



International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.699

Volume 14, Issue 9, September 2025

Material Optimization of Differential Gear Box Mechanism by using FEA

Shaikh Mujib Amirsahab¹, Dr. Abhay Pawar²

PG Student, International Centre of Excellence in Engineering and Management, Ch. Sambhajinagar,
Maharashtra, India¹

Associate Professor, International Centre of Excellence in Engineering and Management, Ch. Sambhajinagar,
Maharashtra, India²

ABSTRACT: The angular velocity of a differential is the average of the angular gears, which is a characteristic of a specific kind of basic planetary gear train. During a turn, the outer drive wheel can rotate more quickly than the inner drive wheel thanks to the differential gear mechanism. This thesis's primary goal is to concentrate on the mechanical design and analysis of gearbox assembly when power is transmitted at various loads, such as 2000 N, 3000 N, and 4000 N. All of the differential's components are modelled and designed under static conditions in the current work to minimize overstressing. Journal articles and the company handbook provide the necessary information. All parts' detailed drawings are provided. Altering the gears' materials—2014 aluminium alloy, alloy steel, beryllium S-65, nickel alloy, and titanium CP-TI—is another way to perform analysis.

KEYWORDS: Gear Box, FEA, Transmit Power, Aluminium Alloy, Alloy Steel, Beryllium S-65, Nickel Alloy, Titanium CP-TI.

I. INTRODUCTION

Finite Element Analysis (FEA) software is used to simulate stress, deformation, and vibration in different materials under operating loads in order to find materials that offer the best balance of strength, weight, and stiffness. This improves performance, lowers costs, and allows for lighter designs without sacrificing durability. This process is known as material optimization of a differential gearbox. A 3D CAD model is usually created, static and modal studies are carried out, findings from various materials, such as cast iron, steel, or aluminium alloys, are compared, and the FEA is validated using testing data. A differential is a specific kind of planetary gear train that is made so that the average of the angular velocities of the sun and ring gears is equal to the angular velocity of its carrier. This mechanical principle is widely used in a variety of industries, such as mechanical design, aerospace engineering, and automotive systems. The differential gear arrangement is set up to maintain a fixed carrier train ratio of $R = -1$ in order to support this averaging function. This ratio implies symmetric gear interactions since the sun and ring gears are of similar size [1].

II. LITERATURE SURVEY

By attempting to decrease weight, increase energy economy, and boost overall performance, this research aids in the creation of more effective differential gearboxes. Manganese Chromium alloy steel (17Mn1Cr95) showed favourable structural behaviour under stress testing among the materials evaluated. At all evaluated rotational speeds—2400 rpm, 1600 rpm, and 1000 rpm—the analysis showed that this alloy had substantially lower values of stress, strain, and deformation than both Carbon Steel and Nickel Chromium Alloy. According to these findings, manganese chromium alloy can be utilized in differential gears with confidence and without worrying about structural failure [2]. In every mechanical system, the gearbox is essential. To extend the life of the internal gears and bearings, the gearbox housing's vibrations must be kept to a minimum. There is a lot of room for development in this area, according to earlier research. The most widely used technique for determining the morphologies of vibration modes is finite element analysis (FEA). The main tool used for virtual prototyping is ANSYS software. Additionally, researchers have compared the outcomes of various simulation tools, and some have used specialized equipment to perform physical

testing. Furthermore, a lot of research uses FFT analysers to verify the simulation results. Overall, the simulated results and experimental observations show a significant correlation [3].

According to R. Karthick, V. Mohan Kumar, and associates, tippers are essential to logistics, and modern infrastructure and enterprises rely significantly on vehicles for the movement of commodities. The differential is an essential part of these cars since it transfers torque from the engine to the back wheels, particularly when there is a lot of load on them. Specifically, Ashok Leyland tippers use a twin rear axle and dual differential system. Despite being built to support large loads, this configuration may fail under severe stress. The current study attempts to improve the differential system's performance and longevity in order to overcome these issues. It concentrates specifically on the design and study of the rear axle differential's crown wheel and pinion, which are composed of G-45 forged steel. The goal is to use CATIA V5 software to create an accurate geometric model of these components. The geometry is then refined and a detailed finite element mesh is produced using HyperMesh 12. To assess deformation and stress fluctuations in the differential assembly, ABAQUS software is used for the finite element analysis. This analytical method aids in predicting probable failure points and evaluating strength characteristics. In the end, this study encourages design optimization to guarantee the differential's long-term dependability and performance under challenging operating circumstances [4].

III. METHODOLOGY

The number of teeth, gear ratio, stress, and strain (deformation) were the design variables used to optimize the optimal material for the differential gear box mechanism. Differential gearbox failure brought on by certain material qualities not being present at a given load. The pinion served as the basis for the design process. As a result, the tooth of the gear was determined by the ratio of the tooth of the pinion to the gear. The design width factor, which ranges from 20 to 40 according to recommendations, was taken into account while determining the face width in the beginning. Solid Works was used to finish the modeling. Solid Works is a mechanical design automation program that utilizes the well-known graphical user interface of Microsoft Windows.

3.1 Modeling

Solid Works was used to finish the modeling. Solid Works is a mechanical design automation program that utilizes the well-known graphical user interface of Microsoft Windows. Mechanical designers may quickly sketch ideas, experiment with features and proportions, and create models and detailed drawings with this simple-to-learn application.

3.2 SOLID WORKS

A feature-based, parametric solid modeling design tool, Solid Works Mechanical Design Automation software benefits from an intuitive Windows TM graphical user interface. In order to capture design intent, we can generate completely associated 3-D solid models with or without the usage of automatic or user-defined relations.

3.3 Meshing & Simulation

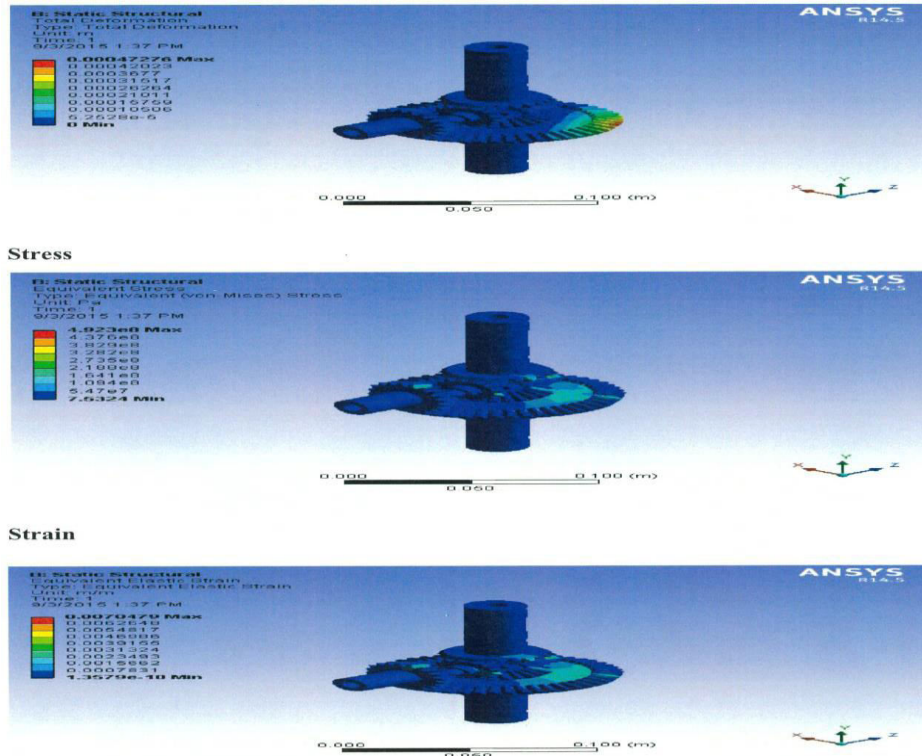
A design analysis tool that is completely integrated with FEM packages is called Ansys Simulation. For linear and nonlinear static, frequency, buckling, thermal, fatigue, pressure vessel, drop test, linear and nonlinear dynamic, and optimization investigations, Ansys Simulation offers simulation solutions.

3.4 Analysis Report by Ansys software

Material-2014 alloy

Load-2000N

Deformation



IV. RESULT & DISCUSSION

4.1 Graphs between Software Result & Analytical Result Graph for load VS Deflection

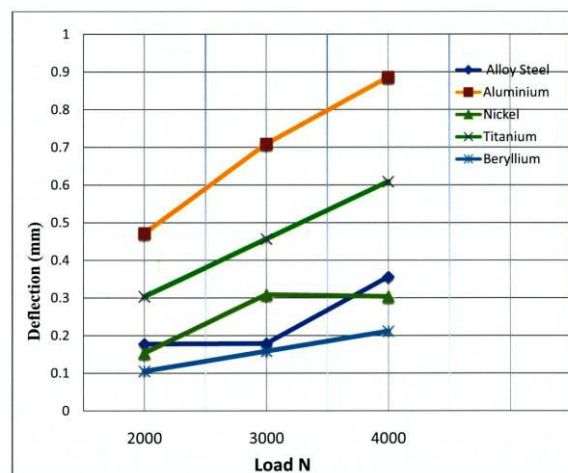


Fig. 4.1 Graph load VS Deflection

Figure 4.1 above illustrates that, under specified loading conditions, the deflection in the 2014 aluminum alloy is greater than that of other materials taken into consideration. Because of its potential to sustain loads, the Beryllium S-65 alloy exhibits less deflection than other materials under consideration. The alloy steel next to the beryllium S-65 alloy in 2014 AL alloy > Titanium > Alloy Steel > Beryllium S65 also exhibits deflection.

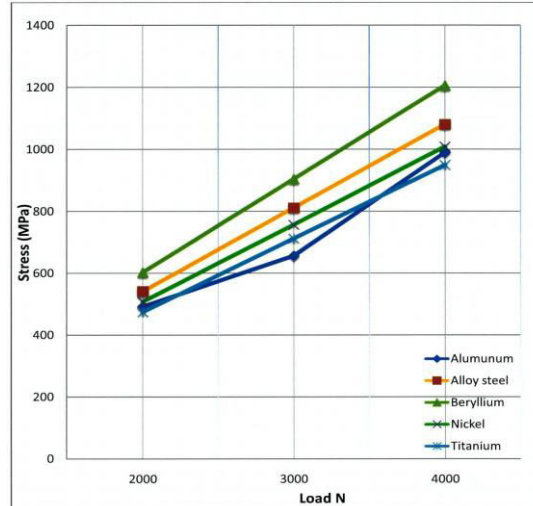


Figure 4.2: Stress vs. Load Graph

As seen in Figure 4.2 above, the stress generated is greater than that of other specified materials when loading parameters are taken into account. Compared to the other materials included in the investigation, titanium experiences less stress. The alloy steel is under a moderate amount of tension.

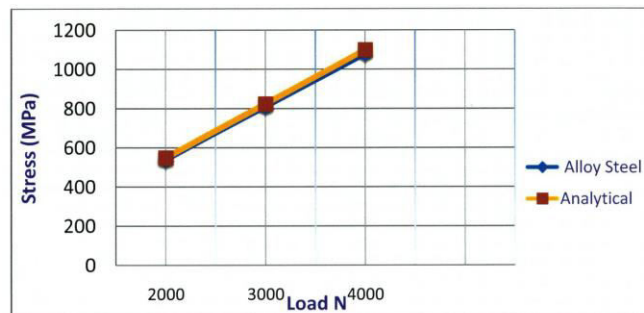


Fig. 4.3 Graph load VS Deflection Formed

In above figure the alloy steel shows less deviation between software result (simulation) and analytical result

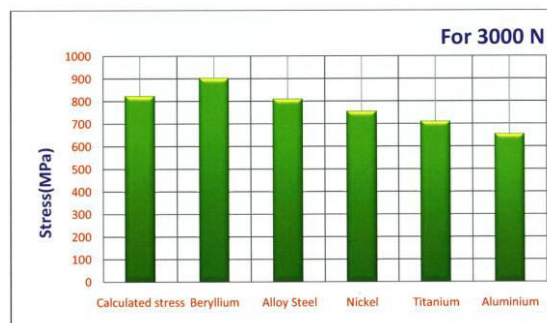


Fig. 4.4 Graph Analytical load VS All material

5.2% error with respect to analytically calculated stress values

| Load Material | 2000 N | Relative Stress | 3000 N | Relative Stress | 4000 N | Relative Stress |
|-------------------|--------|--------------------|--------|--------------------|--------|--------------------|
| Alloy Steel | 541.7 | -1.49 | 811.07 | -1.6 | 1080.7 | -1.74 |
| 2014 Al alloy | 492.03 | -10.53 | 656.4 | -20.43 | 989.7 | -18.29 |
| Beryllium S-65 | 603.2 | 9.68 | 904.5 | 9.65 | 1206.0 | 9.65 |
| Nickel Alloy | 508.2 | -7.59 | 756.7 | -8.27 | 1009.1 | -8.6 |
| Titanium | 474.7 | -13.68 | 712.1 | -13.64 | 949.5 | -13.67 |

Table No. 22 % error with respect to analytically calculated stress values

- The percentage error with regard to analytically determined stress values is displayed in the above table.
- Alloy steel has a lower percentage of error under all specified loading circumstances.
- Alloy steel is more appropriate since the maximum and minimum deviations are +5% with analytically estimated stress permitted.

V. CONCLUSION

The current study effectively illustrates how Finite Element Analysis (FEA) may be used to optimize a differential gearbox mechanism's structural performance and material choice. It is clear by examining stress distribution, deformation, and weight-to-strength ratio that material optimization greatly improves the gearbox system's longevity and efficiency. Using software findings, analytical results, and a graphical method, it can be seen that titanium and alloy steel have lower stress levels than the other two. Compared to 2014 alloy metal and alloy steel, titanium has lower stress values. However, titanium is more expensive than the other two materials. The alloy steel exhibits lower values of stress and deformation. It is heavier than titanium.

A thorough understanding of the mechanical behaviour of many materials under simulated real-world situations has been made possible by the application of FEA. High strength-to-weight ratio materials among those under evaluation demonstrated encouraging outcomes in terms of lowering total weight while preserving or raising performance requirements. This research helps with cost reduction, improved fuel efficiency (in automotive applications), and assistance in addition to demonstrating the usefulness of simulation technologies like FEA in mechanical design.

REFERENCES

- [1] Asso. Prof. Rahul D. Shelke and Pathan Ikhamkha Sharifkha, "A Comprehensive Study on the Design and Analysis of a Differential Gearbox", International Journal of Creative Research Thoughts (IJCRT), Volume 13, Issue 5 May 2025.
- [2] Saravanan, Sai Muthuswami.S, et al. "Design and Analysis of Differential Gearbox drive for Automobiles", International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET), Volume 10, Issue 4,3212-3218, Apr 2021.
- [3] Toshita Dhande, R. B. Patil, et al. "Design Optimization and Analysis of Industrial Gearbox Casing to Reduce Wear of Gear and Bearings Due to Vibrations: Review", International Journal of Science and Research (IJSR), Volume 5, Issue 5, 2043-2045, May 2016.
- [4] R. Karthick, V. Mohankumar, et al., "Design And Analysis Of Differential Gear Box", International Journal of Creative Research Thoughts (IJCRT), Volume 6, Issue 1, 388-393, Feb 2018.
- [5] J.O.Nordiana, S.O.Ogbeide, N.N. Ehigiamusoe and F.I.Anyasi., 2007, "Computer aided design of a spur gear, "Journal of Engineering and Applied Sciences 2 (12); pp 1743 1747.

- [6] Ratnadeepsinh M. Jadejal, Dipeshkumar M. Chauhan whenever "Bending Stress Analysis of Bevel Gears" IJIRSET/ Vol. 2/ Issue 7 July 2013/3041-3046.
- [7] Abhijeet V. Patil, V. R. Gambhire "Analysis of bending strength of bevel gear by FEM" IJIRAE/Vol.1/Issue 6 July 2014/424-429.
- [8] Mohd Abbas, Sanjeev Sharma, Vinit Kumar Sharma "Study of Differential Bevel Gear Through Machining Method" IJETR/Vol.1/ Issue 3 May 2013/
- [9] Nitin Kapoor¹, Virender Upneja², Ram Bhool³ and Puneet Katyal Design And Stress Strain Analysis Of Composite Differential Gear Box "IJSETR/ Vol. 3/ Issue 7 July 2014/1881-1894.
- [10] Maitra, G.M, 2004, Hand Book of Gear Design, Tata McGrawHill, New Delhi. \
- [11] Richard G. Budynas, Shigley's Mechanical Engg Design ninth edition, page no. 734-737/800-808.
- [12] Robert C. Juvinall's Machine Component Design fifth edition, page no. 688-694.
- [13] Faydor L. Litvin, Alfonso Fuentes, New Design and Improvement of Planetary Gear Trains, Nasa/Cr-2004-213101, Arl-Cr-0540
- [14] Lei Wang, Jiancheng Yang & Xiaoqin Han, 2009, "The Performance Study of Hybrid-driving Differential Gear Trains", Modern Applied Science, vol. 3, No. 9, page No 95-102.
- [15] O.C. Zienkiewicz, R.L. Taylor's Elsevier Finite element method sixth edition, page no. 122-125/264-324.



INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details