Structural Analysis of Differential Gearbox

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Abstract-   The main aim of this paper is to focus 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 to replace 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 ANSYS software. It's a product of Solid works. In the present work all the parts of differential are designed under static condition and modelled. 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.

Keywords – Gearbox, Differential, Structural analysis, Ansys

I. INTRODUCTION

A differential is a device, usually but not necessarily employing gears, capable of transmitting torque and rotation through three shafts, almost always used in one of two ways: in one way, it receives one input and provides two outputs this is found in most automobiles and in the other way, it combines two inputs to create an output that is the sum, difference, or average, of the inputs. In automobiles and other wheeled vehicles, the differential allows each of the driving road wheels to rotate at different speeds, while for most vehicles supplying equal torque to each of them. A vehicle's wheels rotate at different speeds, mainly when turning corners. The differential is designed to drive a pair of wheels with equal torque while allowing them to rotate at different speeds. In vehicles without a differential, such as karts, both driving wheels are forced to rotate at the same speed, usually on a common axle driven by a simple chain drive mechanism. When cornering, the inner wheel needs to travel a shorter distance than the outer wheel, so with no differential, the result is the inner wheel spinning and/or the outer wheel dragging, and this results in difficult and unpredictable handling, damage to tires and roads, and strain on (or possible failure of) the entire drive train.

II. FUNCTIONAL DESCRIPTION

The following description of a differential applies to a "traditional" rear-wheel-drive car or truck with an "open" or limited slip differential: Torque is supplied from the engine, via the transmission, to a drive shaft. It comes from British term: 'propeller shaft', commonly and informally abbreviated to 'prop-shaft', which runs to the final drive unit that contains the differential. A spiral bevel pinion gear takes its drive from the end of the propeller shaft, and is encased within the housing of the final drive unit. This meshes with the large spiral bevel ring gear, known as the crown wheel. The crown wheel and pinion may mesh in hypoid orientation, not shown. The crown wheel gear is attached to the differential carrier or cage, which contains the 'sun' and 'planet' wheels or gears, which are a cluster of four opposed bevel gears in perpendicular plane, so each bevel gear meshes with two neighbours, and rotates counter to the third, that it faces and does not mesh with. The two sun wheel gears are aligned on the same axis as the crown

wheel gear, and drive the axle half shafts connected to the vehicle's driven wheels. The other two planet gears are aligned on a perpendicular axis which changes orientation with the ring gear's rotation. In the two figures shown above, only one planet gear (green) is illustrated, however, most automotive applications contain two opposing planet gears. Other differential designs employ different numbers of planet gears, depending on durability requirements. As the differential carrier rotates, the changing axis orientation of the planet gears imparts the motion of the ring gear to the motion of the sun gears by pushing on them rather than turning against them, i.e. the same teeth stay in the same mesh or contact position), but because the planet gears are not restricted from turning against each other, within that motion, the sun gears can counter-rotate relative to the ring gear and to each other under the same force in which case the same teeth do not stay in contact.

III. ANSYS

Ansys is useful software for design analysis in mechanical engineering. That's an introduction for you who would like to learn more about Ansys. Ansys is a design analysis automation application fully integrated with ProEngineer. This software uses the Finite Element Method (FEM) to simulate the working conditions of your designs and predict their behaviour. FEM requires the solution of large systems of equations. Powered by fast solvers, Ansys makes it possible for designers to quickly check the integrity of their designs and search for the optimum solution.

A product development cycle typically includes the following steps:
• Build your model in the ProEngineer system.
• Prototype the design.
• Test the prototype in the field.
• Evaluate the results of the field tests.
• Modify the design based on the field test results

IV. PROPERTIES OF MATERIALS

4.1 Nickel Chrome Steel

Table -1 Properties of Nickel Chrome Steel

Name	Nickel Chrome Steel
Model type	Linear Elastic Isotropic
Default Failure Criterion	Max von Mises Stress
Yield Strength	$1.72339e+0.008$ N/m^2
Tensile Strength	$4.13613e+0.008$ N/m^2
Elastic Modulus	$2e+011$ N/m^2
Poisson's Ratio	0.28
Mass Density	7800 kg/m^3
Shear Modulus	$7.7e+010$ N/m^2

4.2 Aluminium Alloy

Table -2 Properties of Aluminium Alloy

Name	al_alloy7475-1761
Model type	Linear Elastic Isotropic
Default Failure Criterion	Max von Mises Stress
Yield Strength	$1.65e+0.008$ N/m^2
Tensile Strength	$3.0e+0.008$ N/m^2
Elastic Modulus	$7e+011$ N/m^2
Poisson's Ratio	0.33
Mass Density	2600 kg/m^3
Shear Modulus	$3.189e+010$ N/m^2

4.3 Cast Iron

Table -3 Properties of Cast Iron

Name	Malleable Cast Iron
Model type	Linear Elastic Isotropic
Default Failure Criterion	Max von Mises Stress
Yield Strength	$2.75742e+0.008$ N/m^2
Tensile Strength	$4.13613e+0.008$ N/m^2
Elastic Modulus	$1.9e+011$ N/m^2
Poisson's Ratio	0.27
Mass Density	7300 kg/m^3
Shear Modulus	$8.6e+010$ N/m^2

VI. EXPERIMENT TOTAL DEFORMATION AND EQUIVALENT STRESS

4.4 At 2000 RPM

(a)
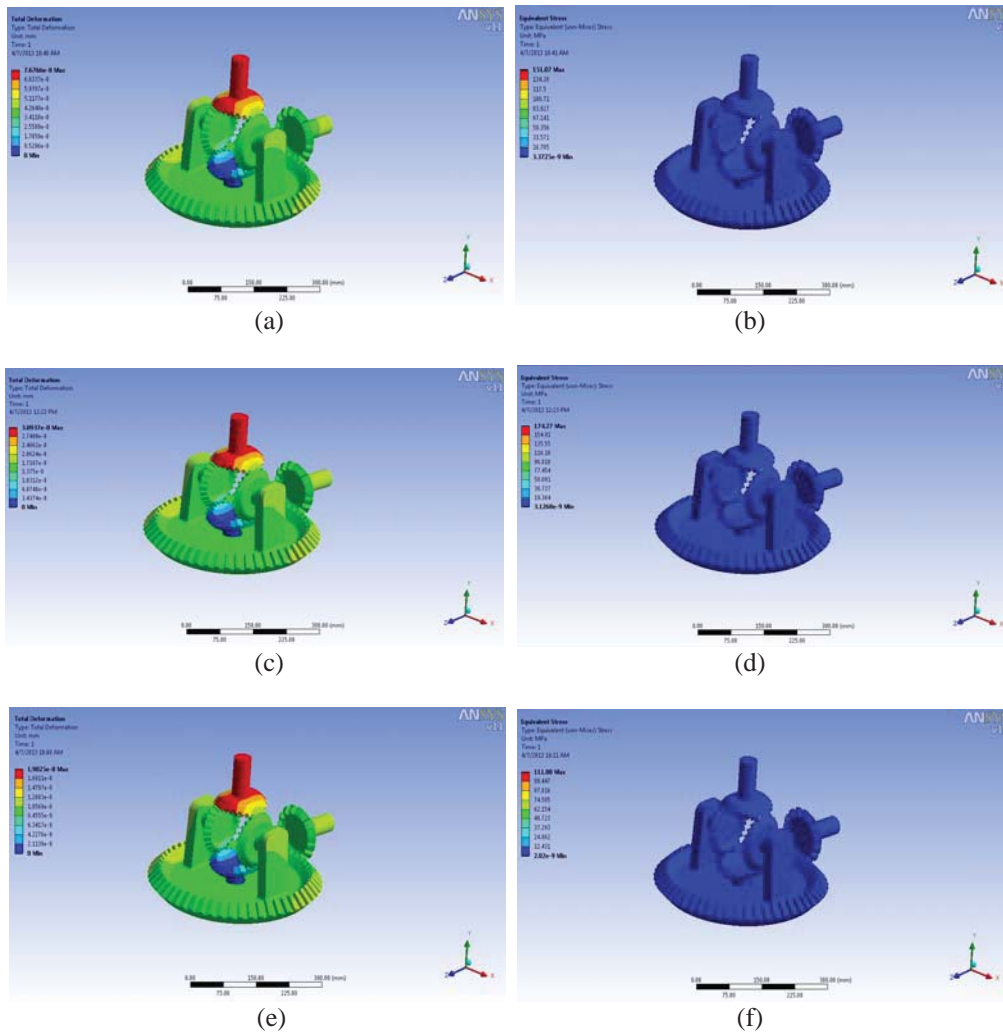

(b)

(c)

(d)

(e)

(f)

Figure 1. (a) Total Deformation Aluminium Alloy (b) Equivalent Stress Aluminium Alloy (c) Total Deformation Cast Iron
(d) Equivalent Stress Cast Iron (e) Total Deformation Structural Steel (f) Equivalent Stress Structural Steel
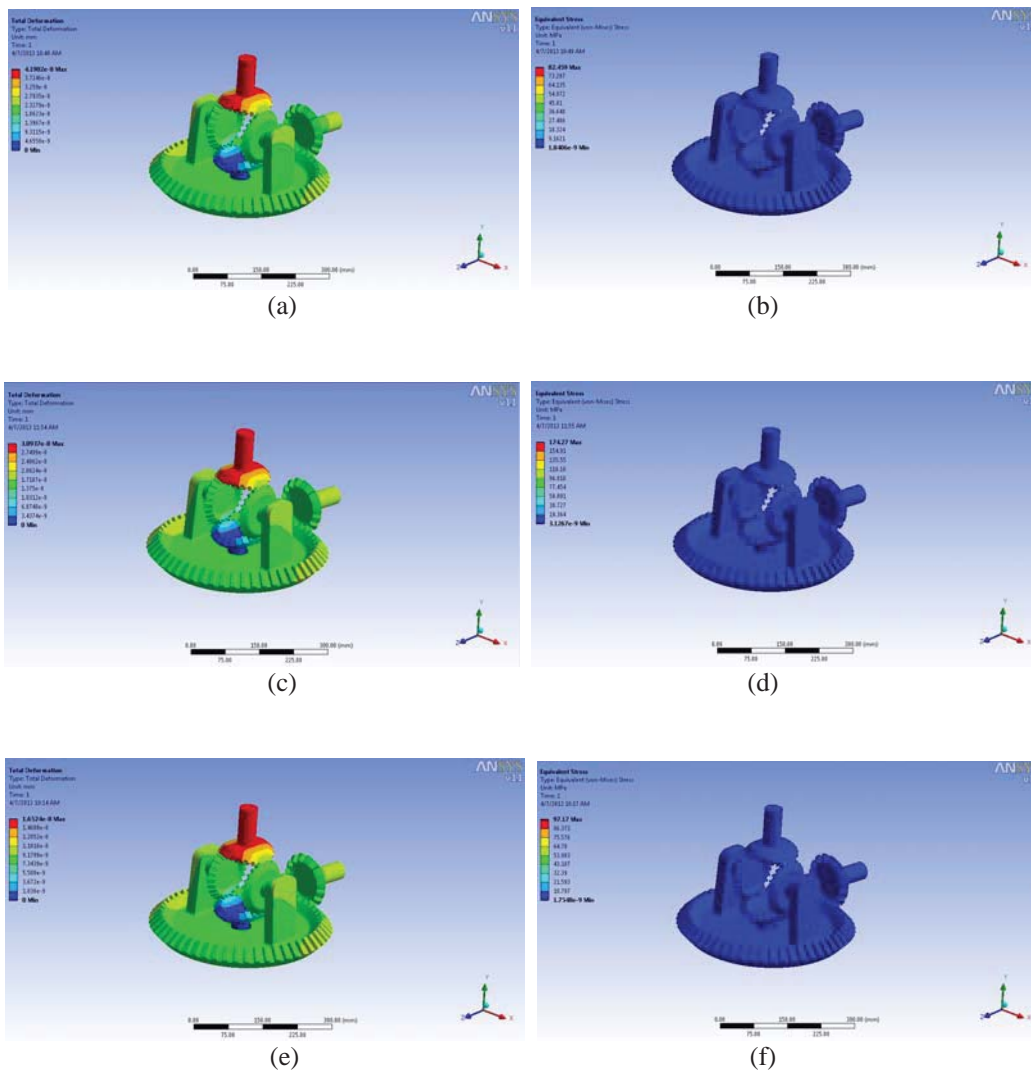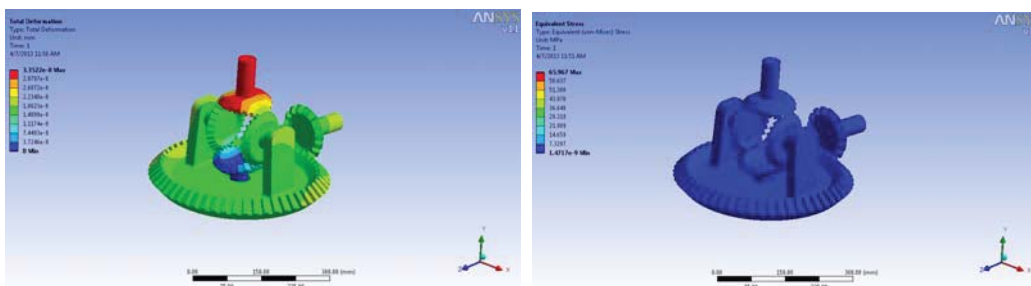
4.5 At 4500 RPM

(a)

(b)

(c)

(d)

(e)

(f)

Figure 2. (a) Total Deformation Aluminium Alloy (b) Equivallent Stress Aluminium Alloy (c) Total Deformation Cast Iron
(d) Equivallent Stress Cast Iron (e) Total Deformation Structural Steel (f) Equivallent Stress Structural Steel

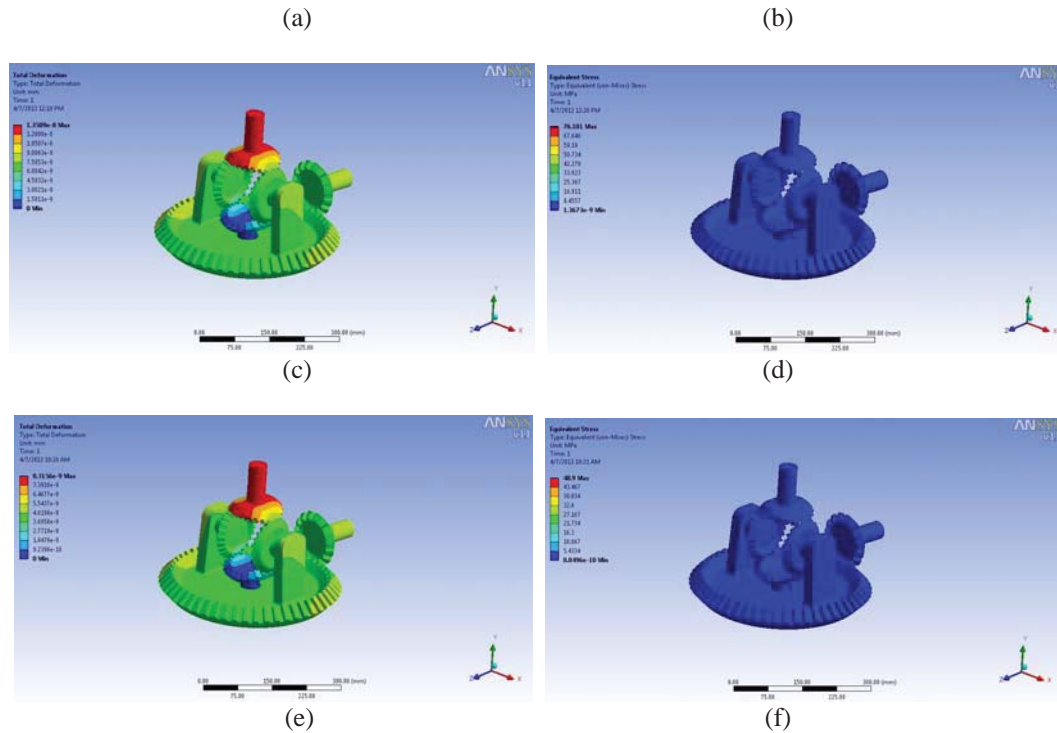*4.6 6000 RPM*

(a) (b)

(c) (d)

(e) (f)

Figure 3. (a) Total Deformation Aluminium Alloy (b) Equivallent Stress Aluminium Alloy (c) Total Deformation Cast Iron
(d) Equivallent Stress Cast Iron (e) Total Deformation Structural Steel (f) Equivallent Stress Structural Steel

VI.CONCLUSION

By observing the structural analysis results using Aluminum alloy the stress values are within the permissible stress value. So using Aluminum Alloy is safe for differential gear. When comparing the stress values of the three materials for all speeds 2000rpm, 4500rpm and 6000 rpm, the values are less for Aluminum alloy than Alloy Steel and Cast Iron. By observing the frequency analysis, the vibrations are less for Aluminum Alloy than other two materials since its natural frequency is less. And also weight of the Aluminum alloy reduces almost 3 times when compared with Alloy Steel and Cast Iron since its density is very less. Thereby mechanical efficiency will be increased. By observing analysis results, Aluminum Alloy is best material for Differential.

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