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Factor Resistance Comparison of a Long Shaft in 955 and 1055 John Deere Grain Combine

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Abstract**—**Transmission shafts are affected by various forces, for example, during acceleration or sudden breaks, bending during transportation, vertical forces that lead to cuts. One of the main failures in combines is breaking shaft which repairmen refer it. Structural resistance of canal against torque is very important in the beginning of the movement. For analyzing stress, a typical sample from a type of combine was selected, called JD955 combine. Long shaft in this combine was analyzed with finite element method by Ansys13 generic package under static load. Conducted analysis showed that there is a maximum stress in contact surfaces of indentations and also in place of changing diameter. Safety factor value is low in parts of the shaft and this increases the probability of failure at these points. To improve the conditions with the least cost and an approach of product improvement, using alternative alloy is important.

Keywords**—**John Deere, Ansys, Shaft, Stress, Grain Combine harvester, Finite element, Failure.

I. Introduction

POWER transmission shaft is one of the important components in machine's operation to transfer rotational power. A shaft will be preferred when due to existing tensions the following issues should be considered [1]:

- Bending torque is less important than the shear torque due to the small amount of power.
- Shafts and bars are so similar to the long shots, therefore the shear stress will be minimal, but bending and twisting with a lot of impacts will occur.

An important issue for today industrial companies is how to reduce time and cost of developing a new product [2]. Accordingly, they tried to use large capacity of memory in computer, fast processing speed, user-friendly products and attractive shape for being ability to interact with each other. In other words, they have dedicated engineering. This action help to reduce product task and consequently cost, and time of developing product will decrease. Computer aided design, computer aided manufacturing and computer aided engineering are the technologies which are used for this purpose during the production cycle [3]. Power transmission shaft to the wheels (canal) in Combine is one of the main components and it needs a very good design since the duty of this component at any moment is to transfer power to the wheels. The breakdown related to canals and Combine`s canal can put them in the warehouse until they`ll be repaired [12].

Reference [5] by using microscope and chemical analysis showed that with SEM photography break in shaft can be estimated. Fraction in narrow strip can reveal the stress of concentration point which will cause axle shaft to fractures improper welding of hardened materials which have also been in heating processes can increase stress in concentration points and fatigue as a result of improper welding [5].

Reference [6] used experimental and numerical methods, for the stress analysis of a frontal truck axle beam, and the results verified with the finite element method which was graphical stress investigation. Researchers began empirical and numerical analysis on frontal shaft a tractor. According to earned results from finite element method, redesign was done for weight reduction, optimization and easy to construction and then five different models was proposed based on ease of production and weight reduction. Earned results were based on finite element method and analysis was based on different ways which it resulted in obtaining 13 test certificates [7].

Reference [11] showed that design and production steps of some components can be examined and evaluated in terms of efficient use and also they showed that with a slight change in manufacturing alloy we can optimize power transmission system of the Combine JD955 and prevent probable failures [11]. The main aim of this study is analyzing long shaft in 955 JD and 1055JD combine under static loading and also surveying its mechanical strength under loading conditions and achieving to this point which under what circumstances it will be failed.

II. Materials and Method

All vehicles are subjected to static and dynamic loads, while it is difficult to determine the exact and definite location applied loads on components to get the answer the unnecessary parts that usually come along with the components should be ignored. But in this analysis in order to transfer power to the axle shaft and head wheel barrel properly, having bush and putting relevant constraints are needed.

A. Static Load on Long Shaft

Applied static load on shaft in JD955 combine is the torque which its main function is driving the wheels in combine. Fig. 2 shows applied loads on shaft under static mode.

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Fig. 1 3ds Model of axle of JD955 and JD1055

B. Stress Analysis

Generic package ANSYS version 13 is one the analysis software in finite element method for solving this problem. Geometric model was provided for left shaft and created 3D design. For comprehensive analysis of the shaft's components, bushing and its gears was included in 3D design and analysis. To achieve maximum accuracy, SOLID92 element was selected with 10 nodes [8]. Any node in SOLID92 element has 6 degrees of freedom which it can model very well regular networks [9]. The shaft in left wheel is provided by two-dimensional volumetric elements from SOLID82 element and 3D cube from SOLID92. Fig. 3 shows 3D model of long shaft in JD955 combine with considering the elements. Average size of elements used in the analysis is 0.537 mm. So, finite element method of shaft in JD955 combine consists of 68758 elements and 205910 nodes.

Fig. 2 Forces acting on axle of JD955 and JD1055 in static displacements

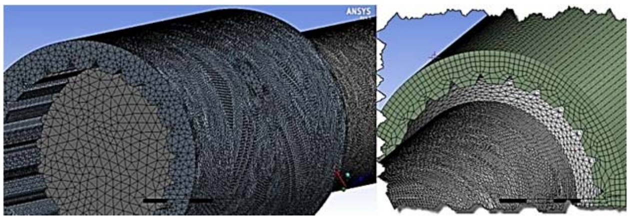

Fig. 3 3ds Meshed Model of axle of JD955 and JD1055 in ansys14 software

C. Shaft to Shaft Connections

In order to stimulate the transfer of power from the gearbox to the wheels by canal, it was necessary to authorize and consider bush connection. For this purpose with the command of shaft to shaft connection in software, page 26, in every direction canal has a connection with bush in 1,717mm tolerance.

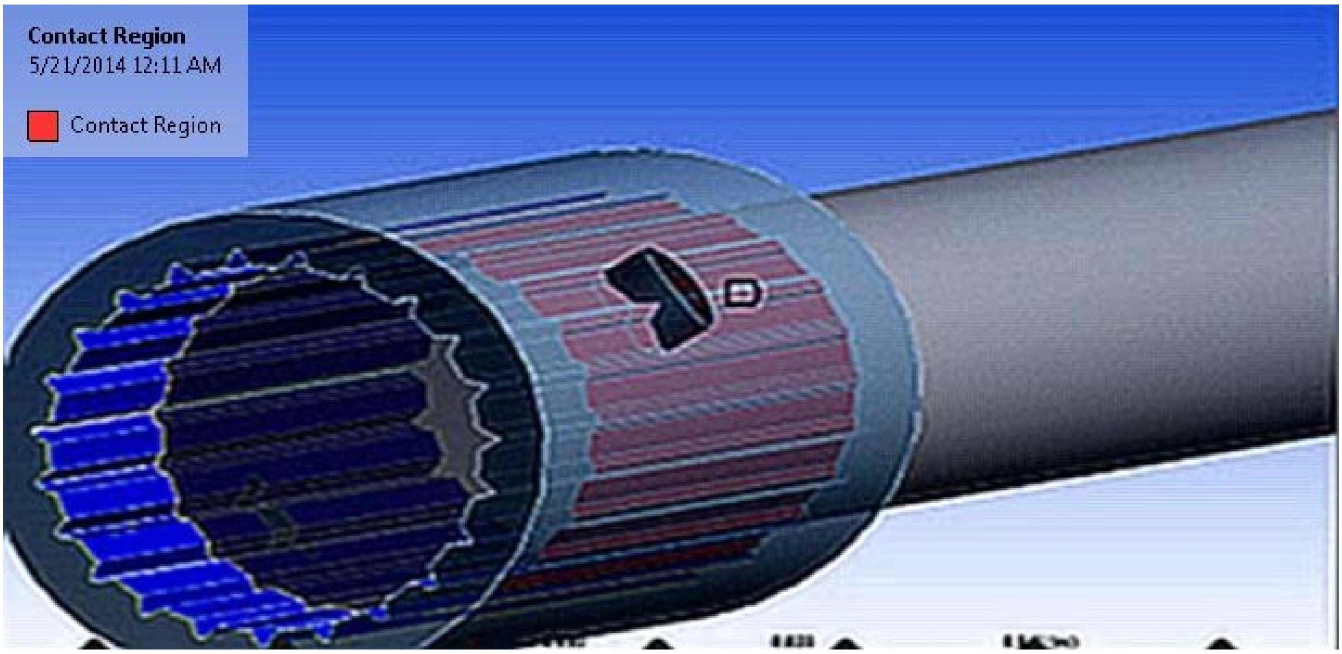

Fig. 4 Connection between Bushes in canal Combines JD955 & JD1055

D. Properties of Materials

Torque transmission axis from the gearbox to the wheel (shaft) usually is built from 16MnCr5 alloy and EN10084:2008 standard. Its mechanical and physical properties are provided in Table I [13].

TABLE I
MATERIAL DATA OF AXLE OF COMBINE HARVESTING

Characteristic	Value	Unit
Young's modulus	E=210000	MPa
Poisson's ratio	υ=0.3	-
Density	ρ=7721³	kg/m
Yield stress	σ_y=590	MPa
Tensile Strength	σ=780	MPa

TABLE II
ROTATIONAL SPEEDS IN DIFFERENT PARTS OF JD955 AND JD1055

Catalog No.	Diameter(mm)	(rpm)	Place
AZ-25702	215	2500	Engine head
H-11497	381	1041-2327	Shaft head of main clutch

TABLE III
REVOLUTION REDUCTION RATIOS IN POWER TRANSITIONS OF JD955 AND JD1055

Gear No. or Place	Speed range (km/h)	Revolution reduction ratio
1	1-2.4	6.27
4	8.5-20	0.78
Differential	-	4.25
Final Drive	-	6.50

E. Needed Power for Combine Motion

Power is calculated from (1) [15]:

$$T = \frac{60000 \times P}{2 \times \pi \times n} \quad (1)$$

where, p= power and n= revolution per minute (rpm)

Revolution per minute is calculated with usage of power transmission system from 4-piece belt in head of engine. Needed power is changed in terms of combine speed, rolling resistance of soil, combine weight and land slope. Maximum power can estimated with following assumptions: combine weight 10 ton, coefficient of rolling resistance against combine wheels 0.2, actual average speed of working combine 2.5 km/h, slip (slipping wheels) 15% and flat land.

According to aforementioned assumptions, first, needed power on the axle of front wheels was calculated from (2) [4]. It equals 16 kW and 2.8 kW in 955JD and 1055JD, respectively.

$$P_{axle} = \frac{W \times g \times f \times V}{3600} \quad (2)$$

where, P_{axle} = Power on front wheel axle (kW), W= Combine mass (kg), g = Acceleration of gravity (9.81 m/s^2), f = rolling resistance , V = Velocity(km/h)

Then, 25% loss in power transmission system and 15% as loss in frictional power are included [14], so:

$$955JD:\ \frac{16}{0.85 \times 0.75} = 25kW$$

$$1055JD:\ \frac{21.8}{0.85 \times 0.75} = 34.2kW$$

Therefore, needed power ratio for moving vehicle to total power in engine equal:

$$955JD:\ \frac{25}{77.5} \times 100 = 32.25\%$$

$$1055JD:\ \frac{34.2}{88} \times 100 = 38.86\%$$

The nominal power of engine is 88 and 77.5 kW in 1055 and JD955 combine, respectively [14]. So needed power for moving vehicle will be 25 kW. Also according to rotational speed in different parts of combine (Table II) and having power, the torque on axis is calculated by (1).

According to Table III and regardless reduction in assistant gear (posi torque), the total ratio of round reduction in gears 1and 4 is 173.4 and 21.6, respectively [14]. So the rotational speed of axle in gears 1 and 4 is 14.41 and 115.74 rpm, respectively.

According to (1), applied torque on shaft for transmitting to the wheels is 16.56 and 58.32 kN.m. Maximum stress range can be calculated with analyzing piece by finite element method and with given values. Where the maximum stress is applied, if piece be fragile, it will break. That is why designers are usually interested to know how much maximum yield strength is. Finally it will break, because after yield strength and the permanent deformation of piece toward failure. This theory is called distortion-energy. It was introduced by Von-Mises about flexible material in 1989 [10]. Von-Mises' stress is calculated by (3):

$$\sigma' = \left[\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_1 - \sigma_3)^2}{2}\right]^{\frac{1}{2}} \quad (3)$$

In (3), σ_1, σ_2 and σ_3 equal applied main stresses on three main axes.

III. RESULTS AND DISCUSSION

Due to the increase in horsepower and higher torque transmission to the wheels, canal Combines has become more fragile toward fractures and this can dramatically reduce the costs associated with the operation and maintenance.

The analysis clearly demonstrated that maximum stress occurred on the contact surface of the dents as well as the location of diameter change which is shown in Fig. 5.

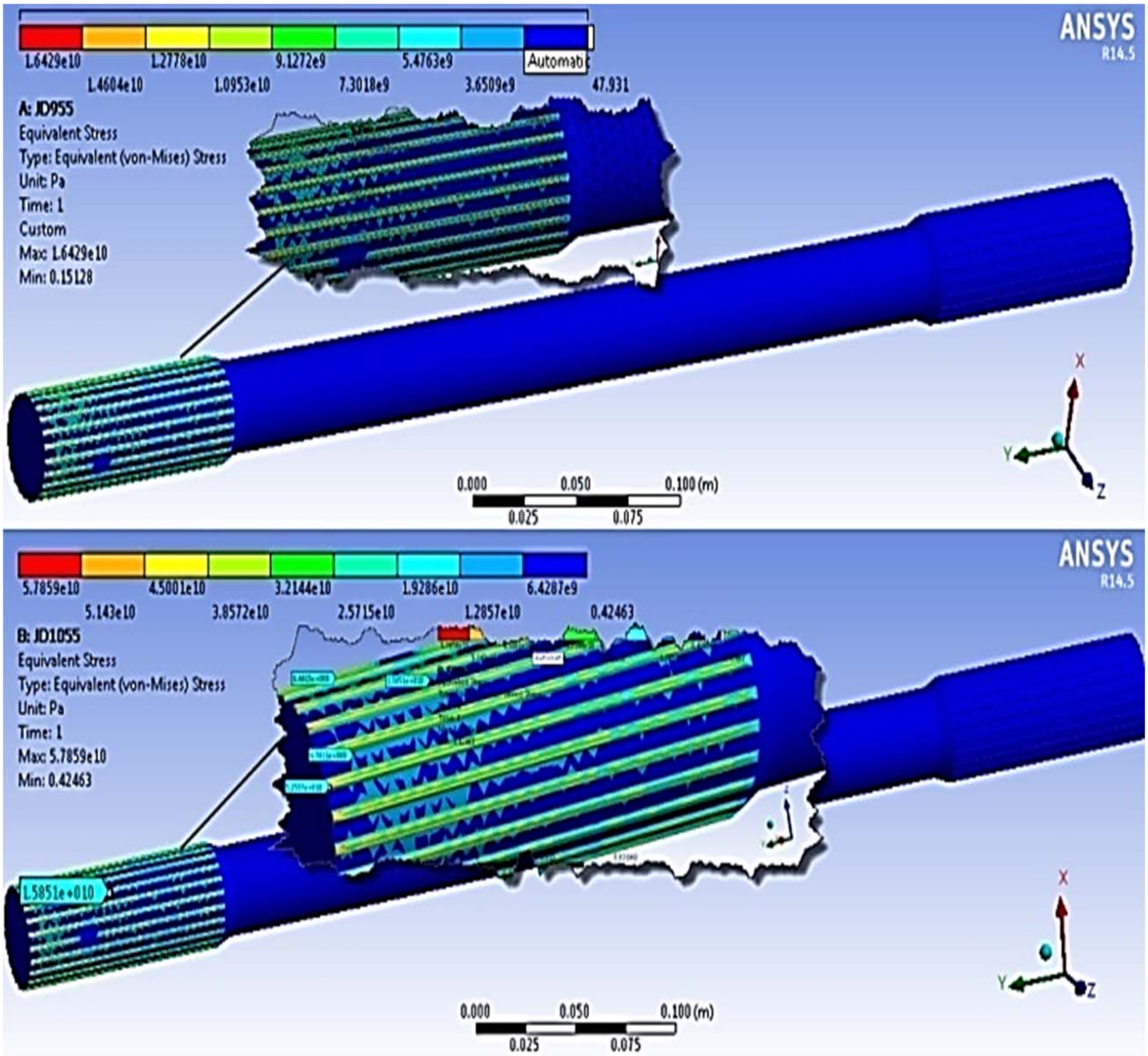

Fig. 5 Stress distribution of Von-Mises in torsion made of long Combine`s canal JD955 & JD1055 under static loading conditions

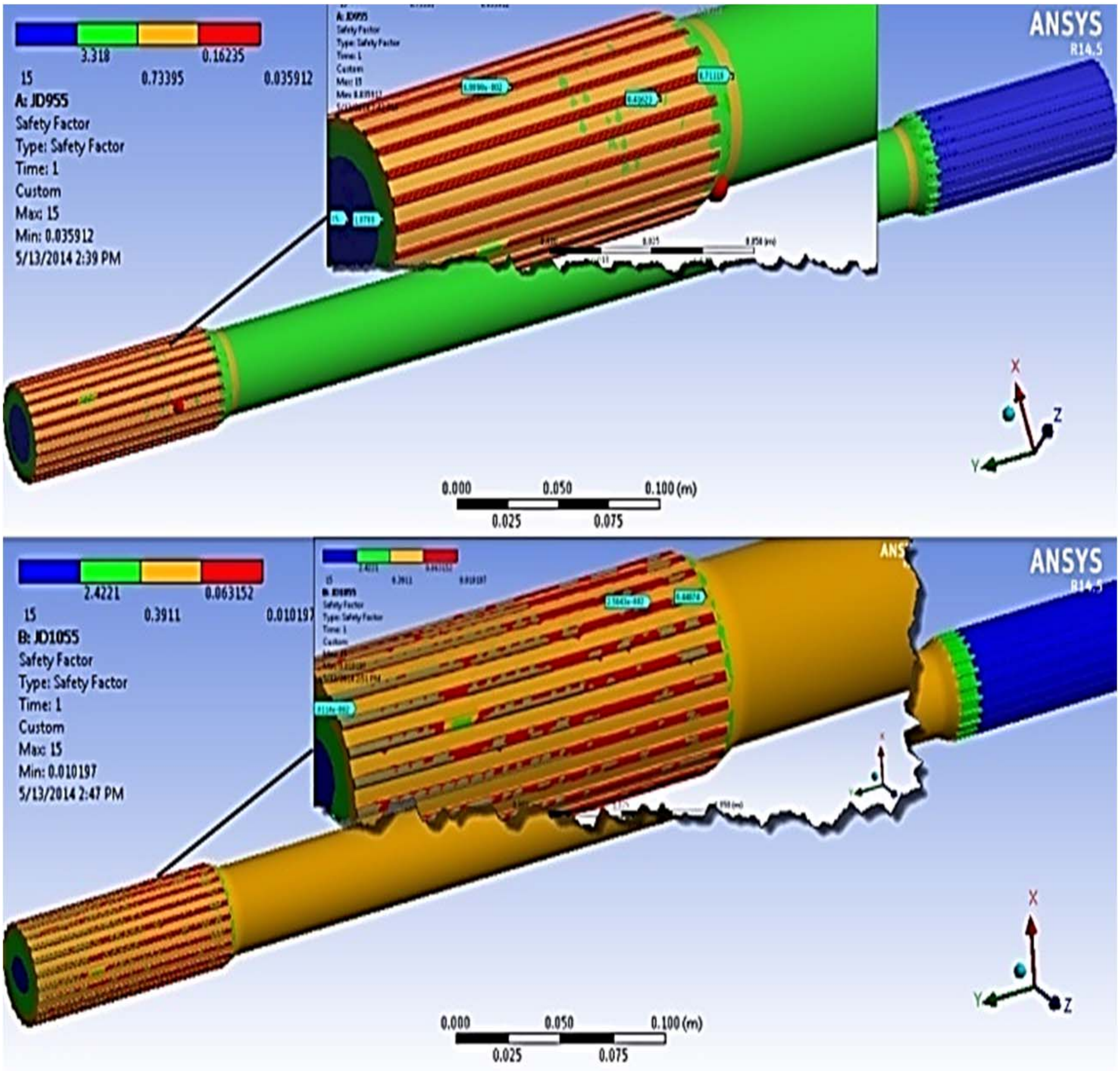

Fig. 6 Factor of safety of axle of JD955 in static loading (zoom section)

According to distortion-energy, when allowable stress equals to yield stress, failure phenomenon will occur. So safety factor can be calculated by (4) via dividing yield limit stress on maximum Von-Mises' stress [16].

$$n_d = \frac{S}{\tau} \tag{4}$$

where, S= strength to fail, τ = allowable stress

Fig. 6 shows conducted analysis by ANSYS13 software for estimating safety factor value. Safety factor in any part of that shaft that is marked in red are critical and it needs to be reformed. The probability of failure in red colored parts is very high in long shaft in JD955 combine.

IV. Conclusion

The results indicate that midsection canal JD1055 will become orange in critical conditions. This can multiply the possibility of fracture. Also the facing surface of Kari has become critical and its confidence has also declined. In analyzing finite element from the axis of JD955 long shaft under static loading specified that safety factor value is low in parts of the shaft which this increases the chance of failure. Obviously, there are the solutions for enhancing safety factor in these areas. Increasing the percentage of some alloys can produce appropriate steel alloy for current work circumstances. Adding some chromium to steel led to the creation of chromium carbides and stiffness of steel. Produced steel is very shapeable in comparison with the steel gains same hardness by adding carbon. Moreover, the existence of chromium in steel results in ordering of grains that it is associated with increased toughness. Chromium increases critical temperature range, for this reason, increasing the percentage of chromium to steel alloy is a low-cost recommendation for manufacturers to eliminate the risk of failure.

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