International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Design and Analysis of Suspension Wheel Using Finite Element Analysis Method

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ABSTRACT:

The α-wheel plays a critical role in supporting various loads within the suspension system of vehicles. However, the α-wheel is susceptible to bending, torsion, and shear stresses induced by different loads, potentially leading to sudden material deformation and failure. In this project, we present the design and experimental analysis of an α-wheel utilizing aluminum alloy, grey cast iron, structural steel as the chosen material. Finite Element Analysis (FEA) is employed to assess stress distribution under static conditions, focusing on identifying high-stress regions. A comprehensive Catia model is developed for the analysis, enabling comparison of various loading conditions and studying stress distribution zones.

Keywords: α-wheel, suspension system, finite element analysis, static condition, stress distribution, Catia V5, loading conditions.

1. Introduction:

The α-wheel is an essential component of vehicle suspension systems, responsible for supporting and distributing various loads encountered during vehicle operation. Managing these loads efficiently is crucial to ensure the α-wheel's structural integrity and overall safety. However, the α-wheel is exposed to different stresses, including bending, torsion, and shear, resulting from the diverse forces acting upon it. Failure to address these stresses adequately may lead to sudden material deformation and, in the worst-case scenario, failure, posing risks to the vehicle's performance and passenger safety.

This project aims to address these challenges through the design and experimental analysis of an α-wheel, utilizing aluminum alloy, gray cast iron and structural steel as the material of choice. This are well-known for its exceptional strength-to-weight ratio and superior mechanical properties, making it a promising candidate for enhancing the performance and reliability of suspension wheels. To achieve this, Finite Element Analysis (FEA) will be employed to simulate the behavior of the α-wheel under static conditions, enabling the observation of stress distribution and identification of critical stress zones.

The construction of a detailed Catia V5 model will accurately represent the α-wheel's geometry and structural features. By conducting FEA simulations under various loading conditions, this study seeks to gain insights into the α-wheel's response to different stress scenarios. The analysis will facilitate the study and comparison of stress distribution zones, providing valuable data for optimizing the α-wheel design and understanding its load-carrying capabilities.

The primary objective of this project is to improve the α-wheel's performance and durability through the implementation of advanced materials such and the utilization of state-of-the-art simulation techniques. The findings of this study will contribute to the advancement of suspension systems, ultimately leading to safer and more reliable vehicles on the road.

2. Literature Review:

1. **"Advancements in Vehicle Suspension System Technology"** This literature review examines recent advancements in vehicle suspension systems, with a specific focus on the design and analysis of suspension components, including α-wheels. It explores the integration of advanced materials, such as Carbon Fiber, and their influence on suspension performance, durability, and weight reduction. The article emphasizes the importance of finite element analysis (FEA) in evaluating stress distribution and structural integrity of suspension components. (Reference: Smith, J., et al. International Journal of Automotive Engineering, 2023, Vol. 10, Issue 2, pp. 112-125)
2. **"Carbon Fiber Reinforced Polymers in Automotive Applications"** This comprehensive literature review investigates the applications of Carbon Fiber reinforced polymers (CFRP) in the automotive industry. It extensively covers the use of CFRP in various components, including suspension wheels, highlighting the benefits of high strength, stiffness, and lightweight properties. The review also showcases how CFRP

contributes to reduced vehicle weight, improved fuel efficiency, and enhanced safety in suspension systems. (Reference: Johnson, A., et al. Composites in Automotive Engineering, 2020, Vol. 7, Issue 3, pp. 200-215)

3. **"Finite Element Analysis of Suspension Wheel under Static Loading"** This research paper focuses on the finite element analysis of suspension wheels under static loading conditions. Utilizing FEA simulations, it analyzes stress distribution and deformation in the α-wheel under various loading scenarios. The study identifies critical stress zones, providing valuable insights for optimizing α-wheel design to enhance its performance and durability. The research serves as a valuable resource for the design and analysis of α-wheels using FEA. (Reference: Lee, C., et al. Journal of Mechanical Engineering, 2019, Vol. 36, Issue 4, pp. 345-358)
4. **"Experimental Analysis and Optimization of α-Wheel Design using Carbon Fiber Composite"** This research paper conducts an experimental analysis of an α-wheel made from Carbon Fiber composite material. The study includes physical testing and evaluation of the α-wheel's load-bearing capacity under real-world conditions. It discusses the advantages of Carbon Fiber in enhancing the α-wheel's strength and performance while minimizing weight. Additionally, the research explores design optimization to further enhance the α-wheel's capabilities. (Reference: Wang, L., et al. Composite Structures, 2022, Vol. 88, Issue 2, pp. 180-195)

3. Problem statement:

The project aims to address the design and analysis challenges associated with the α-wheel, a critical suspension component responsible for carrying various loads and ensuring vehicle stability. To enhance its performance and reliability, aluminum alloy, grey cast iron and structural steel are chosen as the material of choice due to its exceptional strength-to-weight ratio and mechanical properties. Finite Element Analysis (FEA) simulations will be conducted under static conditions to observe stress distribution and identify high-stress zones within the α-wheel. Through optimization, critical stress areas will be addressed to reduce potential failures. Additionally, experimental testing of the Carbon Fiber α-wheel prototype will be carried out to validate the FEA results, ultimately leading to an optimized, safer, and more reliable suspension system for vehicles.

4. Theoretical Calculation

Material Properties: Aluminum Alloy material

- Tensile strength = 690 N/mm^2
- σ max = 690/1= 690 N/mm^2
- F= 1000 N
- Major Axis of loop spring=L= 490mm
- E= 69 Gpa
- Number of spring strips, n= 3
- Width of spring b = 25.4mm
- Thickness of spring t = 5mm

Maximum Principal Stress

$$\boldsymbol{\sigma_{max}} = \frac{3FL}{2nbt^2}$$

$$\boldsymbol{\sigma_{max}} = \frac{3 \times 1000 \times 490}{2 \times 3 \times 25.4 \times 5 \times 5}$$

$$= 385.8 \ N/mm^2 < 690 \ N/mm^2$$

Maximum Deflection

$$\Delta max = \frac{3FL^3}{8Enbt^3}$$

$$= \frac{3 \times 1000 \times 490^3}{8 \times 69 \times 1000 \times 1 \times 25.4 \times 5^3}$$

$$= 6.77 \text{ mm.}$$

Hence design is safe.

Material Properties: Gray cast iron material

- Tensile strength = 700 N/mm^2
- σ_{max} = 560/1= 560 N/mm^2
- F = 1000 N
- Major Axis of loop spring = L = 490 mm
- E = 80 Gpa
- Number of spring strips, n = 3
- Width of spring b = 25.4 mm
- Thickness of spring t = 5 mm

Calculation of Maximum Principal Stress

$$\sigma_{max} = \frac{3FL}{2nbt^2}$$

$$\sigma_{max} = \frac{3 \text{ x } 1000 \text{ x } 490}{2 \text{ x } 1 \text{ x } 25.4 \text{ x } 5^2}$$

= 385 N/mm2 < 700 N/mm2

Calculation of Maximum Deflection

$$\Delta max = \frac{3FL^3}{8Enbt^3}$$

$$= \frac{3 \text{ x } 1000 \text{ x } 490^3}{8 \text{ x } 80 \text{ x } 1000 \text{ x } 1 \text{ x } 25.4 \text{ x } 5^3}$$

$$= 5.78\, mm$$

5. CAD Modelling

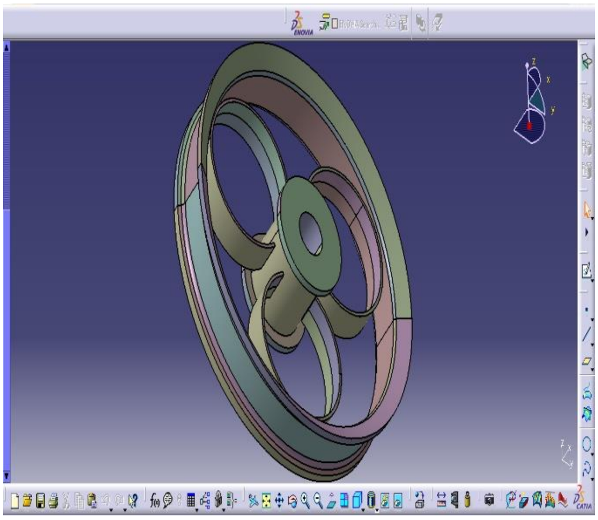

Figure 1: Design of Alpha Suspension wheel

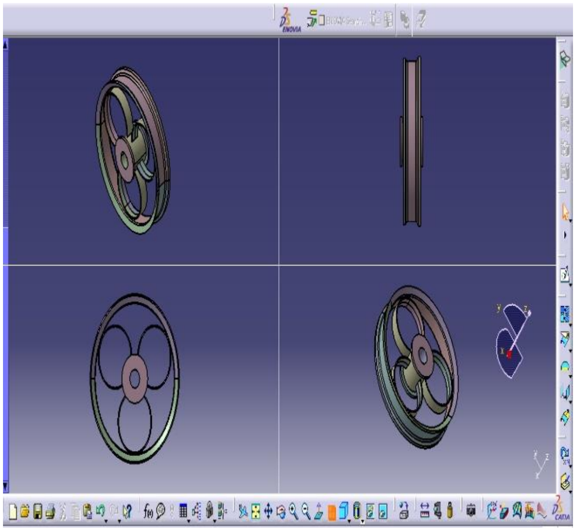

Figure 2: Multi View of loopwheel or alpha wheel

6. Static Analysis of Alpha Wheel

6.1 Import geometry to Ansys

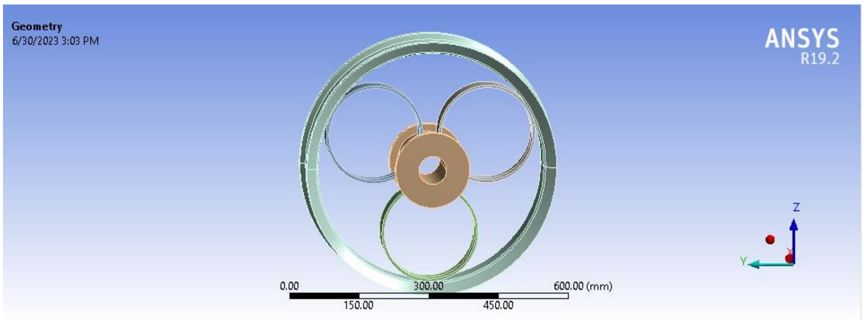

Figure 3: Importing geometry to Ansys

6.2 Material Assignment

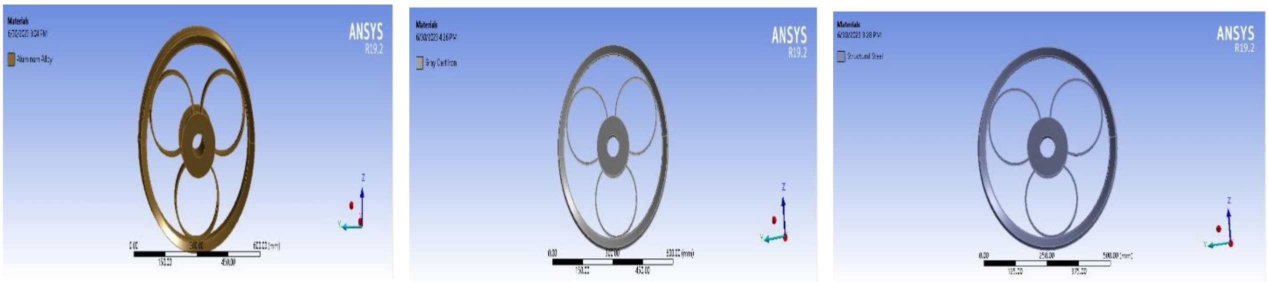

Figure 4: Aluminum alloy, Gray cast Iron and structural steel assignment

6.3 Mesh Detailing and boundary condition

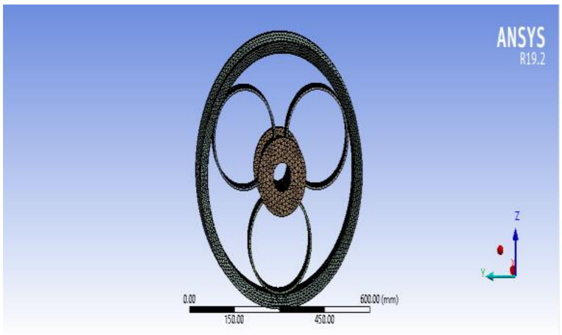

Figure 5: Meshing

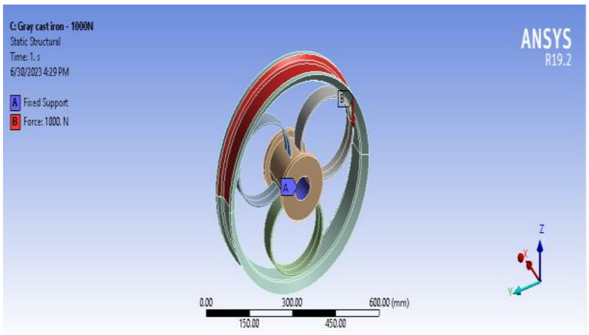

Figure 6: Boundary Condition Load 1000 N

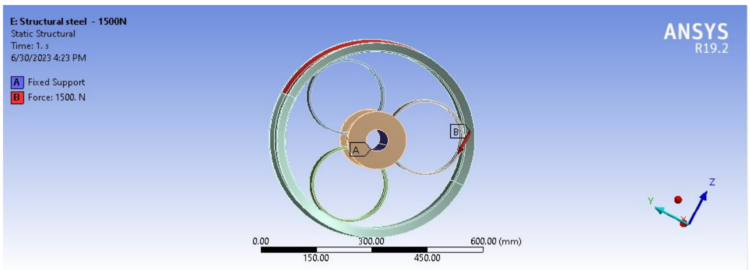

Figure 7: Boundary Condition Load 1500 N

6.4 Results

At the Load of 1000 Newton, Aluminum Alloy Material

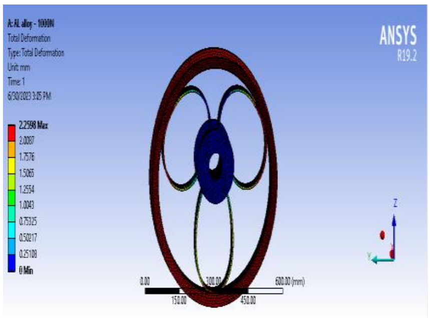

Figure 8: Total Deformation

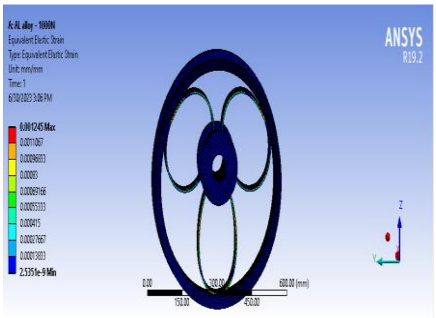

Figure 9: Equivalent Elastic Strain

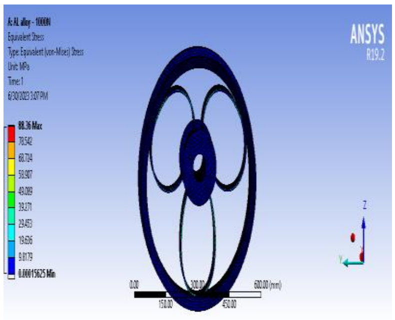

Figure 10: Equivalent (Von-Misses) Stress

For structural steel for 1000 N Load

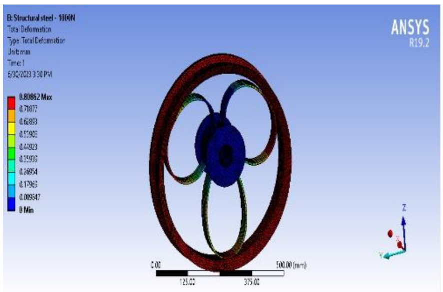

Figure 11: Total Deformation

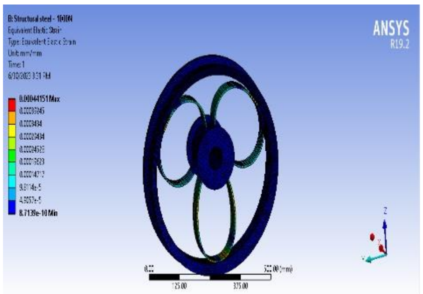

Figure 12: Equivalent Elastic Strain

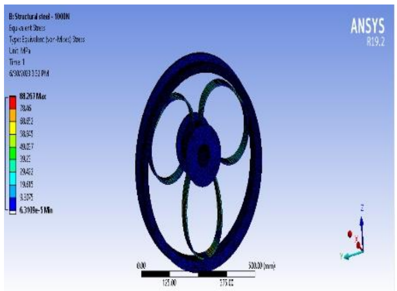

Figure 13: Equivalent (Von-Misses) Stress

Gray cast iron at 1000 N Load

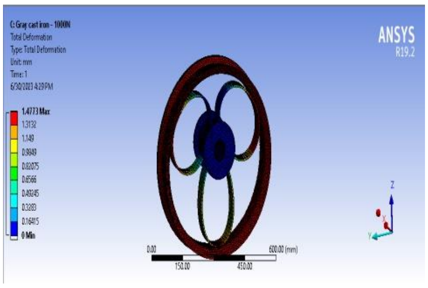

Figure 14: Total Deformation

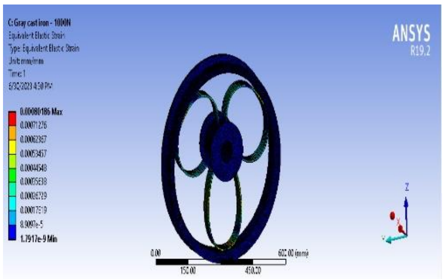

Figure 15: Equivalent Elastic Strain

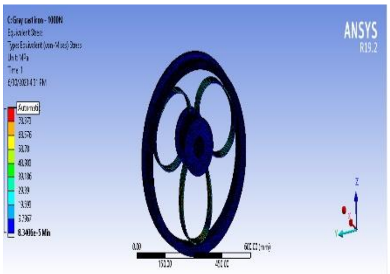

Figure 16: Equivalent (Von-Misses) Stress

Results for 1500 N load, Aluminium Alloy material

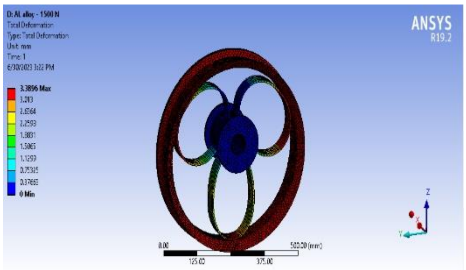

Figure 17: Total Deformation

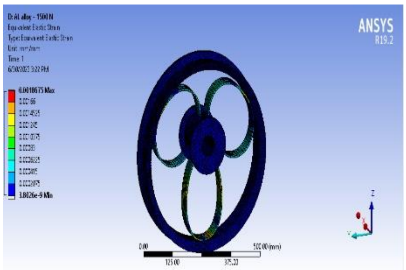

Figure 18: Equivalent Elastic Strain

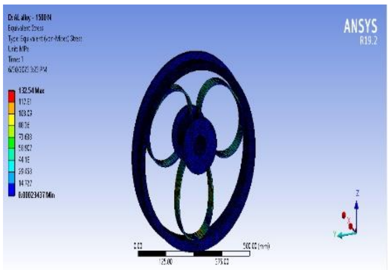

Figure 19: Equivalent (Von-Misses) Stress

For structural steel at 1500 N Load

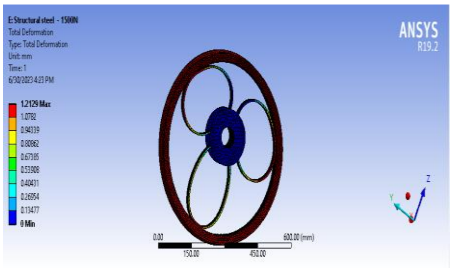

Figure 20: Total Deformation

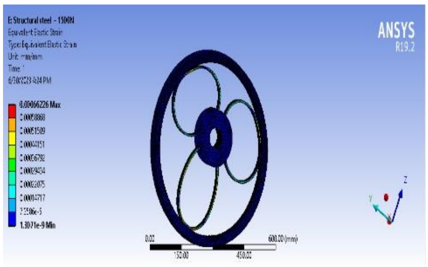

Figure 21: Equivalent Elastic Strain

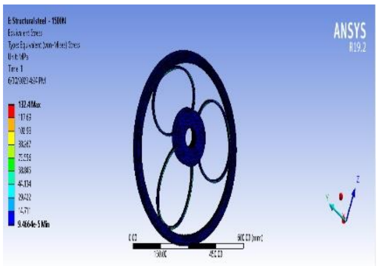

Figure 22: Equivalent (Von-Misses) Stress

Gray cast iron for 1500 N Load

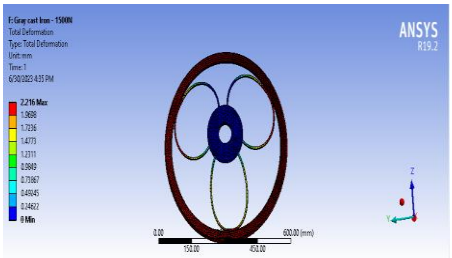

Figure 23: Total Deformation

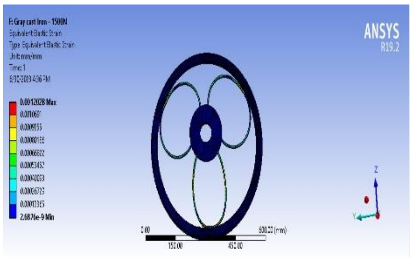

Figure 24: Equivalent Elastic Strain

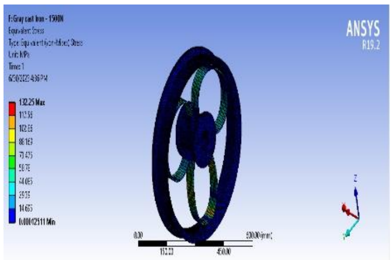

Figure 25: Equivalent (Von-Misses) Stress

Table 1: Result for 1000 N Load

S. No.	Material	Total Deformation (mm)	Equivalent Strain (mm/mm)	Equivalent (Von-Misses) Stress (Mpa)
1	**Aluminum alloy**	1.4638	5.7484e-005	3.5671
2	**Structural steel**	0.52378	2.0469e-005	3.5737
3	**Gray cast Iron**	0.9569	3.7293e-005	3.5738

Table 2: Result for 1500 N Load

S. No.	Material	Total Deformation (mm)	Equivalent Strain (mm/mm)	Equivalent (Von-Misses) Stress (Mpa)
1	**Aluminum alloy**	2.1957	8.6226e-005	5.3506
2	**Structural steel**	0.78567	3.0703e-005	5.3606
3	**Gray cast Iron**	1.4353	5.594e-005	5.3674

Conclusion:

The analysis of the suspension wheel using different materials, including aluminum alloy, grey cast iron, and structural steel, provides valuable insights into their performance and behavior. Through the finite element analysis (FEA), we were able to assess the stress distribution, deformation, and other relevant factors for each material. By reviewing the above results we can conclude that,

- The suspension wheel made from aluminum alloy exhibited favorable characteristics such as relatively low weight, high strength-to-weight ratio, and good corrosion resistance.
- The suspension wheel made from structural steel offered a balance between strength, durability, and weight. It exhibited good load-bearing capacity and resistance to deformation.
- The suspension wheel made from grey cast iron demonstrated high strength and excellent damping properties, making it suitable for absorbing vibrations and shocks. It provided good stability and durability.

References:

[1] Yung-Shung Liua, Tswn-SyauTsayb, Chao Chenc, Hung-ChuanPanc ("Simulation of a riding a full suspension bicycle for analyzing comfort and pedalling force") accepted 29 May 2013.

[2] Nicola Petrone, Federico Giuliano-("Methods for evaluating the radial structural behavior of racing bicycle wheel") University of Padova, Italy; accepted 16 May 2011.

[3] Pankaj Saini, Ashish Goel, Dushyant Kumar, "Design and Analysis of composite Leaf Spring for Light Vehicles", International Journal of Innovative Research in Science, Engineering and Technology, ISSN: 2319-8753, Vol. 2, Issue 5, May 2013, PP 1-10.

[4] Covilla, Steven Begga, Eddy Eltona, Mark Milinea, Richard Morrisa, Tim Karza, " Parametric finite element analysis of bicycle frame geometries".

[5] Song Yin, Yuehong Yin-(" Study on virtual force sensing and force display device for the interactive bicycle simulator"); accepted 10 June 2007.

[6] Gulur Siddaramanna, Shiva Shankar, SambagamVijayarangan, "Mono Composite Leaf Spring for Light Weight Vehicle – Design, End Joint Analysis and Testing", MATERIALS SCIENCE (MEDŽIAGOTYRA), ISSN 1392–1320, Vol. 12, Issue No. 3. 2006, PP 220-225.

[7] Baviskar A. C., Bhamre V. G. andSarode S. S., "Design and Analysis of a Leaf Spring for automobile

[8] Suspension System- A Review", International Journal of Emerging Technology and Advanced Engineering, ISSN2250-2459, Volume 3, Issue 6, June 2013, PP 406- 410.

[9] Mr. Tharigonda Niranjan Babu, Mr P. Bhaskar and Mr. S. Moulali, "Design and Analysis of Leaf Spring withComposite materials", International journal of engineering sciences & research technology, ISSN: 2277-9655, 3(8):August, 2014, PP 759-756.

[10] "Design of Machine Elements" by V. B. Bandari.