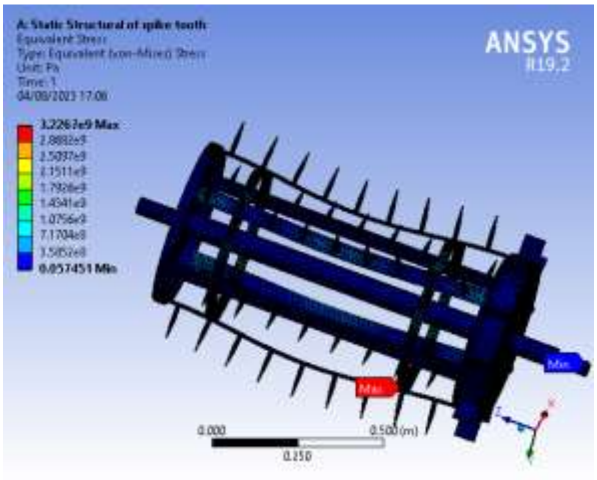


Figure 38: Equiv.(von-Mises) stress at speed of 680rpm Figure 39: Equiv.(von-Mises) stress at speed of 780rpm



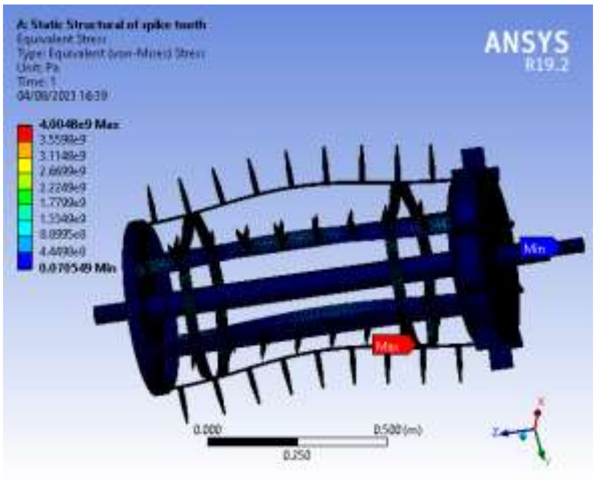
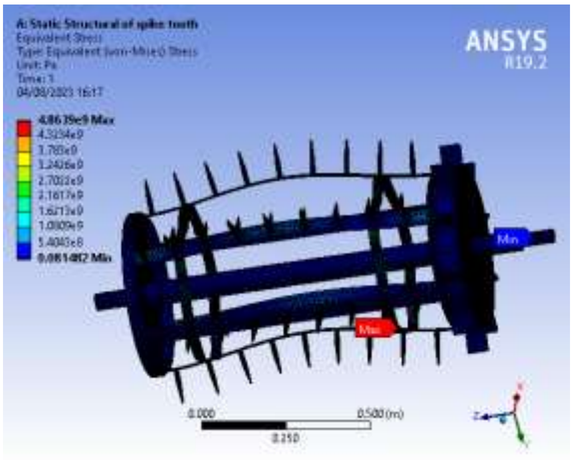


Figure 40: Equiv.(von-Mises) stress at speed of 880rpm Figure 41: Equiv.(von-Mises) stress at speed of 980rpm



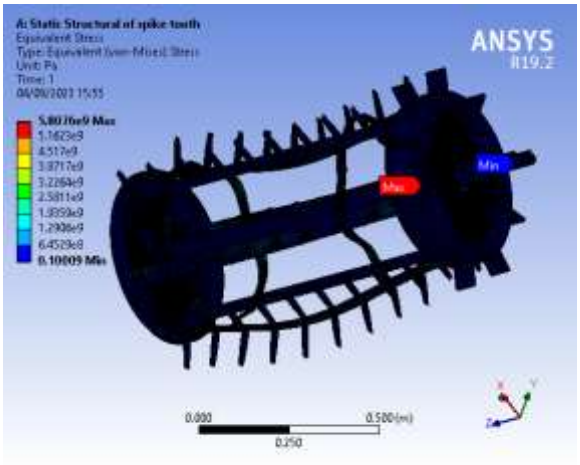


Figure 42: Equiv.(von-Mises) stress at speed of 1080rpm Figure 43: Equiv.(von-Mises) stress at speed of 1180rpm

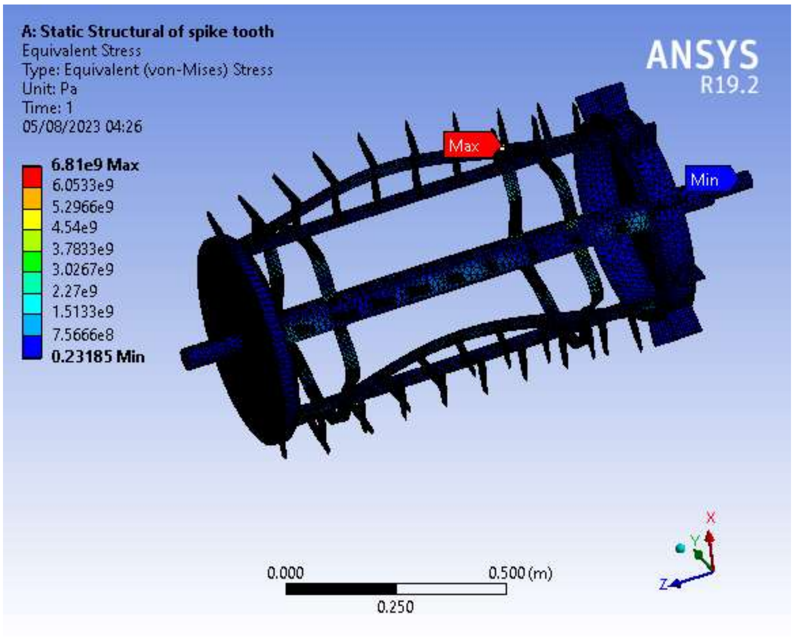


Figure 44: Equiv.(von-Mises) stress at speed of 1280rpm

Table 4: Comparison results of theoretical and ANSYS solution for equivalent (von-misses) stress

| | **Equivalent (Von-Mises) stresses** | |
|---|---|---|
| **Spike tooth speed** | **Numerical solution** | **Analytical Solution** |
| 480 | 92.1 | 97.89 |
| 580 | 133.5 | 139.28 |
| 680 | 185.2 | 192.15 |
| 780 | 241.14 | 252.89 |
| 880 | 310.4 | 322.67 |
| 980 | 383 | 400.48 |
| 1080 | 465 | 486.39 |
| 1180 | 555.3 | 580.76 |
| 1280 | 654.3 | 681 |

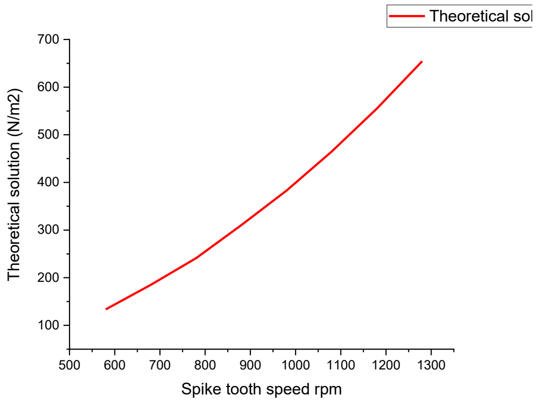


Figure 45: Theoretical solution for vs spike tooth speed

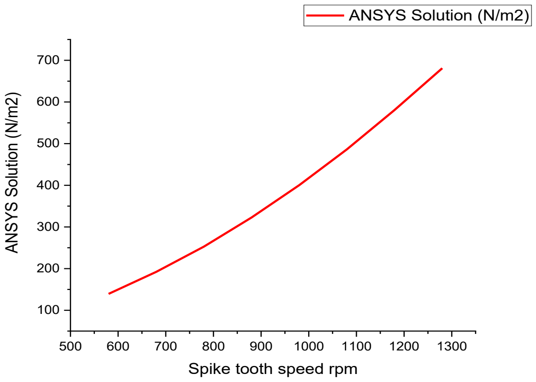


Figure 46: ANSYS solution for vs spike tooth speed

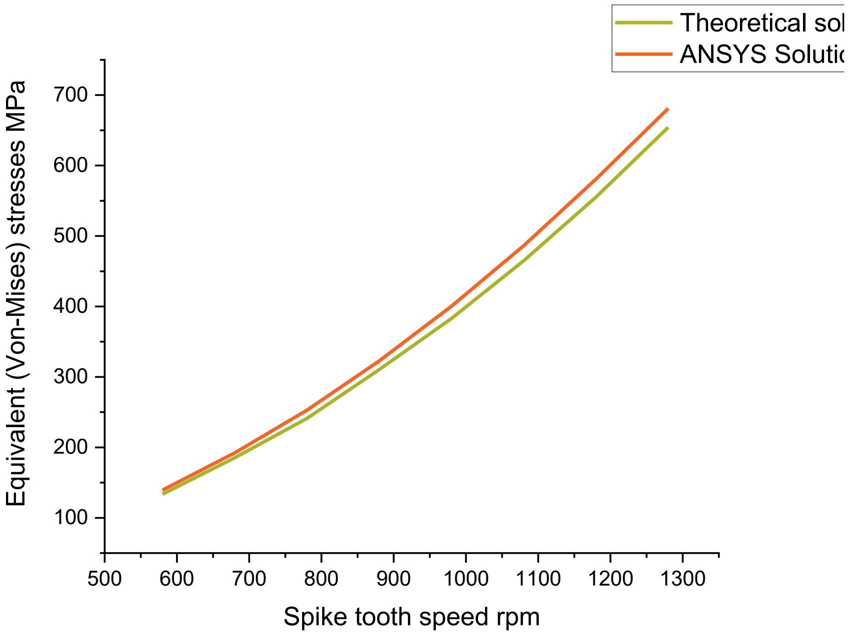


Figure 47: Equivalent (von-misses) stress vs spike tooth speed

The von Mises stress is highest at the supporting structure of the body and decreased away from the center. As shown in table 5 the maximum von Mises stress (681MPa) was resulted at the high speed of the spike tooth (1280 rpm) and minimum of equivalent result (97.89MPa) is noted at low speed (480) of spike tooth cylinder. The analysis also shows that the bodies are experiencing bending stress. The bending stress is highest at the highest speed of the spike tooth cylinder of the bodies and decreases the performance of the threshing machine towards the center. The analysis results indicate that a material may deform or even fracture as a result of bending stress. However, the stresses are below the yield strength of the material, so the bodies are not likely to fail. As shown from figure 37 -45 result analyzed by ANSYS software, the equivalent (Von-mises) stresses increase from 97.89 MPa of minimum level speed (480 rpm) to 681 MPa of maximum level speed (1280 rpm) of the spike tooth cylinder. Most of the time, the rotation per minute of the spike tooth depends on the speed of the motor or engine connected to the spike tooth cylinder. The different forces and different torsional moments because of spike tooth speed also vary the results of equivalent (von-mises) stress.

As shown in graph (figure 46), as forces applied to spike tooth increases, the ANSYS solution also increase and theoretical solution (figure 47) increase as.

Generally, as theoretical and ANSYS solutions are increases, the equivalent (Von-mises) stress of imported spike tooth cylinder also gradually increases (figure 48).

### Performance using statical analysis of R-stat software

The goal of this study was to enhance and assess the performance of a rice spike tooth thresher that could thresh rice grain at three levels of drum speed (680, 980, and 1280 rpm) and three levels of feeding rate (5000, 7000, and 9000 g/min). Functional fulfillment of the spike-tooth cylinder thresher was evaluated using performance indicators such as threshing capacity (TC), threshing efficiency (TE), cleaning efficiency (CE), percentage of visible grain breakage (MD), and percentage of grain loss. The collected results were examined and covered under the following headings:

Table 5: Effect of drum (spike tooth) speed and feed rate on performance evaluation of rice thresher

| **Feed rate (g/min)** | **Drum speed (RPM)** | **Threshing capacity (g/min)** | **Cleaning efficiency (%)** | **Threshing efficiency (%)** | **Breakage (MD)** |
|---|---|---|---|---|---|
| **5000** | **680** | 250.9 | 91.6941 | 99.99 | 0.255915 |
| | **980** | 304.4 | 90.56236 | 99.96 | 0.510284 |
| | **1280** | 362.3 | 93.01716 | 100 | 1.885015 |
| **7000** | **680** | 344.8 | 92.30898 | 99.97143 | 0.472641 |
| | **980** | 365.2 | 95.25163 | 99.97143 | 1.21194 |
| | **1280** | 423.1 | 96.40819 | 100 | 2.978008 |
| **9000** | **680** | 407.6 | 91.28757 | 99.97037 | 1.133197 |
| | **980** | 432.2 | 95.59591 | 99.98148 | 2.444281 |
| | **1280** | 458.3 | 98.15867 | 99.99259 | 3.627994 |

Effects of Drum Speed and Feed Rate on Performance Parameters of rice Thresher

### Threshing Capacity

The relationship between drum speed and threshing capacity for rice grain is shown in the table7 for feed rates of 5000, 7000, and 9000 grams per minute (g/min) and drum speeds of 680, 980, and 1280 revolutions per minute (rpm). The maximum capacity for threshing was discovered to be 458.3 g/min at a drum speed of 1280 rpm and a feed rate of 9000 g/min, while the minimum capacity for threshing was discovered to be 250.9 g/min at a drum speed of 680 rpm and a feed rate of 5000 g/min. The threshing capacity increased from 250.9 g/min to 458.3 g/min at a speed of 680 rpm to 1280 rpm as the feed rate increased from 5000 to 9000 g/min

According to the analysis of variance (ANOVA) results, drum speed and feed rate have high a significantly ($p < 0.05$) effect on threshing capacity. While the interaction of drum speed and feed rate had no significantly ($p > 0.05$) effect on threshing capacity.

Table 6 displays the impact of mean threshing capacity on threshing drum (spike tooth) speed, feeding rate, and the combined impact of these factors

| **parameter** | **Source of variation** | | **Measure difference** | | |
|---|---|---|---|---|---|
| | **Drum speed** | **Mean** | **LSD (5%)** | **SE** | **Cv** |
| | 680 | $334.70^{a}$ | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 980 | | $367.65^{b}$ | | 18.041 | 8.5101 | 4.85 |
| | 1280 | | $415.28^{c}$ | | | | |
| | **Feed rate (g/min)** | | **Mean** | | | | |
| | 9000 | | $433.03^{a}$ | | 8.5101 | 18.041 | 4.85 |
| | 7000 | | $378.38^{b}$ | | | | |
| | 5000 | | $306.22^{c}$ | | | | |
| | **Interaction (speed X Feed rate)** | | | | | | |
| | | 9000 | 7000 | 5000 | 31.247 | 14.740 | 4.85 |
| | 1280 rpm | $458.84^{a}$ | $424.3^{b}$ | $362.72^{c}$ | | | |
| | 980 rpm | $432.3^{ab}$ | $365.7^{c}$ | $304.9^{d}$ | | | |
| | 680 rpm | $407.9^{b}$ | $345.15^{c}$ | $251.01^{e}$ | | | |

*Means followed by the same letters do not have significant difference at 5% level of probability*

## Threshing Efficiency

Table 4:8 contains the test results for feed rate and drum speed on rice threshing efficiency. The table clearly shows that at feed rates of 5000 g/min and 7000 g/min, and drum speeds of 1280 rpm, the maximum threshing efficiency of 100 percent was achieved. While a minimum threshing efficiency of 99.96% was achieved with drum speeds of 980 rpm and feed rates of 5000 g/min. Similar to the findings of Behera et al., as the feed rates increased from 5000 to 9000 g/min, the threshing efficiency likewise increased from 99.961 percent to 100 percent (1990).

The analysis of variance (ANOVA) revealed that drum speed and feeding rate have no significant ($p > 0.05$) effect on threshing efficiency, whereas the interaction of drum speed and feed rate had a significant ($p< 0.05$) effect on threshing efficiency.

Table 7 show the effect of drum (spike tooth) speed, feeding rate, and the combined effect of drum speed and feed rate on mean threshing efficiency.

| **parameter** | **Source of variation** | | **Measure difference** | | |
|---|---|---|---|---|---|
| | **Drum speed** | **Mean** | **LSD (5%)** | **SE** | **Cv** |
| | 680 | $99.978^{a}$ | 0.0336 | 0.0159 | 3.88 |
| | 980 | $99.971^{a}$ | | | |
| | 1280 | $99.998^{a}$ | | | |
| | **Feed rate (g/min)** | **Mean** | | | |
| | 5000 | $99.984^{a}$ | 0.336 | 0.0159 | 3.88 |
| | 7000 | $99.981^{a}$ | | | |
| | 9000 | $99.981^{a}$ | | | |

| | **Interaction (speed X Feed rate)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 5000 | 7000 | 9000 | 0.0582 | 0.0275 | 0.03 |
| | 680 rpm | 99.99$^{a}$ | 99.97$^{a}$ | 99.99$^{a}$ | | | |
| | 980 rpm | 99.96$^{a}$ | 99.97$^{a}$ | 99.98$^{a}$ | | | |
| | 1280 rpm | 100$^{a}$ | 100$^{a}$ | 99.99$^{a}$ | | | |

### Cleaning efficiency

Table 9 show that relationship between feed rate, drum speed, and cleaning efficiency. The maximum cleaning efficiency of 98.16% was achieved at a 9000 g/min feed rate and 1280 rpm of drum speed, whereas the minimum cleaning efficiency of 90.56% was achieved at a 5000 g/min feed rate and 980 rpm of drum speed. As speed of engine connected to spike tooth shaft increased, speed of blower also increased. Then, as speed of spike tooth increased from 680 – 900 rpm, the cleaning efficiency also increased from 90.56% to 98.16%.

As result from Table 9, with increased drum speed, cleaning efficiency increased. Since the speed of the blower increased with drum speed, cleaning efficiency was also affected considerably. The increase in drum speed causes an increase in blower speed, resulting in a high air blast and thereby increasing cleaning efficiency.

Result of the analysis of variance (ANOVA) revealed that drum speed and feeding rate have significant ($p > 0.05$) effect on cleaning efficiency, whereas the interaction of drum speed and feed rate also had a significant ($p>0.05$) effect on cleaning efficiency.

Table 8 show the effect of drum (spike tooth) speed, feeding rate, and the combined effect of drum speed and feed rate on mean cleaning efficiency.

| **Parameter** | **Source of variation** | | | | **Measure difference** | | |
|---|---|---|---|---|---|---|---|
| | **Drum speed** | | **Mean** | | **LSD (5%)** | **SE** | **Cv** |
| | 680 | | 91.340$^{a}$ | | 1.8102 | 0.8539 | 1.93 |
| | 980 | | 93.805$^{b}$ | | | | |
| | 1280 | | 95.876$^{c}$ | | | | |
| | **Feed rate (g/min)** | | **Mean** | | | | |
| | 5000 | | 91.323$^{a}$ | | 1.8102 | 0.8539 | 1.93 |
| | 7000 | | 94.664$^{b}$ | | | | |
| | 9000 | | 95.034$^{b}$ | | | | |
| | **Interaction (speed X Feed rate)** | | | | | | |
| | | 5000 | 7000 | 9000 | 3.1354 | 1.4790 | 1.93 |
| | 680 rpm | 90.397$^{a}$ | 92.306$^{abc}$ | 91.316$^{d}$ | | | |
| | 980 rpm | 90.556$^{a}$ | 95.254$^{bcd}$ | 95.605$^{d}$ | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1280 rpm | $93.014^{ab}$ | $96.434^{cd}$ | $98.181^{d}$ | | | |

## Grain Breakage

Table 10 shows the relation between drum speed, feed rate, and grain breakage in rice at drum speeds of 680 rpm, 980 rpm, and 1280 rpm and feed rates of 5000, 7000, and 9000 g/min. At a higher drum speed of 1280 rpm and a feed rate of 9000 g/min, the greatest breakage recorded was 3.63, and at a feed rate of 5000 g/min and a drum speed of 680 rpm, there was a moderate amount of breakage, with a minimum of 0.255915 breakage being recorded.

Increased impact by the drum's spike tooth to separate the grain from the ear heads caused more grain breakage at higher speeds, which was reflected in the increased breakage %.

As a result of the analysis of variance (ANOVA), it was indicated that drum speed and feeding rate have a significant ($p > 0.05$) effect on grain breakage, whereas the interaction of drum speed and feed rate also has a significant ($p > 0.05$) effect on grain breakage.

Table 9 show the effect of drum (spike tooth) speed, feeding rate, and the combined effect of drum speed and feed rate on mean grain breakage.

| **parameter** | **Source of variation** | | | | **Measure difference** | | |
|---|---|---|---|---|---|---|---|
| | **Drum speed** | | **Mean** | | **LSD (5%)** | **SE** | **Cv** |
| | 480 | | $0.6209^{a}$ | | 0.5095 | 0.2403 | 31.61 |
| | 980 | | $1.3899^{b}$ | | | | |
| | 1280 | | $2.8281^{c}$ | | | | |
| | **Feed rate (g/min)** | | **Mean** | | | | |
| | 5000 | | $0.8831^{a}$ | | 0.5095 | 0.2403 | 31.61 |
| | 7000 | | $1.5545^{b}$ | | | | |
| | 9000 | | $2.4012^{b}$ | | | | |
| | **Interaction (speed X Feed rate)** | | | | | | |
| | | 5000 | 7000 | 9000 | 0.8825 | 0.4163 | 31.61 |
| | 480 rpm | $0.2579^{a}$ | $0.4708^{cd}$ | $1.1339^{ef}$ | | | |
| | 980 rpm | $0.5117^{ab}$ | $1.2174^{de}$ | $2.4407^{ef}$ | | | |
| | 1280 rpm | $1.8798^{bc}$ | $2.9753^{def}$ | $3.6291^{f}$ | | | |

## CONCLUSION, RECOMMENDATION, AND FUTURE WORK

### Conclusion

The research study successfully designed, manufactured, and tested a spike-tooth cylinder for a rice thresher machine, focusing on local materials for low and medium agricultural farmers. The model was created using SOLIDWORK software and analyzed by ANSYS software.

The analysis of the Spike tooth was done using statically steel structural by applying different torsional moment calculated from different drum speed and different vertical forces. Shear stress occurred when parallel forces act on a material in opposite directions, causing it to deform.

As the speed of the spike tooth increased, different maximum shear stresses were recorded. The maximum shear stress (360.87) was recorded at 1280 rpm of the spike tooth cylinder. Shear stress was often used to describe a material's strength, which was the maximum shear stress it can withstand without failing.

The deformation of the spike tooth in a steel structure, analyzing its shape and the force applied across the body. The ANSYS solution results show that the maximum total deformation occurred at high speed, while the minimum deformation occurred at low speed. As forces and torsional moments increased, the spike tooth cylinder's shape changed, and the deformation of the spike tooth gradually increased.

The maximum equivalent stress was generated at disc supports by nine levels of forces, while the torsional moments of the spike tooth cylinder range from 97.89 to 681 4.741 MPa. The bodies were under a combination of axial and torsional loading, with the highest stress at the supporting structure and the lowest at low speed. Bending stress was highest at the highest speed of the spike tooth cylinder, causing the threshing machine to decreased performance to thresh rice. The stresses are below the material's yield strength, preventing failure.

This study also assessed the performance of spike tooth cylinder thresher for threshing rice grain at different drum speeds and feeding rate levels by using statical software called R- STAT. Results included threshing capacity, efficiency, cleaning efficiency, visible grain breakage.

The maximum capacity was 458.3 g/min at 1280 rpm, while the minimum was 250.9 g/min. As feed rate increased, threshing capacity increased from 250.9 g to 458.3 g. ANOVA results showed a significant effect of drum speed and feed rate on threshing capacity, while the interaction had no significant effect.

Maximum efficiency was achieved at 5000 g/min and 7000 g/min, while minimum efficiency is 99.96% at 980 rpm and 5000 g/min. The interaction of drum speed and feed rate has a significant effect on threshing efficiency. The maximum cleaning efficiency was achieved at 9000 g/min feed rate and 1280 rpm, while the minimum was 90.56%. ANOVA analysis showed that drum speed, feeding rate and the interaction of drum speed and feed rate significantly affected cleaning efficiency.

Higher speeds resulted in greater breakage, while lower speeds had a moderate amount. Using ANOVA analysis drum speed, feeding rate, and interaction of speed and feed rate significantly affected grain breakage.

### Recommendation

Depending on the achieved results and conclusions, the recommendations are listed below:

Therefore, the farmers will be advised to purchase a spike-tooth cylinder thresher machine that is light, simple to use, and maintain, yet has a high threshing capacity, high cleaning efficiency, and maximum threshing efficiency at a low cost. Because of this, it is preferable to utilize and popularize it for low- and medium-income rice producers.

Depending on the performance test of the machine, a medium spike tooth cylinder speed has a higher threshing capacity, cleaning efficiency, threshing efficiency, and low mechanical damage than other spike tooth cylinder speeds.

To decrease the stresses, deformation, and failure of the structure of the spike tooth machine, medium and low speeds of the spike tooth cylinder are recommended.

## Future work

In the upcoming study, the designed and fabricated components of the concave and shaker components, including the spike tooth cylinder, among others, should be designed and analyzed.

Given that the principles of design and operation are the same, this proposal might be applied to various grain threshers like wheat, barley, sorghum, and teff. However, further research is required to demonstrate this.

In addition to the performance test, it is better to test the performance parameters, including scatter loss (*SL),* with different moisture contents of crops.

In the future, this machine will multiply mass by three times, which will increase rice production and technology transfer.

It is better to do more optimization life-time by using different forced draft systems.