THE MECHANISM FOR HELICOPTER ROTOR DESIGN AND ANALYSIS

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Abstract

The main objective of the project is to design and research a helicopter rotor mechanism. Applying these approaches correctly and successfully to a complex design, like a helicopter rotor mechanism, where the aerodynamics are complex and changing and the design space has many dimensions, is the current challenge. As optimization methodologies sometimes need for a starting design point, the design phase is just as important as the optimization process. The first optimization of rotors employed simpler computational fluid dynamics (CDF) approaches.

Keywords: Computational fluid dynamics, Solidworks, Ansys, and rigid dynamics analysis

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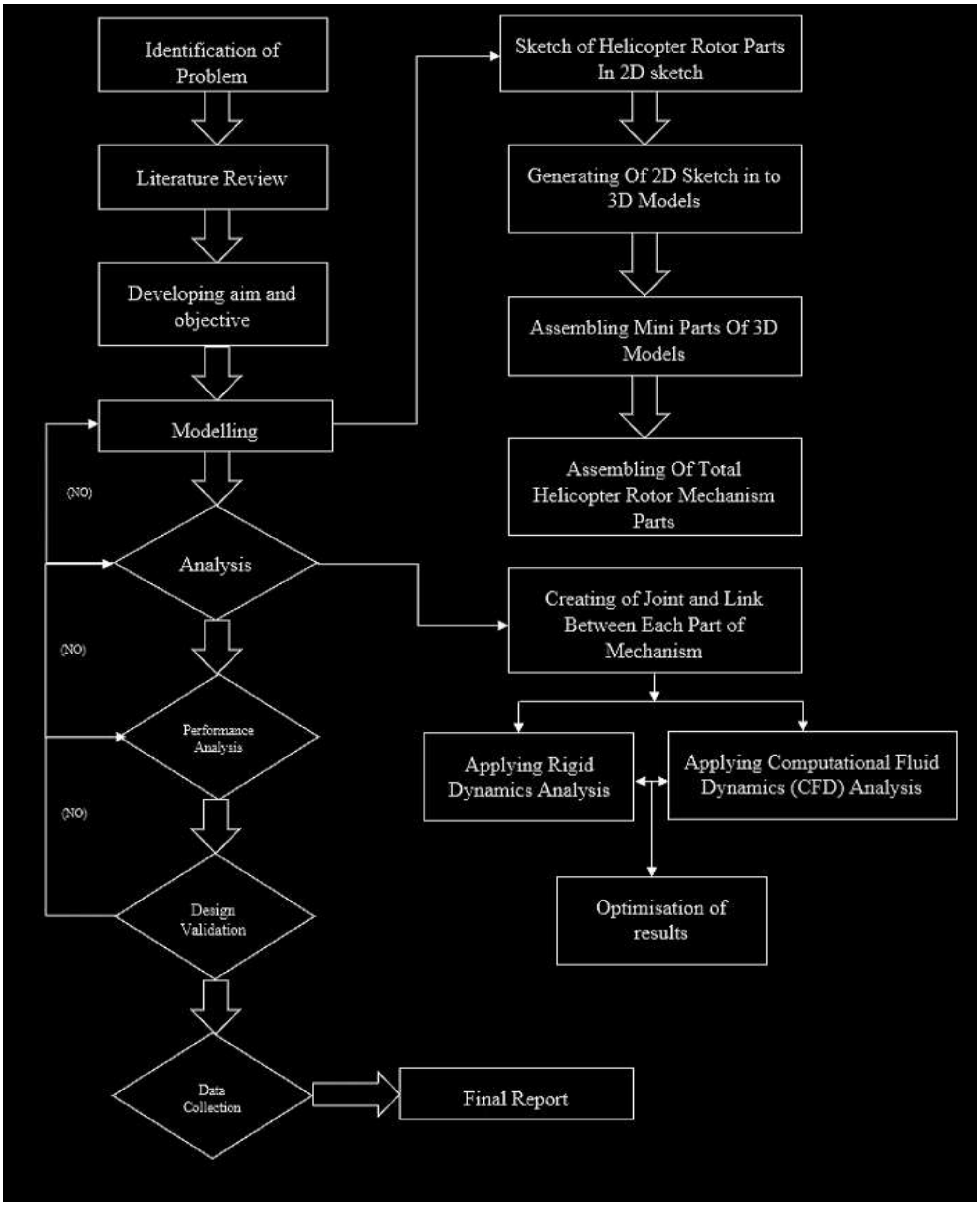
1. Problem statements

- Heavy Rotors require more power to lift a helicopter since they employ more components.
- The retreating blade stall, a dangerous circumstance, is brought on by the helicopter's forward speed, which causes a larger relative airflow over the advancing side compared to the retreating side. A dissymmetry of lift is consequently seen.(Richez, 2018)
- It is crucial to have the same lift over the whole rotor disc.
- Problems with takeoff and landing are brought on by the airfoil blades' streamlined design and drag force.

1.1 Research Objective

1. With the programme Solidworks, create a helicopter rotor system with few components.
2. Rigid Dynamics Analysis will be used to develop an ideal mechanism solution and minimise its impact.
3. Using Computational Fluid Dynamics (CFD) Analysis, create rotor blade aerofoil forms to reduce the stress placed on them.
4. to evaluate the design using FEM tools like Solidworks or Ansys

2. Methodology



- Problem identification: To enhance a rotor mechanism while a helicopter lifts off.
- Review of the Literature: After consulting a number of research articles, the project's potential was recognised. These studies also aided in the right design and analysis processes.
- Development goal and objective: To reduce the stress put on the rotor, connecting rod, and scissor blades when operating at various revolutions per minute.
- Creating software models SOLIDWORKS was used to design every component of the rotor mechanics for the helicopter.
- Analysis: Rigid dynamics analysis and computational fluid dynamics (CFD) analysis were performed on the components using the ANSYS software.(Wie et al., 2009)
- Performance analysis: A significant number of iterations were completed utilising the iteration approach, and performance evaluation was completed.
- Validation of the design: The iteratively acquired data was utilised to complete the design, and the model underwent the corresponding alterations for improved performance.
- Data gathering: To compile correct data from a range of pertinent sources of analysis and measure it.(Wan, 2013)
- Final report: The project report is written documentation of the tasks, procedures, and activities that were done, completed, and applied while pursuing their initiatives.
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3. Helicopter mechanism modelling

3.1 Components of helicopter mechanism design

There are several parts to the mechanics of the helicopter rotor. These parts go into building the rotor mechanism. In the procedure, we first sketched up the components in 2D, and then we used the 2D sketch to produce the parts for the 3D models. After creating the 3D model, we put together a micro assembly by grouping several small assemblies together.(Chatterjee et al., 2021; Shen, 2004) The main assembly of the helicopter rotor mechanism is then built using these single assemblies. These parts make up the helicopter's mechanism.

- Bracket Against Rotation
- Bottom Part of a Ball Holder
- Top Part of a Ball Holder
- Ball
- Base
- For Main Shaft Bearing
- Bearing
- Lower Swash
- Collar
- Command Rod
- Vertical Link
- Horizontal Link
- Ligament Ball
- Long Linkage Ball
- Ball Linkage For Servo Arm
- Household Rotor Main
- Key Shaft
- Hook Rod
- End Rod
- rotating blade
- Arm for Rotor Holder
- Spindle Holder
- Link Servo
- Motor, Servo
- Middle Swash Connector
- Greater Swash
- Fasteners
- Fasteners for rotor heads
- Fasteners for Horizontal and Vertical Link

3.1.1 Bracket Against Rotation

The anti-rotation bracket of the present invention stops an appliance it is mounted in from spinning. A U-shaped member, an attachment mechanism for attaching the U-shaped member to an appliance, and at least one clip extending from each of the U-shaped member's two legs for attaching a rectangular crimped part of a joint are all included in the bracket.(Gennaretti & Bernardini, 2012)

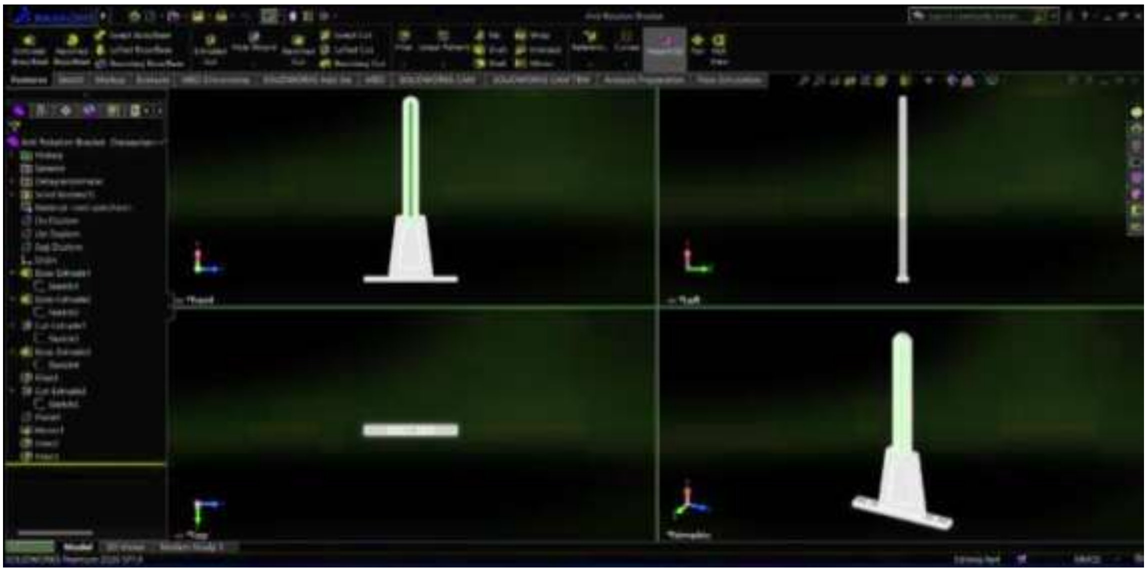

Figure 1: Anti-Rotation Bracket

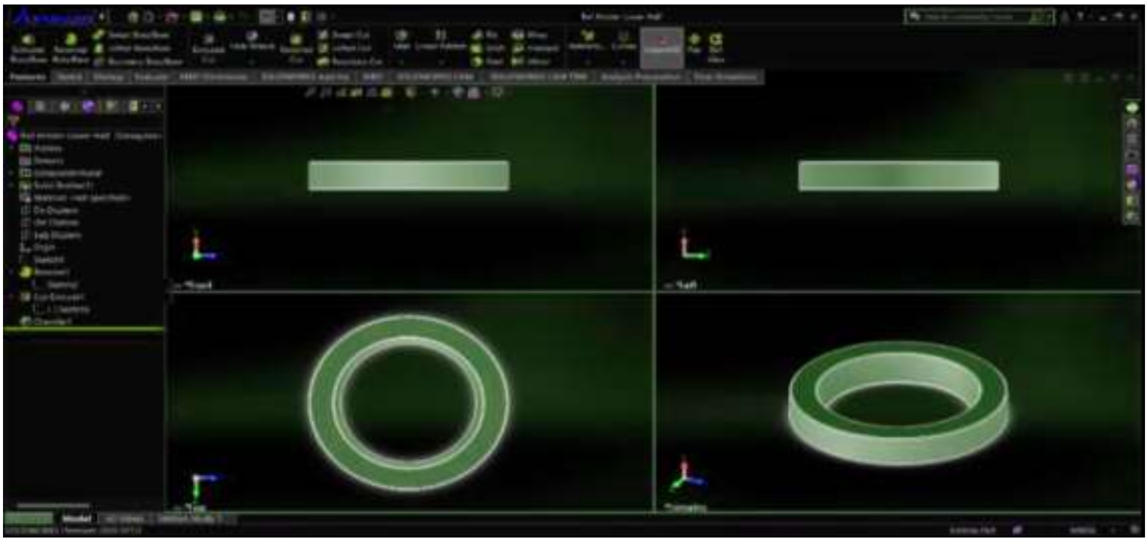

Figure 2: Bottom Part of the Ball Holder

3.1.2 Bottom Part of a Ball Holder

The lower portion of the ball holder is utilised to support and enable rotation in the ball. The ball revolves in relation to the main shaft of the helicopter and is coupled to the main shaft of the rotor. The holder resembles a disc. It is situated above the Swashplate and beneath the ball.(Quaranta et al., 2012, 2014)

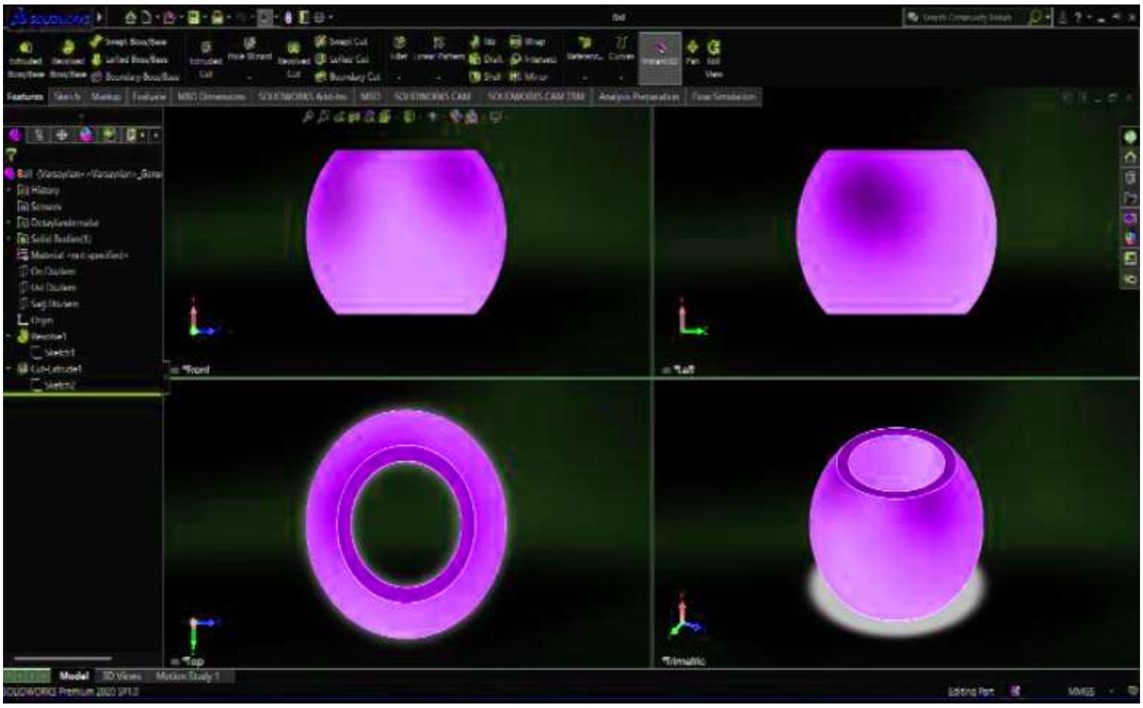

Figure 3: Ball

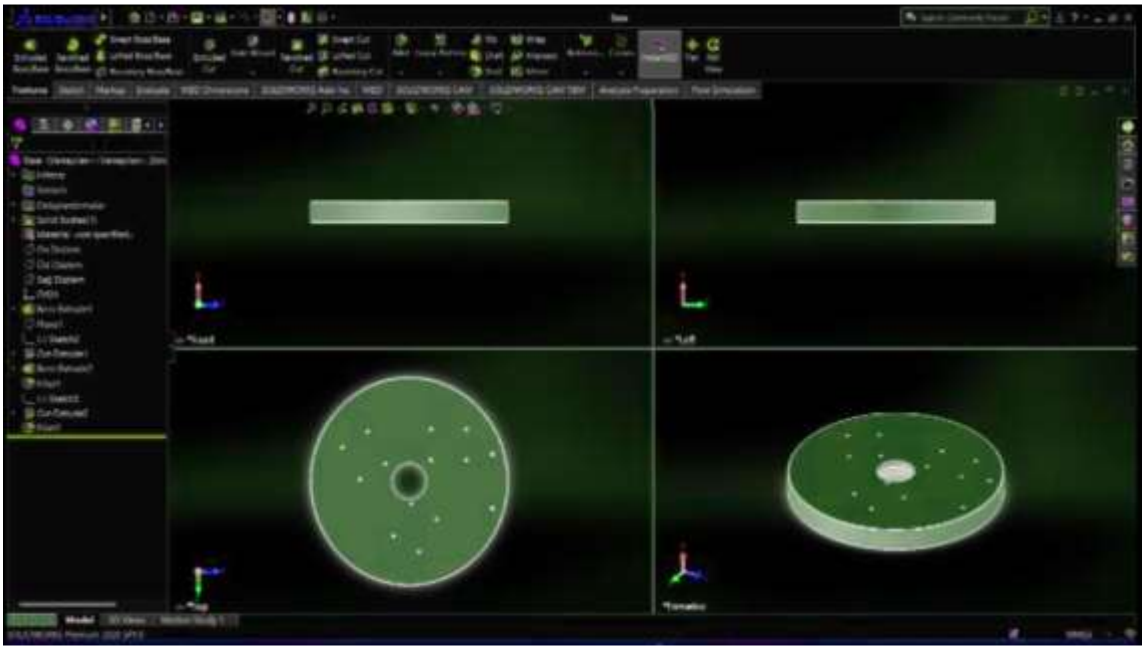

Figure 4: Base

3.1.4 Lower Swash

A swashplate is an apparatus that converts input from the flying controls of the helicopter into movement of the main rotor blades.(Serafini et al., 2014) The swashplate is utilised to transfer three pilot orders from the stationary fuselage to the revolving rotor hub and main blades since the main rotor blades are whirling.(Quaranta et al., 2012)

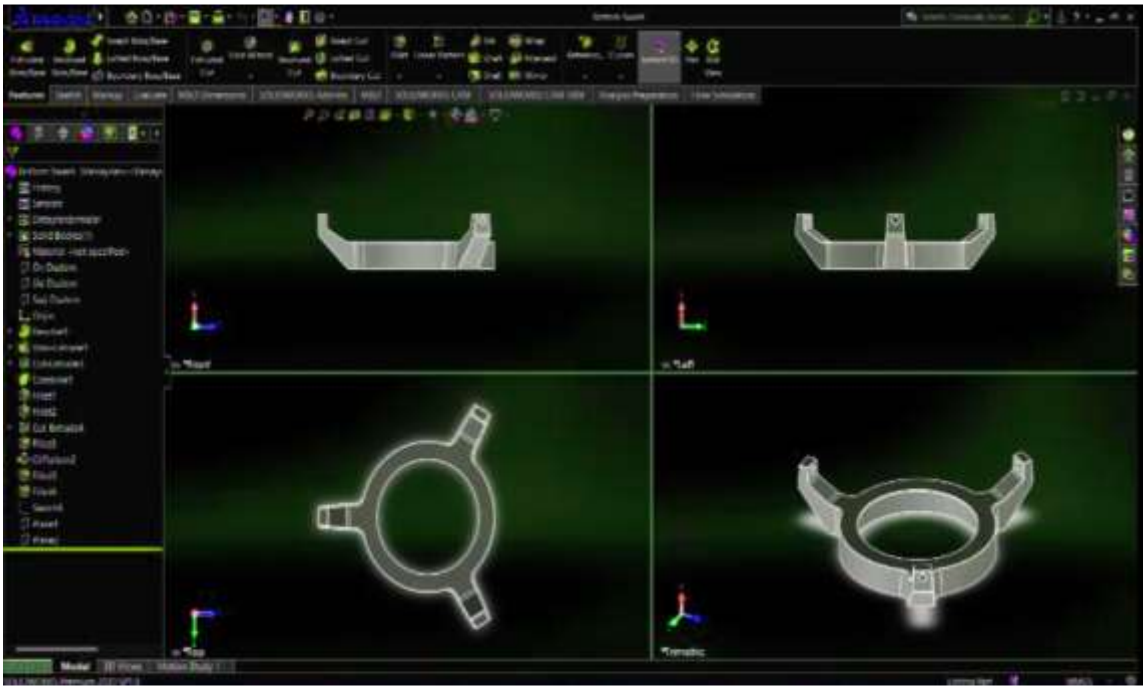

Figure 5: Bottom Swash

3.1.5 Command Rod

Between the bearing centres on the sides of the rotor blades and the swash plate is where the control rod is located in the control rod assembly. Axle housings have bearing structures that are housed in swash plate-side bearing blocks and eccentric structures that are housed in swash plate-side bearing centres.(Hartjes & Visser, 2019)

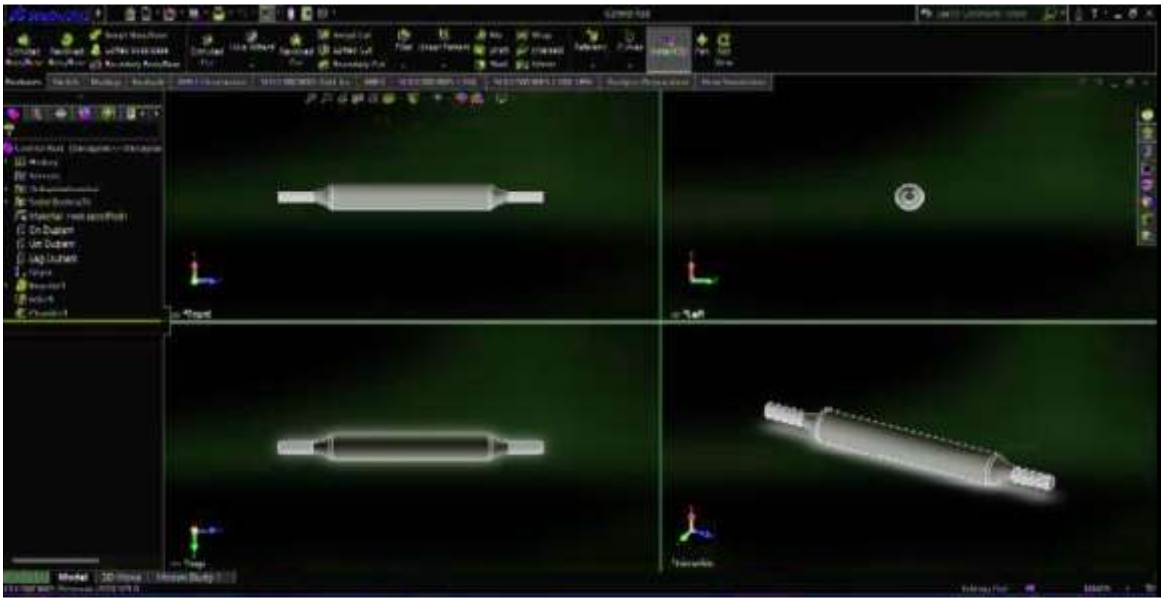

Figure 6: Command Rod

3.1.6 Main Rotor Housing

A helicopter's main rotor, or rotor system, is made up of a number of rotary wings (rotor blades) connected by a control system. This system produces the thrust necessary to combat aerodynamic drag during forward flight as well as the lift force required to sustain the helicopter's weight.(Piccione et al., 2012)

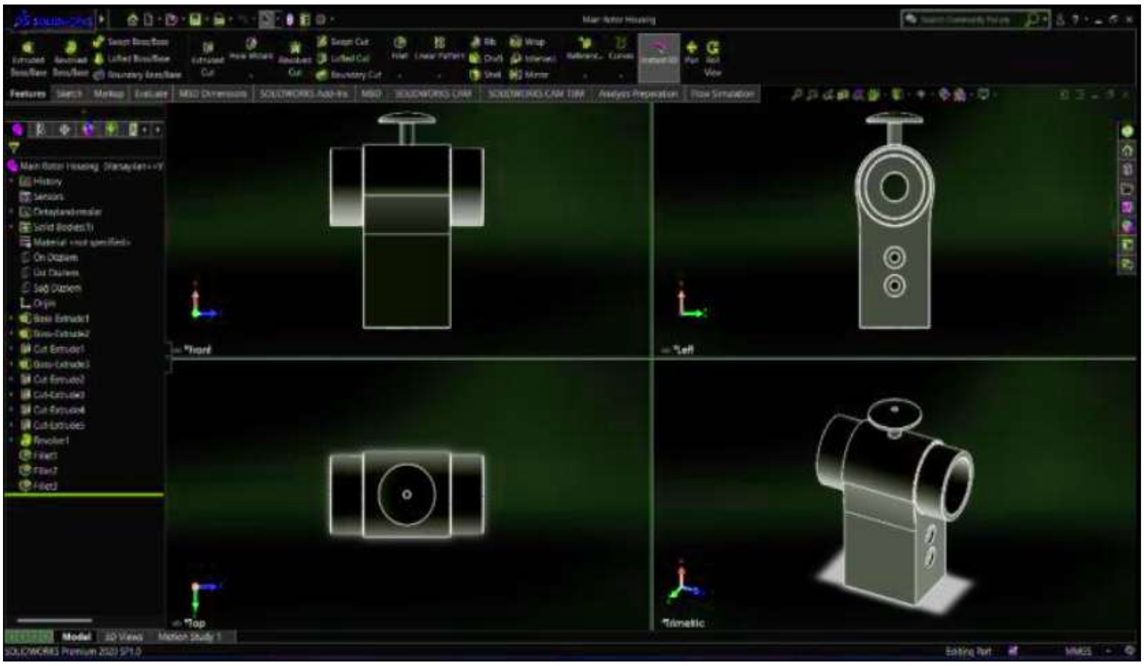

Figure 7: Household Rotor Main

3.1.7 Rotor Blade

A helicopter's blades are long, thin airfoils with a high aspect ratio; this design reduces drag caused by tip vortices. They often have some washout, which lessens the lift produced at the tips, where the wind is strongest and vortex production would be a major issue.

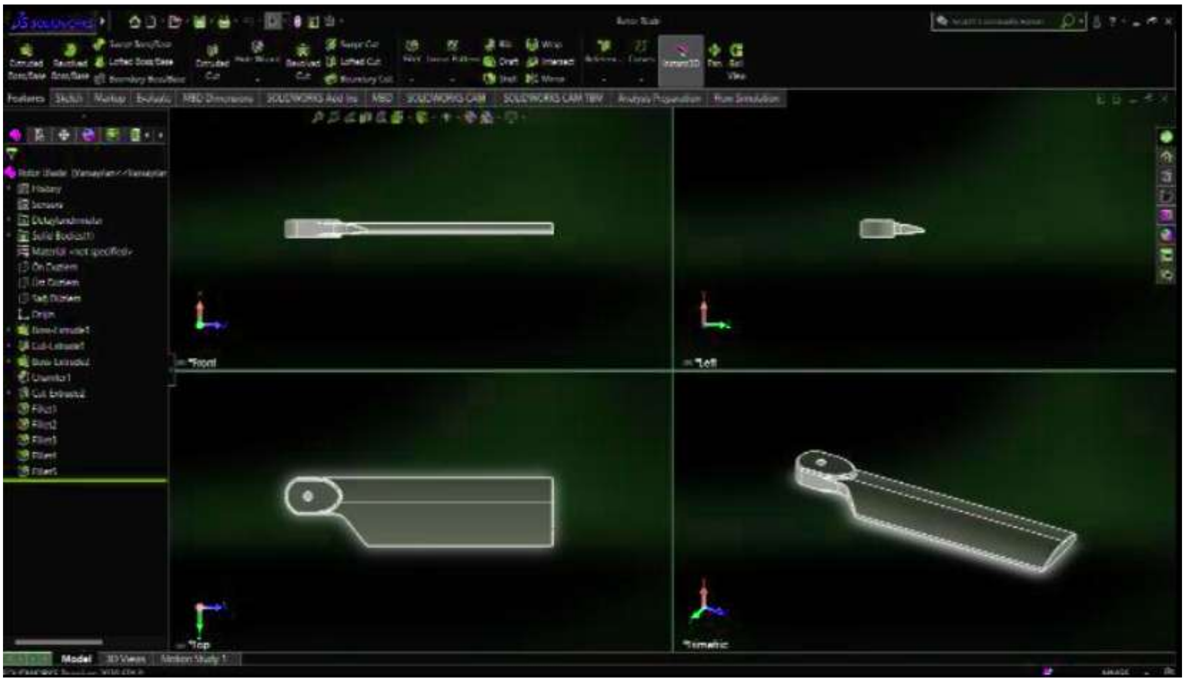

Figure 8: rotating blade

3.2 Massive Construction of The Whole Compound's

File > Open Solidworks choose "assembly model" Go to the assembly menu, click on the word "assembly," then "insert components," then "base mini assembly," then "place on the origin point," then "click OK," then "insert components," then "swash plate mini assembly," then "mate," then "select required mate for both mini assemblies," and then "assembly." choose OK. Click on the "Insert Components" button, choose the "Control Rod Mini Assembly," then "Mate," "Required Mate for Both Mini Assemblies," and "OK." Then, choose the "Pitch Mini Assembly" from the list of available mini assemblies > Click on Insert Components > Choose Horizontal Vertical Mini

Assembly > Click on Mate > Choose Required Mate for Both Mini Assembly > Click OK > Click on Mate > Select Required Mate for Both Mini Assembly > Click OK, then pick Rotor Blades from the Insert Components menu. Click on Insert Components > Choose Rotor Blade's 2 > Click on Mate > Choose Required Mate for Rotor Holder > Click OK > Click on Mate > Choose Required Mate for Rotor Holder > Click OK

Figure 9: major construction of the entire complex

5. Helicopter mechanism analysis

5.1 Static rigid investigation of the mechanism

Use the stiff dynamics explicit solver's capacity to evaluate mechanical systems with complicated assemblies of linked rigid elements that are subject to significant overall motion in a reliable and efficient manner. Use techniques for analysing mechanical systems, such as engine parts, landing gear assemblies, robotic manipulators, and vehicle suspensions.

5.1.1 The rigid dynamic analysis process

1. Engineering Information

Engineering data is information about the chosen material's qualities; as the main idea is to test the mechanism in Ansys, we have picked the structural steel. It is the workbench's default material in Ansys. The material's characteristics are depicted in the accompanying figure.

Common Material Properties	
Density	7.85e-06 kg/mm³
Young's Modulus	2e+05 MPa
Thermal Conductivity	0.0605 W/mm·°C
Specific Heat	4.34e+05 mJ/kg·°C
Tensile Yield Strength	250 MPa
Tensile Ultimate Strength	460 MPa
Nonlinear Behavior	False

Figure 10: Steel's material characteristics

2. Geometry
To create a more realistic model, the geometry was imported from the Solidworks file of the complete helicopter mechanism. The STP file then causes Ansys to mesh the item very finely for the best results.

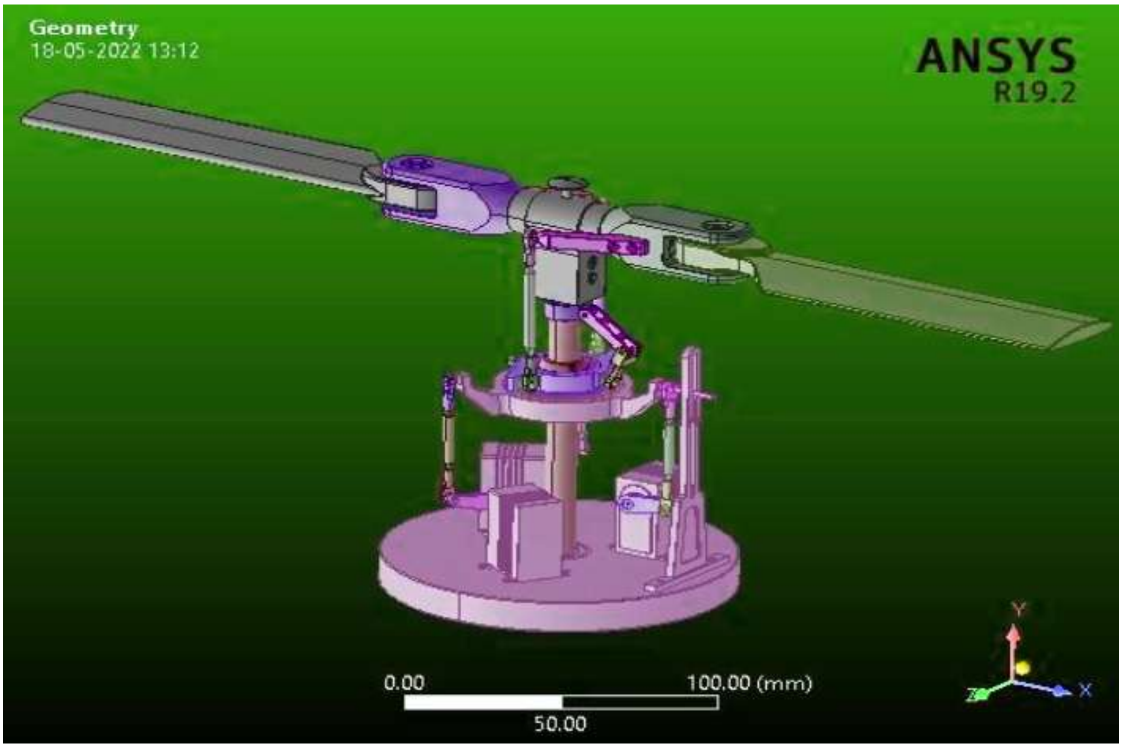

Figure 11: System Geometry

3. Model
The geometry can confine the joint with each link by utilising the revolution joint, fixed link, cylindrical joint, and spherical joint, which causes the pieces to move and rotate when the helicopter moves, such as when it lifts off and lands. This is the next phase in the geometry process.

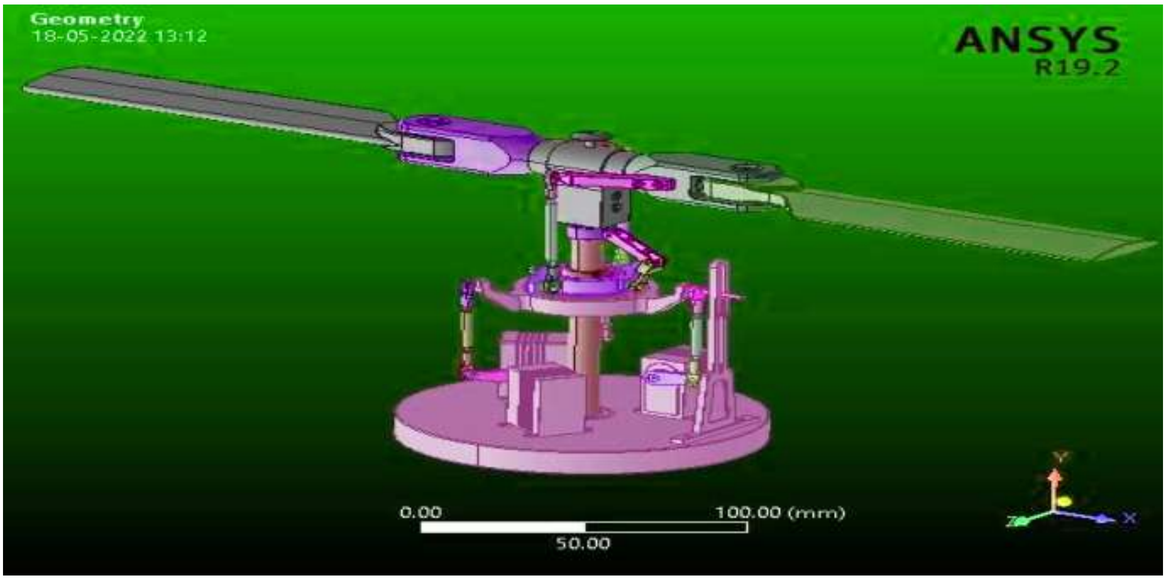

Figure 12: The mechanism's model

4. Setup
The setup comes next once all joint limitations have been assigned to every part. We assign the joint's rotational magnitude based on loads and the number of steps.

Table 1: Setup Values

Steps	Time [s]	Rotation [°]
1	0	1
	1	1
2	2	2
3	3	3
4	4	4
5	5	5
6	6	6
7	7	7
8	8	8
9	9	9
10	10	10

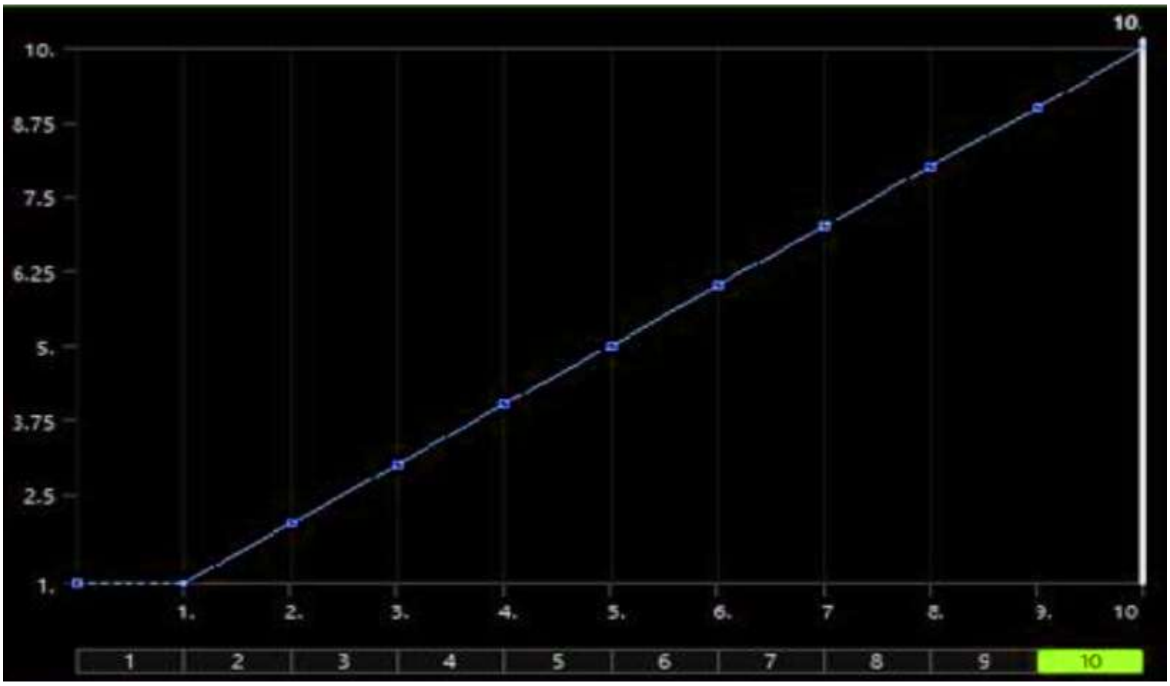

Figure 13: Graph of Time and Rotation

5.2 Study of Rotors Using Computational Fluid Dynamics (CFD)

5.2.1 Computational Fluid Dynamics Procedure (CFD)

1. Mathematics

After your physics are established, you must develop a two- or three-dimensional geometry based on the results of your research of the issue. Certain issues may be resolved in two dimensions, which can speed up calculation and save money. With Ansys, we make use of the Solidworks design module.

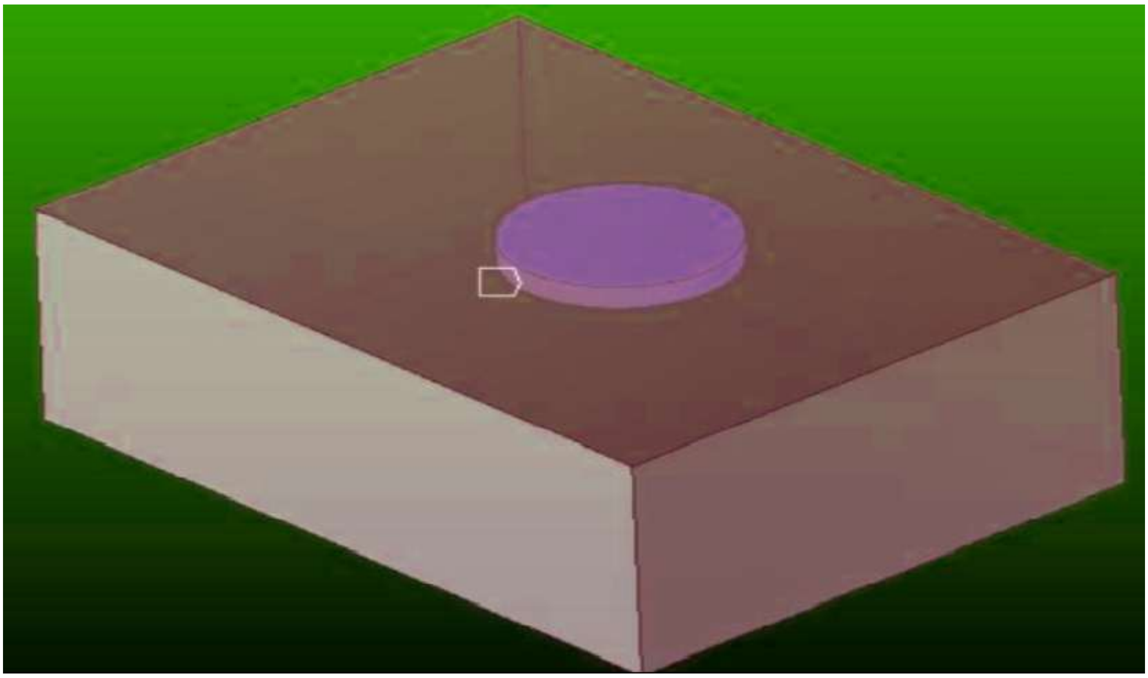

Figure 14: Design of the rotor

2. Blending

Meshing needs to be done carefully since if done incorrectly, it might have a cascade effect on your study. This stage entails dividing your environment's physical realm into predefined areas known as cells or control volumes. The fluid flow equations that control these cells further define them, necessitating that the designer make accurate assumptions about the flow profiles. The majority of designers discover that minimising these cells may help you guarantee precision during the analysis of the main assembly of the helicopter rotor mechanism. Each component was created by us using the Solidworks design tool. Several entities have been utilised in Solidworks to design and model a component. Using certain design guidelines that are relevant to the primary component, we initially model simple, individual components. Afterwards, sub-assemblies containing relevant components are joined to this component. This procedure will lessen its impact on the main assembly's construction, helping to keep the assembly organised and free of obstacles. The main assembly is then created by combining these sub-assemblies into a single assembly. As a result, the last component of the helicopter mechanism is put together and has a mechanical movement. With the use of computational fluid dynamics (CFD) analysis results and rigid dynamic analysis, we tested the mechanism using the Ansys software.

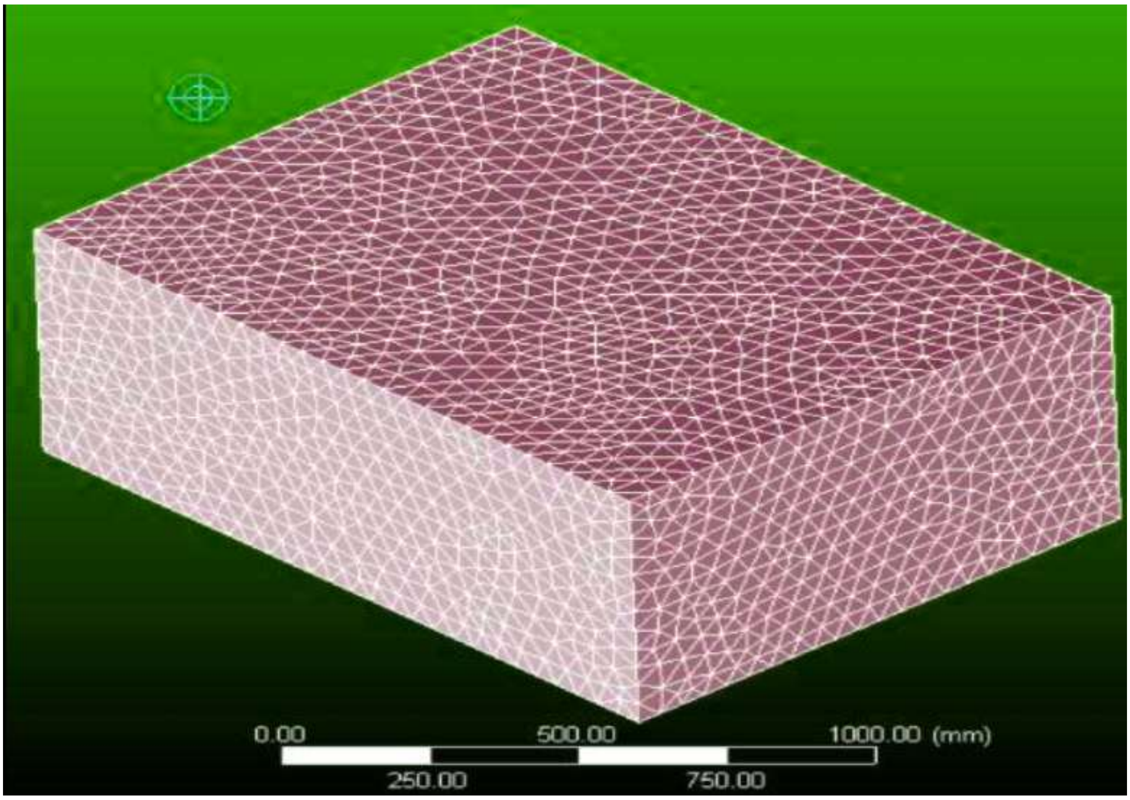

Figure 15: Meshing

6.1 Results of Rigid Dynamic Analysis

3. Setup

The mechanism's results showed total acceleration, total velocity, and total deformation.
Using the use of Rigid Dynamic Analysis
The overall deformation

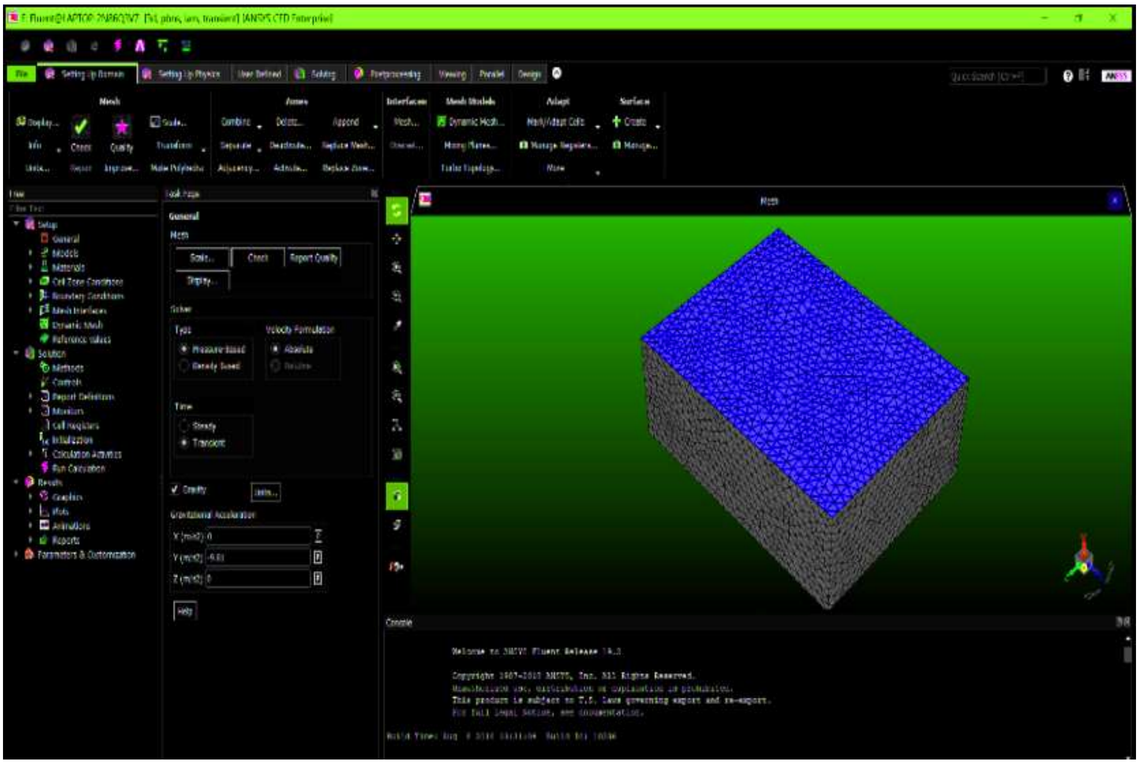

Figure 16: Setup

6. Result and Discussion

There are several parts to the mechanics of the helicopter rotor. These parts go into building the rotor mechanism. In this procedure, the components are first sketched out in 2D, and then the 2D sketch is used to generate the pieces of the 3D model. After creating the 3D model, we put together a micro assembly by grouping several small assemblies together. The main assembly of the helicopter rotor mechanism is then built using these single assemblies. Each component was created by us using the Solidworks design tool. Several entities have been utilised in Solidworks to design and model a component. Using certain design guidelines that are relevant to the primary component, we initially model simple, individual components. Afterwards, sub-assemblies containing relevant components are joined to this component. This procedure will lessen its impact on the main assembly's construction, helping to keep the assembly organised and free of obstacles. The main assembly is then created by combining these sub-assemblies into a single assembly. As a result, the last component of the helicopter mechanism is put together and has a mechanical movement. We tested the mechanism using the Ansys software and the results of computational fluid dynamics (CFD) analysis.

6.1 Results of Rigid Dynamic Analysis

The mechanism's results showed total acceleration, total velocity, and total deformation. Rigid dynamic analysis is used. The overall deformation

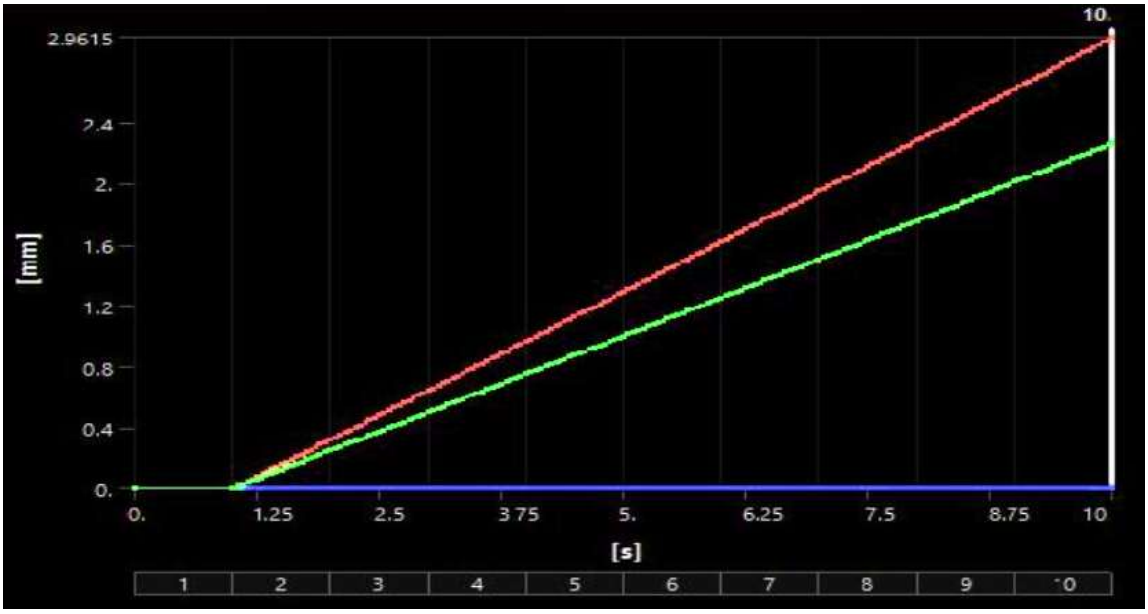

Figure 17: Graph of time vs overall deformation

The graph displays the overall deformation in the helicopter mechanism, with time on the x-axis and the amount of distortion on the y-axis. The greatest and average distortion occur at 10 seconds at 2.96150 mm and 2.26410 mm. The deformation will grow with time on the x-axis. The numbers are displayed in table 2.

Table 2 shows the highest and average total velocities.

Time [s]	Maximum [mm]	Average [mm]
0.00		
1.00		
2.00	0.32018	0.24986
3.00	0.64203	0.50007
4.00	0.96573	0.75065
5.00	1.29150	1.00160
6.00	1.61950	1.25300
7.00	1.95010	1.50490
8.00	2.28360	1.75730
9.00	2.62050	2.01030
10.00	2.96150	2.26410

Velocity Probe Rotor Blade Results

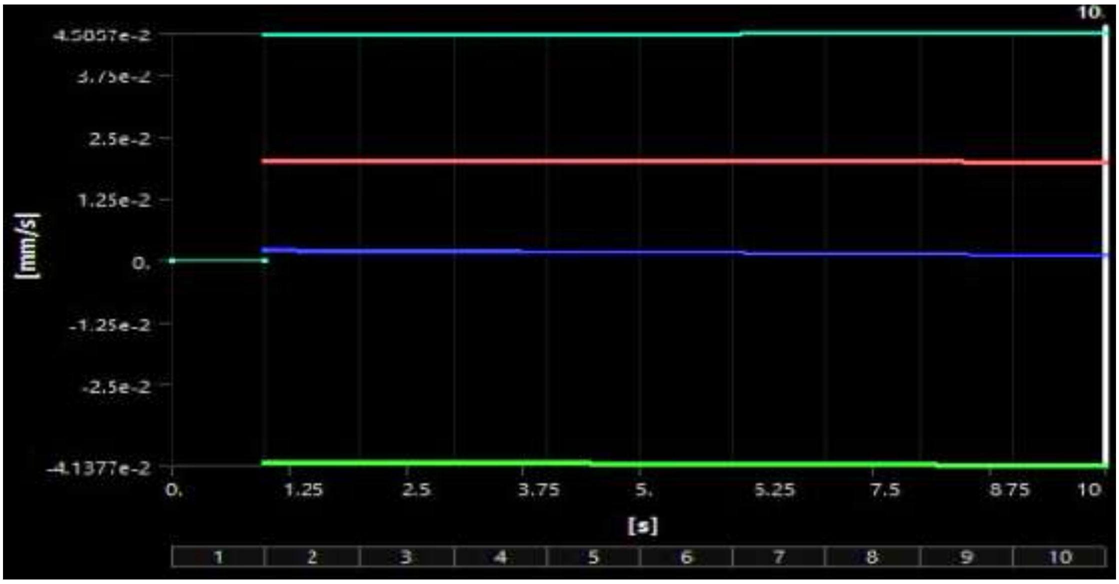

Figure 18: A graph of the rotor blade's speed over time

The velocity probe result for rotor blade 1 in the helicopter mechanism is displayed in the graph above. The velocity probe measures velocity on the y-axis and time on the x-axis. The velocity will steadily drop over time on the x-axis. At 10 seconds, the x-axis velocity is 0.0010 mm/s, the y-axis velocity is 0.01974 mm/s, and the z-axis velocity is -0.04138 mm/s.

6.2 Results of Computational Fluid Dynamics (CFD) Analysis

Because of our work on the rotor blades, we have obtained the streamline, air density, air dynamic viscosity, velocity, total pressure, velocity axial, velocity radial, and flow view. Via CFD analysis

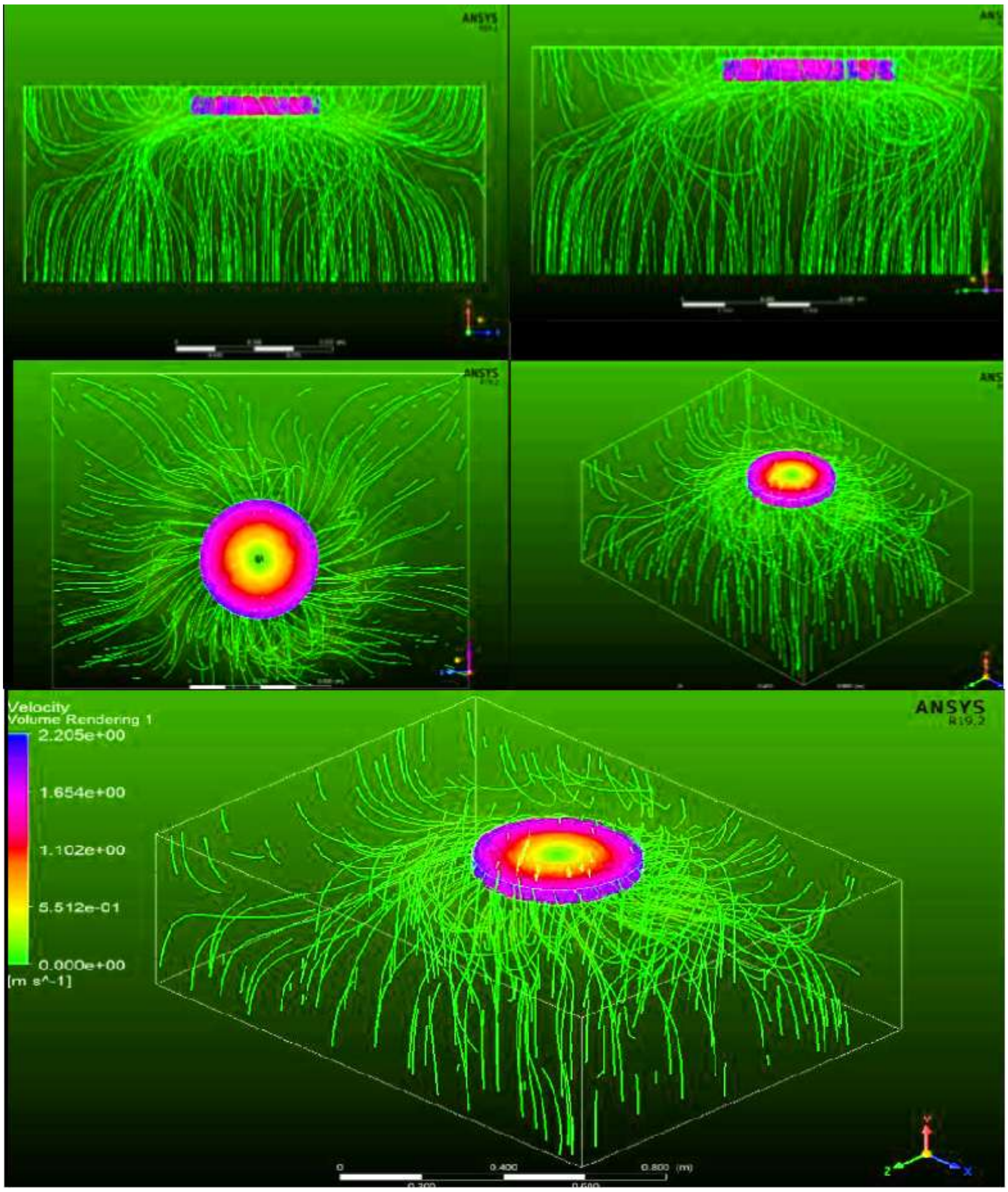

Figure 19: Views and streamlines' speed

Because there is less turbulent flow in the above streamline, there is a correct flow that takes into account each streamline's unique properties. As a result, the streamlines are shifted and shown as a result.

The greatest and minimum velocities in the aforementioned velocity result are 2.205 m/s and 0.00 m/s, respectively.

Complete Pressure

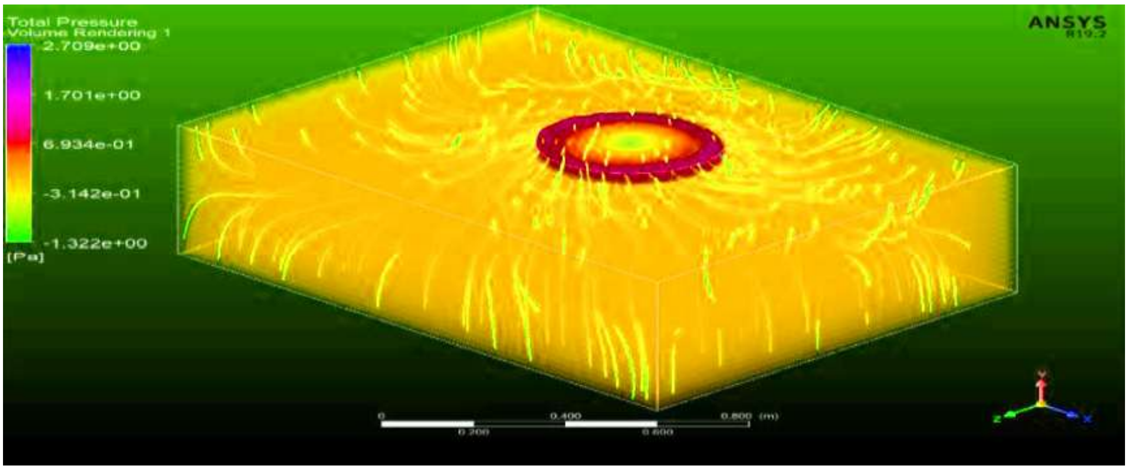

Figure 20: total streamline pressure

The greatest total pressure and minimum total pressure in the aforementioned total pressure result are 2.709 Pa and 1.322 Pa, respectively.

7. Conclusions

The primary objective was to determine the overall deformation, velocity, and acceleration while minimising the influence of heavier components on the main rotor. Aerodynamic computation analyses were performed inside the analysis's framework. Investigations were done on several main rotor designs and flow scenarios. The conclusions gained might be extremely helpful in designing straightforward helicopter mechanics. The utilisation of the data for additional research, such as dynamic analysis, is, nonetheless, the most crucial factor. analysis that considers the primary rotor's stability as well The overall finding of this experiment is that the primary rotor and other spinning parts significantly affect static stability.

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