DESIGN AND ANALYSIS OF BOEING 737-200 AIRCRAFT

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A
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TOPIC - DESIGN AND ANALYSIS OF BOEING 737-200 AIRCRAFT

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ABSTRACT

- This project presents a comprehensive approach to the design and assembly of the BOEING737-200 aircraft using SolidWorks, a powerful and versatile CAD software for 3D modeling and simulation.
- Throughout this project, each major component was meticulously designed with careful consideration for both aerodynamic performance and structural integrity.
- SolidWorks provided robust tools for designing complex geometries, allowing for precise modeling of aerodynamic surfaces and structural features.
- The assembly process involved aligning and integrating these components into a unified model, ensuring that they interact seamlessly and contribute to the aircraft's overall aerodynamic and structural performance.
- The final assembled model provides critical insights into the aircraft’s overall configuration, effectiveness, and functionality. Through this work, the project reinforces the BOEING 737-200 reputation as a benchmark in aerodynamics, efficiency, and luxury, demonstrating that SolidWorks is an invaluable tool for modern aerospace design and assembly processes.

INTRODUCTION

- The Boeing 737-200 is a twin-engine, short-to-medium range jet aircraft that was first produced in 1967.
- Its capabilities include operating at high altitudes with reduced fuel consumption, and it offers a unique combination of speed, range, and comfort, positioning it as a leader in the business aviation market.
- SolidWorks is essential in aerospace engineering, enabling precise 3D modeling, simulations, and design optimization to ensure safety and efficiency while reducing costs and development time. Its advanced tools streamline the evaluation and refinement of complex aerospace components.
- The purpose of this project is to utilize SolidWorks to design and analyze the major structural components of the BOEING 737-200 aircraft, including the wing, fuselage, empennage, and power plant.

- The BOEING 737-200 aircraft comprises several key structural and aerodynamic components that ensure its high

  performance and long-range capability. Below is a brief overview of each major component:

1. **WING**

Design: The wings of the BOEING 737-200 are designed to provide maximum lift with minimal drag, contributing to its long-range capability.

Airfoil: A high-efficiency airfoil shape is used to enhance fuel efficiency and stability.

Structural Components: The wing is built with primary components like spars, ribs, and skins, which maintain the structural integrity during flight.

2. **FUSELAGE**

Structure: The fuselage is the central body of the aircraft, housing passengers, crew, and systems. It is designed to withstand high-pressure differentials and aerodynamic loads.

Material: Lightweight yet strong materials like composite and aluminum alloys are used for weight reduction and strength.

Functionality: The fuselage also integrates various systems, such as environmental control and avionics.

3. EMPENNAGE

The empennage is the tail section of the aircraft, consisting of the horizontal and vertical stabilizers. The horizontal stabilizer helps to control the pitch of the aircraft, while the vertical stabilizer helps to control the yaw. Both stabilizers are essential for maintaining stability and control during flight.

4. POWER PLANT

Engines: The Boeing 737-200 uses Pratt & Whitney JT8D-1 turbofan engines. These engines were mounted under the wings of the aircraft.

Thrust: These engines deliver optimal performance with efficient fuel burn, contributing to the aircraft's extended range.

5. LANDING GEAR

Configuration: The Boeing 737-200 features a tricycle landing gear system for balanced weight distribution during takeoff, landing, and taxiing.

Materials: The gear is made of high-strength alloys to withstand the stresses of repeated landings and takeoffs.

Retractability: For aerodynamic purposes, the landing gear retracts into the fuselage during flight

6. AVIONIC SYSTEMS

Cockpit Systems: The aircraft is equipped with advanced fly-by-wire system and cutting-edge avionics that assist in navigation, communication, and flight control.

Passenger Comfort: The fuselage is fitted with advanced cabin pressurization and climate control systems, ensuring passenger comfort over long distances.

Figure 1.1. BOEING 737-200

SOFTWARE- AN OVERVIEW

SolidWorks, a leading 3D CAD software, is a powerful tool used by engineers, designers, and manufacturers worldwide to create, simulate, and analyse products.

- Core features and Capabilities:

1. 3D Modeling: SolidWorks supports part, assembly, and sheet metal modeling, allowing precise and efficient creation of complex 3D models.
2. Feature-Based Modeling: Users can build models by adding or removing features like holes, fillets, and chamfers, simplifying the design and modification process.
3. Assembly Design: Tools for creating and managing assemblies with defined constraints and motions to simulate real-world behavior.
4. Drawing Creation: Generates 2D drawings from 3D models, including views and dimensions, essential for manufacturing and documentation.

5. Finite Element Analysis (FEA): Performs structural and thermal analysis to identify issues and optimize designs.
6. Motion Analysis: Simulates movement in mechanical systems to assess kinematics and dynamics.
7. Rendering and Visualization: Creates photorealistic renderings and animations for presentations and design reviews.
8. Collaboration and Data Management: Integrates with various CAD formats and supports data management for organized design collaboration.

- **Benefits of Using SolidWorks**

Increased Productivity: SolidWorks' intuitive interface and automation features can significantly improve design productivity.

Enhanced Design Quality: The software's capabilities for analysis and simulation help to create more reliable and efficient designs.

Improved Collaboration: SolidWorks supports collaboration among design teams, enabling better communication and coordination.

Reduced Time-to-Market: By streamlining the design and development process, SolidWorks can help companies bring products to market faster.

Lower Costs: Using SolidWorks can reduce costs associated with physical prototyping and testing.

- **Industries Using SolidWorks**

SolidWorks is used in a wide range of industries, including:

Automotive: Designing cars, trucks, and other vehicles.

Aerospace: Creating aircraft, spacecraft, and components.

Machinery: Designing industrial machinery and equipment.

Consumer Products: Developing consumer goods such as electronics and appliances.

Medical Devices: Designing medical equipment and implants.

LITERATURE REVIEW

The Boeing 737-200 and Its Comparisons with Boeing Aircraft Families

Introduction

The Boeing 737-200, a member of the 737 family, is a narrow-body aircraft that has played a significant role in commercial aviation since its introduction in the late 1960s. This review examines the 737-200 in the context of its family, comparing it to other Boeing aircraft, particularly the later models of the 737 family and its counterparts in other Boeing families such as the 727 and 757. This comparison emphasizes technological advancements, operational efficiency, and market adaptability.

Overview of the Boeing 737-200

The Boeing 737-200 was first introduced in 1967 as an enhancement of the original 737-100. It featured a longer fuselage, accommodating more passengers and increasing its versatility for airlines. The 737-200's range and performance made it a popular choice for regional and short-haul routes. Its two Pratt & Whitney JT8D engines contributed to its relatively low operating costs, which appealed to various airlines globally.

Evolution of the Boeing 737 Family

The Boeing 737 family has evolved significantly since the introduction of the 737-200. The subsequent models—737-300, 737-400, 737-500, and the Next Generation series (737NG) including the 737-600, 737-700, 737-800, and 737-900—showcase advancements in aerodynamics, engine technology, and passenger comfort.

737-300/400/500: The 737-300, introduced in 1984, incorporated CFM56 engines, enhancing fuel efficiency and reducing noise. The 737-400 offered a larger passenger capacity, and the 737-500 was designed for short-haul markets. Compared to the 737-200, these models offered improved range and better payload capacity.

737 Next Generation (NG): The NG series, launched in the late 1990s, introduced advanced wing designs, larger passenger cabins, and the latest CFM56 engines, which provided significant reductions in fuel consumption and emissions compared to the 737-200. The NG models are also equipped with advanced avionics, contributing to better operational efficiency.

737 MAX: The latest generation, the 737 MAX, features the LEAP-1B engines and advanced winglets, offering further enhancements in fuel efficiency and environmental performance. Compared to the 737-200, the MAX models have dramatically increased operational range and reduced per-seat costs.

Comparison with Other Boeing Aircraft Families

To provide a broader context, the 737-200 can also be compared with other Boeing aircraft families such as the 727 and 757.

Boeing 727: The Boeing 727 was a trijet aircraft introduced in the 1960s, designed for medium-haul flights. While the 727 offered more powerful engines and greater range than the 737-200, it also had higher operating costs. The 727 was favored for its ability to operate from shorter runways, but the 737-200 eventually surpassed it in terms of operational flexibility and market share, leading to the 727's decline.

Boeing 757: The Boeing 757, introduced in the 1980s, was a larger narrow-body aircraft capable of longer-haul operations. Its advanced aerodynamics and engines made it more efficient than the 737-200 for certain routes. While the 757 offered greater passenger capacity and range, the 737-200's lower operating costs kept it competitive, especially in regional markets.

Technological and Operational Considerations

The technological advancements in later models of the 737 family highlight the shift in aviation towards increased fuel efficiency, reduced emissions, and enhanced passenger comfort. The transition from the 737-200 to the 737 MAX exemplifies Boeing's commitment to adapting to market demands and environmental regulations. The 737-200, while outdated by modern standards, paved the way for innovations that have become standard in contemporary aviation.

Conclusion

The Boeing 737-200 remains an important chapter in the history of commercial aviation, representing the beginnings of what would become one of the most successful aircraft families in history. Its comparisons with subsequent 737 models and other Boeing families underscore the evolution of aviation technology and the ongoing drive for efficiency and performance in air travel. As the industry continues to evolve, the foundational contributions of the 737-200 provide valuable insights into the development of modern aircraft. Future studies could further explore the operational implications of these advancements on airlines and passengers alike.

DESIGN OF WING AND ITS STRUCTURAL COMPONENTS

Wing dimensions

Parameter	Description	Value
Wingspan	Total distance from tip to tip	28.88 m (94 ft 5 in)
Wing Area	Total surface area of the wing	105.4 m² (1,136 ft²)
Aspect Ratio	Ratio of wingspan to average wing width	7.3
Wing Loading	Aircraft weight per unit area of wing	588 kg/m² (121.3 lb/ft²)
Airfoil Type	Shape of the wing cross-section	NACA 4412 (varies along span)
Mean Aerodynamic Chord	Average chord length of the wing	3.5 m (11 ft 6 in)
Wing Root Chord	Chord length at the root of the wing	5.9 m (19 ft 4 in)
Wing Tip Chord	Chord length at the tip of the wing	3.0 m (9 ft 10 in)
Dihedral Angle	Angle between the wing and the horizontal plane	5°
Control Surfaces	Types of control surfaces on the wing	Ailerons, Flaps
Flap Span	Span of the wing flaps	14.0 m (45 ft 11 in)
Maximum Flap Deflection	Maximum angle for flaps during landing	40°
Wing Material	Material used for wing construction	Aluminum Alloy

COMMANDS USED IN DESIGNING WING:

1. Lofted Boss/Base: Creates a wing profile from airfoil shapes.

2. Swept Wing: Creates a wing with a tappered angle.

3. Extruded Boss/Base: Extrudes a wing rib or spar.

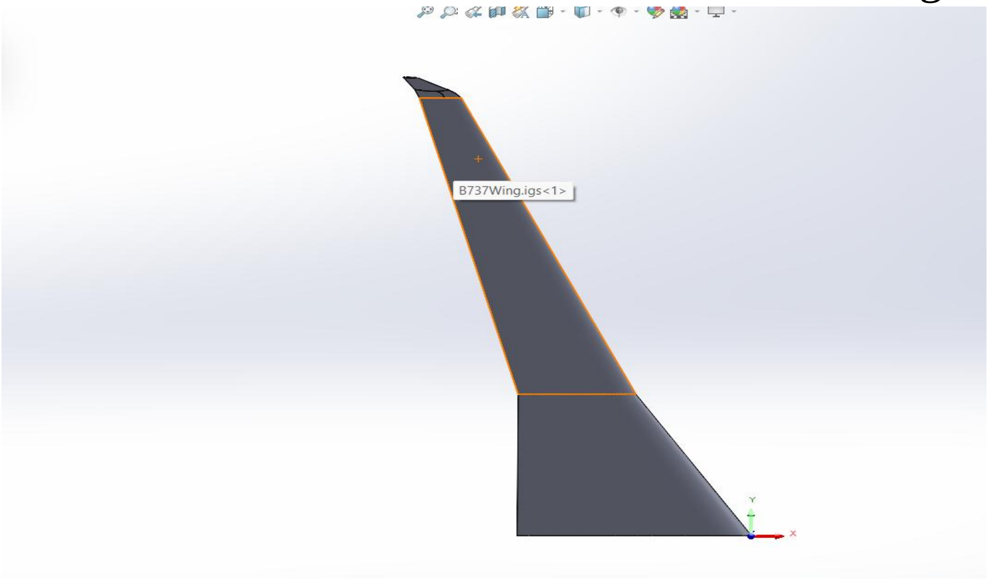
4. Fillet: Smooths edges between wing surfaces.

5. Mirror:Duplicates wing components for symmetrical design.

6.Curve Through XYZ Points: Creates a curve through key points (e.g., wingtips).

7. Surface Fill: Fills gaps between wing surfaces.

8. Trim/Untrim: Trims or untrims surfaces to create wing shape.



Design Process in SolidWorks

Define Parameters: Establish key parameters like fuselage length, diameter, and cross-sectional shape.

Create Geometry: Use SolidWorks' surface and curve tools to design the aerodynamic shape of the fuselage.

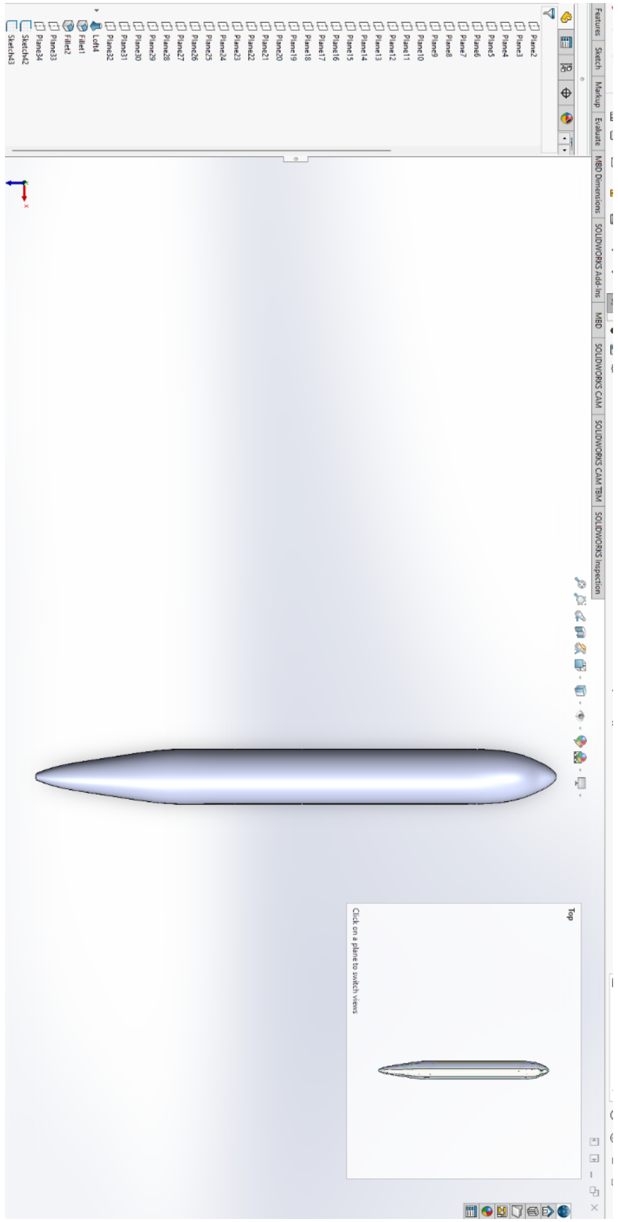
Model Structural Components: Create the frames, stringers, and skin panels using part modeling tools.

Assemble Components: Combine the components into a complete fuselage assembly.

Apply Constraints: Define relationships between components, such as mating conditions and dimensions.

Iterate and Refine: Make adjustments to the design based on analysis results and other considerations.

Create Drawings: Generate detailed drawings of the fuselage for manufacturing and assembly.



Sectional views of fuselage

Design of power plant

Key Components:

1. **Engine Type**: General Electric Passport turbofan engines, known for high thrust-to-weight ratio.
2. **Fan, Compressor, Combustor, and Turbine**: Outline each stage, emphasizing air intake, compression, combustion, and exhaust.
3. **Nacelle**: Describe its role in reducing drag and housing the engine.
4. **Mounting Structure**: Importance in supporting the engine securely with consideration for vibration reduction and aerodynamics.

SolidWorks Tools for Power plant Design

1. **Part Modeling:** Creating individual blades and blade sections.
2. **Surface Modeling:** Designing the aerodynamic profile of the blade.
3. **Sweep:** Creating complex shapes for the blade's root and tip sections.
4. **Loft:** Connecting multiple profiles along a path to create the blade's 3D shape.
5. **Drafting:** Creating detailed drawings of the blade for manufacturing and assembly.

Power plant Design Process

•Step 1: Set Up the Design Parameters.
•Step 2: Sketch Initial Layouts
•Step 3: Create 3D Models of Individual Components
•Step 4: Assembly of Components

Step 1: Set Up the Design Parameters.

Parameter	Description	Value
Blade Length	Total length of the blade	150 mm
Chord Length	Width of the blade at its base	30 mm
Max Thickness	Maximum thickness of the blade	5 mm
Angle of Attack	Angle between the chord line and the incoming airflow	15 degrees
Number of Blades	Total number of blades in the compressor stage	24
Material	Primary material used for the blade	Titanium Alloys
Operating Temperature	Maximum operating temperature	900 °C

Parameter	Description	Value
Overall Length	Total length of the aircraft	33.67 m (110 ft 5 in)
Wingspan	Distance between the wingtips	28.35 m (93 ft)
Height	Vertical distance from the ground to the top of the vertical stabilizer	11.18 m (36 ft 8 in)
Maximum Takeoff Weight (MTOW)	Maximum weight at which the aircraft can take off	59,000 kg (130,000 lb)
Maximum Landing Weight (MLW)	Maximum weight at which the aircraft can land	51,000 kg (112,000 lb)
Typical Seating Capacity	Number of passengers the aircraft can typically seat	110-130
Range	Maximum distance the aircraft can fly without refueling	3,890 km (2,420 mi)
Cruise Speed	Typical cruising speed	Mach 0.79 (860 km/h or 535 mph)
Engine Type	Type of engines used	Pratt & Whitney JT8D turbofan

- **COMMANDS USED IN DESIGNING POWER PLANT:**

Turbine Design:

1. Revolved Boss/Base: Creates turbine blades.

2. Swept Wing: Creates turbine vanes.

3. Extruded Boss/Base: Extrudes turbine hub or shaft.

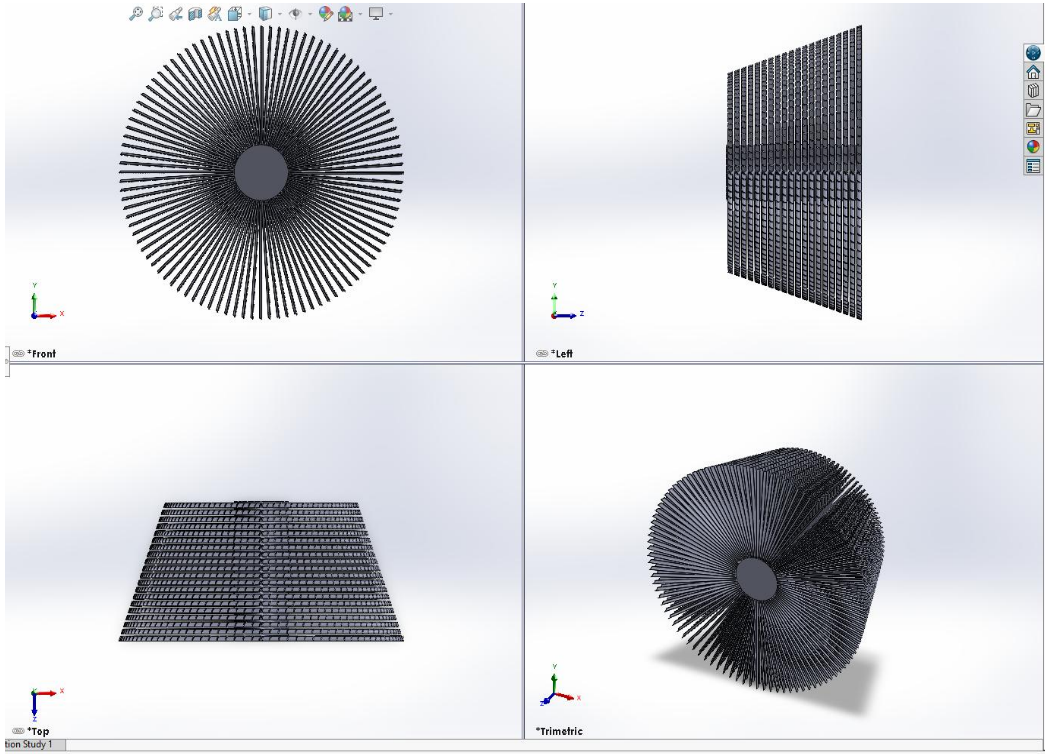
4. Fillet: Smooths edges between turbine components.

5. Lofted Boss/Base: Creates complex turbine shapes.

6. Curve Through XYZ Points: Creates curves for turbine blade design.

7. Surface Fill: Fills gaps between turbine surfaces.

8. Pattern: Creates repeating patterns (e.g., turbine blades).



Compressor Design:

•1. Revolved Boss/Base: Creates compressor blades.

•2. Swept Wing: Creates compressor vanes.

•3. Extruded Boss/Base: Extrudes compressor hub or shaft.

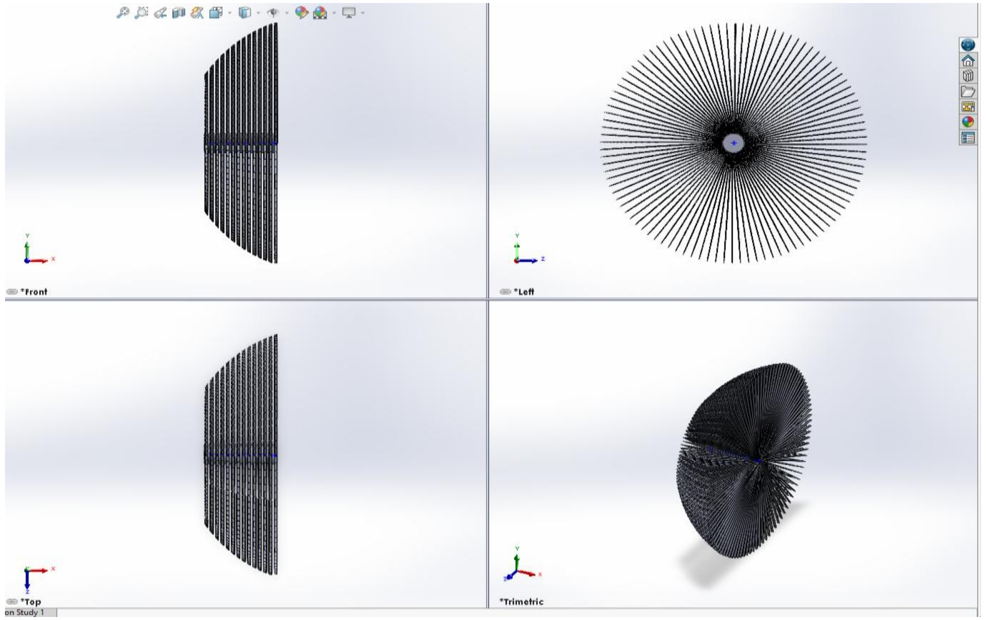
•4. Fillet: Smooths edges between compressor components.

•5. Lofted Boss/Base: Creates complex compressor shapes.

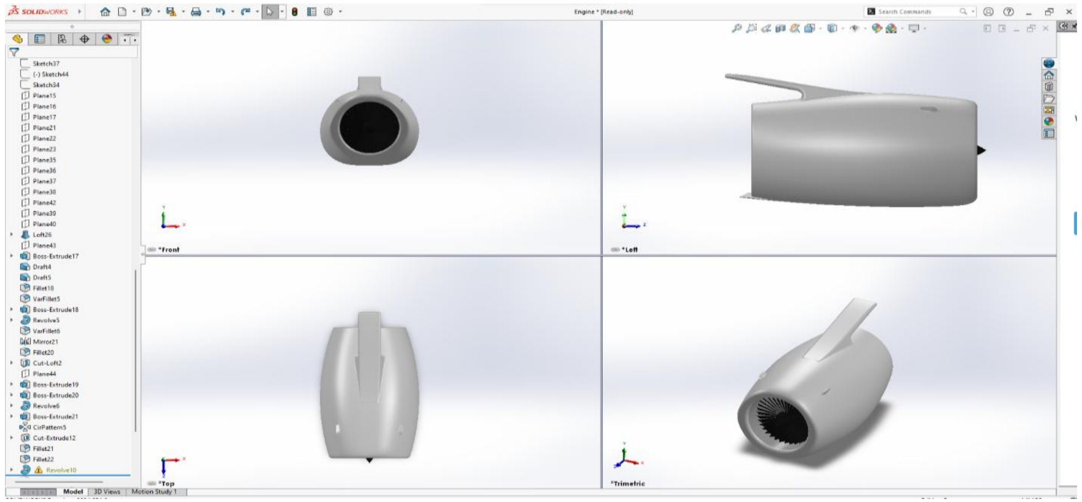
•6. Curve Through XYZ Points: Creates curves for compressor blade design.

•7. Surface Fill: Fills gaps between compressor surfaces.

•8. Pattern: Creates repeating patterns (e.g., compressor blades).



Overall Design Of Powerplant



Final Design Assembly

1.Preparing Components

- **Compatibility**: Ensure dimensions and alignment compatibility.
- **Organize Components**: Import and label each part (wing, fuselage, empennage, power plant, landing gear) in the assembly workspace.
- **Coordinate System**: Set a common origin for accurate positioning.

2. **Assembly Process**

- **Fuselage**: Set as the primary reference, fixing it at the origin.
- **Wings:**

  - Positioning: Align wing roots with the fuselage's wing interface.
  - Mates: Use Coincident, Parallel, and Angle Mates for alignment and dihedral angle.

- **Empennage**:

  - Horizontal Stabilizer: Attach with Coincident and Angle Mates.
  - Vertical Stabilizer: Use Perpendicular Mates to align with the fuselage.

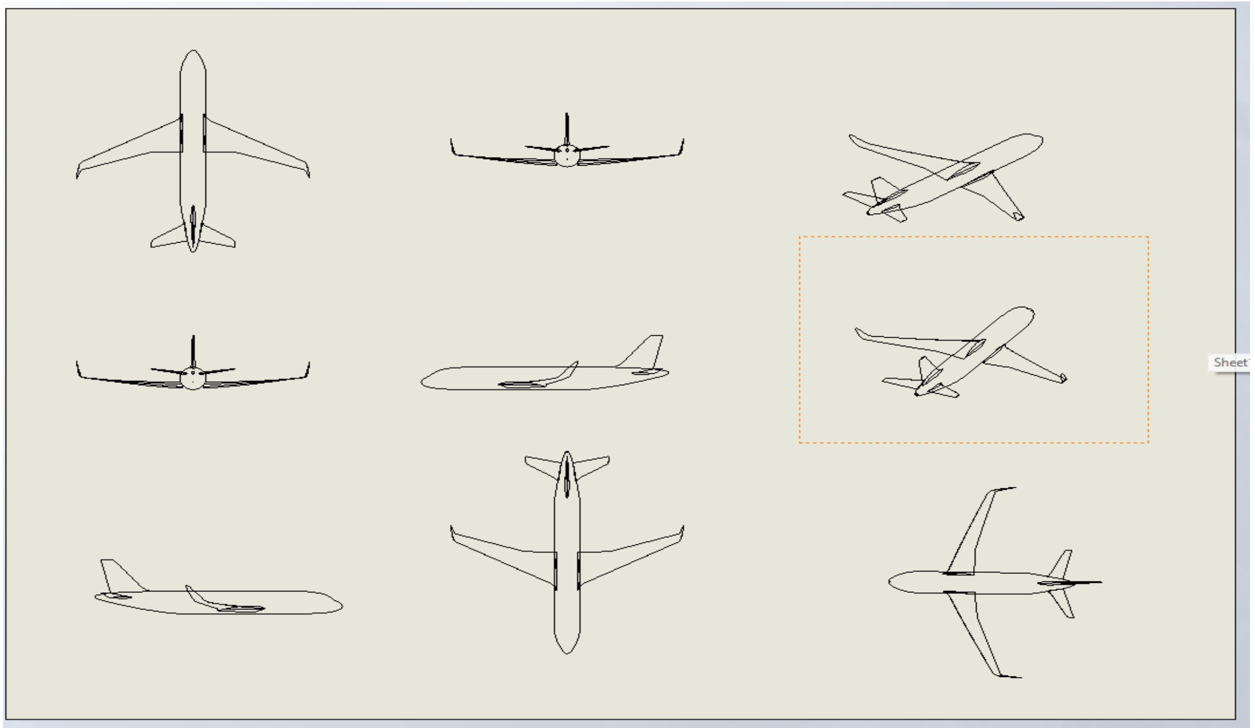
- **Power Plant**:

  - Nacelles: Position under the wing and attach with Coincident and Concentric Mates.
  - Angle Adjustment: Set engine orientation as needed.

- **Landing Gear:**

  - Nose Gear: Align with the fuselage's front gear bay.
  - Main Gear: Attach to wing/fuselage points with Parallel and Coincident Mates.
  - Retraction Test: Simulate gear motion to ensure proper fit and clearance.

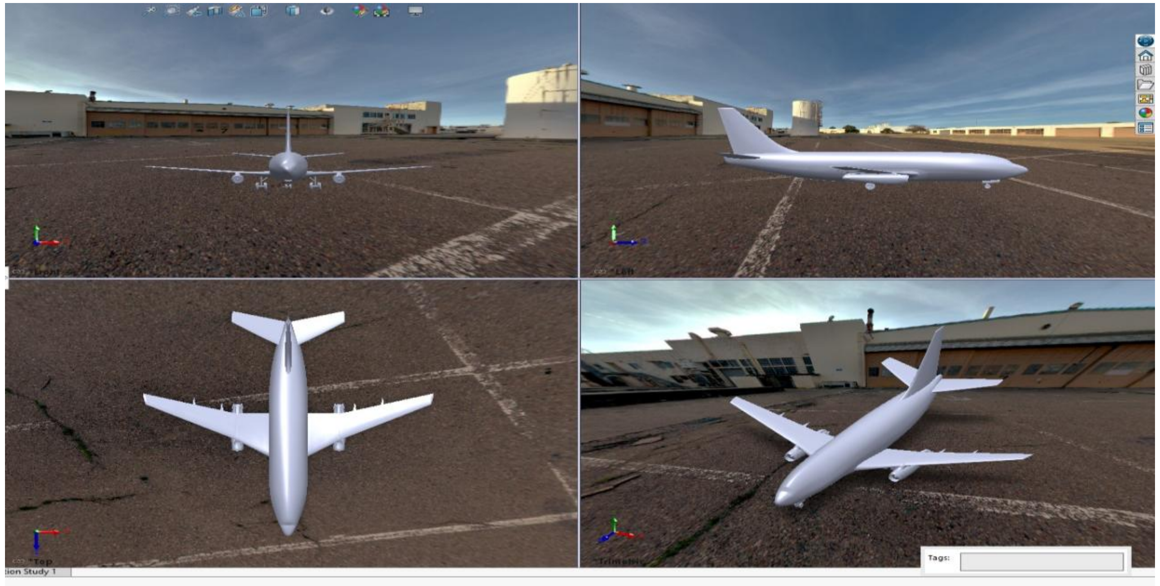
3. **Full Assembly of Aircraft**

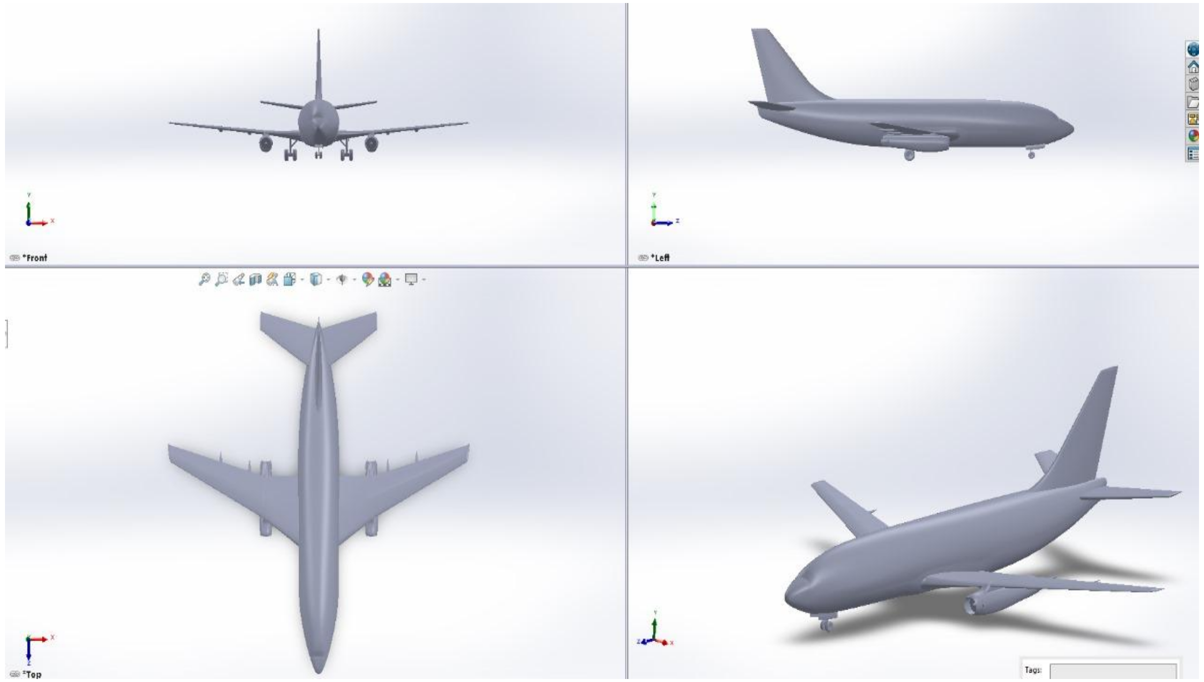


6. **Finalizing the Design**

- **Detailed Views**: Create section, exploded, and annotated views.
- **BOM**: Generate list of components for manufacturing.
- **Export:** Save for rendering or further analysis.

7. **Detailed Assembly**





4. **Final Assembly Adjustments**
- **Tolerance Check:** Run Tolerance Analysis for seamless fit.
- **Interference Detection**: Identify and resolve component overlaps.
- **Mass & Balance**: Verify center of gravity and weight distribution with Mass Properties Tool.

5. **Advanced Assembly Techniques**
- **Motion Simulation**: Test landing gear, engine rotation, and control surfaces.
- **Aerodynamic Testing:** Use Flow Simulation for lift, drag, and flow analysis.
- **Structural Analysis**: Perform Static Analysis for load and stress integrity.

Conclusion

- The design of the BOEING 737-200aircraft in SolidWorks was a comprehensive, structured process focused on accuracy for optimal performance and structural integrity.
- Key components—wings, fuselage, empennage, power plant, and landing gear—were modeled to meet functionality, efficiency, and structural requirements.
- The wing design balanced lift and drag, with internal spars and ribs to ensure strength and load distribution.
- Fuselage design prioritized aerodynamics, passenger comfort, and structural strength, with detailed modeling of elements like windows, doors, and bulkheads.
- Empennage components, including stabilizers and control surfaces, were crafted for stability and precise handling during flight.
- Power plant components were designed with efficiency and precision to adhere to stringent engine performance criteria.
- This project showcased SolidWorks' capabilities in creating a fully integrated aircraft model that meets structural, aerodynamic, and functional standards, ensuring an accurate and reliable design for future application.

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