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MODELLING AND FABRICATION OF CREEL STAND FOR FILAMENT WINDING MACHINE

C. **Sucharitha[1], P. Shashidar[2], Sk. Priya [3], V. Ashok[4], G. Sukumar[5], B.Balaji[6], D.C.Ashmitha[7]**

[1*, 2*] Assistant Professor, [3, 4, 5,6,7] Student, Mahatma Gandhi Institute of Technology, Gandipet, Hyderabad, Telangana.

ABSTRACT:

This Paper focuses on the modeling and fabrication of a creel stand for use in a filament winding machine, a key process in manufacturing composite materials reinforced with carbon or glass fibers. These materials are critical in industries such as aerospace, automotive, and renewable energy due to their high strength-to-weight ratio and superior durability. The creel stand serves as an essential component, functioning as a spool management system that organizes and holds multiple spools. It ensures controlled fiber release and precise tensioning during the winding process, which is vital for achieving structural integrity and uniform material properties in the final composite products.

The Paper's objective was to develop a robust and modular creel stand using advanced CAD software, such as SolidWorks, to enhance design precision and visualization. Key features include adjustable spool holders for flexibility in accommodating spools of varying sizes, tension control mechanisms to maintain uniform tension across all fibers, and guiding systems to ensure smooth and uninterrupted fiber flow. These elements are critical for preventing misalignments and tangles, which can compromise the quality of the final product.

Additionally, the design incorporates features such as collapsible or detachable components for easy storage and transportation. The stand is designed to be compatible with automated processes, integrating seamlessly with CNC systems for enhanced production efficiency. Emphasis on sustainability and cost-efficiency was also a focus, ensuring minimal material wastage during manufacturing. This Paper contributes to advancing filament winding technologies by improving operational efficiency, reducing production costs, and enabling the manufacturing of high-quality composites that meet diverse industrial needs.

1. Introduction to filament winding machine and its types

A filament winding machine is an advanced manufacturing tool used to create composite materials by winding continuous fibers, typically made of glass, carbon, or aramid, around a mandrel. The fibers are impregnated with resin, and the machine precisely controls their placement in a helical pattern to form strong and lightweight composite structures. These machines are commonly used in industries like aerospace, automotive, and pipe manufacturing, where high-performance, durable, and complex-shaped parts are needed.

The filament winding process allows for best fibre alignment, which enhances the mechanical properties of the final product. The machine’s design can vary, with capabilities to adjust winding angles, tension, and speed to meet specific requirements. With automation, filament winding machines offer improved consistency and precision compared to manual methods, enabling the production of high-quality composite structures in large volumes.

1.1 Types of Filament Winding Machines

- **Manual Filament Winding Machine**
  A Manual Filament Winding Machine requires operators to manually control critical parameters such as winding speed, fiber tension, and fiber placement. Unlike automated systems, it relies on human precision to ensure uniformity and accuracy during the winding process. This type of machine is typically used for small-scale or experimental projects where customization is necessary. While cost-effective and versatile, manual machines demand skilled operation to maintain consistent fiber alignment and quality in the final product. They are commonly employed in industries like aerospace, automotive, and research and development for prototyping and low-volume production.
- **Semi-Automatic Filament Winding Machine**
  A semi-automatic filament winding machine combines manual operation with automated controls for specific functions. Key aspects like fiber tension, winding speed, or spindle rotation are managed through automation, while other tasks, such as mandrel setup or spool loading, require operator intervention. This design strikes a balance between cost and efficiency, making it suitable for medium-scale production. It allows for consistent fiber placement while offering flexibility for customization. Semi-automation ensures better quality control compared to fully manual systems, while remaining more affordable than fully automated setups.

- **Fully Automated Filament Winding Machine**
  A fully automated filament winding machine integrates advanced control systems that regulate all critical parameters, such as fiber tension, speed, and layer deposition, without the need for manual intervention. This level of automation ensures high precision, uniformity, and consistency in the production process, significantly reducing human error and variability. The system can automatically adjust settings in real-time, optimizing performance based on material type and production requirements. This results in increased efficiency, reduced downtime, and lower operational costs, making it ideal for high-volume composite manufacturing. Furthermore, automation enhances product quality by maintaining tighter control over the winding process, leading to more reliable and durable composite products.

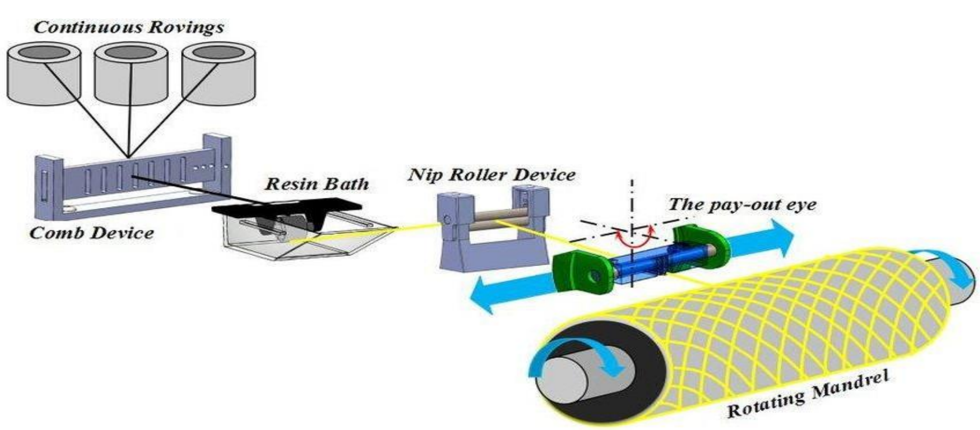

Fig 1.1 Filament Winding Machine

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2. Introduction to Creel Stand for Filament Winding Machines

Filament winding is a widely used manufacturing process for producing composite materials, particularly in industries such as aerospace, automotive, and pressure vessels. The process involves winding continuous strands of filament, such as carbon fiber, fiberglass, or aramid fibers, onto a rotating mandrel to form a cylindrical or spherical structure. A *creel stand* plays a crucial role in ensuring the smooth and efficient operation of this process by providing a stable supply of fibers to the filament winding machine. This comprehensive introduction to the creel stands for filament winding machines will explore its design, working principles, types, and importance in the manufacturing process.

Fig 2 Spools

2.1 Purpose of a Creel Stand

The creel stand acts as the storage and feeding system for the spools of fibers (e.g., carbon, glass, or aramid fibers) that are wound onto the mandrel. It eases the efficient and exact delivery of these fibers to the filament winding head. This uninterrupted and tension-controlled fiber feed is essential for producing composite materials with uniform strength and best performance.

1. **Organized Storage**: The creel stand holds multiple spools of fibers in an orderly manner to streamline the production process.
2. **Tension Regulation**: It keeps consistent tension in the fibres as they are fed to the winding head, preventing defects in the finished product.
3. **Guided Fiber Delivery**: Equipped with guiding mechanisms, the creel stand ensures that fibers are directed accurately to their destination, minimizing errors and wastage.
4. **Adaptability to Project Needs**: Creel stands are designed to accommodate a variety of fiber types and spool sizes, catering to the specific requirements of different projects.

1.2 The Role of the Creel Stand in Filament Winding

A creel stand is a mechanical device designed to hold and organize multiple spools or bobbins of continuous filament fibers. Its primary purpose is to supply these fibers to the filament winding machine at a consistent and controlled tension. The creel stand ensures that fibers are fed to the winding head without any tangling, breakage, or disruption, which is vital for producing high- quality composite products.

In a typical filament winding process, the fibers are unwound from spools mounted on the creel stand and passed through guides to the winding machine. The fibers are then deposited onto a rotating mandrel, which is typically the shape of the final product, such as a cylinder, tube, or pressure vessel. The creel stand serves as the starting point of this process and is critical in ensuring that the fibers stay in good condition and are fed smoothly.

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- **Continuous Fiber Supply**

A creel stand ensures a continuous fiber supply by organizing and managing multiple spools of fiber, preventing interruptions during the filament winding process. It maintains an even tension across all spools, allowing for uninterrupted fiber delivery. This seamless supply is crucial for optimizing production efficiency and minimizing delays, as any disruption in fiber flow could halt the entire process. The stand's design prevents issues such as tangling or misalignment, which can disrupt the manufacturing flow. As a result, it contributes to smoother, faster, and more efficient composite production.

- **Uniform Tension Control**

Maintaining uniform tension is essential in filament winding to ensure consistent fiber placement throughout the process. Variations in tension can lead to defects such as misaligned fibers, uneven distribution, or poor bonding between layers, ultimately affecting the composite's mechanical properties. Tension control systems, such as automated tensioners and feedback loops, play a key role in regulating and adjusting the tension in real-time, ensuring that each spool provides a steady and uniform supply of fiber. This precision is critical for preserving the structural integrity and performance of the final composite product, especially in industries where high-quality standards are required, such as aerospace and automotive.

- **Precise Fiber Alignment**

Precise fiber alignment is crucial in filament winding processes to ensure the structural integrity and strength of the final composite. Misaligned fibers can cause defects such as weak points or inconsistent material properties, ultimately affecting the quality of the composite. The creel stand's guiding system plays a vital role in ensuring that the fibers are correctly aligned as they unwind from the spools. This reduces the risk of tangling or misplacement during the winding process. By maintaining proper alignment, the creel stand contributes to producing a uniform and high-quality composite material with improved performance characteristics. Such alignment also enhances the overall efficiency of the filament winding machine by minimizing the need for corrections during production.

- **Reduction of Material Wastage**

By minimizing fiber tangles, breaks, and misalignments, the creel stand plays a significant role in reducing material wastage during the filament winding process. Efficient tension control and fiber guidance mechanisms ensure that the fibers are delivered smoothly, without interruptions or damage. This helps maximize the use of raw materials, preventing unnecessary losses. Additionally, maintaining proper tension across all spools reduces the likelihood of uneven winding, further enhancing material efficiency. As a result, the creel stand contributes to a more sustainable manufacturing process by improving material conservation and reducing waste.

- **Improved Quality and Efficiency**

Proper tension control and precise fiber delivery are critical for achieving high-quality composites. Consistent tension across multiple spools ensures uniform fiber placement, preventing defects such as uneven fiber distribution or misalignments. These design considerations significantly impact the structural integrity and durability of the final product. Additionally, the controlled release of fibers reduces the likelihood of issues like fiber breakage or tangling, improving the overall efficiency of the filament winding process. By enhancing both quality and efficiency, the creel stand contributes to more reliable production cycles and better performance of composite materials in demanding applications.

3. FEATURES OF MODELING AND ANALYSIS SOFTWARE

3.1 Features of SolidWorks for Design and Simulation

SolidWorks offers an extensive array of features for design and simulation, setting up itself as a robust tool for engineers and designers. On the design front, it accommodates 3D modelling, parametric design, and sophisticated tools for sheet metal, weldments, and Mold design, delivering both flexibility and precision in the creation of intricate shapes and assemblies. Its design library grants access to standard components, while assembly management tools effectively manage large assemblies, featuring collision detection and motion analysis. In terms of simulation, SolidWorks includes finite element analysis (FEA) to evaluate stress, vibration, fatigue, and thermal performance, as well as fluid flow simulation for examining fluid dynamics and thermal interactions. Together, these functionalities, along with the seamless integration of CAD and simulation, make SolidWorks a vital tool for the effective design and validation of engineering projects.

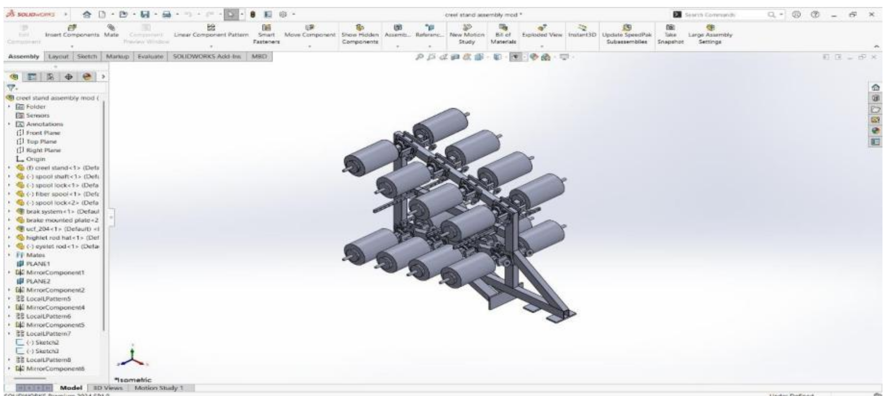

Fig 3.1 SolidWorks Design

3.2 Tools used for Filament Winding Machine analysis

In SolidWorks, tools like Part Design and Assembly are essential for designing a creel stand. The Sketching tool allows for precise 2D sketches, while Extrude, Revolve, and Loft help create 3D components. Mate features are used to position and constrain parts in the assembly. Simulation tools enable assessing the stand's strength and performance under load, ensuring the design's durability. Drawing tools are also used to create detailed engineering drawings for manufacturing. For creel stand analysis in SolidWorks, Simulation tools like Static Analysis and Motion Study are commonly used. These tools allow for the evaluation of stress, strain, and deformation under load, as well as the dynamic behavior of the stand during operation. Additionally, Finite Element Analysis (FEA) is employed for more detailed structural analysis, helping improve the design for strength and stability. Flow Simulation can also be useful to assess the movement of fibers and air within the stand. These tools ensure that the stand's design can withstand operational conditions, minimize risks of failure, and improve overall functionality, making it suitable for high- performance applications. Advanced features, such as Thermal Analysis, can also be used to assess temperature effects on materials, further refining the design for real-world conditions.

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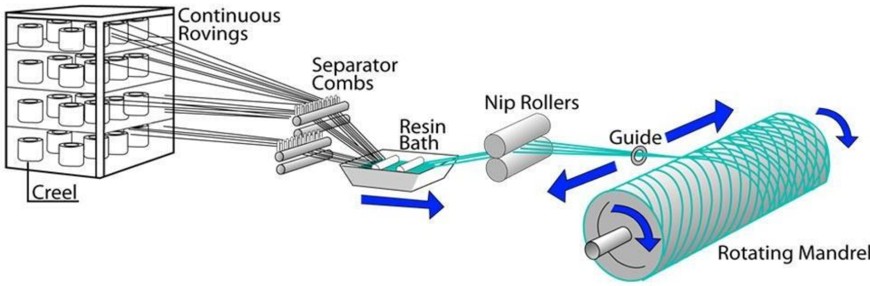
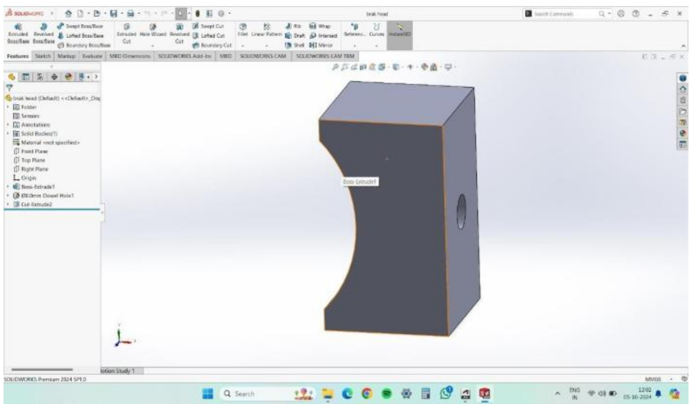
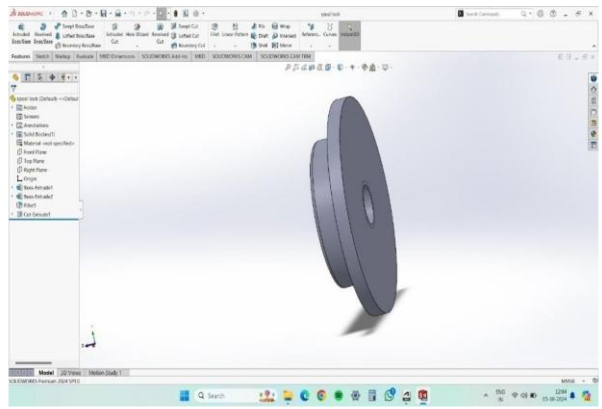


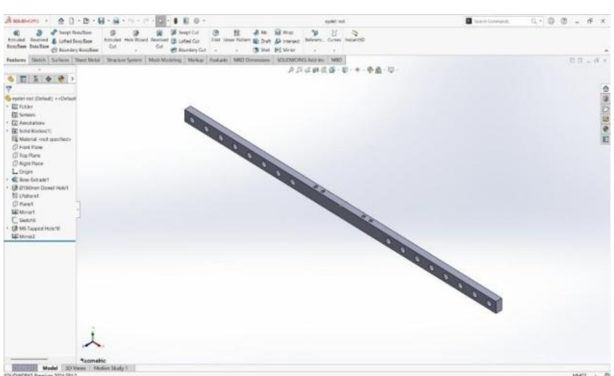
4. Components of Creel Stand



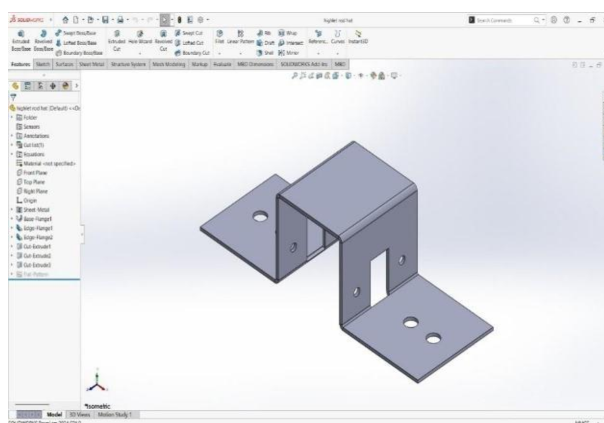
4.1 Brake Head



4.2 Spool Lock



4.3 Eyelet rod



4.4 Highlet Rod Hat

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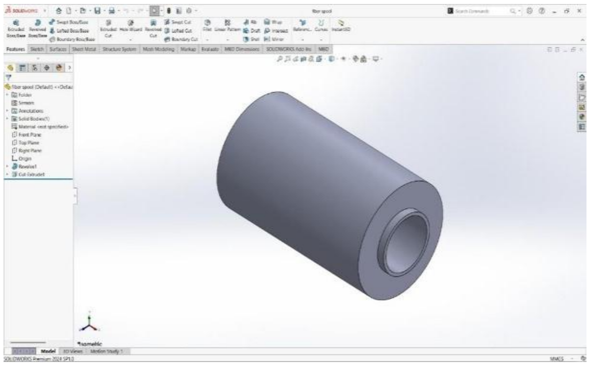
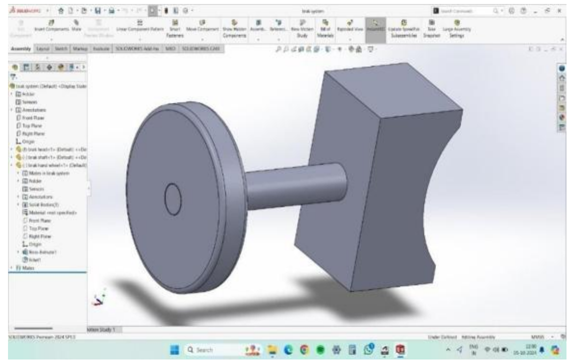
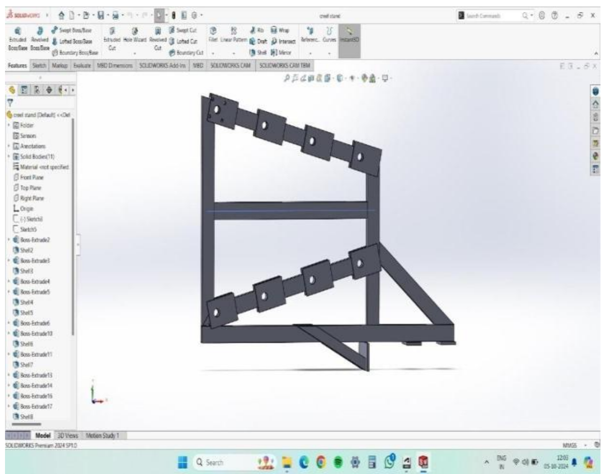


4.5 Fiber Spool



4.6 Brake System



4.7 Creel Stand

5. Fabrication

Fabrication involves the physical creation of the creel stand based on the detailed design specifications. This process typically starts with sourcing the required materials and cutting them to the appropriate sizes. Components may be shaped using various techniques, such as machining, welding, or forming, depending on the material chosen. Once the individual parts are prepared, they are assembled into the final structure. During fabrication, great attention must be paid to quality control to ensure that the components meet the specified standards. This stage also includes verifying that the final product will perform as intended under real-world conditions, ensuring its reliability and functionality once in use.

Fig. 5.1 Fabrication of Creel Stand

RESULT AND DISCUSSION

Results

The design and fabrication of the creel stand for a filament winding machine with 16 spools successfully addressed key challenges associated with fibre delivery, tension control, and operational efficiency. The final design featured a robust yet lightweight structure capable of accommodating the weight and size of the spools while ensuring stability during operation. Tensioning mechanisms were effectively integrated into the design, keeping uniform tension across all spools and preventing fibre misalignment during the winding process. Additionally, the use of guides and rollers minimized fibre entanglement and ensured smooth movement along well- defined paths. Fabrication tests confirmed that the modular spool holders allowed for quick and seamless spool changes, significantly reducing downtime and enhancing overall productivity.

Discussions

The results show that the incorporation of systematic design steps, including detailed analysis and testing, was critical to achieving a functional and reliable creel stand. The choice of materials and structural design proved adequate for handling operational stresses while keeping durability. However, testing also revealed areas for potential improvement, such as refining the tensioning system to manage varying fibre types and loads more effectively. Further, ergonomic adjustments to the spool placement could enhance user interaction and ease of operation. The study highlights the importance of iterative design and evaluation in creating equipment that meets both technical and practical requirements, ensuring best performance and high-quality fibre delivery in filament winding applications.

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