ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 5, Issue 1, January 2018

A Survey on Differential Gear System

Mansi Subirkumar Srivastava

Department of Mechanical Engineering, Galgotias University, Yamuna Expressway Greater Noida, Uttar Pradesh, India
Email: mansi.srivastava@galgotiasuniversity.edu.in

***Abstract*---- The differential may be described as a gear train used to regulate the rear wheel speed and torque. The basic requirement of the vehicle is to control the speed of the rear wheels when taking a turn, so that the vehicle turns smoothly on the road surface. The differential consists mainly of three shafts and an arrangement of gear trains. The first shaft is a propeller shaft that provides the torque and speed required for turning. The remaining two shafts are axle shafts mounted on each rear wheel. These shafts are attached by crown gear and pinion arrangement to the propeller shaft, thus making a pair of bevel gears. The two main parts of the differential transmission system are the crown gear which gives permissible speed to turn the vehicle and the other is the pinion which provides the vehicle with permissible speed and torque. The main objective of this paper is to focus on the mechanical design and analysis when transmitting power at different speeds when assembling gears in gear box. Testing is also carried out by changing the materials for gears, cast iron, cast steels and aluminium alloy etc., the components commonly used for gears and gear shafts are cast iron, cast steel. Replace the materials with Aluminium content in this paper to reduce the product weight. Stress, displacement is evaluated at higher speed by considering weight reduction in the gearbox.**

***Keywords*--- Bevel Gears, Crown Gear and Pinion, Differential Gear, Gearbox, Single Track Vehicle**

I. INTRODUCTION

When a vehicle takes a turn, the differential is used; the outer wheel covers longer distance than the inner wheel. The outer wheel turns faster than the inner wheel which happens when the two rear wheels have a relative motion [1]. If the two rear wheels are rigidly attached to a rear axle, resulting in rapid tire wear, inner wheel can slip, steering difficulty, and poor load hold. Differential is a part of the inner axle housing assembly that comprises the rear axles, wheels and bearings of the differential. The differential consists of a gear system arranged in such a way that the propeller shaft is connected to the rear axles. The research is carried out in order to verify the best material for the gears in the gearbox at higher speeds by measuring tension, displacement and also considering transmission safety. The bevel gears are used to transmit power between two shafts at a constant velocity ratio whose axes intersect at a given angle. For the bevel gear the pitch surfaces are cone frustums as in figure 1. The two pairs of touching cones are shown in figure 2 [2].

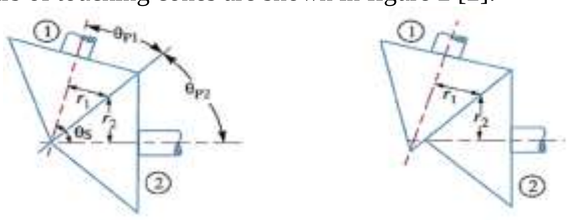

Figure 1: Pitch Surface for Bevel Gears

The cone components converge at the point at which the axis of rotation intersects. Since both gears radii are proportional to their distances from the apex, therefore the cones can roll without sliding together. At the shaft crossing point, the components of both cones do not converge. Therefore pure rolling will occur at just one point of contact and tangential sliding at all other points of contact. These cones cannot be used as pitch surfaces, because at the same time it is impossible to have positive driving and sliding in the same direction. Thus it concludes that at the same point the elements of the bevel gear pitch cones and shaft axes must intersect [3].

1. Theoretical Strength Calculation of Differential Bevel Gear:

Theoretical strength calculation for parameters given by existing products, the known parameter is an input torque T_0 of 2500 N-m, a pinion number of teeth z1 of 10, a gear number of teeth z2 is 14, a spherical radius of 40 mm, a face width F is 11.9 mm, a pressure angle of 25 degrees, a planet gear number n of 2, a module of 4.515 mm. Size factor Ks is calculated as 0.649, speed coefficient K_v is set to 1, geometric coefficient J is 0.288, load factor K_m is set to 1, the substitution of the gear bending stress w formula can be measured as 995.78 Mpa; The material chosen for the differential bevel gear is SNCM4320, tensile strength is 980 Mpa, and the differential gear is made of forged steel, the strength can be raised by 15% to achieve a tensile strength of 1127 Mpa, it can be seen that the theoretical stress value is estimated to be lower than the material strength [4].

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 5, Issue 1, January 2018

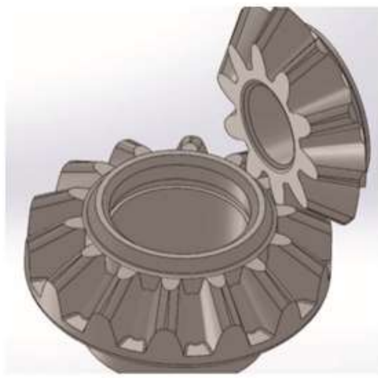

Figure 2: Differential Bevel Gear

$$\sigma_W = \frac{2\times10^3 \times T \times K_0 \times K_s \times K_m}{K_v \times F \times z2 \times m^2 \times J}$$

T = Differential torque transmitted by one planetary gear to one half shaft gear.

$$T = \frac{T_0 \times 0.6}{n}$$

T = 750 N-m.

2. Design Gear Parameter Modelling and Finite Element Analysis:

Straight bevel gears which are the same as the industrial products, a tooth surface with double teeth, not a general standard involute profile, and due to the need for forging processes, must change the gear tooth top and bottom R angle of the tooth [5]. Thus, the discrepancy between real stress and theoretical stress is induced. The model is then imported into the Hyper Mesh pre-processor for meshing of finite element models, setting of constraints, setting of initial condition, selection of touch mode, setting of the gear material properties, etc.

a. Substituting Gear Parameters, Meshing, Condition Setting and Solution:

Teeth pinion number z1 is 10, teeth gear number z2 is 14, module is 4.515 mm, face width F is 11.9 mm and pressure angle is 25 degrees. The above parameters are replaced by the differential gear 3D model [6]. The contact tooth print and its backlash can be assessed through the 3D model assembly, backlash result of assembly position of the tooth in contact. The model is imported for finite element model meshing into the Hyper Mesh pre-processor, after which the setting of the gear material property, the setting of the constraint condition, the setting of the initial condition, and the contact mode are performed [7].

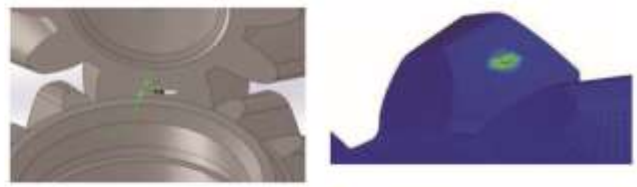

Figure 3: Backlash and Contact Tooth Position

b. Finite Element Analysis Result:

Location of the compressive stress mesh solution, location of the Pinion Pitting stress grid solve, location of the Large gear Bending stress grid, position of the Pinion Bending stress grid solve. The pinion and gear contact stress is 904 MPa and 1040 MPa respectively. Pinion and Gear's maximum bending stress is 519 MPa, and 579.1 MPa respectively [8].

3. Structural Analysis of Crown Gear and Pinion:

Finite element analysis is performed by the program ANSYS15. ANSYS is a general purpose finite-element simulation program designed to solve a wide range of mechanical problems numerically. These include static / dynamic, structural (linear and nonlinear) analysis, heat transfer, and fluid problems, as well as acoustic and electromagnetic issues. The assembly is discrete in around 8671 elements with 15700 nodes by default tetrahedral meshing and mesh size is 2 mm. The solution is obtained by using modeller ANSYS Work Bench. The maximum stress is found, and a comparison has been made among all types of torque from the resulting data [9].

Define Materials: Structural steel.

Constant Material Properties: Young's modulus, Poisson's ratio, Density.

The program ANSYS 15 finite element has been used for Crown and pinion Structural Analysis. To this end the total of 4 models are produced in CAD software (CATIA) depending on the torque and imported into ANSYS. Each model has torque and loading[9].

Sr. No.	Property	Grey Cast Iron	Structural Steel	Titanium Alloy	Polyethylene
1	Density (Kg/m^3)	7200	7850	4620	950
2	Ultimate Strength (MPa)	240	250	1070	33
3	Young's Modulus (MPa)	1.1e05	200000	96000	1100
4	Poisson Ratio	0.28	0.30	0.36	0.42
5	Bulk Modulus (MPa)	83333	16667	114290	2291.7

Table 1: Various Materials Properties for FEM

II. SIMULATION MODELS

1. Single Track Vehicle Model:

Simulation test based on single track vehicle model is

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)

Vol 5, Issue 1, January 2018

conducted to confirm the validity of the above mentioned model matching function. An object-oriented multi-physics modelling language Modelica is developed for the simulation model. Definition of the time-varying state-space method is straightforward.

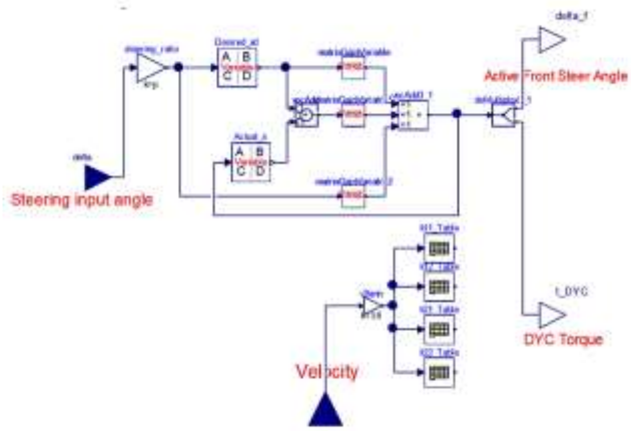

Figure 4: Modelica Model of the Controller

Figure 4 shows the model matching controller Modelica diagram using single-track vehicle model. The definition of the time differing linear state system of both plant and desired dynamics as mentioned above [10].

III. CONCLUSION

SNCM4320 material strength, Tensile strength is 1127 Mpa, approximately 60% (676Mpa) of tensile strength is measured as flexural strength. Carburizing heat treatment surface can increase the compressive strength to 1760 Mpa. Based on the results of the above data and analysis, it may be known to use the same mathematical model forging bevel gear as the product. The findings of the experiment are consistent with the material strength, and found that Gear strength will be greater than theoretical gear strength by adjusting the tooth surface of the double tooth and the R angle of the tip of the tooth and the bottom of the gear. In the initial design, theoretical calculation of gear strength, and confirm the material strength, the theoretical gear strength can be determined to meet the material strength. The actual resistance of the gears produced will also match the material strength. It is inferred from the Finite Element Analysis that the Grey Cast Iron crown gear and pinion assembly is most useful when compared with other material assemblies. Therefore, it is good agreement that, when considering the Crown Gear and Pinion Assembly, the gray cast iron content is most effective as opposed to Structural Steel, Titanium Alloy and Polyethylene.

REFERENCES

[1] T. Tamamoto, K. Sayama, and K. Koganezawa, “Multi-joint gripper with Differential Gear System,” in *IEEE International Conference on Intelligent Robots and Systems*, 2014, doi: 10.1109/IROS.2014.6942534.

[2] S. He, Q. Jia, G. Chen, and H. Sun, “Modeling and dynamic analysis of planetary gear transmission joints with backlash,” *Int. J. Control Autom.*, 2015, doi: 10.14257/ijca.2015.8.2.16.

[3] M. Bozca, “Transmission error model-based optimisation of the geometric design parameters of an automotive transmission gearbox to reduce gear-rattle noise,” *Appl. Acoust.*, 2018, doi: 10.1016/j.apacoust.2017.10.005.

[4] C. Zhou, Z. Li, B. Hu, H. Zhan, and X. Han, “Analytical solution to bending and contact strength of spiral bevel gears in consideration of friction,” *Int. J. Mech. Sci.*, 2017, doi: 10.1016/j.ijmecsci.2017.05.010.

[5] J. Liang and L. Xin, “Dynamic simulation of spiral bevel gear based on solidworks and adams,” *J. Theor. Appl. Inf. Technol.*, 2013.

[6] Y. Zhang, H. Yan, and T. Zeng, “Cutting principle and tooth contact analysis of spiral bevel and hypoid gears generated by duplex helical method,” *Jixie Gongcheng Xuebao/Journal Mech. Eng.*, 2015, doi: 10.3901/JME.2015.21.015.

[7] P. Duanmu, L. Wang, H. Xia, H. Zhao, and Y. Dong, “Dynamic contact simulation and fatigue analysis of a differential gear,” *Yingyong Lixue Xuebao/Chinese J. Appl. Mech.*, 2014, doi: 10.11776/cjam.31.04.B070.

[8] Z. Wang, W. Liu, Q. Liu, J. Tao, T. Wang, and Y. Chen, “Contact fatigue analysis of gear transmission system of drive axle final drive of truck,” in *IOP Conference Series: Materials Science and Engineering*, 2019, doi: 10.1088/1757-899X/612/3/032186.

[9] H. Dong, Z. Fang, Z. Fang, and X. Zhao, “Nonlinear characteristics of herringbone gear four-branching transmission considering gear backlash effect,” *Jixie Qiangdu/Journal Mech. Strength*, 2017, doi: 10.16579/j.issn.1001.9669.2017.05.020.

[10] P. Y. Wang and K. L. Liu, “Analysis and design of differential bevel gear,” in *Proceedings of the 2018 IEEE International Conference on Advanced Manufacturing, ICAM 2018*, 2019, doi: 10.1109/AMCON.2018.8615103.