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Analysis of Axle Tube and Brake Housing of 65 Hp Tractor

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Abstract – Tractors are designed to withstand different types of load, under adverse conditions. Housings which form the basic structure of tractor, experiences internal loads due to transmission line and external loads due to agricultural implements. In a 2-wheel drive tractor, traction force required for pulling agricultural implements is delivered by the massive rear wheels mounted on rear axle shaft. Axle shafts experiences fluctuating loads of combined bending and torsion, which is transferred to the assembly of axle tube and brake housing. The point of failure in the assembly and in transmission line components such as bearings, shafts and gear have been discussed. The present work provides the analysis of axle tube and brake housing of 65 HP tractor and concludes that the same design of axle tube and brake housing can be used that are currently in use for 50 HP tractor.

Index Terms – Axle tube, Brake housing, Static structure analysis, Total deformation.

1. INTRODUCTION

Tractor is a 4-wheeled vehicle used specially for drawing agricultural implements. It can produce high drag force by delivering high torque at slow speed. Tractor delivers maximum torque in 1st gear whereas gives maximum overall efficiency in top gear [1]. Tractors with low horsepower engines are popular in India. In last decade, rapid growth in the demand of high HP tractor are observed, which can perform variety of agricultural tasks like digging, mowing, ploughing, etc. with high efficiency and less fuel consumption [2]. Traction force required for pulling heavy agricultural implement is delivered by tractors massive rear wheels, which are mounted on rear axle shaft. Rear axle shafts are subjected to different degrees of stress concentration and fluctuating loads of torsion and bending [3]. Rear axle shaft is supported by axle shaft bearings and housed inside the assembly of axle tube and brake housing. Rear axle shaft applies internal loads on the assembly causing deformation in various components which are specified individually by KISSsoft [4]. External load on the assembly is applied by the reaction force due to self-weight of the tractor. There is probability of failure of assembly under the internal and external loads. Hence, it is crucial to analyze the axle tube and brake housing assembly before putting it into production.

2. RELATED WORK

Research has been carried out in the field of tractor design by various researchers. Axle tube and brake housings are subjected to various loads in static and dynamic conditions. Research carried out in respective field are briefly discussed below:

- Rear axle and axle tube
- Evaluation of transmission line
- Finite Element Analysis of the assembly

2.1 Rear axle and axle tube.

Forces applied on the rear axle were studied [5,6,7]. These forces are transferred to the axle tube which houses the rear axle of the tractor. Solutions to improve the design of the axle tube has been discussed.

2.2 Evaluation of Transmission line

Loads applied by the transmission line elements like bearings, shafts, gears, epicyclic planetary final reduction etc. on the brake housing and axle tube were studied [8,9,10].

2.3 Finite Element Analysis of the assembly

Finite element analysis simulates real world conditions which are faced by the assembly of axle tube and brake housing. Deflection of assembly and stresses induced under loading conditions were studied [11,12,13]. Solutions to improve the design has been elaborated.

The assembly of axle tube and brake housing of tractor is subjected to different static and dynamic forces in different scenarios. Stresses induced during operating condition are observed and failure points are identified by performing finite element analysis.

3. PROPOSED MODELLING

A systematic methodology was adopted to accomplish the objectives of research work [14]. The methodology adopted for the research has been shown in flow chart in figure 1.

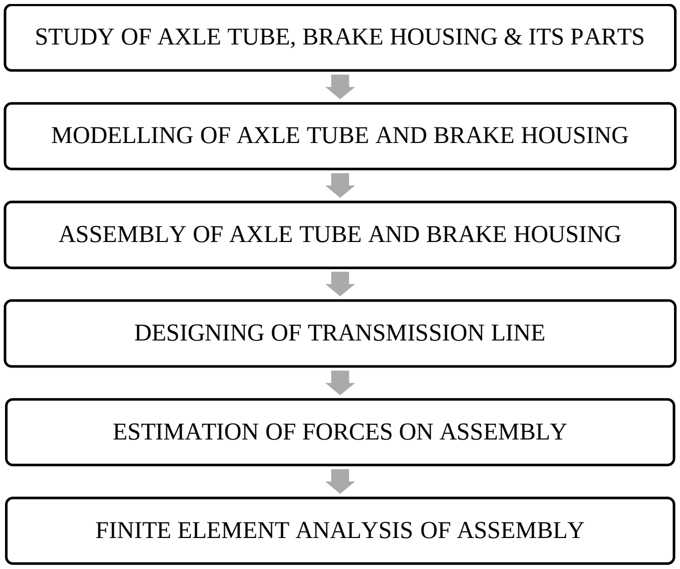

FIG. 1: METHODOLOGY

3.1 Study of axle tube and brake housing and its parts

Axle tube and brake housing are used to house the transmission line and isolating it from the outside environment. The components of the transmission line are:

(i) Axle tube

The main component of the axle tube is axle. An axle is a central shaft for a rotating wheel. The prime purpose of axle shaft is to transmit driving torque to the rear wheel of the tractor. Axle is immersed in oil for efficient heat dissipation and lubrication of the rotating parts. Hence maintaining a proper oil level is crucial task, which is accomplished by oil seal kit consisting of oil seals, washers and gasket for establishing proper seal between brake housing and axle tube. Drain plug is provided below the trumpet of the axle tube for allowing the removal of oil from the axle tube. Axle tube provides fixed support for the bearings, which helps in rotation of axle inside the axle tube and also protect the bearing from external elements.

(ii) Brake housing

Brakes are the mechanical device that inhibits motion by absorbing energy from a moving system. Its prime purpose is to stop the tractor under safe distance in minimum time. With increment in power of tractors, the capability of these machines also increases. For stopping them, new brakes are employed known as oil immersed brakes. In which instead of one-disc, multiple discs are employed, which are kept isolated from the environment. Because environment (field, mud, etc.) in which tractor perform, its functions affects braking performance. In normal brakes, heat is dissipated to surroundings. But in case of oil immersed brakes, heat is carried away by oil which also lubricates the system. Hence in order to protect brakes from environment and for sealing the braking setup, brake housing is employed. It is made by casting process and cast iron is most common material used for casting.

3.2 Modelling of axle tube and brake housing

Axle tube and brake housings that are performing its duty in 50 HP tractor are modelled using SOLIDWORKS 2017 software. There are two brake housings in tractor, one on the left side of differential housing and another on the right side of the differential housing. The part modeler was employed for the task of modelling the axle tube and brake housing. Figure 2 is showing the CAD model of axle tube. Figure 3 is showing the CAD model of left brake housing.

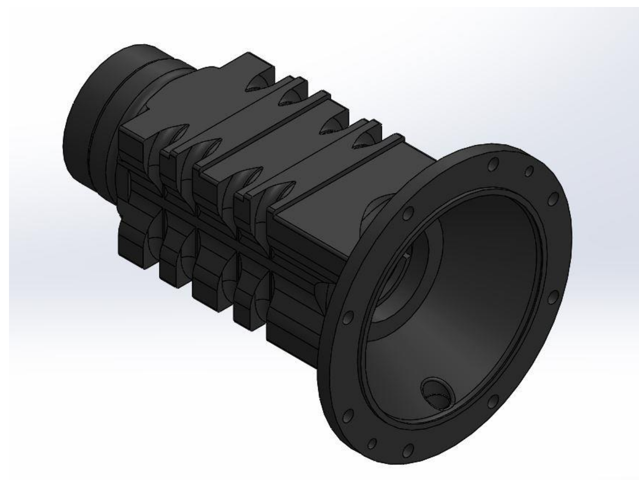

FIG. 2: AXLE TUBE

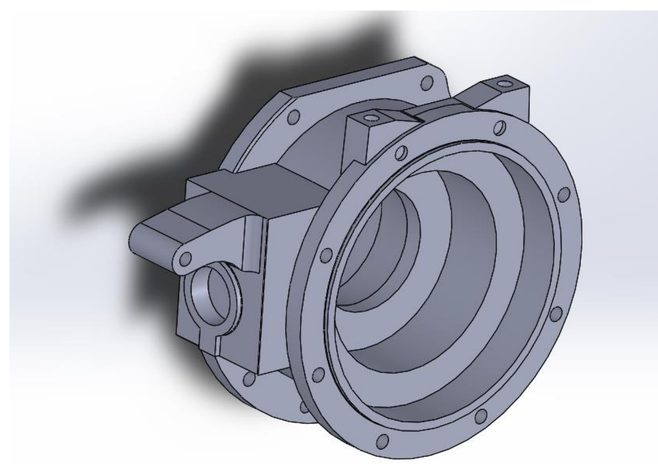

FIG. 3: LEFT BRAKE HOUSING

3.3 Assembly of axle tube and brake housing

The assembly modeler was employed for the systematic assembly of CAD models of the axle tube and brake housing by constraining their motion in respect to each other. Figure 4 shows the assembly of the axle tube and brake housing, which is fully constraint in the assembly modeler of the SOLIDWORKS 2017.

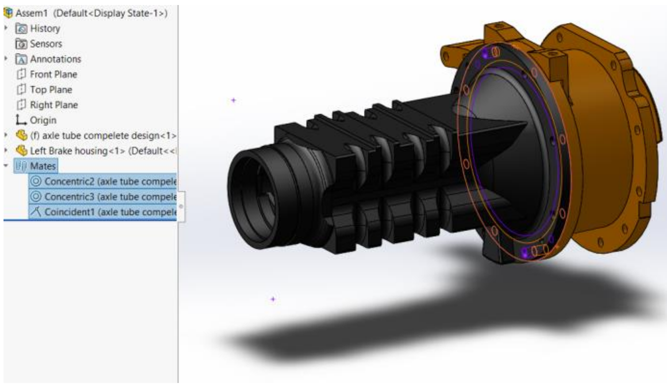

FIG. 4: ASSEMBLY OF AXLE TUBE AND BRAKE HOUSING

3.4 Designing of the transmission line

Tractors generate its maximum torque in first gear which can be transmitted on one wheel by applying differential lock. This comes handy while working in agricultural field, when operator wants to take a sharp turn by locking a rear wheel of tractor. This is the ideal condition for testing the transmission system of tractor for maximum torque output on rear wheel. This condition was simulated with the help of KISSsoft 2017 and KISSsys 2017 software.

Transmission line was modelled and loads applied by the components on the assembly was calculated. 2D view of the transmission line is shown below in figure 5. In which bearings are shown in yellow color and coupling is shown in blue color.

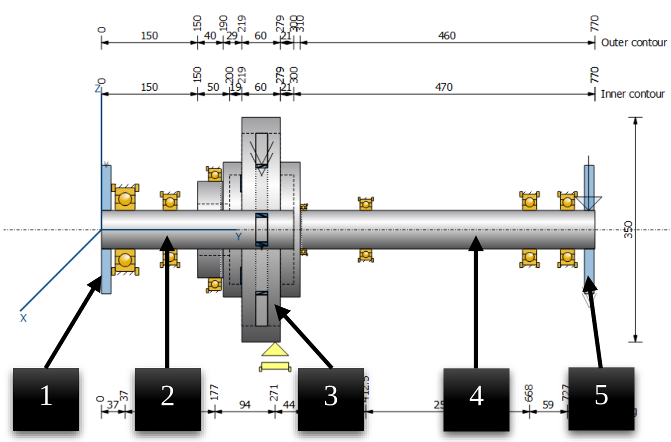

Fig. 5 Labelling Description

1 – Input coupling (representing the crown gear in differential housing)

2 – Sun shaft

3 – Epicyclic planetary final reduction

4 – Carrier shaft

5 – Output coupling (representing the rear wheel)

FIG. 5: 2D VIEW OF THE TRANSMISSION LINE

Figure 6 shows 3D model of transmission line in KISSsys.

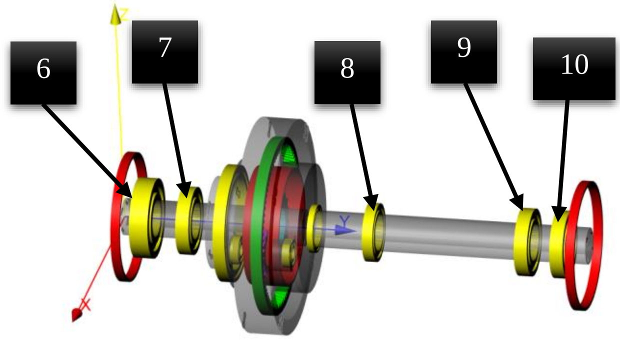

Fig. 6 Labelling description

6 – bearing no. 1 on sun shaft

7 – bearing no. 2 on sun shaft

8 – bearing no. 3 on carrier shaft

9 – bearing no. 4 on carrier shaft

10 – bearing no. 5 on carrier shaft

FIG. 6: 3D MODEL OF TRANSMISSION LINE

Speed and torque values were assigned to the input coupling on sun shaft. Figure 7 is showing the input constraint dialog box after selecting the input coupling on sun shaft.

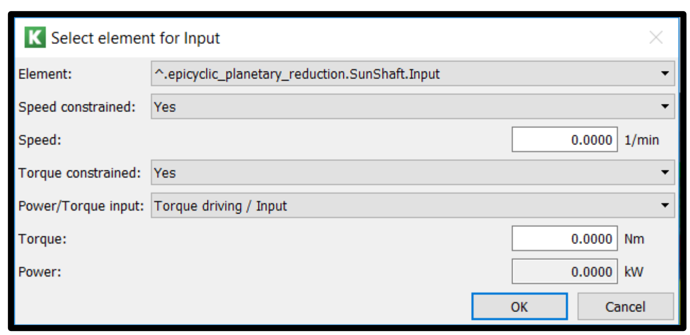

FIG. 7: INPUT CONSTRAINT DIALOG BOX

Speed on the input coupling is 30 rpm which is same in both the case of 50 HP and 65 HP tractor. But torque is different for both the cases. In case of 50 HP tractor, input torque is 11559 Nm and in case of 65 HP, tractor input torque is 15063 Nm. The value of input torque is equal to the torque available on crown gear in tractor rear differential housing operating on 1st gear.

3.5 Estimation of forces on assembly

Assembly experiences two type of force during operation, one is the reaction force due to self-weight and the other is the internal load applied by transmission line.

Reaction forces of the tractor are calculated through analytical formulas for 50 HP and 65 HP tractors. The weight and the wheelbase of the existing tractor was known. For finding the weight and wheelbase of the 65 HP tractor a benchmark study was conducted in which tractor present in the market with 65 HP engines were compared and an average increment in weight and wheelbase were used for the calculation. Table 1 and table 2 is showing the comparison between 50 HP and 65 HP tractor, on the basis of total weight and wheelbase respectively.

TABLE 1 COMPARISON OF TOTAL WEIGHT OF DIFFERENT TRACTORS

S. No.	BRAND (Company)	Weight of 50 HP Tractor (in kg)	Weight of 65 HP Tractor (in kg)	Increment (in kg)
1	Indo Farm	2035	2390	355
2	John Deere	1870	2290	420
3	New Holland	2055	2405	350
4	Swaraj	2170	2330	160
Average Increment				321.25

TABLE 2 COMPARISON OF WHEELBASE OF DIFFERENT TRACTORS

S. No.	BRAND (Company)	Wheelbase of 50 HP Tractor (in mm)	Wheelbase of 65 HP Tractor (in mm)	Increment (in mm)
1	Indo farm	3610	3810	200
2	John Deere	3430	3535	105
3	New Holland	3045	3279	234
4	Swaraj	3420	3590	170
Average Increment				177.25

50 HP and 65 HP tractors of leading tractor manufacturing companies in India are compared on the basis of total weight and wheelbase. Increment of 321.25 kg in weight was observed in 65 HP tractor as compared to 50 HP tractor. Similarly, increment of 177.25 mm in wheelbase was observed in 65 HP tractor as compared to 50 HP tractor.

Figure 8 is showing schematic diagram of a tractor standing on plane surface.

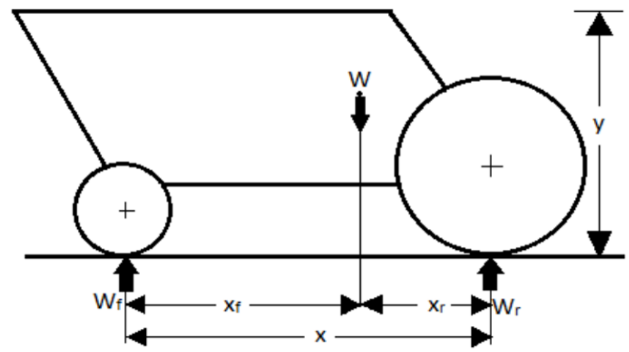

FIG. 8: LINE DIAGRAM OF TRACTOR ON PLANE SURFACE

According to benchmark study of 65 HP tractors, increment in weight was considered to be 300 kg and increment in wheelbase was considered to be 177 mm. Hence, weight of the 65 HP tractor was taken as 2500 kg and wheelbase of the 65 HP tractor was taken as 2107 mm.

Variables:

Wheelbase of 65 HP tractor (X) = 2107 mm

Weight of 65 HP tractor (W) = 2500 kg

W_f - Reaction force on front wheels.

W_r - Reaction force on rear wheels.

X_r - The distance of center of gravity from the center of rear wheels.

X_f - The distance of center of gravity from the center of rear wheels.

Calculations

Total weight of the tractor is considered to be distributed in between front and rear axle, hence from the figure 8:

$W = W_f + W_r$

$X = X_f + X_r$

Dividing according to proportionality law,

$$\frac{X_r}{X} = \frac{W_f}{W}$$

X_r is approximate to 30% of X

$W_f = 0.3 * W = 0.3 * 2500 = 750$ kg

$W_r = W – W_f = 2500 - 750 = 1750$ kg

Reaction forces on front axle = 750 * 9.81 = 7357.5 N

On each end of front axle = 7357.5 / 2 = 3678.75 N

Reaction forces on rear axle tube = 1750 * 9.81 = 17167.5 N

On each end of Rear axle tube = 17167.5 / 2 = 8583.75 N

Internal loads applied by the transmission line on the assembly were calculated by the KISSsys module of KISSsoft software. All the resultant forces like bearing force, and force on brake housing due to ring gear were obtained in KISSsys report after analysis of transmission line. Bearing pressure was calculated by dividing the resultant forces with corresponding areas and compiled in tabular form as shown below. Table 3 shows the comparison of forces exerted by 50 HP and 65 HP tractor transmission line. The bearings and fixed ring gear of epicyclic planetary final reduction of the transmission line is shown in figure 6. Where bearings are shown in yellow color and ring gear is shown in green color.

TABLE 3 COMPARISON OF FORCES EXERTED BY 50 HP AND 65 HP TRACTOR TRANSMISSION LINE

S. No.	Parameters	Bearing pressure on 50 HP Tractor (in MPa)	Bearing pressure on 65 HP Tractor (in MPa)
1	Force on Fixed Support by Ring Gear	9.635	9.635
2	Bearing no. 1 on sun shaft	7.75	7.75
3	Bearing no. 2 on sun shaft	33.04	33.04
4	Bearing no. 3 on carrier shaft	0.0561	0.0715
5	Bearing no. 4 on carrier shaft	0.148	0.166
6	Bearing no. 5 on carrier shaft	0.9035	1.031

These bearing forces were applied on the assembly during analysis to find the deformation and stresses on the assembly.

3.6 Finite Element Analysis of assembly

ANSYS 15.0 was used for FEA of the assembly. The assembly was first subjected to the loads under 50 HP loading condition which was used as benchmark value. Loads of 65 HP tractors were applied on the assembly and point of failure were identified on the assembly.

Analyzing the assembly for upgraded 65 HP tractor loads

Reaction forces applied in case of 65 HP tractor was 8583.75 N. Force on fixed support by ring gear of epicyclic planetary final reduction was 9.635 MPa which was same as that of 50 HP tractor case. Bearing loads by bearing no. 1 was 7.75 MPa, by bearing no. 2 was 33.04 MPa and bearing loads by last three bearings are 0.0715 MPa, 0.166 MPa and 1.031 MPa which were slightly higher than bearing loads of 50 HP tractor. The total deformation was calculated to be 0.2086 mm by ANSYS under loads. Figure 9 is showing total deformation of assembly under 65 HP tractor loads.

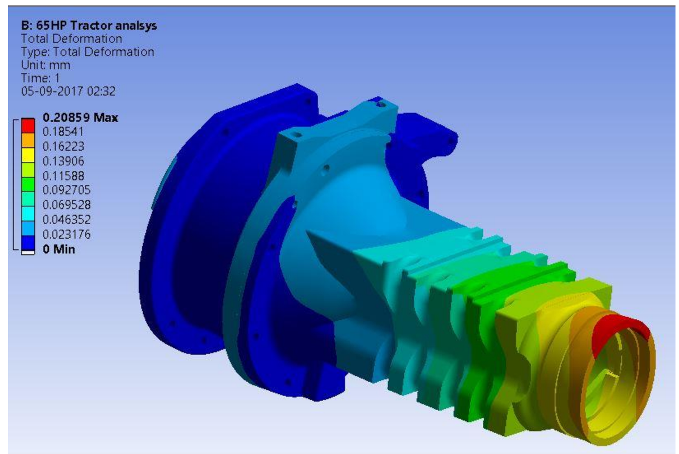

FIG. 9: TOTAL DEFORMATION OF ASSEMBLY UNDER LOADS FOR 65 HP TRACTOR

Directional deformation under the loads of 65 HP tractor was found to be 0.2006 mm as shown in figure. 10.

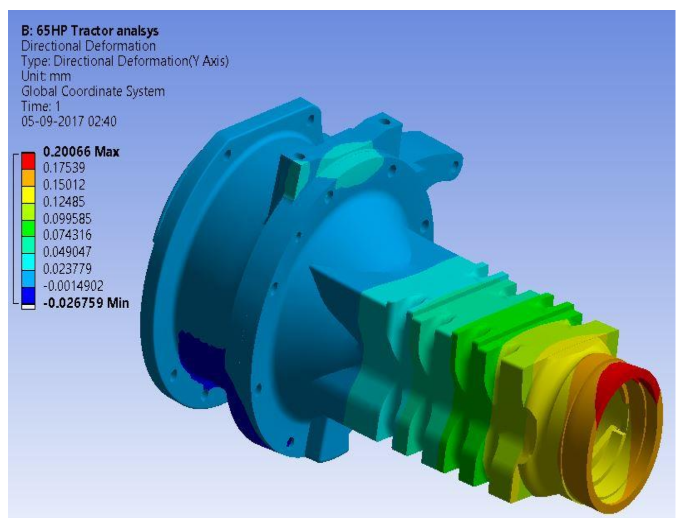

FIG. 10: DIRECTIONAL DEFORMATION OF ASSEMBLY UNDER LOADS FOR 65 HP TRACTOR

Equivalent stresses developed in the assembly under the loads of 65 HP tractor was 151.34 MPa as shown in figure. 11.

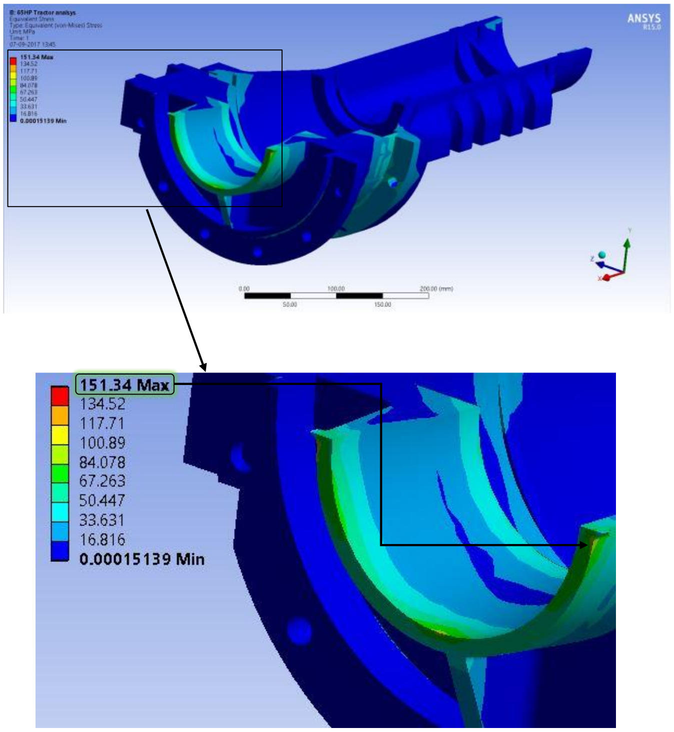

FIG. 11: EQUIVALENT STRESS UNDER LOADS FOR 65 HP TRACTOR

Similarly, the analysis for benchmarking of 50 HP tractor was performed, where values of total deformation was 0.1831 mm, directional deformation was 0.1753 mm and equivalent stress was 142.85 MPa.

4. RESULTS AND DISCUSSION

The results of the analysis performed under 50 HP and 65 HP tractor loading condition has been shown and discussed in detail. The percentage increment in values of total deformation, directional deformation and equivalent stress when comparing 50 HP tractor with 65 HP tractor are shown in tabular form in table 4.

TABLE 4 DEFORMATION AND STRESSES WHILE UPGRADING FROM 50 HP TO 65 HP TRACTOR

S. No.	Parameter in ANSYS	50 HP Tractor	65 HP Tractor	Increment [in %]
1	Total Deformation [in mm]	0.1831	0.2086	13.92
2	Directional Deformation (in y-axis) [in mm]	0.1753	0.2006	14.43
3	Equivalent Stress [in MPa]	142.85	151.34	5.94

After analyzing the assembly of axle tube and brake housing under loads for 50 HP and 65 HP tractors; increment of 13.92 % was observed in total deformation of assembly in 65 HP tractor as compared to 50 HP tractor. Directional deformation in y-axis was 14.43 % more in case of 65 HP tractor when compared to the 50 HP tractor. Equivalent stress value was 5.94 % higher in 65 HP tractor as compared to 50 HP tractor.

The value of factor of safety was calculated by dividing the ultimate strength of the FG250 to the calculated equivalent stress. Factor of safety for existing 50 HP tractor was found to be 1.75 and factor of safety for upgraded 65 HP tractor was 1.65.

5. CONCLUSIONS

The existing design of 50 HP tractor assembly was analyzed for the loads of 65 HP tractor. The case of existing 50 HP tractor was used as standard for comparing with the upgraded 65 HP tractor. Deformation and stresses are observed on assembly in both the cases of 50 HP and 65 HP tractor. Factor of safety was calculated on the bases of these induced stress values. When these values were compared with each other following conclusion are drawn:

- Total deformation in 65 HP tractor assembly was 0.2086 mm which was under safe limit.
- Equivalent stresses in 65 HP tractor assembly was 151.34 MPa, which was less than the maximum limit of 250 MPa of the FG250 used of casting of axle tube and brake housings.
- Factor of safety of 65 HP tractor assembly was 1.65 which is above 1, hence the assembly is safe under the loading conditions.
- Factor of safety was 0.06 % less in the upgraded 65 HP tractor as compared to the existing 50 HP tractor.

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