MODELLING AND STRUCTURAL ANALYSIS OF REAR AXLE CASING OF TRACTOR

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ABSTRACT:  
Automobiles based on the structural stability of the kinematic components. Present project deals with the rear axle casing of Mahindra tractor 275 for the analysis. structural objectives under stress load conditions for different materials of cased ferro alloys. modelling done in Uni-Graphics Nx 12.0 and the analysis carried in Ansys work bench 2020R1. The axle casing breaks due to the cracks formed during running conditions. Considering the problem and taken into account, the existing model is fed into the structural analysis. In this analysis, we predict the maximum stress concentration area. To perform the static analysis to find the deformation and tensile stress of the rear axle casing, by applying the various loads is the main objective of the work.

1.0 INTRODUCTION:  
An Axle shaft is a rotating member usually of circular cross-section (solid or hollow), which is used to transmit power and rotational motion in machinery and mechanical equipment in various applications. An axle is a central shaft for a rotating wheel. The wheel may be fixed to the axle, with bearings or bushings provided at the mounting points where the axle is supported. The axles maintain the position of the wheels relative to each other and to the vehicle body. Dead axle does not transmit power like the front axle, in a rear wheel drives are dead axles. On the dead axle suspension system is mounted, so it’s also called suspension axle. Generally axle shafts are generally subjected to torsional stress and bending stress due to self-weight or weights of components or possible misalignment between journal bearings. Most shafts are subjected to fluctuating loads of combined bending and torsion with various degrees of stress concentration. For such shafts the problem is fundamentally fatigue loading. Eccentric Shaft is widely appreciated for its features like corrosion resistant, long service, effective performance and reliability.

1.1 AXLE:  
An axle is a central beam for a rotating wheel or gear. On wheeled vehicles, the axle may be fixed to the wheels, rotating with them, or fixed to its surroundings, with the wheels rotating around the axle. In the former case, bearings or bushings are provided at the mounting points where the axle is supported. In the latter case, a bearing or bushing sits inside the hole in the wheel to allow the wheel or gear to rotate around the axle.

1.2 Types of rear axles:  
In rear wheel drive vehicles, the rear wheels are the driving wheels, whereas in the vehicles with front wheels drive the front wheels are the driving wheels. Almost all the rear axles in the modern cars are live axles, which mean that these axles move with the wheels, or revolve with the wheels and are known as live axles. Dead Axles are those axles which remain stationary and do not move with the wheels.

1.3 PROBLEM OF THE STATEMENT:  
The failure occurs due to continuous running of the tractor. The failure occurs in the form of crack. During running condition, the tractor lifts and lowers in the bump, mud and Fig 1 Rear Axle Casing rock etc., due to that the entire weight, the impact load and vibration acts on the wheels and the axle casing. The axle casing breaks due to the cracks formed during running...
conditions. Considering the problem and taken in to account, the existing model is fed in to the structural analysis. In this analysis, we predict the maximum stress concentration area.

1.4 BACKGROUND OF THE STUDY:
The rear axle casing problem occurs only because of continuously running for a long period and also the place where it is functioning. For example highly dry area like where the atmospheric temperature will be more than 39 to 51oC. The company people have a detailed report of it says and out of every 1,000 components 5 components get failed during long running. In this one third of the defective casings is found in dry place area.

2.0 LITERATURE REVIEW
Meng Qinghua et al [1] analyzed for fatigue failure of truck rear axle housing excited by random load distribution from the uneven road profile. During operation of the truck the random load acts on the axle housing in vertical direction causes severe impact on the fatigue life of the components. By using random load distribution data the fatigue life of the truck is analyzed and also design optimization is proposed to increase the fatigue life of the components according to the simulation results and location of failure.

G Raje sh Babu et al [2] carried out the static and dynamic analysis of banjo type rear axle housing by using FE method for two different materials like cast iron and mild steel. The induced deformation in cast iron housing is greater than mild steel housing and also the natural frequencies of the cast iron are lower than the mild steel. Also observed that the stress induced in the cast iron is lower than the mild steel and concluded that the cast iron is preferred for production of rear axle housing.

M.M. Topaç et al [3] “Fatigue failure prediction of a rear axle housing prototype by using finite element analysis.” Premature fatigue failure of a truck rear axle housing prototype was investigated by using finite element analysis. In the analyses, stress concentrated regions were predicted at the banjo transition area. The regions in which the fatigue cracks originated were well-matched with the results of the analyses. Critical regions determined are subjected to a combined steady and cyclic tensile stress.

Manish S Lande et al [4] “comparative analysis of tractor's trolley axle by using FEA. (by considering change in materials existing shape and size)” Evaluate that the existing rear axle shaft used in tractor trolley shows that the existing axle has greater factor of safety so unwontedly heavy axle is used for trolley in existing condition which increase the weight of axle as well as cost of axle. But the newly designed axle with different cross section and different material show that we can maximally reduces the 33.92% weight as compare to the existing axle. Also reduces the cost of trolley axle as the weight of the axle reduces.

Sanjay Aloni [5] carried out the comparative study on tractor trolley axle by using FE method. The fatigue behavior of the existing axle is analyzed and found that failing before the expected life. Further design optimization and fatigue life analysis is carried out to improve the fatigue life and to reduce the weight of axle by using finite element method.

Khairul Ak mal Shamsuddin[6] “Stress Distribution Analysis of Rear Axle Housing by using Finite Elements Analysis” A premature failure that occurred due to the higher loading capacity of the heavy vehicle is studied. In this analysis, in which the stress are distribu, stress concentration from the load given to the axle housing make the axle housing failure. The reason failure occurs is because the axle housing no longer can prevent the load given onto it. From the several load given, the maximum load for the housing can stand was determined by using FE analysis. The result show that the maximum load can be carried by this rear axle housing is 4224.755 kg ≈ 42000 N.

3.0 METHODOLOGY
The word tractor originated from the Latin word “trahere”, meaning pull. Today, tractors are used for drawing in, towing or pulling objects that are extremely hard to move. The tractor on farms which is used to push agricultural machineries or trailers that plough or harrow fields.
3.1 REAR AXLE CASING: The rear axle is one of the components of the tractor which is present in the differential. Its main function is to transmit power from differential to wheel. This component is mounted on the back wheels of the tractor, so it is named as Rear Axle. The rear axle casing is the outer cover of the rear axle. Its main function is to protect the rear axle. The rear axle case is connected to 5 cases of transmission and has an inner peripheral surface, ring gear included in planetary reduction mechanism, ring gear being mounted on inner peripheral surface of rear axle case.

4.0 RESULTS AND DISCUSSIONS:
As previously stated, the major assumption made for this analysis was that the effect of tyres and hydraulic suspension ram were not considered in the analysis. There are three stages or processes involved in the static and structural analysis of the component. These are namely pre-processing, processing and post processing. In pre-processing the axle model is set up for analysis by converting it into a finite element model by adding and defining some or all of the following finite element model characteristics. The characteristics defined for the model include the geometry of the model, material used in the model and its properties, type of elements, meshing, boundary conditions or constraints and the loads applied. In processing, convergence and outputs are set and these are discussed in more detail in subsection Post processing was the final stage of analysis where the results of the analysis were analysed, factor of safety calculated and plots of different loading cases and deformed axle model were created.

![Figure 4.1 Max Stress against P Loop pass for 1g Load case](image1)

![Figure 4.2 Max displacement against P Loop pass for 1g Load case](image2)
Figure 4.3 Strain Energy against P Loop pass for 1g Load case

Table 4.1 The measures and percentage convergence for 3g Load case

| Name            | Value            | Convergence (%) |
|-----------------|------------------|-----------------|
| max_disp_mag:   | 1.369998e-02     | 0.3             |
| max_disp_x:     | 4.814254e-03     | 0.0             |
| max_disp_y:     | 1.353858e-02     | 0.3             |
| max_disp_z:     | -3.376410e-03    | 0.1             |
| max_prin_mag*:  | 5.061278e+01     | 8.0             |
| max_stress_prin*: | 5.061278e+01    | 8.0             |
| Strain energy:  | 8.228287e+01     | 0.1             |

Figure 4.4 Max Stress against P Loop pass for 3g load case
4.1 Analysis of axle:
The existing axle and proposed axle geometry is generated in ANSYS 12.0 by selecting toolbox where various commands like draw, dimensioning, constraints, extrude, generate, rotate etc. are used. Then mesh is generated on the model and after that load points are defined and load values are given. Then the results are generated automatically for stress, strain and deformation in solution phase.
4.3 Analysis of Rear Axle Shaft for Circular Section:
The geometry is drafted based on the dimensions of geometric design parameters. The axle is 3dimensionally modeled then meshed properly to divide it into elements and nodes. Finite element model was generated using free meshed 4 nodes quadratic tetrahedral element due to their flexibility in curved and complex shapes, which has three degrees of freedom per node i.e. translation in x, y, z directions were used. Quality checks and mesh optimization for elements were also performed taking into consideration of aspect ratio, distortion, stretch. Geometric models of rear axle shaft were developed in one sections.
Figure 4.11 Stress Analysis image in ANSYS (For Carbon Fiber)

Figure 4.12 Stress Analysis Image in ANSYS (For E-Glass)

Figure 4.13 stress analysis image in ANSYS (for composite material)
Rear Axle shaft function and location in transmission layout discussed. Imperial approach for estimation of load case were possible established along within causing variation in final usage.

5.0 CONCLUSION:
The design requirement for the front axle support part is not to fracture during the lifetime of the tractor. The fracture of the component could happen in two ways: an overload causes an exceeding stress situation on the critical locations of the component or fatigue fracture caused by repeated loading on the field operations although the occurring stresses are far below the material tensile strength. This research work analyzed 36 Load case scenarios and come up with worst Load case scenarios experienced by Ursus 3512 60hp Tractor Front axle support. The worst load case scenario was found to be the dynamic load case of 3g with wheel force of 9810N and axle angle of $6^\circ$. The Factor of Safety for the component design was calculated to be 2.84 which were lower than the recommended value of 5.5 to 6.5. The Minimum allowable stress and Maximum allowable stress for the Component design would be 484N/mm$^2$ and 572N/mm$^2$.

It was observed that the fatigue cracks originated from welded areas. Results indicate that the axle shaft fractured in reversed bending fatigue as a result of improper welding. Due to heavy load on rear axle specifically in tractor, its life is reduced. So it is important to analyze optimized design to increase its life run. We can optimize rear axle for increasing mechanical strength and easy manufacturability. The objective of this project is increasing working strength and increasing life cycle of rear axle casing of tractor with using different material.

From the bar chart it is clear that the stress produced is minimum in carbon fiber and maximum in e-glass. Ductile cast iron and composite material have 7392.1 and 7482.8 Pascal stress respectively. From the bar chart it is clear that the value of the stress produced into the composite material is less than that of stress calculated, thus the composite material is safer than that of the structural steel. So, we can use this composite material for making the rear axle shaft which has more stress handling capacity than the structural steel.

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