Comparative Analysis of Swing Arm Materials for Suspension System Using CATIA and ANSYS

Putti Venkata Siva Teja[1], Sasubilli Appala Naidu[2], Tatipamula Sri Harsha [3], Patan Yousaf Khan[4], and Munnalauri Ratna Kumar[5]

[1,2,3,4,5]*Dhanekula Institute of Engineering & Technology, Ganguru, Vijayawada, Andhra Pradesh, India, 521139*

***Abstract*— This study focuses on designing, modeling, and analyzing a swing arm for a suspension system using CATIA software, followed by Finite Element Method (FEM) analysis in ANSYS. The materials examined include AL-7075, Cr-Mo Alloy, STEEL AISI 4340, and INCONEL 718. The analysis evaluates von Mises stress, total deformation, shear strain, and equivalent elastic strain for each material to assess their mechanical performance. The results reveal that AL-7075, Cr-Mo Alloy, and STEEL AISI 4340 exhibit higher values of these mechanical parameters compared to INCONEL 718. Despite this, INCONEL 718 stands out for its exceptional strength, durability, and resilience, making it highly suitable for handling heavy loads and providing reliable support in swing arm applications. However, its higher weight relative to other materials could affect the overall system performance. The study concludes that INCONEL 718 offers a well-rounded balance of mechanical properties, including the ability to return to its original shape after deformation, along with cost-effectiveness and availability. Therefore, it is recommended as the preferred material for the swing arm, considering its superior strength, durability, and practicality in real-world applications.**

***Index Terms*— AL-7075, Cr-Mo Alloy, STEEL AISI 4340, and INCONEL 718.**

I. INTRODUCTION

Extensive research has been conducted on the design and analysis of motorcycle swing arms, exploring various materials, optimization techniques, and performance requirements. Studies show that topology optimization is effective in reducing weight and improving stiffness, as demonstrated in swing arms for electric motorcycles and superbikes [1,3,6,7]. Carbon fiber composites have gained attention for their superior stiffness-to-weight ratio compared to traditional aluminum [2,4,5]. Reviews highlight the significance of material selection, with aluminum alloys, carbon fiber, and advanced composites being widely used for lightweight and durable designs [9,12,20]. Optimization techniques, including genetic algorithms and metaheuristic approaches, have further enhanced swing arm performance [7,13,14]. Computational simulations and experimental testing are critical for validating dynamic behavior and structural integrity [14,15]. Recent advancements also focus on additive manufacturing, sustainability, and the integration of eco-friendly materials [18,19,20]. Applications in sports, high-performance, and electric motorcycles emphasize stiffness, handling, and energy efficiency [8,10,16,17]. Comprehensive reviews underline the impact of manufacturing processes and material advancements on the evolving design methodologies for swing arms [11,17,19].

II. PROBLEM IDENTIFICATION

Swing arms often fail due to the multi-axial loads applied at their connection points during prolonged use, leading to stress concentration and eventual structural failure. These failures are exacerbated by forces encountered during braking and cornering. To address these issues, this study leverages ANSYS software for structural analysis to identify stress concentration areas. Insights from this analysis are utilized to optimize the design for improved durability and load-handling capability. Existing swing arms were analyzed under realistic load conditions to understand failure patterns and areas prone to high stress. Material properties, as detailed in Table 1, were a critical aspect of this evaluation. Identifying critical regions aids in enhancing the strength and performance of the swing arm, preventing premature failure and improving overall vehicle safety.

III. OBJECTIVES AND METHODOLOGY

The primary goal is to develop a durable and efficient swing arm chassis. This involves gathering data on existing designs, material properties, and loading conditions. Materials such as AL-7075, Cr-Mo Steel, AISI 4340, and Inconel 718, whose properties are summarized in Table 1, were analyzed for their strength, stiffness, and cost-effectiveness. A fully parametric 3D model was created in CATIA, enabling easy modifications for design optimization. Static analysis was conducted using ANSYS 23 to simulate stress, strain, and deformation under operational conditions. The results were compared across the materials in Table 1 to evaluate their suitability. Based on the comparative study, recommendations were made for the optimal material and design improvements, focusing on enhanced performance and reduced costs.

TABLE: 1 MATERIAL PROPERTIES

Materials	Density (Kg/m^3)	Possions ratio (μ)	Youngs modulus (GPA)	UTS (MPA)
AL-7075	2810	0.33	71	570
Cr-Mo Alloy	7850	0.3	200	700
STEEL AISI4340	7850	0.27	200	745
INCONEL 718	8170	0.33	210	1375

IV.BRAKING CALCULATIONS

Braking condition

Braking is one of the important criteria in design on motorcycle components. During braking, different Components are subjected to variation in loads in magnitude as well as direction. In case of swing arm, high lateral forces act in unbalanced state.

Loads and boundary conditions-

It is assumed that weight of a sports bike200 kg and weight of a rider is 75 kg so combine them to get mass of a vehicle (m) is a 275 kg

i. Normal force F Normal =m*g

Where: Mass of a vehicle (m) is a 275 kg Acceleration due to Gravity g=9.81 m/s2

F Normal =275 kg *9.81 m/s2 F Normal = 2695 N

Assuming a coefficient of friction (μ) of, for example, 0.7 (typical for dry road conditions), use the braking force formula:

ii. F brake =μ × F Normal

F brake =0.7×2695 N =1886.5 N

Thus, there are imbalanced forces acting during braking. For analysis, the maximum value

i.e. the braking F brake is 1886.5 N middle parts is analyzed. The inner side Swing arm will experience more force than outer one.

V. RESULTS AND DISCUSSIONS

The modeling of the swing arm for a formula car was done using CATIA software, ensuring accurate representation of critical features based on an existing design. The 3D model was followed by a multi-sectional view for detailed analysis. The model was meshed in ANSYS Workbench, resulting in 8929 nodes and 4633 elements to strike a balance between computational efficiency and accuracy. Boundary conditions, reflecting forces from braking and cornering, were applied, with load application points and support constraints identified for realistic simulations.

The static structural analysis assessed the swing arm's performance using Al 7075, Chromium-Molybdenum Alloy, Steel AISI 4340, and Inconel 718. For Al 7075, the maximum von Mises stress, total deformation, shear stress, and strain showed significant deformation under load, indicating moderate strength but lower rigidity as shown in Figure 1.

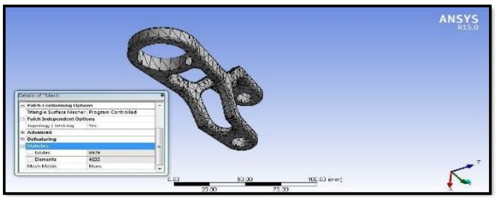

Figure 1 Catia Model Mesh: Nodes: 8929, Elements: 4633

In contrast, Cr-Mo Alloy displayed better strength with reduced deformation and shear stress, highlighting its capability to handle higher loads as shown in Figure 2.

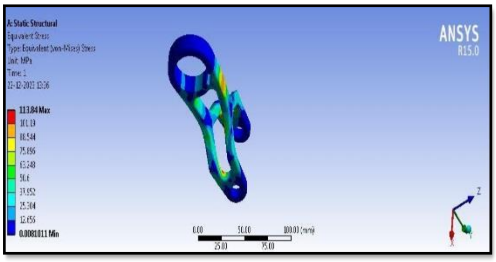

Figure 2 Vonmisses Stresses of Cr-Mo Alloy

Steel AISI 4340 further improved performance, showing even less deformation and lower shear stress as shown in Figure 3.

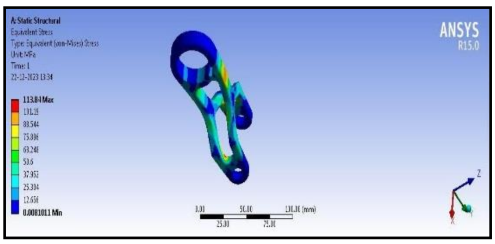

Figure 3 Vonmisses Stresses of Steel AISI 4340

Inconel 718 demonstrated the best overall performance, with minimal deformation, von Mises stress, and shear stress as shown in Figure 4.

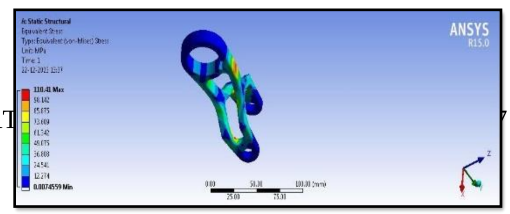

Figure 4 Vonmisses Stresses of Inconel 718

Its strain results confirmed its superior resistance to high loads, making it the most suitable material for high-performance applications. Modal analysis of Cr-Mo Alloy as shown in Figure 5 and Inconel 718 as shown in Figure 6 revealed similar first mode shapes, but Inconel 718 exhibited higher natural frequencies, indicating better vibrational stability. These findings confirmed Inconel 718 as the ideal choice for the swing arm, offering both superior static and dynamic performance.

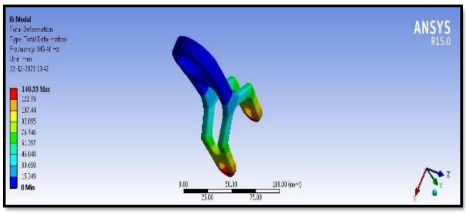

Figure 5 Modal Analysis of Cr-Mo Alloy

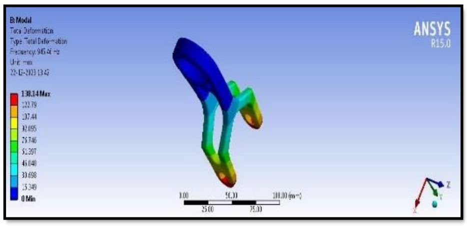

Figure 6 Modal Analysis of Inconel 718

The static structural analysis of Inconel 718 showed a lower von Mises stress of 110.41 MPa, compared to the higher value of 115.36 MPa observed for Al 7075. For equivalent elastic strains, Inconel 718 exhibited a lower strain of 0.02, while Al 7075 had a higher value of 0.001. The total deformation for Inconel 718 was 0.084 mm, significantly lower than the 0.276 mm for Al 7075. Shear stresses were also lower in Cr-Mo steel at 0.37 MPa, whereas Al 7075 showed a much higher value of 4.11 MPa.

VI. CONCLUSION

In this research, the swing arm of a suspension system was designed and analyzed using CATIA and ANSYS software. Four materials were considered for the swing arm: AL-7075, Cr-Mo Alloy, STEEL AISI 4340, and INCONEL 718. The analysis revealed that INCONEL 718 performed better in terms of von Mises stress, total deformation, shear strain, and equivalent elastic strain, making it the most durable and strong material for handling heavy loads. Despite its higher weight, INCONEL 718's resilience and ability to return to its original shape after deformation make it suitable for repeated compression and extension in the swing arm. Additionally, INCONEL 718 is widely available and cost-effective compared to other materials like AL-7075. Therefore, INCONEL 718 is recommended as the ideal material for manufacturing swing arms in suspension systems.

REFERENCES

[1] Design and Structural Analysis of a Front Single-Sided Swingarm for an Electric Three-Wheel Motorcycle (2023) by P. Stylianou, E. Chrysostomou, and N.C. Tsiokanos

[2] Design and Analysis of Swingarm Using Carbon Fiber Composite by Using Creo 2.0 and ANSYS (2020) by K. Satyanarayana, M. Sridharan, and Balamurugan

[3] Design and Analysis of Swing Arm for Performance Electric Motorcycle (2019) by S.Swathikrishnan

[4] A carbon fibre Swingarm design, (2015) by B. Smith and F. Kienhöfer

[5] Design and analysis of single sided swing arm for modified bike, (2023) by D. Balamurugan, M. Srinivasan, and M. Sridharan

[6] Recent Advances in Design and Analysis of Swing Arms for Motorcycles: A Review, (2023) by S. K. Gupta, P. K. Mishra, and M. K. Singh

[7] Application of Topology Optimization in Swing Arm Design for Motorcycles: A Review, (2023) by M. A. Khan, M. A. Qureshi, and A. A. Awan

[8] Review of Swingarm Design and Analysis for Electric Motorcycles, (2022) by M. A. R. El-Osta, A. S. M. El-Shafei, and M. M. Abd El-Aleem

[9] Advances in Swing Arm Design and Analysis for Lightweight Motorcycles, (2022) by P. K. Mishra, S. K. Gupta, and M. K. Singh

[10] Review of Swing Arm Design and Analysis for High-Performance Motorcycles (2021) by M. A. Khan, M. A. Qureshi, and A. A. Awan

[11] Recent Developments in Swing Arm Design and Analysis for Motorcycles: A Comprehensive Review: (2023) by J. Wang, S. Li, and H. Zhang

[12] Impact of Material Selection on Swing Arm Design and Performance: A Review (2023) by A. Kumar, A. Kumar, and P. Singh

[13] Optimization Techniques for Swing Arm Design: A Review of Recent Developments: (2023) by J. Lee, S. Park, and H. Kim

[14] Computational Modeling and Simulation of Swing Arm Dynamics: A Review: (2022) by T. Chen, S. Liu, and H. Zhang

[15] Experimental Methods for Swing Arm Testing and Validation: A Review: (2022) by M. A. R. El-Osta, A. S. M. El-Shafei, and M. M. Abd El-Aleem

[16] Recent Trends in Swing Arm Design and Analysis for Sports Motorcycles: A Review (2023) by M. A. Khan, M. A. Qureshi, and A. A. Awan

[17] Impact of Manufacturing Processes on Swing Arm Design and Optimization: (2023) by P. K. Mishra, S. K. Gupta, and M. K. Singh

[18] Sustainability Considerations in Swing Arm Design and Material Selection: A Review (2023) by J. Wang, S. Li, and H. Zhang

[19] Additive Manufacturing Techniques for Swing Arm Fabrication: A Review: (2022) by J. Lee, S. Park, and H. Kim

[20] Advanced Materials for Swing Arm Design: A Review of Recent Developments: (2022) by T. Chen, S. Liu, and H. Zhang

[21] Application of Topology Optimization in Swing Arm Design for Motorcycles: A Review (2023) by M. A. Khan, M. A. Qureshi, and A. A. Awan

[22] Review of Swingarm Design and Analysis for Electric Motorcycles (2022) by M. A. R. El-Osta, A. S. M. El-Shafei, and M. M. Abd El-Aleem

[23] Advances in Swing Arm Design and Analysis for Lightweight Motorcycles (2022) by P. K. Mishra, S. K. Gupta, and M. K. Singh.