Analysis of Rear Differential Housing of 65 Hp Tractor

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Abstract – Tractors play a vital role in aiding a farmer during farming. It is the most important tool for a farmer in present scenario and helps in production of crops. The study here represents an approach for upgrading the rear differential housing of 50 HP tractor to 65 HP tractor. The various loads which acts on rear differential housing depends on the rated power of the engine thus when the rated power increases the loads on housing also increases. The study comprises of two stages. Firstly, modelling of the part was done and in second stage the model was analysed for the loading of 65 HP tractor. Finite element analysis has been carried out to find out the failure points in the housing. A comparative analysis has been carried out between the benchmarked differential housing and upgraded housing It was found during present research that the upgraded 50 HP tractor successfully endured all the torques and forces to which a 65 HP tractor can be subjected under all running conditions and hence no changes were required in the existing model of rear differential housing of 50 HP tractor.

Index Terms – Tractors, Rear differential housing, Finite element analysis.

1. INTRODUCTION

Agricultural tractors are used as a power source for various field operations such as planting, harvesting, tillage, transportation, through driving axles, and PTO devices [1]. The tractor consist of assembly of different parts like clutch housing, gear box housing, rear differential housing, brake housing and axle tube housing. The rear differential housing provides the outer cover for differential and other parts.

The rear differential housing connected with gearbox housing at front and two axle tubes connected sidewise and fluid tight container hold the lubricant that baths those components. Thus an effective design of rear differential housing greatly increases the strength and life of the tractor. Transmission of a tractor is a component that takes about 25-30% of its total cost. Therefore, a proper design of transmission is important [2].

It is necessary to select the optimal gear to get better performance and durability of a tractor during field operation. Rear differential housing consists of special attachment provided to achieve 8 forward speeds of gearbox into 16 forward speed and 4 reverse into 8 reverse speed. By using this arrangement, numerous variation in torque and speeds for different work are carried out by the tractor. The second major component is differential used to divert power at 90^0. In case of tractor, the differential is used to reduce speed by a greater extent i.e. 5.125:1. Another major component is PTO Shaft, which is used to take power from the tractor engine to run different implements like grass cutter, thrasher etc. All forces transmitted by PTO directly comes on rear differential housing. Last major component is three point hitches, which is provided to attach attachments of various configuration.

2. RELATED WORK

An extensive study has been carried out in the field of agriculture tractor by various researcher. Rear differential housing is subjected to various internal loads and draft forces produced by the implements used. Research work carried out in the field of housing analysis by various investigators are given below:

- Rear differential housing
- Evaluation of transmission line
- Finite element analysis of housing

2.1 Rear differential housing

Draft Forces on rear differential housing were studied [3, 4, 5]. These external forces are transferred to differential housing of the tractor.

2.2 Evaluation of transmission line

Load applied on housing by transmission elements of rear differential housing like shafts, bearing, gears, ring and pinion etc. have been studied [6, 7, 8, 9].

2.3 Finite element analysis of housing

Finite element analysis simulates real world conditions which are faced by the rear differential housing. Deflection housing and stresses induced under different loading conditions were studied [10, 11, 12]. The rear differential housing of tractor is subjected to different static and dynamic forces in different scenarios. In the present work, stresses induced during

operating condition are observed and failure points are identified by performing finite element analysis.

3. PROPOSED MODELLING

A systematic approach was utilized for conducting the study [13]. The methodology adopted is given in the flow chart in figure 1.

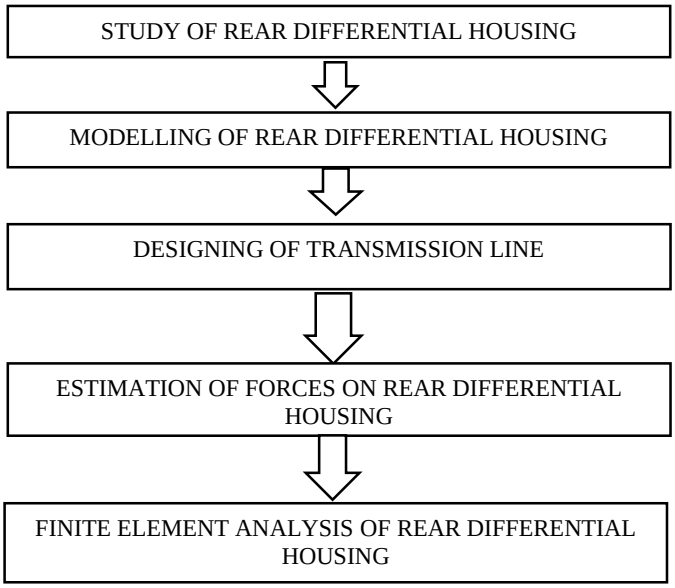

FIGURE 1: METHODOLOGY

3.1 Study of rear differential housing of exiting tractor

The rear differential housing provides the outer cover for differential and other parts. Its main function is to protect the differential and other parts. A study of rear differential housing and its parts are executed and associated information is collected. All components of rear differential housing were considered for the study to get the appropriate idea about the rear differential housing. Following parts of rear differential housing have been studied and modelled:

(i) Special attachment of gear pair for speed reduction

The torque required at the wheel of tractor is not directly achieved by the gearbox used because of its very high value, specifically for ploughing work. Therefore, a special attachment of gears is attached at the end of gearbox to reduce the speed. The special attachment (high and low) is provided in differential housing to achieve 24 speeds. This attachment divides the 8 forward speeds of gearbox into 16 forward speed and 4 reverse speed into 8 reverse speed.

(ii) Ring and pinion gears

Differential consist of a set of gear i.e. ring, pinion, and spider gears. Differential is mainly used to divert power at 90^0 and provide stability when tractor take turn. The differential gearing allows the outer drive wheel to rotate faster than the inner drive wheel during a turn. Average of the rotational speed of the two driving wheel equals the input rotational speed of the drive shaft. An increase in the speed of one wheel is balanced by a decrease in the speed of the other. Specifically in case of tractor, the differential is also used to reduce the speed by a greater extent i.e. 5.125:1 ratio.

(iii) Power take-off system

Power take-off shaft is used to take power from the tractor engine, to run different implements and separate machine like rotavator, thrasher, grass cutter and other implements. The differential housing provides support to the end of PTO shaft. All forces transmitted by PTO directly comes on rear differential housing. The PTO of the tractor under consideration has two speeds 540 and 1000 rpm.

(iv) Three-point hitch

A three point hitch system is provided to attach attachments at various configuration. The drawbar system is virtually the exclusive method of attaching implements (other than direct attachment to the tractor) before Harry Ferguson developed the three-point hitch.

3.2 Modeling of rear differential housing

The rear differential housing connected with gearbox housing at front and two axle tubes connected sidewise. After studying the housing, it was modeled with the help of "SOLIDWORKS ® PREMIUM 2017 x 64" software.

With the help of part module of solid works, three dimensional model of rear differential housing has been modeled. Figure 2 represents the model of rear differential housing developed in solid works environment.

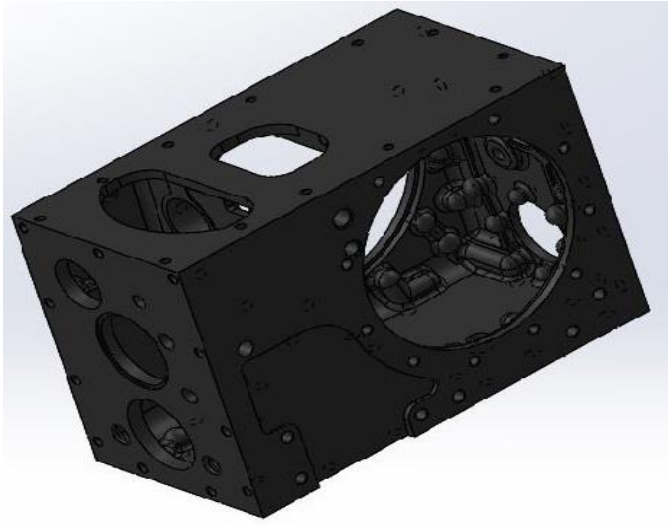

FIGURE 2: REAR DIFFERENTIAL HOUSING

3.3 Designing of the transmission line

The gear box output become input for rear differential housing. A special arrangement of gears is attached before rear differential called low and high gear, which is used for torque variation. At low gear, power directly goes on differential and at high gear, torque is increased. Radial pressure of bearing has been determined with the help of KISSsys 2017. Three-dimensional view of the transmission line is shown in figure 3.

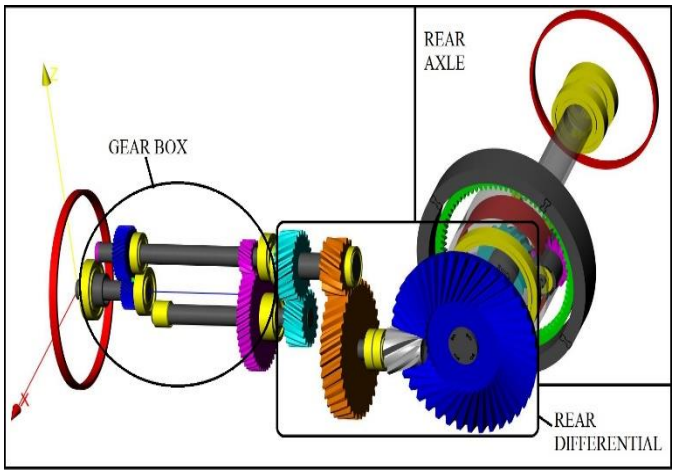

FIGURE 3: THREE DIMENSIONAL VIEW OF TRANSMISSION LINE OF TRACTOR

Figure 4 shows the three dimensional view of transmission line under rear differential housing and also indicate the bearing which affect the housing by yellow colour.

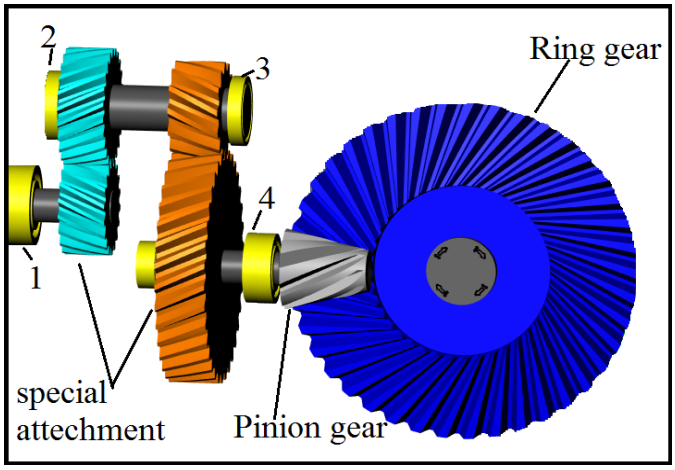

Figure 4 Labelling description

1- bearing no. 1 on input shaft for differential

2-bearing no. 2 on counter shaft

3-bearing no.3 on counter shaft

4-bearing no.4 on input shaft to ring gear

FIGURE 4: THREE DIMENSIONAL VIEW OF TRANSMISSION LINE OF REAR DIFFERENTIAL

Transmission line is operated for high torque for both cases 50 HP and 65 HP tractors. The speed available on input coupling is 530 rpm for both cases and maximum torque is available on the gear box in 1st gear is 675 Nm and 891.96 Nm for 50 HP and 65 HP tractors respectively.

KISSsys calculates the loads and moment coming onto the gears, bearing and shafts during application of 65 HP input to the transmission line.

These bearing pressure are applied on the housing during analysis to find equivalent stresses and total deformation on the rear differential housing.

3.4 Estimation of forces on housing

Rear differential housing was subjected to many loads like internal loads and external loads due to which it may fails. At the design stage, it ensures that the housing has sufficient strength to avoid failure either due to fracture or general yielding. The housing was tested for internal loading due to bearing thrust.

The force required to pull a tillage tool through the soil is called its draft. The draft force is located at the point where the tool is attached to the power unit, called hitch. Draft force is required to pull many seeding implements and minor tillage tools being operated at shallow depth.

Optimum Draft Force Calculation for 65 HP tractor

Rated engine speed of tractor = 2200 rpm

Rated engine power of tractor = 65 HP

Rated maximum torque of tractor = 242 Nm

Considering available power = 80 % of rated power

= 0.8 x 65 = 52 HP.

Considering axle power = transmission efficiency x available power

= 0.9 x 52 = 46.8 HP.

Considering drawbar power = tractive efficiency x axle power

= 0.6 x 46.8 = 28.08 HP

= 20939.252 W

Assuming operating speed of 8 km/hr

Optimum pull was given by drawbar power / operating speed

Optimum pull = 20939.252 / [(8 x 1000) / 3600]

= 9422.66 N = 9.43 kN

The forces as obtained from calculations for 50 HP (benchmark) and 65 HP tractors are 7.24 kN and 9.43 kN respectively. It is clear from the data that maximum draft force produced is in case of mould board plough. For analysis purpose, a pulling force of 17000 N was applied on rear differential housing. Table 1 shows the draft forces of various implements.

TABLE 1 Draft forces of various implements

Sr. No.	Implement	Draft forces (N)
1.	Disc Harrow	1800
2.	Cultivator	3490
3.	Chisel Plough	15410
4.	Mould Board Plough	16300

FG 250 cast iron is used for manufacturing of housing, as standard material and the optimum wall thickness for this material is 8 -12 mm.

Bearing pressure was calculated by dividing the resultant forces with corresponding areas and compiled in tabular form shown below. Table 2 shows the comparison of forces exerted by 50 HP and 65 HP tractor transmission line.

TABLE 2: BEARING PRESSURE AND FORCES EXERTED BY 50 HP AND 65 HP TRACTOR TRANSMISSION LINE

Bearing No.	Forces (kN) on Tractor		Area (mm^2)	Bearing Pressure (MPa) on tractor	
	50 HP	65 HP		50 HP	65 HP
1.	18.92	24.362	3817.04	4.96	6.38
2.	14.83	19.095	3116.40	4.76	6.12
3.	24.74	31.846	14152.87	1.75	2.22
4.	340.08	459.503	6622.48	51.35	69.38

3.4 Finite Element Analysis of Housing

The finite element analysis provides engineering information (stress, deformation, etc.) about a structure. The aim of analysis was to observe the stress and deformation induced in rear housing under 50 HP loading condition which was used as benchmark value, then same housing was subjected to loads of 65 HP tractor and the point of failure were determined.

Analyzing the housing for 65 HP tractor loads bearing pressure For analysing the upgraded 65 HP tractor design with internal loads on different points where pressure is applied on bearing numbers 1, 2, 3, and 4 were 6.38 MPa, 6.12 MPa, 2.22 MPa and 69.38 MPa respectively. The pulling force of 17 kN acting on the link point was considered. Front face of housing was made fixed for the analysis. The material of the housing was taken as FG 250. The directional deformation was calculated as 0.1092 mm using ANSYS under loads for 65 HP. Figure 5 shows the direction deformation of rear differential housing under 65 HP tractor loads.

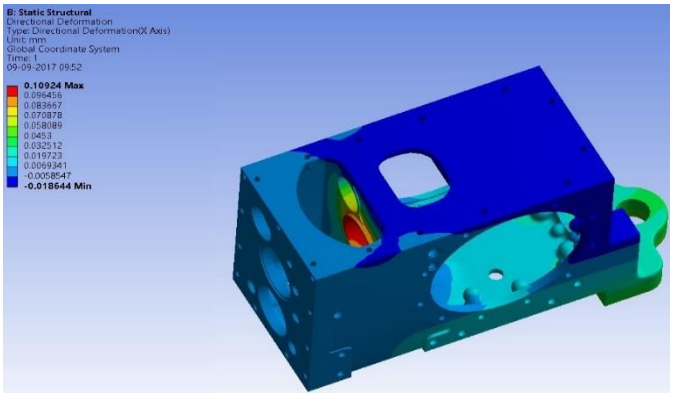

FIGURE 5: DIRECTIONAL DEFORMATION OF HOUSING UNDER LOADS FOR 65 HP TRACTOR

Total deformation was found to be 0.2548 mm under loads of 65 HP tractor as shown in figure 6.

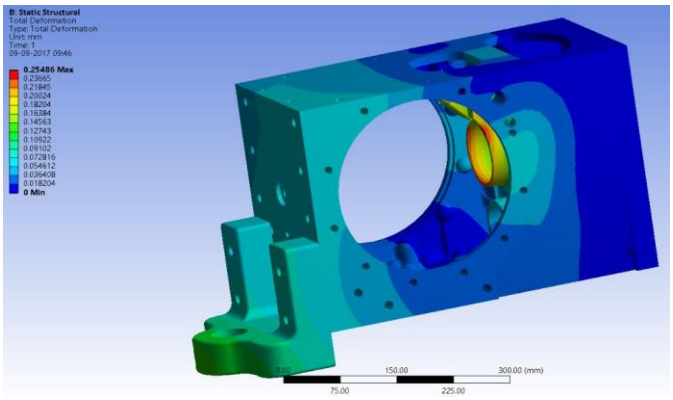

FIGURE 6: TOTAL DEFORMATION OF HOUSING FOR 65 HP TRACTOR

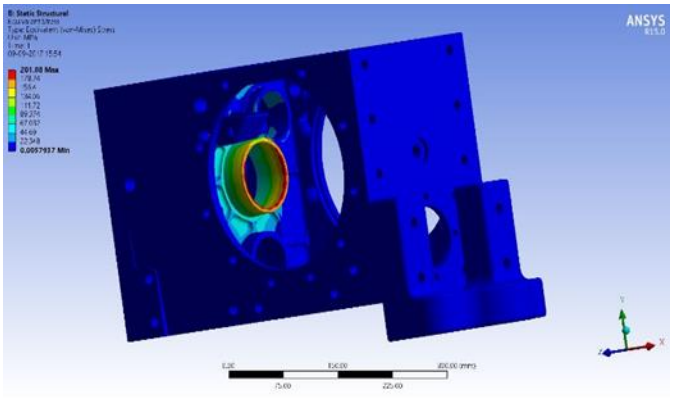

FIGURE 7: EQUIVALENT STRESS OF HOUSING FOR 65 HP TRACTOR

When loads of 65 was applied on housing, the stress induced on housing was 201 MPa as shown in figure 7.

Similarly, the analysis for benchmarking of 50 HP tractor was performed, where values of directional deformation, total deformation and equivalent stress were 0.0812 mm, 0.01896 mm, 176.01 MPa respectively.

4. RESULTS AND DISCUSSION

The results of analysis for 65 HP and 50 HP (benchmark) tractor loading condition on rear differential housing has been shown and discussed in detail. When comparing total deformation, directional deformation and stresses for 50 HP and 65 HP tractor, percentage increment was found as shown in tabular form in table 3.

TABLE 3: COMPARATIVE ANALYSIS

Sr. No	Parameter	50HP Tractor	65 HP Tractor	Increment (%)
1.	Maximum stress induced (MPa)	176.01	201.08	14.24
2.	Directional deformation (mm)	0.01812	0.1092	34.39
3.	Total deformation (mm)	0.18962	0.25486	34.40

After analysing the rear differential housing under loads for 50 HP and 65 HP tractors. Maximum stress increases by 14.24 percent in 65 HP as compared to 50 HP tractor. Direction deformation and total deformation were increased by 34.39 and 39.40 percent respectively. Factor of safety is also calculated as 1.42 for 50 HP and 1.24 for 65 HP tractor.

5. CONCLUSIONS

The design of housing analysed and induced stress, total deformation and total deformation calculated under load for 65 HP tractor. Firstly, the housing was tested for Benchmarked loads of 50 HP tractor, the stresses induced and total deformation occurred gave us a standard to begin with. Than the same housing design was tested for the new loading cases of 65 HP tractor. After comparative study, it was clear that if the rear differential housing of 50 HP tractor is used for 65 HP tractor, no modification in the design is required. It was found that the upgraded 50 HP tractor successfully endured all the torques and forces to which a 65 HP tractor can be subjected under all running conditions and hence no changes were required in the existing model of rear differential housing of 50 HP tractor. From the comparative analysis following conclusions were drawn:

- Maximum stresses in 65 HP tractor housing was 201.08 MPa, which was less than the maximum limit of 250 MPa of the FG250 used for casting rear differential housing.
- Directional deformation was 0.01815 mm and total deformation was 0.1896 mm in 65 HP tractor housing.
- Factor of safety of 65 HP tractor assembly was 1.24 which is above 1, hence the assembly is safe under the 65 HP tractor loading conditions.
- Factor of safety was dropped by 12.67 % in the upgraded 65 HP tractor as compared to the existing 50 HP tractor.

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