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Design and Analysis of Aircraft Landing Gear

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ABSTRACT
Landing gear design is a critical aspect of aircraft engineering, vital for safe takeoffs and landings. Shock absorbers, lug joints, and torque links are key components influence structural integrity significantly influencing performance. Traditional materials like Ti alloy, HSSS, Al alloys and AISI 4130 steel are commonly used, each with distinct advantages and drawbacks. Titanium alloys offer high strength-to-weight ratios but are costly, while aluminum alloys provide cost-efficiency but may lack strength under high stress. Composite materials reduce weight and enhances performance. Failures often stem from material fatigue, overload, and improper installation, emphasizing the need for meticulous design and analysis. Applying Finite element method (FEM) and Genetic algorithm (GA), enhance the reliability and efficiency of landing gear systems, ensuring improved safety and performance in modern aircraft. In the present work an effort is made to study the materials and methods that are being used for providing structural integrity of aircraft landing gear.

Keywords**: Shock absorbers, lug joints, torque links, FEM, GA, structural integrity, aircraft safety, weight reduction.**

INTRODUCTION

A brief study of aircraft landing gear. The main purpose of using landing gear in aircraft is for take-off and landing the aircraft on runway. The common materials include Titanium alloys, high-strength stainless steel, Aluminum 7075, and Alloy Steel 4340. These materials offer strength and durability under stress.

1.1. STRUCTURAL SUPPORT:

The landing gear provides the primary structural support to the aircraft while it is on the ground. It absorbs the impact forces during landing and supports the aircraft's weight during taxiing, takeoff, and landing.

1.2. SHOCK ABSORPTION:

The landing gear includes shock absorbers, typically oleo-pneumatic struts, which compress to absorb the impact energy during landing. These struts contain a combination of hydraulic fluid and compressed gas, which cushion the landing impact and prevent damage to the aircraft structure.

1.3. RETRACTION AND EXTENSION:

Most modern aircraft have retractable landing gear to reduce aerodynamic drag during flight. Hydraulic or electric actuators extend the landing gear before landing and retract it after takeoff. The retraction and extension mechanisms are controlled by the pilot through the aircraft’s control systems.

1.4. BRAKING SYSTEM:

The landing gear is equipped with a braking system, typically found on the main wheels. This system helps to slow down and stop the aircraft during landing roll-out and during ground operations. Modern braking systems often include anti-skid features to prevent wheel lock-up and maintain control during braking.

1.5. STEERING MECHANISM:

Nose landing gear usually includes a steering mechanism that allows the pilot to control the direction of the aircraft while taxiing on the ground. This is typically achieved through hydraulic actuators linked to the aircraft’s steering controls.

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1.6. TIRE AND WHEEL ASSEMBLY:

The tires and wheels of the landing gear are designed to withstand the high loads and stresses encountered during takeoff and landing. They provide the necessary friction for braking and the structural integrity to support the aircraft.

1.7. SENSORS AND MONITORING SYSTEMS:

Modern landing gear systems are equipped with sensors and monitoring systems that provide real-time data to the pilot and maintenance crews. These systems monitor parameters such as strut pressure, wheel speed, and gear position to ensure the landing gear operates correctly and safely.

LITERATURE REVIEW

Pravin Sonwane et.al., [1] The optimization of aircraft design, particularly through the analysis of airfoil performance, has garnered significant attention in aeronautical engineering. The S1223 airfoil is noted for its excellent lift-to-drag ratio, making it effective for low-speed operations. However, its thin trailing edge presents manufacturing challenges and risks during flight. Modifications were made to enhance its structural integrity while maintaining high lift capabilities. The results indicate that the redesigned S1223 airfoil not only improves manufacturability but also ensures a smoother trailing edge, contributing to overall aircraft performance. Additionally, the integration of a servo-controlled robotic claw for payload delivery enhances operational efficiency, demonstrating the importance of iterative design processes in advancing unmanned aerial vehicle technology. This research underscores the critical balance between performance, safety, and cost-effectiveness in aircraft design.

Donghui LI et.al., [2] The optimization of composite leaf springs has been explored in various studies, highlighting their advantages over traditional materials like steel, particularly in terms of weight reduction and performance. Previous research has focused on static strength design and dynamic analysis, primarily applicable to UAVs and automotive applications. However, there is a notable gap in studies addressing laminate optimization for leaf springs. This paper presents a two-stage optimization process for the composite leaf spring landing gear of an electric aircraft, utilizing a genetic algorithm to minimize structural weight while adhering to strength and workability constraints. The first stage involves continuous thickness optimization, followed by the optimization of layer sequence and discrete thickness. The results indicate a significant weight reduction from 4.9 kg to 3.8 kg, achieving a 22.4% decrease in mass. The optimized design meets the required stiffness and strength criteria, as verified by static experiments, demonstrating the effectiveness of the proposed optimization method in enhancing the performance of composite leaf spring landing gear.

Haoyuan SHAO et.al., [3]The literature on aircraft arresting systems highlights the complexity of modelling the arresting process, which involves various dynamic interactions among components such as the airframe, landing

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gear, and arresting gear system. Previous studies have utilized finite element and multibody dynamics methods to simulate these interactions, emphasizing the need for precise modelling to capture the dynamic characteristics accurately. Researchers have developed full-scale models and dynamic simulations to analyse the arresting process, focusing on factors like stress wave reflection and the impact of off-centre landings. The proposed rigid-flexible coupling dynamic model in this study effectively integrates these components, allowing for a comprehensive analysis of the arresting dynamics. The model's validity was confirmed through simulations that compared results with established military standards, demonstrating its capability to predict the aircraft's dynamic response during arresting. The findings indicate that variations in off-centre distance and yaw angle significantly affect the arresting load and aircraft attitude, providing valuable insights for the design and optimization of carrier-based aircraft arresting systems.

Roberto Merino-Martínez et.al., [4] The study focuses on the significant issue of noise emissions from aircraft, particularly from the nose landing gear (NLG), which is a major contributor to airframe noise during approach. The research builds on previous findings that highlight the need for effective low-noise technologies (LNTs) to mitigate this problem. The paper evaluates four distinct LNTs, including a ramp door spoiler, a solid wheel axle fairing, wheel hub caps, and perforated fairings, both individually and in combinations. Results indicate that the solid wheel axle fairing emerged as the most effective LNT, achieving noise reductions of 2 to 6 dBA, especially in the flyover direction. The study also reveals that while some combinations of LNTs can enhance noise reduction, the performance is not always additive, with certain configurations yielding lower reductions than expected. The findings underscore the complexity of aeroacoustics applications and suggest that further research is necessary to refine design criteria for these technologies, particularly in real-world flight conditions. Overall, the research contributes valuable insights into the development of strategies for reducing aircraft noise, aligning with regulatory requirements for future aircraft designs.

Lehlohonolo Francis Monahenget.al., [5]The study investigates the failure analysis of a landing gear nose wheel fork produced from Ti6Al4V(ELI) using selective laser melting (SLM). It highlights the growing interest in additive manufacturing for producing aircraft components, particularly due to the potential for weight reduction and enhanced mechanical properties. However, challenges such as inherent surface roughness and porosity associated with additive manufacturing complicate the certification of these components. The research employs an experimentally validated finite element analysis (FEA) to assess the fatigue performance of the nose wheel fork, revealing that stress overloading was not the primary cause of crack initiation. Instead, the study emphasizes the importance of surface treatment to mitigate the effects of surface roughness. The results indicate that the FEA simulation showed a maximum deviation of 48% and a minimum of 5% when compared to experimental data, underscoring the reliability of the simulation in predicting performance. Overall, the findings suggest that with appropriate surface treatment and validation methods, SLM can be effectively utilized for producing mission-critical aircraft components.

ZHU Shixing et.al., [6]The research on MRF dampers highlights their growing significance in various fields, including aerospace and automotive engineering, due to their enhanced performance capabilities. This study specifically investigates the application of MRF dampers in aircraft landing gear through a series of drop tests designed to evaluate their shock absorption performance. The tests involved varying parameters such as drop height, drop mass, and initial pressure of the accumulator, which were meticulously analyzed to understand their impact on landing gear performance. Results indicated that the efficiency of the MRF damper improved with increased current, particularly under milder conditions, demonstrating a stable performance curve. The comparative analysis of the two drop tests revealed that reasonable parameters for the landing gear were established, providing valuable insights for future research and practical applications of MRF dampers. This work serves as a foundational reference for further exploration into the performance characteristics and practical implementations of MRF technology in various engineering domains.

Kong Xiangjun et.al., [7] The study focuses on the measurement and verification of ground loads on landing gears of large passenger jets, particularly in the context of Engineered Material Arresting Systems (EMAS). Previous research primarily addressed methods for measuring loads on individual landing gears, often using bench tests. This paper expands on these methodologies by analyzing the motion characteristics of aircraft during EMAS tests and establishing a comprehensive load measurement system. The results from verification tests, including engine ground run-up, taxi braking, and short EMAS bed tests, demonstrate that the developed load measurement system meets the necessary requirements for actual aircraft tests. The filtering techniques employed effectively captured the actual loadings on the landing gears, ensuring accurate data collection. The allowable loads calculated for the front and main landing gears were found to be within the designed limits, confirming the system's reliability and accuracy in real-world applications. Overall, the findings indicate that the proposed measurement system is suitable for future EMAS verification tests, contributing valuable insights to the field of aviation safety and engineering.

Misagh Ketabdari et.al., [8] The literature indicates that landing overruns are a significant concern in aviation safety, with engineered materials arresting systems (EMAS) being proposed as a solution to mitigate their consequences. Previous studies have explored various materials for arresting beds, including low-density

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concrete and gravel-based mixtures, focusing on their effectiveness in reducing aircraft braking distances. The research highlights the limitations of traditional soft ground materials like clay and sand, which were found inadequate for effective stopping distances. The development of numerical methodologies, particularly using MATLAB, has allowed for simulations of tire-pavement interactions under different conditions, providing insights into aircraft behavior upon entering EMAS. The results demonstrate that low-density concrete with the highest crushing strength significantly shortens the aircraft's arresting distance, thereby enhancing safety. Additionally, sensitivity analyses reveal that the configuration of EMAS and the choice of materials play crucial roles in optimizing performance, ultimately aiding land-locked airports in meeting FAA recommendations for runway end safety areas. This study emphasizes the importance of innovative materials and methodologies in improving aviation safety standards.

Rishabh Chaudhary et.al., [9] The study of landing gear dynamics is crucial in aerospace engineering, particularly in understanding the modal properties of structures. Modal analysis has been widely recognized for its role in optimizing and validating designs, especially in the context of flutter analysis and ground vibration testing. Previous research has highlighted the importance of identifying natural frequencies and mode shapes to prevent resonance, which can lead to catastrophic failures. In this paper, the authors conducted a modal analysis of landing gear under both unloaded and pre-stressed conditions using ANSYS 2019. The analysis revealed the natural frequencies for four distinct mode shapes, providing insights into the dynamic behavior of the landing gear assembly. The results indicated that the gear assembly, designed in CREO3.0, is subjected to low-frequency vibrations during landing, necessitating careful consideration of its dynamic properties to ensure safety and performance. This investigation contributes to the existing body of knowledge by offering a detailed examination of the landing gear's response to vibrational forces, thereby enhancing the understanding of its structural dynamics in real-world applications.

M. Bruno et.al., [10] The development of Health Monitoring & Management Systems (HMMS) for aircraft landing gears has gained significant attention due to the need for enhanced reliability and reduced maintenance costs. Previous studies have highlighted the importance of integrating various sensor technologies, such as MEMS accelerometers and fiber Bragg grating (FBG) sensors, to monitor structural health effectively. These systems utilize advanced algorithms for data processing, enabling real-time diagnostics and prognostics. The innovative design presented in this paper focuses on a modular and scalable HMM system that can be adapted to various applications, ensuring its effectiveness in hostile environments. The results indicate that the system successfully identifies critical parameters and potential damages, demonstrating promising capabilities in fault detection and maintenance management. The testing phase revealed that variations in shock absorber pressure significantly affect the system's performance, while the integration of ultrasonic waves enhances damage detection. Overall, the findings support the feasibility of implementing such systems in military trainer aircraft, ultimately leading to improved operational efficiency and safety.

Angela Brindisi et.al., [11] The literature on weight-on-wheel systems highlights the importance of accurately determining whether an aircraft is on the ground or in flight, which is critical for safety and operational efficiency. Various architectures have been proposed, including those utilizing strain gauges and proximity sensors. Recent advancements suggest that fiber Bragg grating (FBG) sensors can serve as effective strain detectors, providing reliable data on the aircraft's standing. Preliminary tests conducted on a model landing gear demonstrated that the FBG sensors accurately reflected the stress states induced by the aircraft's weight. The results indicated that when the aircraft is grounded, the sensors registered a positive strain on the outer surface and a negative strain on the inner surface of the landing gear, confirming the system's capability to detect ground contact. This innovative approach not only minimizes cabling and installation complexity but also enhances the overall reliability of the weight-on-wheel system, paving the way for further integration into modern aircraft subsystems. The findings support the potential of FBG sensors in improving safety-critical applications within aerospace engineering.

Byung-Hyuk Kang et.al., [12] The study focuses on the development of dynamic models for an aircraft landing gear system equipped with magnetorheological (MR) dampers, addressing the limitations of previous simplistic linear models. It introduces three models: the nonlinear aircraft model (NLAM), the linear approximated aircraft model (LAAM), and the fully approximated aircraft model (FAAM). These models are constructed based on nonlinear equations of motion and linear approximations, allowing for a comprehensive evaluation of the landing gear's performance during drop tests. The validation of these models was conducted using RecurDyn, a powerful multi-body analysis tool, which facilitated a comparison of the models' drop performances. The results indicated that the NLAM provided the most accurate representation of the aircraft's dynamics, as evidenced by higher coefficients of determination and lower root mean square errors when compared to the RecurDyn model. This study contributes valuable insights into the design and optimization of MR damper systems in aircraft landing gear, enhancing stability and passenger comfort during landings.

Zhipeng Zhang et.al., [13] The study of dual-sidestay (DSS) landing gear retraction mechanisms has gained attention due to their ability to share ground loads and reduce wing stress in large aircraft. Previous research has highlighted the importance of joint clearance and node deviation on the synchronous locking performance of

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these mechanisms. The current paper establishes a rigid-flexible-coupling dynamic model that incorporates these factors, validated through experimental results. The findings indicate that as node deviation increases, the locking behavior of the mechanism lags, leading to incomplete locking on one side. Additionally, the impact of structural clearance on synchronous locking is relatively minor. The results provide a feasible parameter region for ensuring synchronous locking, which is crucial for the design and functionality of DSS landing gear systems. This research lays the groundwork for future studies that could integrate hydraulic and control systems to further enhance the performance of landing gear mechanisms.

Qiwei Lin et.al., [14] The structural integrity of aircraft nose landing gear is crucial, especially under towing taxi-out conditions, which present unique challenges due to low-speed maneuvers and the absence of reverse thrust. Previous studies have highlighted the impact of environmental factors and compressive stresses on the performance of landing gear, yet there remains a gap in research specifically addressing the vibrational and strength characteristics during towing. This study developed a finite element model for a Class C aircraft, the B-727, and conducted modal testing to validate the model against experimental data, achieving a high accuracy in natural frequency predictions. The results indicated that under high-speed and heavy-load conditions, the nose landing gear experienced significant loads, with maximum deformation occurring at the shock strut's outer cylinder. Importantly, an optimized design was identified, resulting in a 22.32% reduction in the mass of the outer cylinder while maintaining structural safety. This optimization not only enhanced the overall strength of the landing gear but also demonstrated effective performance under the specified operational conditions, thereby contributing valuable insights to the field of aircraft structural analysis.

Stefania Gualdi et.al., [15] The literature on landing gear-induced instabilities, particularly "gear walk," highlights the complex interplay between the landing gear's structural dynamics and the brake anti-skid system. Previous studies have identified that gear walk manifests as a low-frequency oscillation, typically within the 10-50 Hz range, influenced by factors such as tire pressure and hydraulic system conditions. The development of multibody models has emerged as a crucial tool for simulating these dynamics, allowing for a stepwise enhancement of model parameters to accurately reflect the system's behavior. This paper presents a comprehensive multibody model that incorporates significant mass, stiffness, and damping characteristics of the landing gear, validated against experimental drop test data. The results demonstrate that the model effectively predicts the onset of gear walk instability and provides insights into the design of an anti-skid controller aimed at mitigating this issue during braking maneuvers. The findings underscore the importance of detailed modeling in understanding and addressing landing gear instabilities, paving the way for improved aircraft safety and performance.

Quoc Viet Luong et.al., [16] The study explores the limitations of traditional passive dampers in aircraft landing gear, which are designed for single landing conditions and lack adaptability. In contrast, magnetorheological (MR) dampers offer a semi-active solution, allowing for real-time control of damping forces through electric current. This paper introduces a neural network controller trained using genetic algorithms and policy gradient estimation, enabling the system to autonomously adjust to various landing scenarios without requiring prior system knowledge. Comparative simulations demonstrate that the proposed controller performs comparably to an adaptive hybrid controller across different aircraft masses and sink speeds. Notably, the results indicate that the intelligent control system not only maintains effective damping during the initial compression stroke but also achieves higher energy absorption efficiency and faster stabilization of the landing gear. The findings suggest that the GA-NN and PGE-NN methods provide enhanced performance over traditional systems, showcasing their potential for improving aircraft landing gear functionality in diverse conditions.

Rosario Pecora et.al., [17] The study of oleo-pneumatic landing gear dynamics has evolved significantly, with various approaches employed to analyze the impact loads during landing. Previous research has highlighted the limitations of finite element analysis in capturing the complexities of oleo-pneumatic systems, particularly due to the need for detailed models that can adapt to design changes. Innovative methods have been proposed, such as the integration of multibody dynamics software with finite element solvers, which have shown promise in addressing load instabilities. The current work presents a rational numerical method that balances model sophistication with accuracy, utilizing a set of intercommunicating routines in MATLAB to simulate drop dynamics effectively. The results from the drop test simulations of a reference landing gear demonstrated a strong correlation with experimental data, validating the proposed method's effectiveness. This approach not only facilitates the preliminary design phase but also supports iterative updates throughout the design process, ensuring that the landing gear can efficiently absorb and dissipate kinetic energy during touchdown, thereby minimizing the impact on the aircraft structure.

Byung-Hyuk Kang et.al., [18] Magnetorheological (MR) shock absorbers have gained attention for their application in aircraft landing gear systems, particularly due to their ability to adapt to varying conditions. Previous studies primarily focused on major pressure losses, which are significant at low stroke velocities, typically below 0.5 m/s. However, this research highlights the importance of considering both major and minor pressure losses, especially in high-speed applications like aircraft landing gear, where the minor loss becomes increasingly relevant. The proposed design model incorporates these factors, leading to a more accurate

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prediction of pressure drops and damping forces. Experimental validation through drop tests demonstrated that the model considering both losses showed a root mean square (RMS) error of only 4.5%, compared to 15% for models that only accounted for major losses. This significant improvement underscores the necessity of integrating both loss types in the design of MR shock absorbers for high-performance applications, ensuring enhanced landing efficiency and overall system reliability.

Dr. V. Jaya Prasad et.al., [19] The design and structural analysis of aircraft landing gear is crucial for ensuring safety and performance during ground operations. Various materials, including aluminum alloys and titanium alloys, have been evaluated for their ability to withstand significant compressive loads, drag loads, and side loads. The analysis typically involves static structural assessments using software like ANSYS, which helps in determining displacements, stresses, and strains under steady loading conditions. The results indicate that titanium alloy 10V-2Fe-3Al exhibits the highest factor of safety, demonstrating superior performance with the least maximum stress and deflection compared to other materials. This finding underscores the importance of material selection in enhancing the structural integrity and safety of landing gear systems. The study emphasizes that effective stress analysis not only aids in selecting appropriate materials but also in optimizing geometrical dimensions to improve overall design safety. Ultimately, the research advocates for the use of titanium alloys to mitigate structural failures in landing gear systems, thereby contributing to the reliability of aircraft operations.

Rajesh et.al., [20] The literature on high-pressure turbine (HPT) blades highlights the challenges posed by demanding operating conditions, particularly the time-dependent degradation mechanisms such as creep. Previous studies have utilized finite element methods (FEM) to model the behavior of turbine blades under various thermal and mechanical loads, often relying on flight data records (FDR) to inform their analyses. This paper builds on these foundations by developing a comprehensive FEM model specifically for HPT blades, incorporating real-world data from a commercial aviation company. The methodology involved scanning a blade scrap to obtain its 3D model and material properties, followed by simulations that began with a simplified rectangular block before transitioning to the actual blade geometry. The results demonstrated that the model accurately predicted displacement behavior, especially at the blade's trailing edge, indicating its potential utility in forecasting turbine blade life based on FDR data. This advancement not only enhances the understanding of turbine blade performance but also contributes to improved maintenance strategies in aviation, ultimately leading to increased safety and efficiency in aircraft operations.

Chad Forrest et.al., [21] The study investigates the fatigue failure of a 2014-T6 aluminum alloy wheel flange from a Piaggio Avant P180 aircraft, which experienced a catastrophic fracture after 22 years of service. The failure was initiated by fatigue crack propagation, with the crack measuring approximately 8 cm in length and 5 cm in depth. The analysis revealed that multiple initiation sites were present, primarily due to corrosion pits exacerbated by fretting between the tyre bead and the tube well, leading to the removal of protective coatings. Despite a non-destructive inspection conducted four years prior, no defects or overheating were detected, and the wheel had completed 1200 flight cycles since its last inspection, which was below the scheduled limit of 1500 cycles. The results emphasized the need for immediate visual inspections of similar aged wheels and recommended reducing inspection intervals to enhance maintenance reliability. The findings highlight the critical importance of regular inspections and maintenance procedures to ensure the integrity of aircraft components, particularly those subjected to fatigue and corrosion.

F. Bagnoli et.al., [22] The fatigue analysis of the P180 aircraft's main landing gear wheel flange revealed significant insights into the failure mechanisms. The wheel, made from 2014-T6 aluminum alloy and in service for 22 years, experienced a catastrophic failure due to fatigue crack propagation, which grew to approximately 8 cm in length and 5 cm in depth. This failure was primarily attributed to corrosion pitting, exacerbated by fretting between the tyre bead and the tube well, leading to the removal of protective coatings. The analysis indicated that multiple initiation sites existed, with the largest corrosion pit measuring around 315 micrometers deep. The fatigue life assessment confirmed that the number of flight cycles supported by the wheel during crack propagation aligned with those accumulated since the last inspection, emphasizing the need for improved maintenance procedures and reduced inspection intervals to ensure the integrity of similar components in the fleet.

Osman Asi et.al., [23] The investigation into the failure of piston rod ends in aircraft landing gear has highlighted the prevalence of similar damage across various cases. In this study, a specific incident involving a fractured piston rod end from a hydraulic actuating cylinder was examined, revealing that the failure occurred during taxiing after landing. The analysis included visual inspections, chemical assessments, and mechanical testing, which indicated that the failure was primarily due to fatigue, with cracks initiating near mechanically damaged areas. Finite element analysis was employed to identify stress concentrations, revealing maximum von-Mises stress values of 597 MPa for the original design and 845 MPa for the damaged condition. The presence of ratchet marks on the fracture surface suggested high stress concentrations, while the distinct features of the fracture surface indicated a combination of fatigue and overload failure mechanisms. This comprehensive evaluation underscores the critical need for regular inspections and stress analysis in maintaining the integrity of aircraft components, particularly those subjected to high loads and potential damage.

M. Freitas et.al., [24] The analysis of landing gear failures is critical for ensuring aircraft safety, as these components endure significant loads during landing and ground operations. Previous studies have identified fatigue and corrosion as primary causes of failures, particularly in steel and aluminum components. This paper focuses on a specific incident involving the nose landing gear axle of a twin turboprop transport aircraft, which failed during landing due to unexpected wind conditions that caused the aircraft to land on the nose gear instead of the main gear. A comprehensive material analysis and fracture surface examination revealed that the failure was attributed to an overload condition resulting from combined shear and bending stresses. Finite element analysis confirmed that the strength of the axle was exceeded during landing, with calculated loads reaching 316 kN, significantly surpassing the axle's maximum load capacity of 170 kN for single-wheel contact. The findings underscore the importance of understanding loading conditions and material integrity in the design and maintenance of landing gear systems to prevent future failures.

Asad Hameed et.al., [25] The literature on landing gear failures highlights that issues often stem from material defects, human error, and design inadequacies. Common material-related failures include fatigue and stress corrosion cracking, while human errors can arise from improper inspections or excessive loads during landing. Design flaws may involve stress concentration sites that compromise structural integrity. In this study, the analysis focused on a nose landing gear support strut that failed during landing, revealing that the eye-end bolt fractured due to overload without pre-existing defects. The investigation found that the dislodging of a retaining pin, attributed to improper installation, led to stress levels exceeding the ultimate tensile strength (UTS) during landing impacts. The results indicated that normal operations would not have caused the failure, as even hard landings were sustainable. The study employed finite element analysis to simulate stress conditions, confirming that the stress at the fractured region remained within safe limits under normal circumstances, but surged beyond UTS when the retaining pin was compromised. This underscores the critical importance of proper installation and maintenance in preventing such failures in aircraft landing gear systems.

Mohammed Imran et.al., [26] The literature on landing gear systems highlights the importance of structural integrity and performance under various loading conditions. Studies have focused on the nonlinear properties of oleo shock struts and the impact forces experienced during landing, emphasizing the need for accurate modeling and simulation techniques. Research has shown that polymer and ceramic matrix composites are advantageous for aircraft structures due to their lightweight and high strength characteristics. Finite Element Analysis (FEA) has been widely utilized to optimize the design of landing gear, with particular attention to stress and buckling analysis. The results indicate that composite materials, such as Carbon-Hercules AS4, exhibit lower stresses and deflections under static and dynamic loads compared to traditional materials. The analysis also revealed that the landing gear's design must accommodate specific aircraft characteristics to ensure effective energy absorption during landing. Overall, the findings underscore the critical role of advanced materials and analytical methods in enhancing the safety and performance of landing gear systems, ultimately contributing to the reliability of aircraft operations.

P. Kadarno et.al., [27] The safety of aircraft systems, particularly landing gear, is critical due to the potential catastrophic consequences of component failures. Previous studies have emphasized the importance of failure analysis in enhancing the reliability of aircraft systems, highlighting the industry's slow response to these safety concerns. Recent analyses have focused on various failures in landing gear mechanisms for both commercial and military aircraft, underscoring the need for precise design and manufacturing processes. The results of this study reveal that any deformation in landing gear components can significantly impact the overall mechanism, potentially leading to lock failures. The kinematic analysis performed indicates that maintaining precise dimensions and material properties is essential to prevent malfunctions. Computer simulations demonstrated how deformations could affect the locking mechanism, with specific angles exceeding design requirements posing risks for lock failures. The findings stress the importance of rigorous design and testing protocols to ensure the safe operation of landing gear systems throughout their intended lifespan.

Andrew LaTour et.al., [28] The study explores the use of laser powder bed fusion (LPBF) to produce Titanium 10 V-2Fe-3Al (Ti 10-2-3) landing gear components, highlighting the advantages of additive manufacturing in creating complex geometries. Previous research indicates that LPBF can yield materials with high density and moderate fatigue life, but challenges such as oxidation and porosity remain significant concerns. The results of this study reveal that the high-cycle fatigue strength of LPBF-produced coupons is substantially lower than that of wrought materials, with values of 40 ksi (276 MPa) compared to 90 ksi (621 MPa). Additionally, low-cycle fatigue tests show that printed coupons fail at 1000 cycles under 0.75% strain, while wrought materials endure up to 1% strain. Microstructural analysis indicates that printed samples exhibit larger grains and defects, contributing to their reduced fatigue performance. Despite these limitations, the study concludes that Ti 10-2-3 components produced via LPBF may be suitable for non-safety-critical applications, particularly those not subjected to cyclic loading exceeding 10,000 cycles, paving the way for future research into enhancing mechanical properties through advanced processing techniques.

Thoai Nguyen et.al., [29] The analysis of nose landing gear during landing is critical for ensuring aircraft safety and performance. This paper provides a comprehensive modeling and analysis guide utilizing finite element analysis (FEA) to assess stress and displacement behaviors in nose gear. The study emphasizes the importance of understanding component interactions and worst-case loading scenarios, particularly when the shock absorber is fully compressed. The shock absorber analyzed is an oleopneumatic type, known for its efficiency in energy absorption during landing. The results indicate that the maximum stress occurs in the wheel assembly, specifically where loads are applied, with a calculated factor of safety of 3.0, exceeding the FAA's minimum requirement of 2.0 for cast materials. This analysis not only validates the modeling approach but also serves as a valuable resource for manufacturers to optimize designs before physical testing, ultimately saving time and resources. The findings underscore the significance of proper boundary conditions and detailed result analysis to ensure the validity of the study, contributing to safer and more efficient aircraft landing gear designs.

Jarosław Pytka et.al., [30] The development of a wheel dynamometer system for aircraft landing gear testing is crucial for understanding the loads and dynamics experienced during airfield maneuvers. Previous studies have highlighted the importance of accurately measuring vertical and lateral forces, as well as moments acting on landing gear, to ensure safety and reliability in aircraft operations. The unique challenges posed by grassy and unpaved runways necessitate specialized testing equipment to assess the structural loads that can lead to fatigue and potential failures. The dynamometer system designed in this study incorporates a sensor unit embedded in the wheel hub, capable of measuring force components and moments effectively. Initial tests conducted on a PZL 104 Wilga 35A demonstrated the system's capability to perform under real-world conditions, with successful data acquisition during taxiing at low speeds. The results indicate that the system can reliably capture the necessary data for evaluating landing gear performance, paving the way for future certification processes for ground and flight tests. This innovative approach contributes significantly to enhancing the safety and operational efficiency of aircraft on varied runway surfaces.

Yu Li et.al., [31] The study investigates the critical issue of tyre temperature elevation during aircraft touchdown, emphasizing the impact of friction generated by the speed difference between the runway and landing gear. A mathematical algorithm developed in MATLAB simulates tyre friction and heat generation under various pre-rotation conditions, aiming to mitigate high-speed friction. The research validates the algorithm through experimental comparisons and employs a transient thermos-mechanical analysis using ANSYS as a reference. Results indicate that the algorithm can effectively calculate tyre temperature, achieving a temperature change of 175.13 °C with a 6.0% error margin compared to existing literature. The findings reveal that pre-rotation strategies can significantly reduce friction strength at touchdown, although low pre-rotation speeds may lead to a slight increase in maximum tyre temperature. This work contributes to understanding the thermal dynamics of aircraft tyres, providing a reliable framework for future studies and practical applications in enhancing flight safety and reducing maintenance costs associated with tyre wear.

S.G. Aftab et.al., [32]The literature on aircraft landing gear emphasizes its critical role in ensuring structural integrity and safety during landings. Various studies have utilized finite element analysis (FEA) to evaluate the performance of landing gear under different loading conditions and materials. Research indicates that materials such as Titanium alloy 6Al-4V, 7075-76 Aluminum alloy, and SAE 1035 Steel have been extensively analyzed for their mechanical properties. The findings reveal that SAE 1035 Steel exhibits superior performance, with a significant reduction in deformation—approximately 35% less compared to other materials—indicating its potential for enhanced durability and longevity in landing gear applications. Additionally, studies have shown that the maximum stress experienced by components, such as the nose landing gear of small aircraft, can exceed material yield strengths, necessitating careful design considerations. The analysis of a Boeing 737's nose landing gear prototype demonstrated that the selected materials could withstand the calculated design loads while maintaining a factor of safety above one, confirming their suitability for use. Furthermore, the results from various simulations indicated that the stress and deformation levels remained within acceptable limits, ensuring the structural safety of the landing gear. The research collectively underscores the importance of material selection and design optimization in preventing structural failures, thereby enhancing the overall safety and reliability of aircraft landing systems.

Plabita Sonowal et.al., [33] The design and analysis of landing gear shock absorbers are critical for ensuring the safety and performance of commercial aircraft. Various studies have explored the mechanical characteristics of materials used in landing gear, particularly focusing on titanium alloys and high-strength stainless steel, which are favored for their strength-to-weight ratios. The structural analysis often employs finite element analysis (FEA) to evaluate stresses and deformations under different loading conditions, such as axial compression, bending, and torsion, which occur during landing. Researchers have developed models that simulate the behavior of landing gear under various scenarios, including adverse conditions like impact landings and taxiing over uneven surfaces. The results from these analyses indicate that the shock absorber must effectively dissipate kinetic energy to prevent failure during high-stress events. In a comparative study, it was found that the model constructed from high-strength stainless steel exhibited lower stress and deformation levels compared to titanium alloy models, suggesting a potential advantage in using stainless steel for certain applications. This finding highlights the importance of material selection in the design process, as it directly impacts the structural integrity and longevity of the landing gear system. Overall, the integration of advanced simulation tools and material science in the design of landing gear shock absorbers is essential for optimizing performance and ensuring the safety of commercial aircraft operations.

Arif Krisbudiman et.al., [34]The structural design analysis of torque links in the nose landing gear of light aircraft is crucial for ensuring safety and performance during landing operations. Torque links serve to connect the inner and outer cylinders of the oleo-pneumatic shock strut, preventing torsion and vibrations that could compromise the landing gear's integrity. Previous studies have highlighted the importance of optimizing these components to reduce weight while maintaining structural strength. The analysis typically involves evaluating static and dynamic loads, with the maximum stress occurring near the connection points and holes in the torque link. The use of finite element methods has been instrumental in simulating stress and deformation under various loading conditions, allowing for the identification of optimal designs. Recent findings indicate that modifications in hole geometry can lead to significant weight reductions, with one study achieving a reduction of up to 23.75%. The results also showed that the maximum stress reached 157.4 MPa, which is critical for ensuring the component's reliability. Furthermore, modal analysis revealed natural frequencies ranging from 4.2259 kHz to 6.1319 kHz, which remain below the critical threshold, thus avoiding resonance issues. The final design achieved a Factor of Safety of 1.78, surpassing the minimum requirement of 1.5, indicating a safe structural strength under both static and dynamic loads. This comprehensive approach to torque link design not only enhances the performance of light aircraft but also contributes to advancements in aerospace engineering by integrating innovative materials and design methodologies.

Andrzej Tywoniuk et.al., [35]The design and numerical optimization of landing gear systems are critical for ensuring the safety and performance of aircraft during take-off and landing. This paper focuses on a tricycle-type landing gear system designed for a 1400 kg take-off mass aircraft, adhering to the CS-23 regulations. The landing gear features a retractable design, oleo-pneumatic amortization, and a mechanical emergency release system, which collectively enhance the aircraft's operational efficiency and safety. The main landing gear consists of a composite leg with aluminum fittings, hydraulic brakes, and an electric retraction system, which significantly reduces aerodynamic drag while maintaining structural integrity. Finite Element Method (FEM) analysis was employed to assess the stiffness and energy absorption capabilities of the landing gear, revealing that a high stiffness is essential for stable wheel traction during landing and taxiing. The results indicated that the design met a safety factor of 1.5, confirming the robustness of the structure. The optimization process utilized advanced software tools, including Hyperworks and SolidEdge, to refine the design and minimize weight without compromising performance. The successful completion of laboratory tests further validated the shock absorption capabilities of the landing gear, demonstrating its effectiveness in real-world scenarios. Overall, the integration of modern engineering techniques and a thorough understanding of design requirements led to a successful prototype that meets all specified client needs, showcasing the complexity and importance of landing gear systems in aviation.

Mahesh Ashok Raut et.al., [36] The design and analysis of aircraft landing gear is a critical aspect of aviation engineering, focusing on the structural integrity and performance of this essential component. Landing gear serves as the undercarriage that supports the aircraft during ground operations, including taxiing, takeoff, and landing. It must withstand significant forces and impacts, making its design a complex engineering challenge. Various materials have been explored for landing gear construction, with a focus on optimizing weight, strength, and durability. Recent studies have utilized advanced software tools, such as ANSYS, to simulate stress and deformation under operational loads, allowing for a detailed analysis of different material properties. The results of these analyses indicate that titanium alloys, particularly Ti-8Al-1Mo-1V, exhibit superior performance characteristics, making them a preferred choice for landing gear applications. The findings suggest that this material not only meets the necessary strength requirements but also contributes to a reduction in overall weight, enhancing the aircraft's efficiency. Furthermore, the analysis highlights the importance of selecting appropriate landing gear configurations to effectively absorb impact energy and distribute loads, which is vital for maintaining the aircraft's structural integrity. Overall, the ongoing research in landing gear design emphasizes the need for innovative materials and engineering solutions to improve safety and performance in aviation. The integration of computational methods in the design process has proven to be invaluable, providing insights that lead to the development of landing gear systems that are both lightweight and robust, ultimately contributing to the advancement of aircraft technology.

Naif Ismail Ibrahim et.al., [37] The design and analysis of aircraft landing gear are critical for ensuring safe takeoff and landing operations. Landing gear must absorb significant loads during these phases, including vertical, drag, and side loads, which necessitates robust structural integrity. A common focus in the literature is the design of lug joints, which are essential for transferring concentrated loads from the landing gear to the aircraft's airframe. The failure of these joints under static and fatigue loading conditions is a primary concern, leading to extensive finite element analysis (FEA) to evaluate stress concentration factors and predict fatigue life. Recent advancements in computational methods, particularly explicit transient dynamic finite element analysis, have enhanced the feasibility of simulating crash scenarios, allowing for more accurate assessments of landing gear performance under extreme conditions. The literature also highlights the importance of nonlinear

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structural effects, such as high damping and stick-slip friction, which can significantly influence the dynamic response of landing gear systems. Results from various studies indicate that optimizing the geometry of landing gear components can lead to improved performance and safety, with specific designs tailored to different aircraft types. The integration of numerical simulations has proven invaluable in understanding the dynamics of landing gear interactions and energy absorption during landings. Overall, the ongoing research emphasizes the need for innovative design approaches and rigorous testing to ensure the reliability and safety of landing gear systems in modern aircraft.

J. Wong et.al., [38] The dynamics of aircraft landing gear assemblies have been extensively studied, focusing on various modeling techniques to simulate their behavior under dynamic loading conditions. Traditional approaches often relied on rigid body assumptions, which limited the accuracy of simulations, particularly in capturing phenomena such as shimmy and touch down dynamics. Recent advancements emphasize the importance of modeling components as deformable bodies to account for vibrational loading, which significantly influences the design and performance of landing gear. The literature highlights the necessity of integrating multi-body dynamics (MBD) analysis with structural loading considerations to enhance design optimization processes. A notable methodology introduced is the Equivalent Static Load Method (ESLM), which allows for effective topology optimization while addressing the complexities of dynamic loading. In this study, a high-fidelity multi-disciplinary design optimization approach was applied to a commercial landing gear assembly, specifically focusing on a slave link subassembly. The results demonstrated a significant weight reduction of 67% in one design iteration, although this came with a 74% increase in peak stress and no cost savings due to complex features. Conversely, a second design aimed at manufacturability achieved a 36% weight saving, a mere 6% increase in peak stress, and an estimated 60% reduction in manufacturing costs. These findings underscore the potential of combining advanced modeling techniques with optimization strategies to meet the evolving demands of aircraft landing gear design, ultimately leading to more efficient and cost-effective solutions in the aerospace industry.

David Gerhardinger et.al., [39] The analysis of fatigue life in light aircraft landing gear legs is crucial due to the significant impact of fatigue damage on component failure. Previous studies have established that accumulated fatigue damage is influenced by various factors, including component geometry, material properties, aircraft takeoff mass, and load profiles. This research builds upon earlier work by employing a systematic approach that includes finite element method (FEM) analysis to gather fatigue-relevant data. The study identifies probable failure locations using the Von-Mises yield criterion, focusing on stress locations designated as A and B. The Coffin-Manson low cycle fatigue equation is utilized to calculate fatigue life across different load profiles, while the Palmgren-Miner rule is applied to assess accumulated damage at these critical locations. The methodology incorporates correlation and regression analyses to explore the interdependence between fatigue life and various parameters, employing statistical software for rigorous data evaluation. Results indicate a significant relationship between independent variables, such as stress and strain intensities, and the dependent variable of fatigue life. The analysis reveals that the regression model effectively explains the variability in fatigue life, although it also highlights the limitations of the R-squared statistic in assessing prediction bias. The study concludes with recommendations for improving fatigue life prognosis methods, emphasizing the need for a more nuanced understanding of the factors influencing fatigue in light aircraft landing gear legs. This comprehensive approach not only enhances the predictive accuracy of fatigue life assessments but also contributes to the development of more effective maintenance strategies for light aircraft.

M.C. Kushan et.al., [40] The safe operation of aircraft heavily relies on the integrity of critical components, particularly propellers, which are subjected to complex dynamic loads. This paper investigates the root causes of fatigue failures in a Cessna-185 aircraft propeller blade, specifically focusing on fatigue crack propagation induced by foreign object damage (FOD). During the manufacturing, service, and maintenance processes, various failures can occur due to human error, environmental factors, and material inconsistencies. Despite rigorous design calculations and periodic inspections, fatigue failures remain unpredictable and can lead to catastrophic outcomes. The analysis reveals that microcracks initiate in dented areas of the blade, leading to stress concentrations that propagate under cyclic loading. The study identifies three stages of crack development: initiation, growth, and final rupture, with significant portions of the fracture surface attributed to fatigue. The investigation also highlights that the dent, which likely existed prior to 2001, had a specific surface area that contributed to the fatigue failure. The results indicate that the thickness of paint in the dent area may have exacerbated the issue, as it could strip under impact loads. The findings emphasize the importance of meticulous maintenance practices and the need for improved predictive measures to mitigate fatigue failures. Overall, the research underscores the critical nature of understanding fatigue mechanisms in propeller blades to enhance flight safety and operational reliability.

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CONCLUSION

The studies highlight the critical role of advanced analysis techniques such as CFD and stress analysis in optimizing the design and performance of aircraft landing gear. Effective implementation of low-noise technologies and optimal material selection, particularly titanium alloys, not only enhances structural safety but also addresses operational challenges such as noise reduction and weight management. These findings underscore ongoing opportunities for research and development in enhancing aircraft safety and performance through innovative engineering solutions.

REFERENCES

1. Pravin Sonwane, mayank Yadav, Nidhi Bunker, Sarthak sonwane, vaishalishirsath. Economical Design Perpective for Aincraft By Optimizing Airfoil S1223" "e-Prime Advances in Electrical Engineering, and Electronics Energy", Pg No: 1to8, doi. ông/10.1016/j. Prime. 2024. 1005311, March 2024.
2. DonghuiLI, ZhenweiFAN, YeweiZHAN, JianZANG,FengtianYANG "Optimum design and experiment of composite leaf Spring landing gear for electric aircraft, Chinese Journal Of Aeronautics,doi.org/10.1016/j.cja.2020.03.010, Page 2649-2659, 10 June 2020.
3. Haoyuan SHAO. Daochun LIa,Zi KAN, Lanxi BI, Zhuoer YAO, Jinwu XIANG," Numerical simulation of aircraft arresting process with an efficient full-scale rigid-flexible coupling dynamic mode" Chinese Journal Of Aeronautics, doi.org/10.1016/j.cja.2020.03.010, Page 582-602, 13 August 2023.
4. Roberto Merino-Martínez, John Kennedy, Gareth J. Bennett developed "Experimental study of realistic low–noise technologies applied to a full–scale nose landing gear," Aerospace Science and Technology, Volume: 113, Article: 106705, DOI: 10.1016/j.ast.2021.106705, Pages: 1-20, May 2021.
5. Lehlohonolo Francis Monaheng , Willie Bouwer du Preez , Claudia Polese Failure analysis a landing gear nose wheel fork in Ti6Al4V(ELI) selective laser melting, Engineering Failure Analysis, doi.org/10.1016/j.engfailanal.2023.107548, Page 1-16 2023.
6. Zhu Shixing, Wang Peng, and Tian Jing "Experimental Research on Aircraft Landing Gear Drop Test Based on MRF Damper," Procedia Engineering, doi:10.1016/j.proeng.2011.08.882, Volume 15, Pages 4712-4717, August 2011.
7. Kong Xiangjun, Le Ningning, Li Chunsheng, Xiao Xianbo, Lin Bo, Xu Bing " Landing Gear Ground Load Measurement and Verification Test fora Large Passenger Jet "Procedia Engineering. doi:10.1016/j.proeng.2014.12.679, Page 1426-1433 ,2015.
8. Misagh Ketabdar, Emanuele Toraldo, „Mauriziol Crispino, Vardham lünkar". Evaluating the Engincering Interaction Between engineering materials and Aincraft tyres as arresting systems in landing averrun, Events" "Case Studies in Construction materials". Pg no: 1 to 13, doi.org/10.1016/j.cscm. 2020.000 446, October 2020.
9. R. Chaudhary "Investigation on structural dynamics of landing gear," Materials Today: Proceedings, doi: 10.1016/j.matpr.2020.03.324, Volume: 54, Pages: 152-158, September 2021.
10. G.Petrone, M.Bruno, F. Bocchetto, G. Breglio, M. Rugliere, A. Caldara, A. Nacella, A. Cavallari S. Schiano la mariello, G. Capuano, D. Rossetti." An innovative Health manitoring system for Aircraft landing Gear. "8th European workshop on structural Health monitoring" ,5-8 July 2016.
11. Angela Brindisi, Cristian Vendittozzi,Li dia Travascio , Luigi Di Palma, marika Belardo, michele Ignara, Vincenzo Fiarilla and Antonia concilia. Preliminary Assessment of an FBG Based Landing Gear weight on wheel System ". "Actuators'', Pageno:1to13,doi.org/10.3390/act1107019,1 July 2022 .
12. Byung-Hyuk, Bang-Hyun Jo, Bo-Gyo kim, Jai -Nyuk Hwang and Seung-Bok choi, Linear and Non linear models for Drop Simulations of on Aircraft landing Gear system with MR Dampers" Actuators". PgNo: 1 to 21, doi. dig/10.3390 /act 12070287,july 2023.
13. Zhang, H., Jiang, P., Zeng, J., Feng, Z., Liu, X., & Yang, S. "Analysis of the Synchronized Locking Dynamic Characteristics of a Dual-Sidestay Main Landing Gear Retraction Mechanism," Aerospace. doi:10.3390/aerospace11000356, Volume: 11, Pages: 1-17, 2024.
14. Qiwei Lin,Chang Yang , Yuhao Bai ,Jiahao Qin "Structural Strength Analysis and Optimization of Commercial Aircraft Nose Landing Gear under Towing Taxi-Out Conditions Using Finite Element Simulation and Modal Testing," Aerospace, doi:10.3390/aerospace11040414, Volume: 11, Pages: 414, July 2024.
15. Stefania Gualdi, marco Morandini, Gian Luca Ghoringhelli". Anti-skid Induced Aircraft landing Gear instability. Aerospace Science and Technology. Pgno: 627to637, doi: 10.1016, i.ast.2008.02.002, May 2008.
16. Q. V. Luong, D.-S. Jang, and J.-H. Hwang "Intelligent Control Based on a Neural Network for Aircraft Landing Gear with a Magnetorheological Damper in Different Landing Scenarios," Applied Sciences, vol. 10, no. 5962, pp. 1-16, doi:10.3390/app10175962, 2020.
17. Rosario Pecara." A Rational Numerical method to simulation of Drop Impact Dynamic of Oleo-Pneumatic Landing Gear". "Applied Sciences''. Pg no: 1 to 22,doi. dig 110.3390 /app11094136 ,April 2021.
18. Byung-Hyuk, Bang-Hyun Jo, Bo-Gyo kim, Jai -Nyuk Hwang and Seung-Bok choi, Linear and Non linear models for Drop Simulations of on Aircraft landing Gear system with MR Dampers" Actuators". PgNo: 1 to 21, doi. dig/10.3390 /act 12070287,july 2023.
19. Dr. V. Jaya Prasad, P. Sandeep Kumar Reddy, B. Rajesh, T. Sridhar developed "Design and Structural Analysis of Aircraft Landing Gear Using Different Alloys," International Journal of Mechanical Engineering and Technology (IJMET), Volume: 11, Issue: 7, ISSN Print: 0976-6340, ISSN Online: 0976-6359, Page No: 7-14, July 2020.
20. Rajesh A and Abhay BT ,Design and Analysis Aircraft Nose and Nose Landing Gear , JAEE ,Volume 4 . Issue 2 . 1000144,DOI: 10.4172/2168-9792.1000144 , ISSN: 2168-9792 , 29 September 2015.
21. Chad Forrest, Clint Forrest, Doug Wiser " Landing Gear Structural Health Monitoring (SHM) " doi.org/10.1016/j.prostr.2017.07.025, September 2017
22. F. Bagnoli, M. Bernabei " Fatigue analysis of a P180 aircraft main landing gear wheel flange " Engineering Failure Analysis doi:10.1016/j.engfailanal.2007.10.00318,Page 664-665,October 2007.
23. Osman Asi, Onder yesil . Failure Analysis of an Aircraft Nose Landing gear piston Rod End . Engineering Failure Analysis.pgno:283to291,doi.org/10.1016, April 2013.
24. M. Freitas, V. Infante, R. Baptista " Failure analysis of the nose landing gear axle of an aircraft " Engineering Failure Analysis. /doi.org/10.1016/j.engfailanal.2019.03.010.Page 113-120 March 2019.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 08, August-2024

25. Asad Hameed, Oama Zubair, Taimur Ali Sham-, Zahid Mehmood, Ali Javed, Zahid Mehmood "Failure analysis of a broken support strut of an aircraft landing gear", Engineering Failure Analysis, doi.org/10.1016/j.engfailanal.2020.104847, Page 1-15, 13 Aug 2020.
26. Mohammed Imran,Shabbir Ahmed .R.M, Mohammed Haneef,Materials Today Proceeding,doi:10.2016/j.matpr.2015.07.228, Page 2170-2178, 2015.
27. P.Kadarno,M.A.Barrinaya,A.O.Manurung Mechanism analysis of a main landing gear of transporting aircraft,Engineering Failure Analysis,doi.org/101016/j.engfailanal, Page 1-8, 2020.105015,Indonesia, 15 October 2020.
28. Andrew LaTour, Matthew Charles, Narsimhan Raghunathan, Magnus Ahlfors "Towards production of landing gear materials with laser powder bed fusion," International Journal of Refractory Metals & Hard Materials, Volume: 91, Article 105272, April 2020. doi: 10.1016/j.ijrmhm.2020.105272, Pages: 1-13.
29. Thoai Nguyen, Alexandra Schonning, Paul Eason, and David Nicholson have developed "Methods for Analyzing Nose Gear During Landing Using Structural Finite Element Analysis," Journal of Aircraft, Corrected proof. doi:10.2514/1.C031519, Volume 49, Pages 275-287, January–February 2012.
30. Jarosław Pytka, Jerzy Józwik, Piotr Budzyński, Tomasz Łyszczyk, Arkadiusz Tofil, Ernest Gnapowski, and Jan Laskowski "Wheel dynamometer system for aircraft landing gear testing," Measurement, doi: 10.1016/j.measurement.2019.106918, Volume 148, Pages 106918, August 2019.
31. H. Mirzaei, A. Ansarirad, "Temperature elevation of aircraft tyre surface at touch down with pre-rotations," CEAS Aeronautical Journal. doi:10.1007/s13272-023-00652-3, Volume: XX, Pages: 1-15, 2023.
32. S.G. Aftab, Sirajuddin, B. Sreedhara, E. Ganesh, N. Ramesh Babu, S. Kiran Aithal have developed “Finite element analysis of a passenger aircraft landing gear for structural fatigue safety” Materials Today: Proceedings, doi: 10.1016/j.matpr.2021.08.199, Volume: 54, Pages: 152-158, September 2021.
33. Plabita Sonowal, K.M. Pandey, K.K. Sharma “Design and static analysis of landing gear shock absorber of commercial aircraft”, Material Today: Proceedings, Volume: 45, Pages: 6712-6717, February 2021.
34. Arif Krisbudiman ,Khairu Rezgi, "Structural Design Analysis Torque of Landing Gear Aircraft" International Journal Advanced Science Engineering Information Technology, Vol.14 (2024) No2 ISSN: 2088-5334, Page 507-513, 30 APRIL 2024.
35. Andrej Tywoniuk Rafal Jakubowski "A Design of and Numerical optimization of a landing gear for 1400kg (AT-6) Take mass Aircraft",Journal of KONES Powertrain and Transport Pg no: 541 to 547, Volume 23, 16.32016, D01: 10.5604/12314005.1216489,ISSN: 1231-4005 , e-ISSN 2354-0133 ,2016.
36. Mahesh Ashok Rout, Rohit Thirrupathi Tumma, Shravani Suresh Desai, Satyendra Rajkumar Upadhyay, Prathamesh preetam Choughule . Design and Analysis of Aircraft landing Gear. IJARIIT, Page no : 831 to 838 , Volume 7, Issue 2-V712-1437 ,ISSN :2454-1325 ,2021.
37. aif Ismail Ibrahim,Mohd karma khadeer, Mohammad Abdul Kareem, Vikas Kumar Tiwari. Design Optimization and Analysis of Aircraft landing Gear. IJMEC, Page no: 1 to 13 , Volume 8, Issue 6 ,doi -ds.org/doilink/06.2023 -96269511 ,ISSN : 2556-4265 , June 2023.
38. J. Wong. L. Rayan. Y.Kim,"Design optimization of aircraft landing gear Assembly under dynamic landing" Industrial Application,DOI 10.1007/s00158-017-1817-y, 30 September 2017.
39. David Gerhardinger, Born Abramovic,Landing gear leg fatigue life Analysis for aircraft,Transportation Research Procedia,dio.org./10.1016/j.trpro.2022.09.003, Page 14-24, India ,2022.
40. M.C. Kushan , S.F. Diltemiz , I. Sackesen “Failure analysis of an aircraft propeller”,Engineering failure analysis, doi:10.1016/j.engfailanal.2006.11.069,pg:1693-1700 November 2006.