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Stress Analysis of the Drum Shaft Used in Threshing Machines by Finite Element Method

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Abstract: Threshing machine is commonly manufactured (produced) and used in Turkey. In this study, 3D model and motion analysis of threshing machine's drum shaft was done by using Cosmosmotion 2009 computer programme. Stress distributions were investigated by using finite element method. It was determined that the system was reliable, but material safety factor was found as 3.96 which is higher than required 1.5 -2.0 range. This shows that the drum shaft of threshing machine had been manufactured more than necessary thickness. Unnecessary material using should be considered carefully to decrease costs in agricultural machinery manufacturing.
Key words: Threshing machine, Drum shaft, Finite element, Stress analysis

INTRODUCTION

The use of threshing machines which emerged in Turkey's conditions is quite common in our country. In addition to their threshing function, these machines also convert stalks into a form which animals can easily consume. This function of threshing machines also meets the need of Turkish farmers regarding animal feeding.

The production of threshing machines rapidly increased starting from 1970 and the amount of production reached to 3932 pieces in 2007 (Anonymous, 2009). The drum system of threshing machines is composed of a cylindrical part (drum) which has fingers in the radial direction and which rotates at a certain speed and a concentric concave around this part existing in a fixed position. It is necessary to finely adjust certain factors such as straw feeding, drum speed, drum-concave clearance and crop condition for the quality of the threshing process in the drum-concave threshing system in threshing machines, in other words, for threshing the ears in a manner in which ears are threshed without leaving any grains on and without damaging the grains.

Today, the competitive environment in the production sector makes it necessary particularly for agricultural machinery producers to utilize engineering parameters in the most efficient manner. Concerning production planning, a precise determination of the physical characteristics (dimensions and shape) of the machines which will be produced ensures that the producers design quality machinery in the most economical way and at the same time increases the competitive power of the producers.

The waste of material is regarded as a significant problem in the agricultural machinery sector especially in Konya region, where nearly 80% of the sector employs less than ten workers and production is carried out in a way highly deprived of the utilization of engineering devices.

There are a good number of numerical methods which can solve this type of complex and difficult physical problems with an acceptable approximation. Finite element method has been the most significant and the most commonly used of these analysis methods in the area of engineering in recent years.

The basic idea of the finite element method is to represent continuous functions with local continuous functions (generally polynomials). This means that the value of the quantity to be calculated in an element (e.g. displacement) is found through interpolation by using the values at the nodes of that element. For this reason, the values which are not known and are desired to be calculated in the finite element method are the values at the nodes. A set of equations can be obtained for the values of the quantity area at the nodes by using a variational principle (e.g. the minimum energy principle). The expression of this equation set in matrix form is as follows:

$$[\mathbf{K}] \, . \, [\mathbf{D}] = [\mathbf{R}]$$

Where, [D] is the vector which represents the unknown values of the quantity area at the nodes; [R] is the known load vector and [K] is the known constant matrix. In stress analysis, [K] is known as the rigidity matrix.

In the method known as the finite element method, the problem geometry is divided into a number of elements which are tied to each other at nodal points. The finite element model of the problem enables a piecewise approach to characteristic equations. The solution domain is turned into a mesh of elements. Problems with a complex geometry can easily be modeled as the elements have different geometric shapes. The operation performed by this method is the solution of the structure which is described with differential equations by turning them into algebraic equation sets. The solution of the obtained equation set can rapidly be performed by using computer software. It is possible to see the examples of the use of this method in the field of agricultural machinery, as well as in other fields of engineering.

In a research study, Brown et al. (1989) managed to provide a material saving of 23% in the cultivator frame by using the finite element method.

Topakçı et al. (2008) conducted a stress analysis study on rotary tillage motion gears by using the finite element method. As the result of their study, they evaluated the gears according to the material yield strength; they had been produced and showed that the gears operated without suffering damage.

In his study, Zeytinoğlu (2002) performed the strength analysis of the curved beam element belonging to a single-furrow plough.

In the present study, the three dimensional modeling of the drum system of a threshing machine produced by the Tarım-iş company, which has a prevalent number of production in Konya region, was performed and the motion analysis was carried out by using Cosmosmotion 2009 software and the stress distributions were analyzed by using the finite element method.

MATERIAL AND METHOD

The threshing machine used in the study is a device which is powered from the tractor power take-off, which cleans out the crop grains by removing them from the ears or chaff, turns stalks into straws and conveys grains and straw to separate outlets. Certain technical properties of the modeled threshing machine produced by the Tarım-iş company are presented in Table 1.

The modeling of the drum mechanism of the threshing machine analyzed in the study was performed by using Solidworks 2009 Premium software.

Table 1. Some Technical Characteristics of the Threshing Machine

Characteristic	Unit	Value
General Dimensions		
Total Length	mm	6420
Total Width	mm	3050
Total Height	mm	3700
Drum		
Drum Diameter	mm	760
Drum Shaft Rotation Speed (For Chickpea)	min^{-1}	540

Solidworks 2009 Premium software is a general-purpose computer program which is used for developing, analyzing and dimensioning models for design purposes in machinery production.

The stress analysis of the drum shaft was performed by using the Cosmosmotion program, which is among the analysis modules of Solidworks 2009 Premium and performs the analyses based on the finite element principle.

During the stage of creating the system model, each part was separately modeled and mounted on Solidworks 2009 Premium program (Figure 1). During the mounting process, each part was mounted by being associated with each other for the motion analysis.

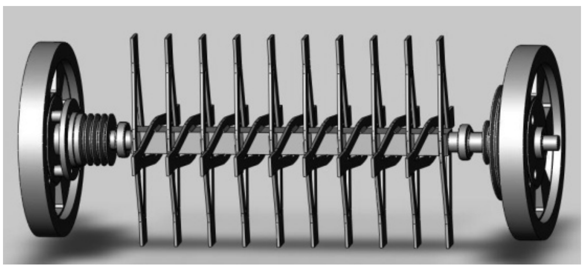

Figure 1. Drum shaft mechanism of threshing machine

The properties of the 80x80 St 37 ingot iron needed for the drum shaft used on the threshing machine were defined in the program.

- Modulus of elasticity : 210000 N/mm^2
- Poisson ratio : 0,28

The definition of the motion analysis is illustrated in Figure 2. The driving torque was given as 35 kpm and applied to the driven pulley (Demir, 1985).

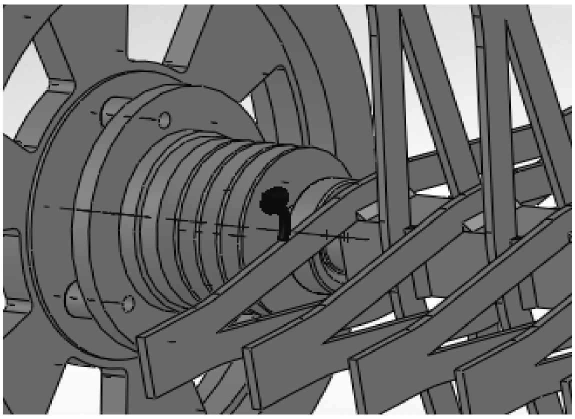

Figure 2. Application of the driving torque to the drum shaft

Maximum drum shaft torque (driving torque) for threshing the chickpea plant was taken as 35 kpm and drum shaft rotation speed was taken as 540 min^{-1} and the power requirement of the threshing machine was calculated by using the following equation (Evcim, 1983):

$$N = \frac{M_d \, . \, n}{716.2} \quad (1)$$

N = Power requirement of the threshing machine (HP)

M_d = Drum shaft torque (kpm)

n = Drum shaft rotation speed (min^{-1})

The power requirement of the sieve shoe and the cleaning unit of the threshing machine was taken as approximately 15% of the total power requirement. (Kadayıfçılar 1991). The power requirement of the aspirator was determined according to this ratio.

The following formula was used for calculating the belt tensile forces (Niemann, 1950).

$$U = 75 \frac{N . C_1}{v} \quad (2)$$

U = Peripheral force (kp)

N = Power (BG)

C_1 = Coefficient for belt and pulley mechanisms (1,1)

v = Peripheral Speed (m/s)

The calculated belt tensile forces were defined in the program by taking the angles into consideration (Figure 3).

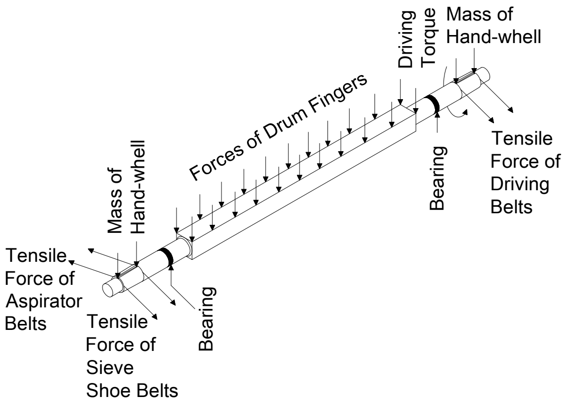

Figure 3. Application of the forces to the drum mechanism

RESULTS AND DISCUSSION

Material characteristics of the system model and the motion analysis depending on time were performed following the stress applications. As the result of the general system analysis, the stress analyses of all the parts were observed and the drum shaft was worked on and analyzed separately (Figure 4).

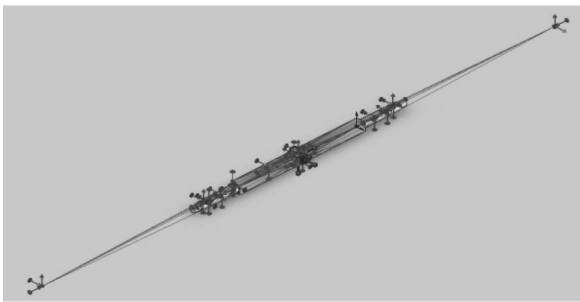

Figure 4. System based forces on the drum shaft

The drum shaft was meshed according to the finite element method (Figure 5).

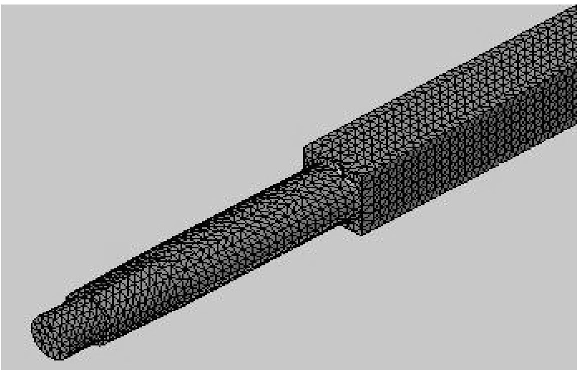

Figure 5. Application of mesh to the drum shaft

It was found that 78156 nodes were formed and these nodes were divided into 51416 elements as the result of the meshing process, the system analysis was performed, and stress and safety factor values were found (Figures 6 and 7).

The maximum stress value obtained was observed as 156.9 MPa on the shaft rabbet.

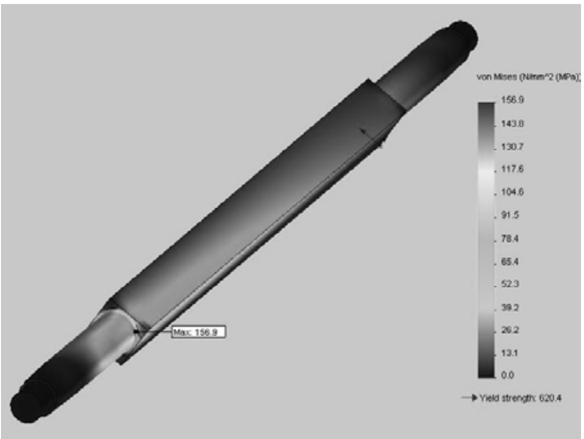

Figure 6. Stress values applied to the drum shaft by the system depending on time

The safety factor of the drum shaft was determined to be 3.96 as minimum (Figure 7). The safety factor in the slotting is given in Figure 8.

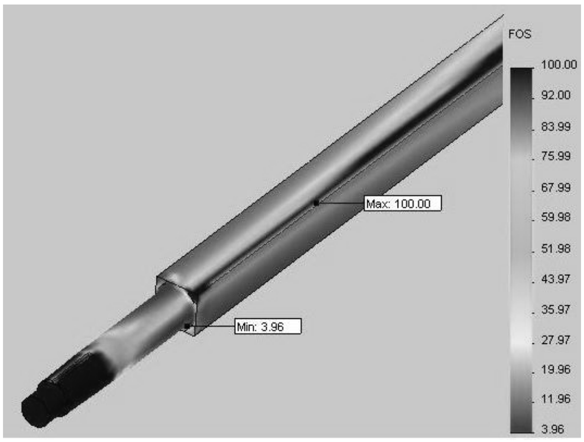

Figure 7. Safety factor of the 80x80 mm drum shaft

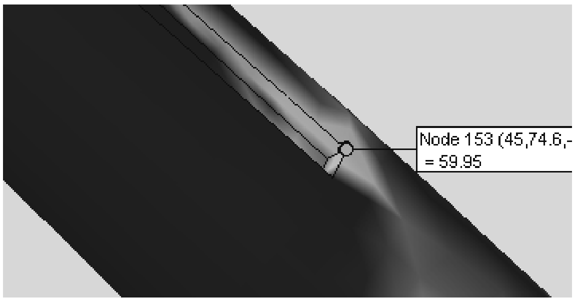

Figure 8. Safety factor in the drum shaft slotting

This study shows that the system is safe, but the 3.96 value found as the result of the analysis, while it has to be between 1,5-2, shows that the cross sectional area of the drum shaft is larger than necessary. Furthermore, the drum shaft made of 70x70 mm ingot iron was evaluated in present conditions through a new analysis and the safety factor was found to be 1.77 on the shaft rabbet where stresses are most intensely observed (Figure 9).

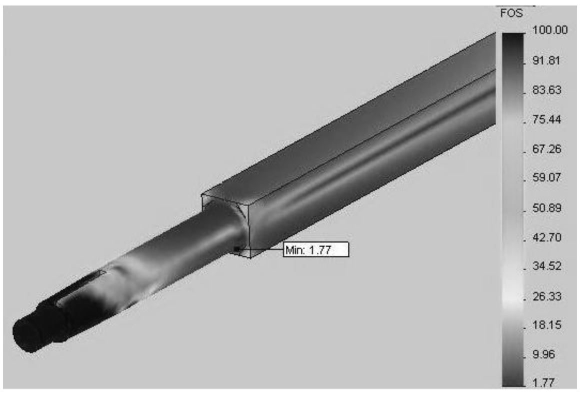

Figure 9. Safety factor of the 70x70 mm drum shaft

This finding also shows that the use of 70x70 ingot iron instead of 80x80 ingot iron provides a material saving of 23,5%.

Similarly, the results show similarity with the results of the theoretical strength calculations performed by Kuşhan (1975) for the domestic type threshing machine produced in Erzurum. It was determined also in the mentioned study that the drum shaft was produced by using material in an amount more than required.

In conclusion, the results that will be obtained by using these types of software in agricultural machinery production will increase the production quality and at the same time provide comprehensive economic support by preventing the use of unnecessary material.

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