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A Review On Variation In Differential Gearbox Design and Its Materials

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***Abstract*— The primarily objective of this research to design CAD model & perform the static structural analysis of differential gear box of three different grades of Aluminum Alloys that are "AA5182, AA6061 & AA7108" iterated at three different magnitude of torque value that are 190N-m, 235N-m & 320N-m, to calculate the total deformation & equivalent stress value for each. This paper will also show that among these three alloys which one is the light & helps to reduce the weight of vehicle. To design the CAD model in CATIA v5 & for the static structural analysis ANSYS 15.0 has been used.**

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Keywords*— Differential Gear Box; Static Structural Analysis; Design and Structural Analysis; Aluminum Alloys Grade; Magnitude of Torque.

I. INTRODUCTION

A transmission or gearbox provides speed and torque conversions from a rotating power source to another device using gear ratios the term transmission refers to the whole drive train, including gearbox, clutch, prop shaft (for rear-wheel drive),differential and final drive shafts. In American English, however, the distinction is made that a gear box is any device which converts speed and torque, whereas a transmission is a type of gearbox that can be "shifted" to dynamically change the speed: torque ratio, such as in a vehicle.

Differential gear box is the component in the automobile that have the set of gear arrangement that provide different angular velocity to inner & outer wheels of automobile while taking turn or slippage between ground surface & wheel. This is necessary when the vehicle turns, making the wheel that is traveling around the outside of the turning curve roll farther and faster than the other. The average of the rotational speed of the two driving wheels 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. When used in this way, a differential couples the input shaft (or propeller shaft) to the pinion, which in turn runs on the ring gear of the differential. This also works as reduction gearing. On rear wheel drive vehicles, the differential may connect to half-shafts inside axle housing, or drive shafts that connect to the rear driving wheels. Front wheel drive vehicles tend to have the pinion on the end of the main-shaft of the gearbox and the differential is enclosed in the same housing as the gearbox. There are individual drive-shafts to each wheel.

A. Types of Differential

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- Epicyclic Differential
- Spur Gear Differential

Epicyclic Differential An epicyclic differential can use epicyclic gearing to split and apportion torque asymmetrically between the front and rear axles. An epicyclic differential is at the heart of the Toyota Prius automotive drive train, where it interconnects the engine, motor generators, and the drive wheels (which have a second differential for splitting torque as usual). It has the advantage of being relatively compact along the length of its axis (that is, the sun gear shaft).

Fig 1 Epicyclic Gear Differential Arrangements

Spur Gear Differential A spur-gear differential has two equal-sized spur gears, one for each half-shaft, with a space between them. Instead of the Bevel gear, also known as a miter gear, assembly (the "spider") at the centre of the differential, there is a rotating carrier on the same axis as the two shafts. Torque from a prime mover or transmission such that the drive shaft of a car rotates this carrier. Mounted in this carrier are one or more pairs of identical pinions, generally longer than their θ diameters, and typically smaller than the spur gears on the individual half-shafts. Each pinion pair rotates freely on pins supported by the carrier. Furthermore, the pinion pairs are displaced axially, such that they mesh only for the part of their length between the two spur gears, and rotate in opposite directions. The remaining length of a given pinion meshes with the nearer spur gear on its axle. Therefore, each pinion couples that spur gear to the other pinion, and in turn, the other spur gear, so that when the drive shaft rotates the carrier, its relationship to the gears for the individual wheel axles is the same as that in a bevel-gear differential.

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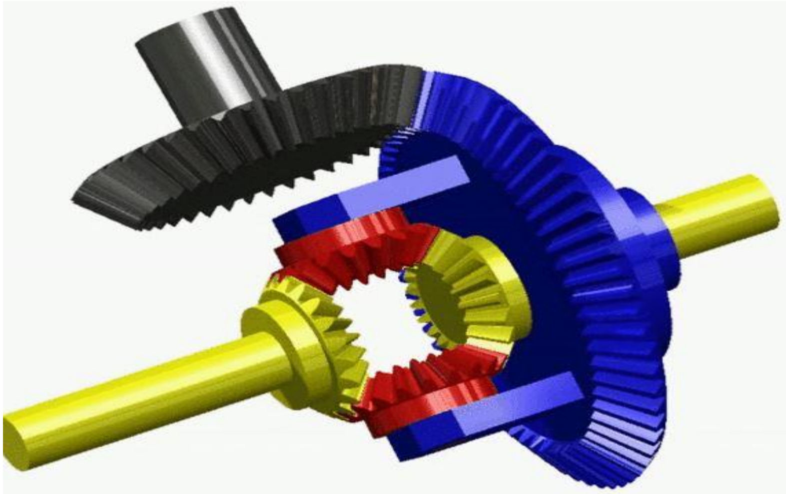

Fig 2 Spur Gear Differential Arrangements

II. LITERATURE REVIEW

N. Siva Teja 2017 [1]-Performed the mechanical design of differential gearbox and analysis of gears in gear box. We have taken grey cast iron and aluminum alloy materials for conducting the analysis. Presently used materials for gears and gears shafts is Cast Iron, Cast Steel. So, in this paper we are checking as the aluminum can be the other material for the differential gear box for light utility vehicles so, we can reduce the weight.

N.Vijayababu & Ch.Sekhar 2015 [2]-Conducted the analysis to verify the best material for the gears in the gear box at higher speeds by analyzing stress, displacement and also by considering weight reduction. The analysis is done in Cosmos software. Modeling is done in the Pro/Engineer.

P.Vinay., Ch. Venkata Satya Sri Vamsi., M.Hemanth., A.Saiteja., Mohammad Abid Ali & P. Ashok Kumar 2017 [3]-In this paper they mainly subsume design and development of MEMS based accelerometer for crash detection and air bag deployment in automobiles. So far modern cars uses traditional accelerometers which gives high linearity and high cross sensitivity these can be replaced with cutting edge MEMS technology through which the entire accelerometer can be made within micro meters i.e.;(1-1000µm) which increases the operational speed in crash detection and air bags deployment. It is assumed that car moves at initial velocity of 0 Kmph and final velocity of 60 Kmph and maximum value final velocity of 180 Kmph it develops a g force range of 6g-18g. When sudden displacement occurs due to impact the comb gets shock loads or forces and that movement is observed by differential capacitance concept with dielectric as air. The simulations were carried out in COMSOL, the actual theoretical calculation and the simulations were compared in order to get accurate results. The capacitance output obtained was carried to the Electronic control unit which sends the impulse signal to air bag system and deployment of air bags takes place.

K. Sunil Kumar, Dr. Sumathy Muniamuthu, S. Arun & A. Mohan 2016 [4]-In this study they consider a Wind Turbine which has many rotating parts, making it a real challenge. To conduct modal analysis in operating Conditions. The issue is to separate the structural modes from the harmonic components. In addition to that gearbox itself, there is also the generator, the pitch-drive and the yaw-drive producing harmonic vibration for a complete Wind Turbine in operating condition. The 63 ton gearbox tested in FFT test bench with a rotational speed of 1110 rpm and mounted in a test rig. Since the high speed shaft is running at Gearbox housing, the key point observed from FFT Analyzer report is noise in the form of whistling from gearbox housing. In this paper several approaches and techniques have been used in order to extract the structural modes. Modal analysis is applied here to get the natural frequencies of the gearbox housing itself. The FFT analyzer shows the results of excited frequency occurs inside the gearbox housing with the predicted noise level at 105 decibals (offshore) The noise is in the form on huge whistling which may cause severe damage to the living organisms in the sea. Hence gearbox housing is taken into account and applied necessary boundry conditions, we have proved the FFT Results with Ansys Results. Hence we added mass to overcome the resonance of the Gearbox housing

G.Srikanth Reddy & M.Promod Reddy 2015 [5]-In this paper the discussion on the design and analysis of gears assembly in differential gear box. During operation of gears, there is a problem of failure at contact regions. This can be minimized by modification of the gear material by assuming the bevel gears in static and dynamic conditions. The purpose of this paper is to develop the model of a bevel gear assembly and to determine the effect of meshing gear tooth stresses and displacement. In present market, the materials used for gears manufacturing are Cast Iron and Cast steel. In this study comparison was done between Ni-Cr steel and steel. The design is done in Solid works software and analyzed using ANSYS work bench. The justification has been done by considering a full literature review.

Ronak P Panchal 2015 [6]-Consider the bevel gears as a subject to research interest because the dynamic load, attention of the noise level during operation and demand for lighter and smaller. In such type of gears there is a problem of failures contact at meshing the teeth. This can be avoided or minimized by proper method analysis and modification of the different gear parameters. This thesis presents characteristics of a bevel gear in dynamic condition involving meshing stiffness and other stresses produce. The purpose of this thesis is by using numerical approach to develop theoretical model of bevel gear and to determine the effect of meshing gear tooth stresses by taking material case hardened alloy steel (15Ni4Cr1) . To estimate the meshing stiffness, three-dimensional solid models for different number of teeth are generated by Solid works and the numerical solution is done in Ansys which is a finite element analysis.

Sachindra Kumar., Anjani Kumar Singh., Nitesh Kumar., Sushil Patel & Ajit Kumar 2014 [7]-In this study they consider an involute gear system including contact stresses analysis of gears in mesh. Gearing is one of the most critical components in mechanical power transmission systems. Transmission error is considered to be one of the main contributors to noise and vibration in a gear set. Transmission error measurement has become popular as an area of research on gears and is possible method for quality control. To estimate transmission error in a gear system, the characteristics of involute spur gears were analyzed by using the finite element method. The contact stresses were examined using 2-D FEM models. The bending stresses in the tooth root were examined using a 3-D FEM model. Current methods of calculating gear contact stresses use Hertz's equations, which were originally derived for contact between two cylinders. To enable the investigation of contact problems with FEM, the stiffness relationship between the two contact areas is usually established through a spring placed between the two contacting areas. This can be achieved by inserting a contact element placed in between the two areas where contact occurs. The results of the two dimensional FEM analyses from ANSYS are presented. These stresses were compared with the theoretical values. Both results agree very well. This indicates that the FEM model is accurate.

Luciana Sgarbi Rossino 2014 [8]-Did the investigation to determine the causes of surface contact fatigue failure of a case hardened driver pinion located in the intermediate shaft of a reducer gearbox used in a sugar and alcohol mill. The examination of the component revealed the presence of a cemented layer substantially thicker than that generally specified for pinions devised for this application. This, associated with the massive presence of brittle threadlike carbon-rich cementite phase (Fe_3C) in prior austenite grain boundaries of the pinion teeth, favored surface crack nucleation and propagation during cyclic loading, leading to spallation of the contact surface with the counterpart gear, which impaired the system's operation. Poor carburization practice was discovered as the root cause of the mechanical failure, thus demanding the implementation of a new manufacturing route to avoid problems in similar load-bearing rotating components**.**

I.Barsoum 2014 [9]-In this paper a finite element modeling framework to determine the torsion strength of hardened splined shafts by taking into account the detailed geometry of the involute spline and the material gradation due to the hardness profile. The aim is to select a spline geometry and hardness depth that optimizes the static torsion strength. Six different spline geometries and seven different hardness profiles including non-hardened and through-hardened shafts have been considered. The results reveal that the torque causing yielding of induction hardened splined shafts is strongly dependent on the hardness depth and the geometry of the spline teeth. The results from the model agree well with experimental results found in the literature and reveal that an optimum hardness depth maximizing the torsional strength can be achieved if shafts are hardened to half their radius.

Samareh Mohammadzadeh Polami 2014 [10]-In this research describes the application of compressive stresses on friction welded drive pinion fabricated by using the joint-site structure (JSS) method, three different variants were followed: (A) the initial design with two joints was carried out. Two different burn-off lengths were examined for this variant. (B) The optimum burn-off length was considered for only one weld zone. (C) The weld zone was moved radially from the initial location and two different gap sizes were compared. The smallest gap size for the third variant led to the largest weld length. The lack of structural welding defects for this variant was assessed by ultrasonic testing. Hardness of the material after friction welding (FW) was correlated to the Continuous Cooling Transformation (CCT) diagram of the used materials and revealed the phase/microstructure transformation of the material. The simulated applied stresses on the optimized friction welded design of the drive pinion showed suitable results. The new drive pinion friction welded by the JSS method reduced the weight of the component by approx. 14%.

Grégory Antoni 2014 [11]-Study focuses on the mechanical friction losses liable to occur in differential automobile gearboxes, which can lead in the long term to the scuffing of these mechanical systems. The friction losses involved were modeled, using a simple analytical approach, which is presented and discussed.

S. H. Gawande., S.V. Khandagale., V. T. Jadhav., V. D. Patil & D. J. Thorat 2013 [12]-In this paper performed mechanical design of crown wheel and pinion in differential gear box of MFWD (FWA) Axle (of TAFE MF 455). Detailed modeling, assembly and analysis of tooth of crown gear and pinion is explained which is performed in Pro-E.

Daniel Das.A 2013 [13]-Focus in this paper on the mechanical design and analysis on assembly of gears in gear box when they transmit power at different speeds. Analysis is also conducted by varying the materials for gears, Cast Iron, Cast Steels and Aluminum Alloy etc., presently used materials for gears and gear shafts is cast-iron, cast steel. In this paper the replacement of materials with Aluminum material for reducing weight of the product. Stress, displacement is analyzed by considering weight reduction in the gear box at higher speed. The analysis is done in ANSYS software. It's a product of Solid works. In the present work all the parts of differential are designed under static condition and modeled. The required data is taken from journal paper. Modelling and assembly is done in Pro Engineer. The detailed drawings of all parts are to be furnished.

S. Puttaswamaiah, Dr. J.N. Prakash and K.B. Kiran 2012 [14]- Investigates the characteristics of an involute gear system using Finite Element (FE) Methods. Bending and contact stresses are evaluated using nonlinear FE methods and then compared against AGMA standards to establish an accurate design procedure. The study started with evaluation of contact stress using ANSYS code for simulating a pair of cylinders in contact. The results obtained are in good agreement with Hertz's equation. A single tooth model was then analyzed for arriving at the bending stress. Forces were applied at different radii of the tooth and peak stresses obtained at the root were compared with AGMA standard evolved out of basic Lewis formula with several corrections taken into account.

Ing. T. Schulze 2010 [15]-worked on the design of gears - especially planetary gears - can just be carried out by the consideration of influences of the whole drive train and the analysis of all relevant machine elements. In this case the gear is more than the sum of its machine elements. Relevant interactions need to be considered under real conditions. The standardized calculations are decisive for the safe dimensioning of the machine elements with the consideration of realistic load assumptions. But they need to be completed by extended analysis of load distribution, flank pressure, root stress, transmission error and contact temperature.

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Sumair Sunny, Siddhesh Ozarkar & Sunny Pawar 2006 [16]-In this paper the designing of a differential with a reduction ratio greater than 6. The paper includes all the calculations as well as a strength based analysis performed on Altair-Hyper mesh, to prove the success of the design.

Zeping Wei 2004 [17]-In this thesis investigates the characteristics of an involute gear system including contact stresses, bending stresses, and the transmission errors of gears in mesh. Gearing is one of the most critical components in mechanical power transmission systems. Transmission error is considered to be one of the main contributors to noise and vibration in a gear set. Transmission error measurement has become popular as an area of research on gears and is possible method for quality control. To estimate transmission error in a gear system, the characteristics of involute spur gears were analyzed by using the finite element method. The contact stresses were examined using 2-D FEM models. The bending stresses in the tooth root were examined using a 3-D FEM model. Current methods of calculating gear contact stresses use Hertz's equations, which were originally derived for contact between two cylinders. To enable the investigation of contact problems with FEM, the stiffness relationship between the two contact areas is usually established through a spring placed between the two contacting areas. This can be achieved by inserting a contact element placed in between the two areas where contact occurs. The results of the two dimensional FEM analyses from ANSYS are presented. These stresses were compared with the theoretical values. Both results agree very well. This indicates that the FEM model is accurate. This thesis also considers the variations of the whole gear body stiffness arising from the gear body rotation due to bending deflection, shearing displacement and contact deformation. Many different positions within the meshing cycle were investigated.

C.Veeranjaneyulu & U. Hari Babu 2002 [18]-Focus in this paper on the mechanical design and analysis on assembly of gears in gear box when they transmit power at different speeds i.e-2500 rpm, 5000 rpm and 7500 rpm. Analysis is also conducted by varying the materials for gears, Cast Iron, Cast Steels and Aluminum Alloy. Presently used materials for gears and gear shafts are Cast Iron, Cast steel. In this paper replacing the materials with Aluminum material for reducing weight of the product. Stress, displacement is analyzed by considering weight reduction in the gear box at higher speed. The analysis is done in Cosmos software. It's a product of Solid works. In the present work all the parts of differential are designed under static condition and modeled. The required data is taken from journal paper. Modeling and assembly is done in Solid Works. The detailed drawings of all parts are to be furnished.

Gianni Nicoletto 1993 [19]- Implemented a compact although approximate approach to the determination of stress intensity factors (SIFs) for cracked gears based on the use of the weight function method and the complex potentials method of gear tooth stress analysis is presented. A computer code implementing these ingredients in a scheme for stress intensity factor (SIF) determination is described and its accuracy established by comparison with recent results from the literature. The effects of various parameters on SIFs such as number of teeth, type of loading, and direction of crack propagation are presented**.**

Chung-Biau Tsay 1988 [20]-Evaluated the solutions to the following problems: (1) Setting up a mathematical model for the involute helical gears; (2) Computer simulation of the conditions of meshing and bearing contact; (3) Investigation of the sensitivity of gears to the errors of manufacturing and assembly; and (4) Stress analysis of the gears. In this paper, the theory of gearing and the concept of differential geometry have been applied to deal with the relations of two mating helical gears and their bearing contact. Computer program for tooth contact analysis (T.C.A.) has been developed for the gears. The T.C.A. computer program makes it possible to simulate gear meshing and bearing contact, and to investigate the influence of gear misalignment on kinematic errors. A method of compensation for the dislocation of bearing contact and for kinematic errors induced by errors of manufacturing and assembly has been proposed. Four numerical examples have also been presented to illustrate the influence of the above-mentioned errors and the method of compensation for the dislocation of bearing contact. Based on the derived mathematical model, an automatic mesh generating computer program—AMG has been developed to define the geometry of the gears and to divide the gear tooth into elements as well as to generate nodal points automatically. The results of T.C.A. provide the locations and directions of the applied loadings for the finite element method (F.E.M.) stress analysis.

III. OBJECTIVE

- The objective of this research is to analyze the deformation & equivalent stress develops in differential gear box of different grade of aluminum alloy i.e. AA5182, AA6061 & AA7108 by the application of variable torque magnitude i.e. 190N-m, 235N-m & 320N-m on crown gear. For performing this structural analysis are going to use.
- Another aim is to investigate among three of them which one is lightest in weight & help to reduce the weight of differential gear box & also help to reduce the overall weight of vehicles.

IV. CONCLUSION

In this thesis "Design analysis of differential gear box of Ashok Leyland 2156M of different grade of Aluminum Alloys" will conclude. From the results we will get the Following conclusion in coming chapters:

- From the result we are able to determine the effect that on total deformation with increase in the torque magnitude, in the differential made up of different grade of aluminum alloy.

- The result will show the less deformation occur in among three of aluminum alloy i.e.5182, 606 & 7108 grade differential gear box for all three cases of different torque magnitudes i.e. 190N-m, 235N-m & 320N-m.
- The result wills also show the value of the equivalent stresses develops in Aluminum Alloys 5182, 6061 & 7108 grades.
- The result will show, among three of them which one is lighter.

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