Abstract. This paper is on the design and analysis of the landing gear retraction actuator for a 12-ton class helicopter. The existing design for landing gears is fixed landing gears. At high speeds, presence of the landing gear poses a reduction in performance of the helicopter by producing drag. Hence there is a need to retract the landing gear. This design is required to effectively retract and extend the landing gear in the time required for this class of helicopter. Retraction mechanisms are designed for combination of friction, inertia, brake torque and air loads occurring during extension and retraction. The actuator required for the mechanism designed is then worked out and used for both Nose and Main Landing Gear. Further, a mathematical model of the same is made using Simulink® and simulated. The analysis of the model is made to understand the dynamic behavior of the system to support further development of the design process. The constraints of designed Stroke length require to be 40% the length of total actuator/drag strut are taken care for the analysis and the result shows significant effect in the performance.

Keywords— Landing Gear Retraction, 12-ton class helicopter, Retraction Mechanism, Actuator

1 Introduction

Actuators are mechanical components that facilitate the motion of mechanical parts of a mechanism. The actuator requires a control signal and energy to facilitate movement. The control can be provided by various methods viz. electric current, pneumatic or hydraulic pressure. In a hydraulic actuator, a pump driven by a prime mover creates a flow of fluid, in which the pressure, direction and rate of flow are controlled by valves. Main concerns in the design of actuators for landing gear mechanisms are the Single-acting cylinders and Double-acting cylinders. According to the type of return they are classified as gravity return and spring return types.

Retraction is the pulling of the landing gear done to immerse the gear into the body to prevent the drag created as a result of the presence of the body in the fluid
flow. This drag significantly affects the velocity of the flight vehicle at high speed and hence proves beneficial to immerse it into the body and thus maintain an aerodynamic body. As a requirement, the landing gear must be able to retract or extend satisfactorily under adverse flight conditions. The paper involves the design of the mechanism of the landing gear in order to design the actuator required. The detailed study of the mechanisms followed in developing the landing gear actuator is done and the mechanism is chosen.

In Model-Based Design, a system model is at the center of the development process, from requirements development through design, implementation, and testing. After model development; simulation shows whether the model works correctly. When software and hardware implementation requirements are included with the model, such as fixed-point and timing behavior, you can generate code for embedded deployment and create test benches for system verification, saving time and avoiding manually Coded errors.

The existing design for landing gears is fixed landing gears. This is due to the small effect of the presence of a landing gear during flight. However, at high speeds, the presence of the landing gear poses a reduction in the performance of the helicopter by producing drag. Hence there is a requirement to retract the landing gear. The design is required to effectively retract and extend the landing gear in the time required for the class of helicopter.

2 Design Process for Mechanism of Landing Gear

The design process involves the selection and modification of the landing gear mechanism available. Once the mechanism is selected, the dimension is obtained within the given constraints.

The first step in selection of a mechanism suitable to a certain design of the mechanism for the retraction of a landing gear is the use of the concepts of Kinematics. The basic guidelines those are required to followed are

- The start with a geometrical layout and change to a mathematical model as soon as possible.
- Ensure that satisfactory moment arms are provided throughout the travel.
- Use Simple possible kinematics
- Approximate the dead length in the initial stages of design.

The Constraints for the design of mechanisms for the nose landing gear and the main landing gears are

- Stroke length requires to be 40% the length of total actuator/drag strut
- The moment arm requires to be about 100-125 mm in the retracted position
• Same actuator requires to be used for both nose and main landing gear. The mechanisms are simulated and verified by carrying it out both on CATIA and Microsoft Office Excel.

3 Load Calculations for The Retraction Actuator

Load Calculations are done for the purpose of designing the actuator with the dimensions of its components. It is done to help provide with the maximum load
the actuator must be designed to work on efficiently. The Load Calculations involves plotting a Load curve and the plotting done is between Load and Jack travel, where Load is in Newton and Jack Travel is in Degrees.

The plot is between the load on the actuator and the jack travel percentage. This plotted by finding the load step by step from the moment obtained from the drag and the weight present on the landing gear. The Drag is calculated from the generalized formula available for the object in motion through a fluid.

\[ FD = \frac{1}{2} \rho u^2 C_D S \]

Where, \( FD \) is the drag force, which is the force component in the flow, velocity direction, \( \rho \) is the mass density of the fluid, \( u \) is the flow velocity relative to the object, \( S \) is the reference area, \( C_D \) is the drag co-efficient.

\[ M_D + M_W = X F \]

Where, \( M_D \) is the moment caused due to the drag, \( M_W \) is the moment caused due to the weight of the landing gear, \( X \) is the moment arm at the angle of the landing gear to the reference, \( F \) is the load experienced by the landing gear. Once the loads are obtained for various points during retraction of the landing gear, it can be plotted against the angle of the actuator-jack to the leg.

![Fig.3 Load VS Retraction angle plot](image-url)
3.1 Sizing of The Actuator

This step involves the scaling of the various components of the landing gear assembly from the diagram to the life size of the helicopter. Hydraulic actuators in general have the following components:

**Seals**- Dynamic: These are PTFE Glass filed backing rings
Static : O Ring with two backing rings

**Eye End**- Thread Efficiency 25%

**Bleed Screws**- Added only on Customer’s request

**Grease Nipples**- Usually one per bearing

**Piston** – steel 599 rod hard chromed. Seal groove and loads flash chromed

Full Area (A) = \( \pi D^2/4 \)

Rod Area (\( \alpha \)) = \( \pi d^2/4 \)

Annular Area (a) = A - \( \alpha \)

\[
A = \frac{\text{Maximum Load during Extension (W)}}{0.87 \times \text{System Pressure (P)}}
\]

\[
a = \frac{\text{Maximum Load during Retraction (w)}}{0.815 \times \text{System Pressure (P)}}
\]

\[
D = \left(\frac{4A/\pi}{}\right)^{1/2}
\]

This value of D may have to be increased to suit the standard seal. Calculate A and a from the standard D and work out W and w.
Now the rod is checked under compression and calculated
\[ I = \frac{\pi}{64}(d_o^4 - d_1^4) \]
\[ A_{rod} = \frac{\pi}{4}(d_o^2 - d_1^2) \]

Radius of Gyration \( k = (I / A_{rod})^{1/2} \)

After this the next higher standards thread size, rod outer diameter is chosen. This Diameter is again revised and the values for \( a \) and \( w \) are calculated and revise \( A \) is required. Recalculate \( W \) for \( A \) and \( \alpha \).

Using a maximum working length the slenderness ratio is calculated then the crippling stress \( s \) calculated

Crippling Load \( \sigma_a \times a_{rod} \)

### 3.2 Mathematical Modeling

Modeling is a process in which you describe a dynamic system with mathematical equations and then create a simplified representation of the system with a model. The equations define the science of the system and the model uses the equations to define the time-varying behavior.

Modeling is implemented in MATLAB/Simulink software, widely used in control engineering around the world the various components part of the model.

The equations are as follows:
\[
M1*\ddot{X}_1 + K1*(x2 - x1) + M2*\ddot{X} + 2 + K_{fluid}*x2 + B1*\dot{X} 2 + B2*\dot{X} 2 + K1*(x1 - x2) + P2*A2 + FR = P1*A1
\]
Fig. 5. Mathematical Model of Actuator
Where $M_1$ is the Mass of the landing gear, $F_R$ is the force acting on $M_1$ during retraction, $K_1$ is the spring rate constant of the rod, $K_{\text{fluid}}$ is the spring constant of the hydraulic oil and is equal to sum of $K_2$ and $K_3$, $B_1$ and $B_2$ are the viscous friction coefficient.

$$P_1 = \frac{\beta}{v_1(x_2)} \times (Q_1 - a_1 \times \dot{x}_2)$$

$$P_2 = \frac{\beta}{v_2(x_2)} \times (Q_2 + a_2 \times \dot{x}_2)$$

Where $\beta$ is the bulk modulus of the hydraulic fluid, $Q_1$ and $Q_2$ is are the flow rates to chamber 1 and 2 respectively.

The actuator chamber volumes $V_1(x_2)$ and $V_2(x_2)$ are defined as,

$$V_1(x_2) = A_1(L_{1o} + x_2)$$
$$V_2(x_2) = A_2(L_o - (L_{1o} + x_2))$$

Where $L_{1o}$ is the length corresponding to dead volume in chamber 1 and $L_o$ is the sum of actuator stroke length and dead volume corresponding to both chambers of the actuator.

After creating the top-level structure for the actuator model we use the system equations to create a Simulink model. Build the model for each component separately. The most effective way to build a model of a system is to consider components independently. The assumptions that can affect the accuracy of your model are identified and accordingly added. Iteratively details are added until the level of complexity satisfies the modeling and accuracy requirements. Once the steps are complete the system is simulated. This simulation provides validation for the design.
3.3 Dynamic Analysis

The graph in Fig.7 gives the time response of the mathematical model created for the actuator as created on Simulink®. The system of equations obtained is first linearized and the transfer function is obtained. This transfer function is used in MATLAB to find the step response and the other required parameters of the dynamic system such as damping ratio natural frequency, poles and zeros. Further this Transfer function is altered in order to obtain an improved parameters and steady response. A comparative study on the system is made followed by further improvements on the system design and would include adding required components to achieve better response for the system.
The steps to be followed in the design of an actuator are as stated in the previous chapters and the required results were obtained. The mechanism of the landing gear was designed for the nose landing gear and main landing gear. This was followed by the load analysis as a result of the mechanism on the actuator. This load obtained was used in determining the parameters of the actuator to be designed. Further, the actuator was created on Simulink obtaining the dynamic analysis of the system.

4 Result
The steps to be followed in the design of an actuator are as stated in the previous chapters and the required results were obtained. The mechanism of the landing gear was designed for the nose landing gear and main landing gear. This was followed by the load analysis as a result of the mechanism on the actuator. This load obtained was used in determining the parameters of the actuator to be designed. Further, the actuator was created on Simulink obtaining the dynamic analysis of the system.

5 CONCLUSION
The actuator required for the retraction of the landing gear is designed following the methodology as explained and advised at Hindustan Aeronautics Limited, Bangalore. The process was followed and the mechanism was designed for the retraction. A load analysis was carried out in order to size the actuator which was the final step in the design of the actuator. As required, the constraints are met and
the design satisfies the requirement of the landing gear. Further, the mathematical model of the Actuator is created and a stability analysis of the same is conducted.

6 FUTURE ENCHANCEMENTS
The project involved the design of the mechanism of the landing gear in order to design the actuator required for the particular landing gear. The detailed study of the mechanisms followed in developing the landing gear actuator was done and a mechanism was chosen. Further a different mechanism could be developed to optimize the use of the actuator for the given configuration and also to make optimal use of the space available for the undercarriage for both the Nose Landing Gear and the Main landing gear in the stowage wing. From the results obtained from the dynamic analysis of the system, studies have to be done to further make alterations to the system in order to achieve a steady, stable actuator motion.

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