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The Surveying of Exerted Stresses on Gearbox Gears in MF285 Tractor

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Abstract Simple gears are used as one of the simplest transmitting factors of the power in parallel shafts in gearboxes. Gearbox in MF285 tractor is from sliding gear type and power transmission is done by simple gears. In this study, first 3D model of gearbox in MF285 tractor was designed in SOLIDWORKS 2010 and additional software of Geartrax and then designed model was used for analyzing by finite elements method in ANSYS WORKBNCH 11 software. The values of exerted stresses were calculated by Von-Mises theory in both engaging gears together. Maximum stress values were estimated by ANSYS WORKBENCH 11 and in proportion with those points, a safety factor was obtained. Result showed that increasing numbers of gear, maximum stress value will increase and in edge of gears is more failure than the rest.

Keywords Stress, Gearbox, Gear, MF285 Tractor, ANSYS

1. Introduction

As one of the transmitting factors of power, it has vast applications in industry and engineering field and as one of the simplest transmitting factors of power; gears are used in parallel shaft in gearboxes. Because gearbox in MF285 tractor does not need to change gear when moving, so it is sliding gear type and power transmission is done by simple gears. While spiral gears bear well heavy load, they are sensitive to imbalance axles which make sound [13]. It is possible to modify gear teeth and make some optimal points in teeth [4]. In other words, smoothing and staying clean of contact edges is considered more to determine failure point, surface and bending stresses in analysis [1]. Reference [2] designed 3D model of straw walker crankshaft in grain combine harvesters on Solid Works 2010 software then analyzed by using finite element method on Ansys Work Bench 11 software and obtained the maximum stresses and determined associated safety factor for maximum stresses. 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 in tractor frontal shaft. 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 resulted in obtaining 13 test certificates [7]. Reference [8] used empirical and numerical approaches for design change from casting to coating based welding.

In this study, generated stress values in both of involved gears together was calculated using Von-Mises theory, maximum stress values were estimated by ANSYS WORKBENCH 11 and safety factor was obtained in appropriate with those points.

2. Material and Methods

In this study, first, 3D model of gearbox in MF285 tractor was made in SOLIDWORK 2010 and additional software Geartrax 2010 and then made model was examined by finite elements approach in ANSYS WORKBENCH 11.

2.1. Static Load on Gears in Gearbox

Applied static load on lower gears is the torque which its duty is moving upper gears and finally output torque for assistant gear and keeping continuing power transmission. Figure 1 provides isometric images from gearbox in MF285 in 4 states from gear 1 to gear 4 as other gears and shaft have been removed in any gear and only two desired gears have been showed.

2.2. Stress Analysis

After inserting the gears into ANSYS WORKBENCH 11 and selecting analysis type for solving problem, first the gears are modeled by SOLID 82 2D volumetric elements and SOLID 92 3D [5]. Because of this, SOLID 92 element was used. This element is the most widely used two-dimensional elements. It has four nodes and in the more complex part, it has more accuracy. It can also used in irregular shapes without losing accuracy [9]. Figures 2 to 5 provide images from meshing and table 1 shows information related to conducted meshing.

Figure 1. Isometric image from gearbox in MF285 tractor in 4 states

Table 1. Information related to conducted meshing.

Gear No.	Element No.	Node No.
1	88020	139306
2	102484	160519
3	115530	179370
4	129553	196245

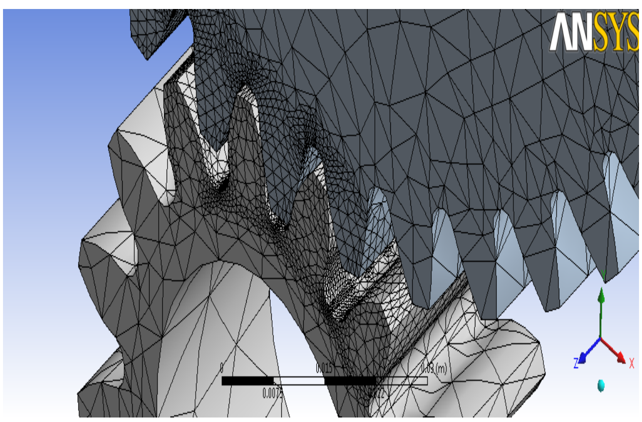

Figure 2. Image from first gear meshing.

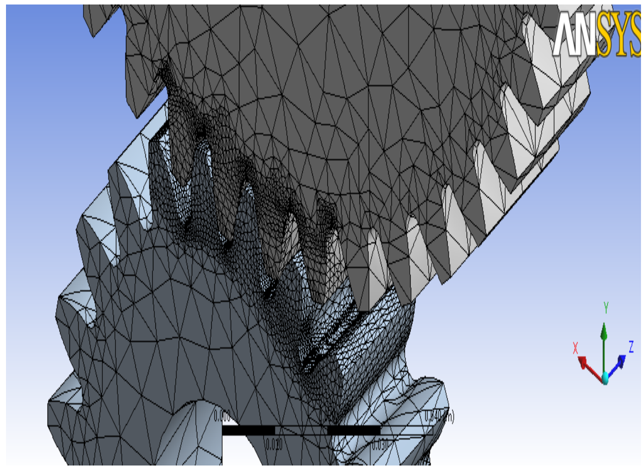

Figure 3. Image from second gear meshing.

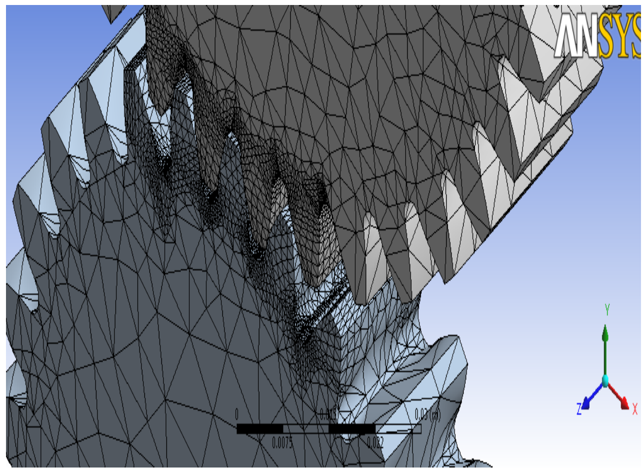

Figure 4. Image from third gear meshing.

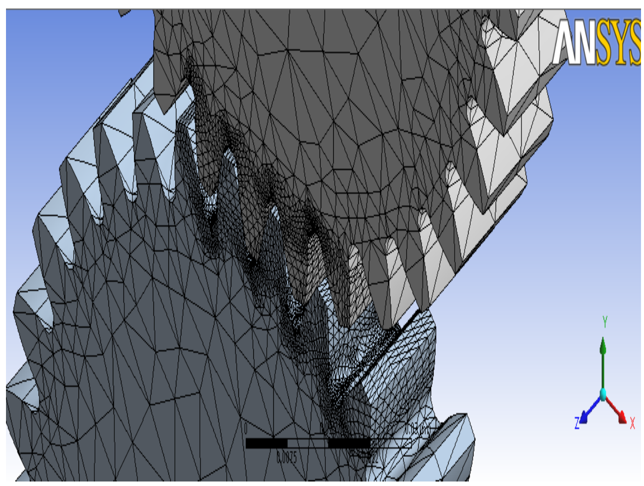

Figure 5. Image from fourth gear meshing.

2.3. Properties of Material

Gearboxes gears in most tractors and also MF285 tractor are produced from 20MnCr5. Table 2 shows its mechanical and physical properties [11].

Table 2. Specification of 20MnCr5 steel.

Specification	Quantity
Density	7700 (Kg M^{-3})
Poisson's ratio	0.3
Tensile strength	1080 (MPa)
0.2 % Proof stress	740 (MPa)
Modulus of elasticity	190 (GPa)
Hardness	217(HB)

2.4. Exerted Torque on Gears

First, nominal output revolution was estimated based on engine maximum power(75 hp), output torque from clutch(358 N.m) and engine rated revolution(2000 rpm) using equation 1 [10].

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

Where, n is nominal revolution in the engine (rpm), T output torque from clutch (N.m) and P output torque from the engine (kW).

After calculating input torque to drive shaft, the analysis of gears was done in ANSYS VERKINCH and with usage of static analysis. It is important to note that in this analysis, other gears have been removed and only desired gear was considered. After meshing, applied torque on drive shaft was calculated using equations 2 and 3 [3].

$$\frac{G_2}{G_1} = \frac{45}{25} \quad (2)$$

$$T_t = T \times \frac{G_2}{G_1} \quad (3)$$

In equation 2, G2 is the numbers of teeth in gear which places on output shaft in clutch. It tramits the power to G1 gear which is on drive shaft in gearbox. In equation 3, T_t is the torque value which is applied on drive shaft. T is output torque value from the engine which is calculated from equation 1. Related information to above calculations is following:

G_1=24، G_2=45، T=358 (N.m) ،T_t=671.25 (N.m)

After calculating applied torque on drive shaft, proper supports should be selected. The cylindrical support which is the most appropriate support was used in this study. Then obtained torque was inserted in small gears that it places in lower parts. Next, critical points was calculated, these points where obtained maximum limit stress in Von- Mises. With analyzing piece with finite elements method and with having given values, the maximum stress range can be estimated. If piece is fragile, the part that have maximum stress, it will break. Because of this, designers are interested to know how much yield strength is. Because after this resistance limit and permanent reformation, piece moves toward failure and finally it will break. This theory is called distortion-energy which is introduced by Von- Mises about flexible material in 1989 [12]. Von- Mises stress is calculated from equation 4:

$$\sigma' = \left[\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_1-\sigma_3)^2}{2}\right]^{\frac{1}{2}} \quad (4)$$

2.5. Determination of Safety Factor

Safety factor was calculated for static analysis by dividing final stress of resistance on maximum applied stress in gears and result were shown in table 3. Suderberg equation for calculation safety factor for fatigue was used which equation 5 shows it [12].

$$\frac{1}{F.S} = \frac{\sigma_{ave}}{\sigma_y} + K\frac{\sigma_r}{\sigma_e} \quad (5)$$

Where, F.S = safety factor in fatigue state, σ_{ave} = average stress, σ_e= tolerance stress σ_r = alternating stress, σ_y = yield point stress and K = concentration factor of stress

Values of σ_{ave} and σ_r have been estimated based on equations 6 and 7 [12].

$$\sigma_r = \frac{\sigma_{max} - \sigma_{min}}{2} \quad (6)$$

$$\sigma_{avg} = \frac{\sigma_{max} + \sigma_{min}}{2} \quad (7)$$

Table 3. Safety factor for gears.

Gear No.	F.S (Max)	F.S (Min)
1	15	0.83807
2	15	0.64688
3	15	0.61414
4	15	0.61996

3. Results and Discussion

Figures 6 to 9 show the values of Von- Mises stress distribution in gears. As can be seen and it already was predictable, stress is maximum at the points shown in figure 10 and it is true practically. There is most failure at the point shown in MF285 tractor.

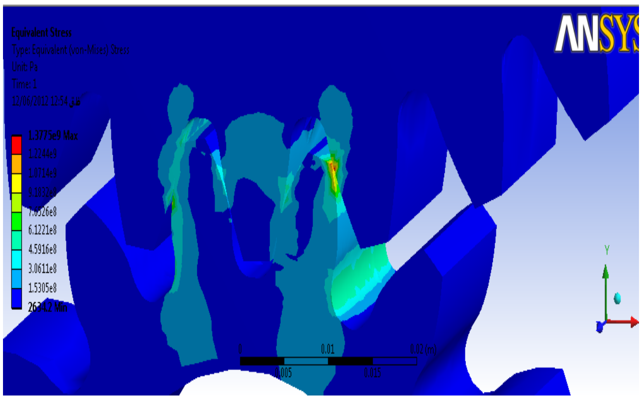

Figure 6. Von-Mises stress distribution at the first gear. Max= 1.3755 *10^9 (Pa), Min = 2634.2 (Pa)

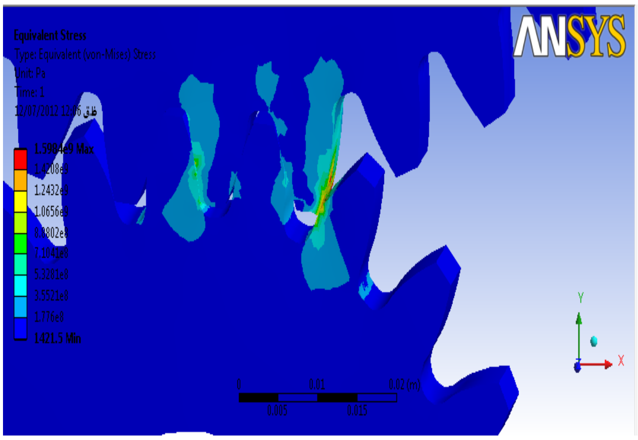

Figure 7. Von-Mises stress distribution at the second gear.Max= 1.5984 *10^9 (Pa), Min = 1421.5 (Pa)

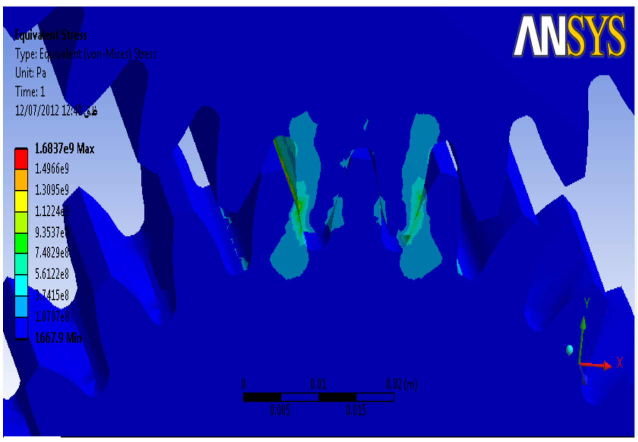

Figure 8. Von-Mises stress distribution at the third gear.Max= 1.6837 *10^9 (Pa), Min = 1667.9 (Pa)

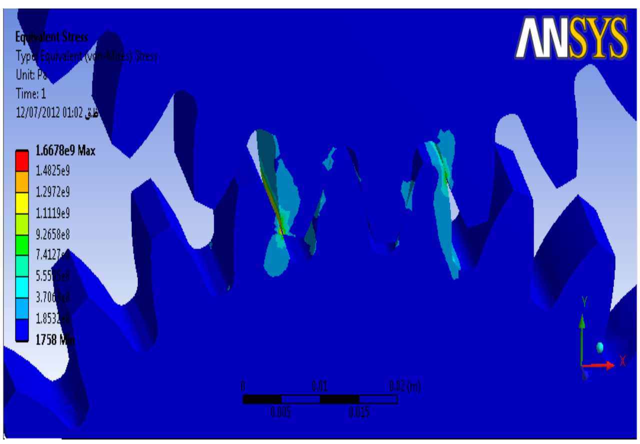

Figure 9. Von-Mises stress distribution at the fourth gear.Max= 1.6678*10^9 (Pa), Min = 1758 (Pa)

According to figure 11, can be seen that with increasing numbers of gear (lighter gear), maximum stress value will increase. It can be explained that such events is acceptable in terms of physical properties of gear including height, thickness, length and gear pitch. Because of increased numbers of gear, thickness, height and pitch will decrease and this results in increasing stress in lighter gears.

Figure 10. Image of failure points in MF285 tractor.

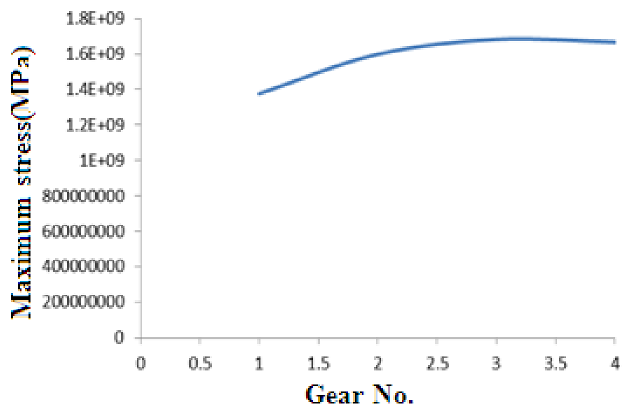

Figure 11. Gear No. and maximum stress relation.

4. Conclusion

Considering conducted analysis and also F.S values, it can be concluded that in edge of these gears is more failure than the rest. This could be due to decreasing the surface of indentations. If it decreases gradually, these failures will occur less. But if bending occurs or decreases suddenly, there failures will occur more and also the maximum stress value will occur on lighter gears. 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 leads to various chromium carbides that are very hard. Produced steel is very shapeable in comparison with the steel has 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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