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Structural Analysis of A Spur Gear Pair of Rotavator Gear Box by using Ansys Software

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Abstract: In this work, we have considered the gear box of agricultural implement Rotavator of a particular make, consisting of an arrangement of transmission shaft, spur and bevel gears. This gear box is facing the problem of heating up, which sometimes lead to early mechanical failure during the operations. So, the main focus of this work is to reduce the stresses of the existing gear box. The limitations in the process of designing are identified and analysed with the help of the software tool used in the machine design applications. We have modified the designs of existing spur gear pair only, by making the changes in their geometric dimensions and performed structural analysis of the whole gear box assembly. The designing of CAD models, structural analysis of the existing and modified gear box is carried out by CREO and ANSYS software. From the results, the designed gear box has shown the considerable reduction of shear stress and von-mises stress as compared to the existing gear box, the contact stresses of the designed gear box are also reduced.

Keywords: Gear box, Spur gear, Bevel gear, CAD, CREO, ANSYS, Shear stress, Von-mises stress & contact stress.

1. INTRODUCTION

Due to the crisis of aging population and the sharp decrease of agricultural labour force, India attaches more and more importance to the development of agricultural machinery. As a key part of agricultural machinery, gear is complex and difficult to model; there is a lot of repeated design work, which seriously affects the research and development cycle of agricultural machinery. The key to the sustainable development of agricultural machinery is to introduce modern design methods such as knowledge engineering, 3D reconstruction modelling and virtual simulation to improve the intelligence and automation of agricultural machinery product design in India.

Knowledge engineering is the basic theory of virtual design. In recent years, many organizations at home and abroad have carried out in-depth research on knowledge engineering, and achieved a series of important results. Agricultural University of India has carried out a lot of work on intelligent agricultural machinery and equipment, and established key model knowledge base such as crawler tractor.

In the process of gearbox virtual design and simulation, there are many gear models and low knowledge reuse rate, which affect the research and development cycle of the whole machine. In order to improve the level of intelligent design of agricultural machinery, this research takes the design of gearbox and spur gear assembly as an example, applies the methods of knowledge engineering and parametric design to the virtual design of gears, develops the virtual design system of gearbox gears based on knowledge, and verifies the feasibility and effectiveness of this method through in study.

2. RELATED WORK

Pradeep Kumar Singh et. al. (2014), studied the Hertz theory of contact stress calculations and used Lewis formula for calculating the bending stress in a pair of gear which plays significant role in the design of gears. Theoretically, the results obtained by Lewis formula and hertz equation are compared with the results of finite element analysis of spur gear. And from the results it was found that, if the contact stress minimization is the primary concern and large power is to be transmitted then spur gears with higher model be preferred.

Krishana Gupta et. al. (2015), studied the equivalent stresses and strains of the symmetric involute spur gears through finite element meshing simulation for finding out the gear pair with least stress when the pressure angles are increased. A comprehensive study on the variation of static stresses with four different pressure angles that might be developed in spur gear teeth, using a commonly used finite element-based software package.

Ahmed Saeed Mohamed et. al. (2018), investigation was conducted in both time and frequency domains. A finite element analysis was performed to determine the variation in stiffness with respect to the angular position for different combinations of crack lengths. A simplified nonlinear lumped parameter model of a one-stage gear box with six degrees of freedom was then developed to simulate the vibration response of faulty external spur gears. Four different multiple-crack scenarios were proposed and studied.

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B. Sivakumar et. al. (2018), analysis was carried out by optimizing the material such as carbon fibre high modulus. The results such as total deformation, equivalent elastic strain and equivalent stress for each material are determined. Compared the optimized materials and the conventional material, carbon fibre high modulus material has the low values of total deformation, stress and strain. The results found that, the carbon fibre high modulus material was suitable for the spur gear manufacturing.

Anirudh Tallam et. al. (2020), studied contact stress of spur gear by application of static analysis. Using Finite element method, a numerical study has been carried out to examine the effects of the material on contact stress behavioural characteristics of a gear. The gears used for the analysis are spur gears and the contact stress analysis is performed between pair of mating gear teeth. The benefit of comparing is to calculate the bending stress analysis using Lewis equation and contact stress with principle of Hertz equation. The results found are satisfactory in comparison with the Hertz equation.

.3. METHODOLOGY

3.1 Problem Definition:

a) We have studied that, when the torque is transmitted in the gear box through the transmission shaft the temperature increases due to the presence of friction between the mating teethes of the gear.

b) Checking through FEA, the temperature of the existing gear box and also of optimized or designed gear box by making the modifications in the surface area, diameter or teeth of the spur gear pair.

c) If the temperature of the designed gear box decreases, then we will compare the results with the existing one.

d) For performing analysis, the Power required is considered and the value of Torque for a given RPM is calculated.

3.2 Objectives :

a) To study existing design and identify the scope in design modifications in the gear box.

b) To study the geometric and operating parameters of the existing gear box and perform analysis.

c) To modify or design the gear box model by changing the geometric parameters of the spur gear pair and study its operating parameters.

d) To perform the structural analysis and undertake the comparative study of the designed gear box with the existing gear box.

3.3 Selection of Appropriate Data

Mechanical Properties of the existing gear box materials are taken from the design data. The CAD Models of existing and modified gear box are created in the CREO Software. These mechanical properties are also used while performing structural and thermal analysis using ANSYS software.

A) Spur Gear & Pinion Shaft

The existing gear material given for our optimization process is 20MnCr5. The table 1 shows the mechanical properties of the material 20MnCr5.

Table 1: Mechanical Properties of 20MnCr5

Sr. No.	Mechanical Properties	Units	Value
1	Ultimate Tensile Strength	MPa	520
2	Young’s Modulus	GPa	210
3	Shear Modulus	GPa	50
4	Poisson’s Ratio	-	0.3
5	Density	Kg/m3	7800
6	Thermal Conductivity	W/m2 K	45.6

B) Bevel Gear

The existing gear material given for our optimization process is EN353. The table 2 shows the mechanical properties of the material EN353.

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Table 2: Mechanical Properties of EN353

Sr. No.	Mechanical Properties	Units	Value
1	Ultimate Tensile Strength	MPa	1030
2	Young's Modulus	GPa	190
3	Shear Modulus	GPa	50
4	Poisson's Ratio	-	0.3
5	Density	Kg/m3	8000
6	Thermal Conductivity	W/m2 K	11.3

C) Gear box Casing

The existing gear box casing material given for our optimization process is SG Iron 450/15. The table 3 shows the mechanical properties of the material SG Iron 450/15.

Table 3: Mechanical Properties of SG Iron 450/15

Sr. No.	Mechanical Properties	Units	Value
1	Young's Modulus	GPa	204
2	Shear Modulus	GPa	79
3	Poisson's Ratio	-	0.29
4	Density	Kg/m3	7300
5	Thermal Conductivity	W/m2 K	36

4. CAD MODEL

To perform the processes of analysis given in 3.2 above, the following steps are undertaken.

The data used for designing the models in CREO software is taken from the drawings provided by the manufacturer. The CAD models of Spur gears Fig. 1 & 2, Bevel gears Fig. 3 & 4 and Gear box assembly with casing Fig. 5 are shown. The internal arrangement of gear box is shown hiding the casing from gear box assembly.

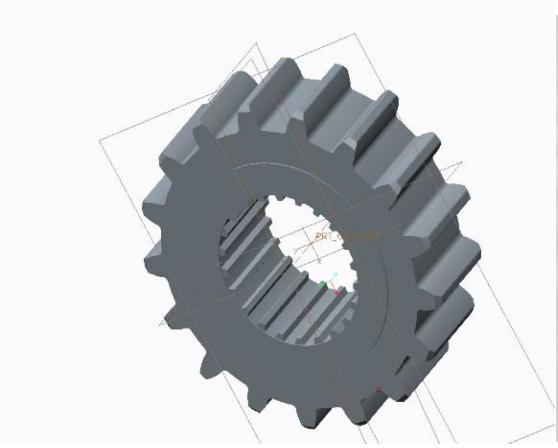


Figure 1: CAD Model of Spur Gear Z=17



Figure 2: CAD Model of Spur Gear Z = 18

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Figure 3: CAD Model of bevel Gear Z-22



Figure 4: CAD Model of bevel Gear Z-14

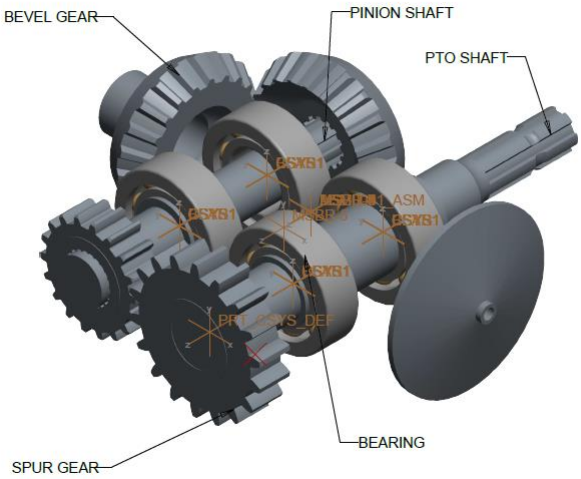


Figure 5: Internal Arrangement of Gear Box

According to the problem statement mentioned, we have mainly focused on the temperature reduction inside the gear box assembly by changing the dimensional parameters of the spur gear pair. Thus, surface area of the gears has been increased by changing the radius of curvature of the gears see Fig. 7 and performed the structural analysis of this optimized gear pairs. From the results of the structural analysis see Fig. 10 & 11, the gear box with optimized spur gear pair has shown the less values of maximum von-mises stresses and shear stresses than the existing gear box. To validate the changes made in the radius of curvature, the contact stress of the gear pair is calculated and compared.

CAD Model of the Spur Gear Before changes made in the Radius of Curvature and the Curve Length.

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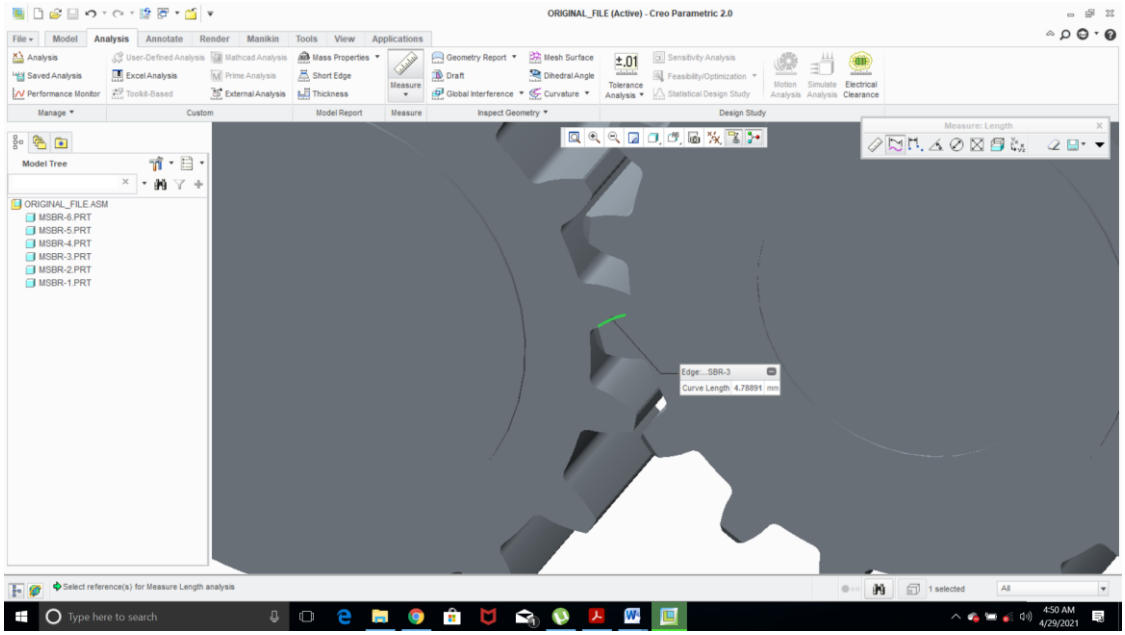


Figure 6: Mentioning Length L = 4.788

The contract stress is given by the formula.

$$\sigma_H = \sqrt{\frac{F_n \times \left(\frac{1}{P_1}+\frac{1}{P_2}\right)}{\pi \times \left[\frac{1-\mu_1^2}{E_1}+\frac{1-\mu_2^2}{E_2}\right] \times L}} \qquad \text{Eq. 1}$$

E1 = Elastic module of pinion

E2 = Elastic module of Gear

Fn = Normal Force acting on gear pair

P1 and P2 = Curvature radius of pinion and gear

L = total carrying length

$P_1 = 2.174\ mm$

$P_2 = 4.075\ mm$

$F_n = 15847.29\ N$

$E_1 = E_2 = 2 * 105\ N/mm^2$

$L = 4.788$

$$\boldsymbol{\sigma_H = \ = 9.077 \times 10^3\ N/mm^2} \qquad \text{Eq. 2}$$

CAD Model of the Spur Gear pair after changes made in the Radius of Curvature and the Curve Length. Length was reduced and radius of curvature was increased which leads to the increase in the surface area.

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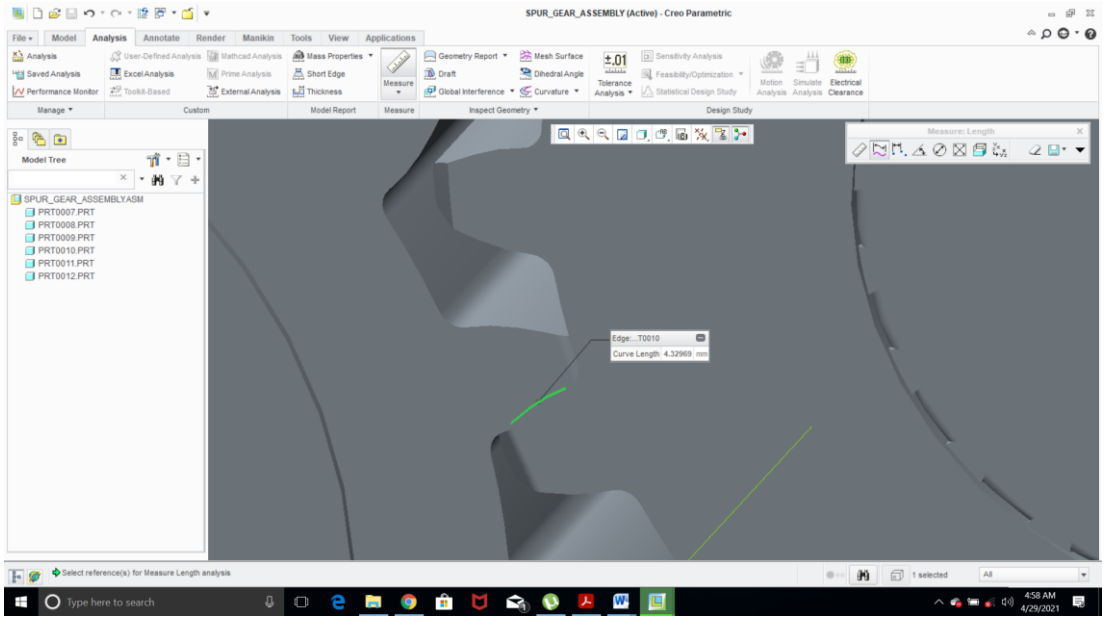


Figure 7: Changes made in Length L = 4.329

$\rho_1 = 3.613$
$\rho_2 = 4.434$
$L = 4.329$
$\boldsymbol{\sigma_H = 8.020 \times 10^3\ N/mm^2}$ … Eq. 3

From the calculations, the contract stresses before modification (eq.2) and after modification (eq.3) are compared. Now, we can say that, the stress is minimum when the radius of curvature is increased, which in turn results in increase of surface area. So, the CAD model Fig. 7 has been taken for the structural analysis performed in ANSYS.

6. RESULTS AND DISCUSSIONS

After performing the structural analysis over the optimized gear box following results were recorded through ANSYS software. The structural analysis was performed by using the boundary conditions of the gear box. The rotational twisting moment on the transmission shaft was in all six degrees of freedom, only rotational degree was allowed while the other five were locked. Finally, the results of the structural analysis are recorded and compared with the results of the analysis before modifications.

Structural Analysis Results

In Structural Analysis of the gear box, we have focused mainly on the results of the Shear and Von-mises stresses as all over the assembly, only rotational twisting moment over the shaft is considered throughout the complete analysis. The boundary conditions considered, while performing the structural analysis were rotational twisting movement over the shaft, torque for the motor power of 41 KWatts and speed of 540 rpm.

A) Results of the Existing Gear box Assembly

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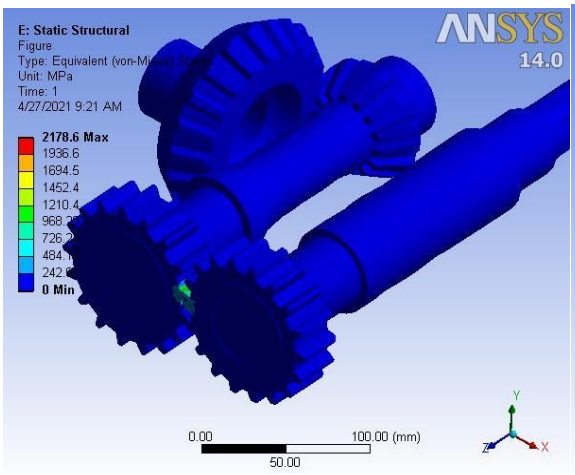


Figure 8: Von Mises Stress

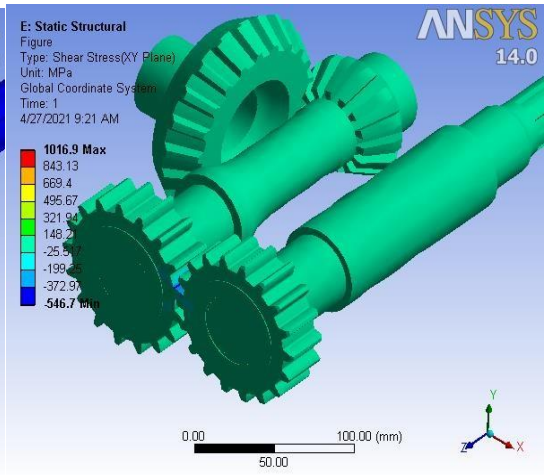


Figure 9: Shear Stress

B) Results of the gear box assembly when the Spur Gear pair was optimized and the bevel gear pair dimensions kept constant

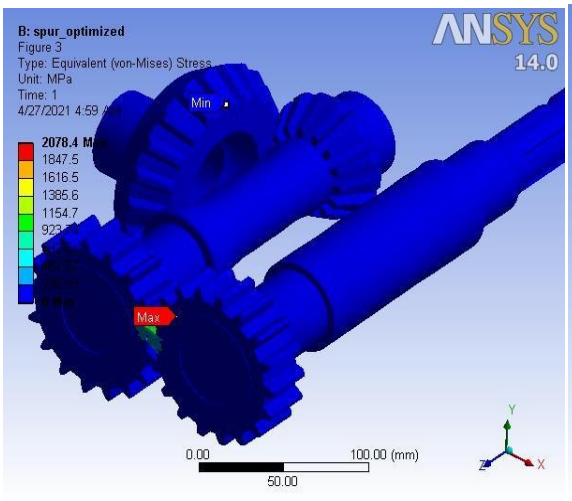


Figure10: Von Mises Stress

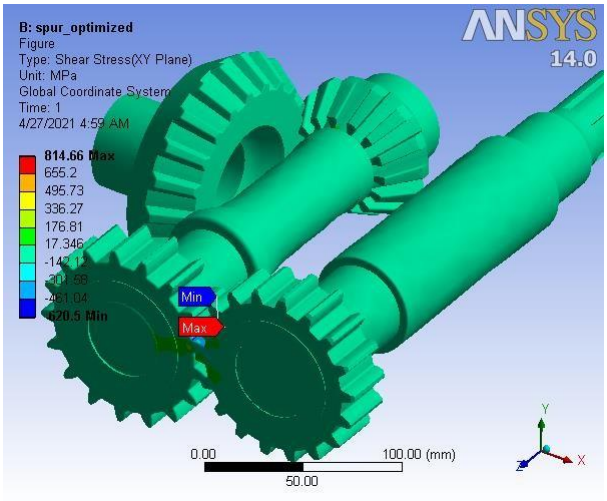


Figure11: Shear Stress

Table 4: Structural Analysis Results

Sr. No.	Existing Gear box Assembly		Optimized Gear box Assembly	
	Von Mises Stress (MPa)	Shear Stress, (MPa)	Von Mises Stress (MPa)	Shear Stress, (MPa)
1	242	-372	232	-461
2	484	-199	463	-301
3	726	-25	694	-143
4	968	148	923	17
5	1210	321	1154	176
6	1452	495	1385	336
7	1694	669	1616	496
8	1936	843	1847	656
9	2178	1016	2078	815

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7. CONCLUSION

From the results of structural analysis, we can conclude that, when the surface area of the spur gear pair is increased by changing the radius of curvature, the shear stresses as well as von-mises stresses are decreased. The maximum values of von-mises stresses and shear stresses before modifications of the gear box are 2178 MPa and 1016 MPa respectively. While the maximum values of von-mises stresses and shear stresses after modifications are 2078 MPa and 815 MPa respectively.

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