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Kinematics of Nose Landing Gear for RLGS Mechanism of MALE UAV

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Abstract— **Electrical linear actuators reduce the weight of landing gear retraction / extension mechanism which helps in keeping the gross takeoff weight of aircraft weight low. Reduction in weight of the aircraft has manifold advantages in which noticeable are increased endurance, range, climb performance, acceleration performance and fuel efficiency. Use an electrical linear actuator in landing gear system is a simplification in the kinematics of landing gear retraction/ extension sequence. In this research, a retraction/ extension mechanism for nose landing gear (NLG) of a MALE UAV has been designed and tested according to FAR CFR 25.729. The design process of a Retractable Landing Gear System Mechanism (RLGS) started with selection of pivot point on NLG and axis for the rotation in free space available which resulted in least power requirement. Pivot point was selected such that no part of gear posed hindrance to other part of an aircraft. Next, the path of rotation about pivoting axis and position kinematics were calculated using vector loop closure equation. Essential parameters regarding retraction / extension sequence were calculated from trigonometry. Forces and power required for complete retraction/ extraction sequence were calculated. During the research, it was found that retraction force on NLG depended upon the aerodynamic drag, inertial loads and gravitational force. In this research analysis of these forces is presented with much detail. Effect of velocity variation of linear actuator on the retraction force is commented upon. Computational analysis is carried out using multibody dynamics MSC ADAMS® software. The research concluded with experimental validation of a planner triangular retraction mechanism of NLG actuated by electrical linear actuator.**

Keywords—Retraction mechanism, Electric linear actuator, NLG kinematics, Actuation Force

I. Introduction

Landing gear system is the under carriage system that provides support to the aircraft during takeoff, landing and taxing[1][3]. Each landing gear is unique as it is designed for particular aircraft. The type of aircraft determines the location where landing gear will be placed during design phase of an aircraft keeping in view constraint of fuselage housing space. Availability of space inside fuselage is the important deciding factors for designing of retraction mechanism system of landing gear [2][3]. The landing gear retraction system of an aircraft involves the kinematics of mechanical linkages and the actuating mechanism which may be hydraulic or electronic [4]. UAVs Landing gear consist of four major systems; these are;

(a) Landing gear shock absorption system
(b) Landing gear strut
(c) Retractable mechanism system
(d) Braking system
(e) Steering system
(f) Electric / hydraulic system
(g) Landing gear traction control

For the analysis of retraction and extraction of

Landing gear system design is dependent upon gross takeoff weight calculations and shape (outer contour) of landing gears primarily for drag calculations of components of landing gear [5]. Actuation force required to retract and extend landing gears depends upon aerodynamic drag, weight of NLG, inertial loads and joint angular acceleration [6].

In UAVs electric actuation system is usually implementing to decrease the overall weight of retraction mechanism system which increases the fuel efficiency of UAVs [11]. Electric linear actuator is a device that consists of power or lead screw which is connected with gear train powered by electric motor. In a mechanism actuator is the driving component which initiates the motion throughout the mechanism. Actuator are available in different size, shape and power ratting. For the implementation of actuator for retraction / extension of landing gear it should fit into the space available to the actuator. The location of joints is selected such that a suitable dead length is available for actuator [12]. Retraction mechanism of landing gear driven through electric linear actuator is a planner three bar or link mechanism with one variable length. As the length of actuator varies the landing gear retract or extract accordingly.

Mechanism is a combination of resistant bodies that are connected with the help of joints to transmit motion. For the analysis of any mechanical mechanism, some basic assumption like mechanism links are consider to be rigid throughout the analysis of mechanism. For complete dynamic analysis of mechanism, it is compulsory to find kinematics (positions, velocity and acceleration) and kinetics (forces acting on the system) of mechanism [12,13].

Planner retraction mechanism is available in different types and shapes. Common retraction mechanism is four bar link mechanism driven through rotary motion and linear actuator mechanism. Depending upon the requirement different types of actuator are available in market. Any design process is start with the conceptual design which is then leads to detail design of product. Conceptual design of retraction mechanism of landing gear starts with stick diagram of landing gear. stick diagram of landing gear includes the details of mounting point, Path of rotation and joint motion type. Nose landing gear of UAV is a planner case of retraction mechanism [3].

This research work is organized as follows. Section II discusses details of kinematics of retraction / extension mechanism. Section-III includes the factors that affect the retraction mechanism of landing gear and the governing equations of aerodynamic loads and gravitational forces. Selection of appropriate linear actuator along with calculations of the stroke length & dead length is addressed next. Calculation of velocity, acceleration and power requirements culminates this research work.

II. KINEMAICS OF NOSE LANDING GEAR (NLG)

1.1. *Local Frame of Reference*

Aircraft whole assembly has its own globe frame of reference. Every part of aircraft is place according to that frame of reference. In case of MALE UAV, the globe frame of reference is placed at the nose of UAV. A local frame of reference for landing gear is selected which is mounted on the pivoting point. In the Figure1 schematic of placement of landing gear is mentioned.

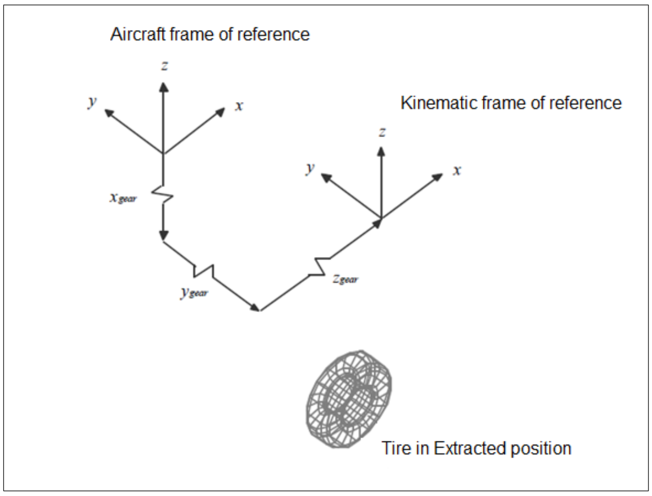

Figure 1 Local and global frame of reference

1.2. *Pivoting Axis Calculation for NLG*

For the calculation of kinematic analysis of NLG, a mathematical model is developed that is more effective and accurate. In the Figure 2 the retraction/extraction scheme of Nose Landing gear is explained. First of all, local coordinates are place on mounting point from that point of reference all the vectors and dimensions are measured. In design process of landing gear up till now, shape, size and material of landing gear has been selected. The exact dimensions of landing gear have been calculated according to ground clearance and stability requirement of landing gear. Kinematics of landing gear largely depends upon the space available inside the housing of landing gear. The position vectors of fully extracted and fully retracted position are known. In the Figure 2. Position vector V_1 representing the fully extracted position of landing gear and the other vector V_2 representing the fully retracted position of landing gear. The pivoting axis is calculated using equation (1).

$$\boldsymbol{V} = \boldsymbol{V_1} * \boldsymbol{V_2} \qquad (1)$$

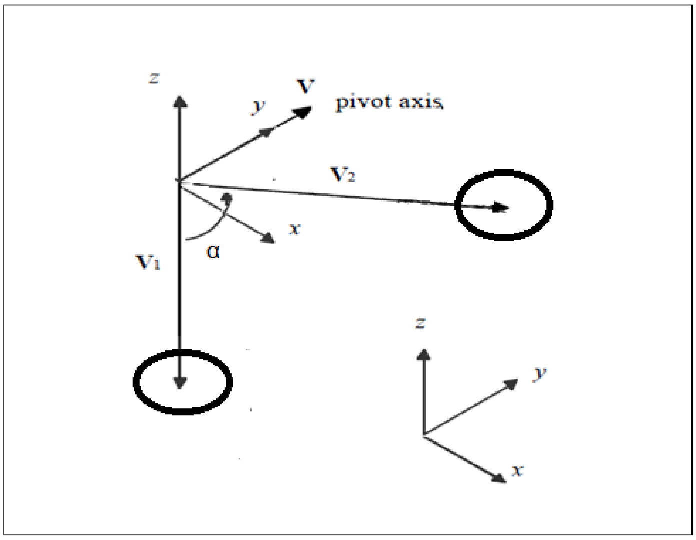

Figure 2 Retraction angle and sequence of retraction in 3 dimensional space

- $V_1 = -164.96i + 0j - 935.5k$
- $V_2 = 946.68i + 0j + 82.78k$
- $V = V_1\ X\ V_2 = -871569.88j$

Cross product of V_1 and V_2 shows that this is a planar case where axis of rotation is aligned with the Y-axis.

1.3. *Direction Cosines*

Direction cosine of position vectors and pivoting axis can be calculated by using following expressions. These directioncosines are required for the calculation of angle of rotation and finding position of the revolute joint between actuator and NLG.

$$\boldsymbol{l} = \frac{\boldsymbol{X}}{\sqrt{(\boldsymbol{X^2}+\boldsymbol{Y^2}+\boldsymbol{Z^2})}} \qquad (2)$$

$$\boldsymbol{m} = \frac{\boldsymbol{Y}}{\sqrt{(\boldsymbol{X^2}+\boldsymbol{Y^2}+\boldsymbol{Z^2})}} \qquad (3)$$

$$n = \frac{Z}{\sqrt{(X^2+Y^2+Z^2)}} \quad (4)$$

1.4. *Design Constrains for NLG*

Each designing process has its own constrain that are provided to the designer to use these as starting parameters. Design constrains are compulsory to be followed to ensure appropriate working of product as it integrated with other system of whole product. Following are the design constraints as shown in Figure 3 for the MALE UAV.

- Fixed Distance between bulkheads = 745 mm
- Length of fixed link OA = 686.479 mm
- Length of NLG strut assembly AD= 950 mm
- Angle of Fixed Link OA with horizontal Axis = 21.16 degrees. Angle of strut line with vertical axis = 10 degrees

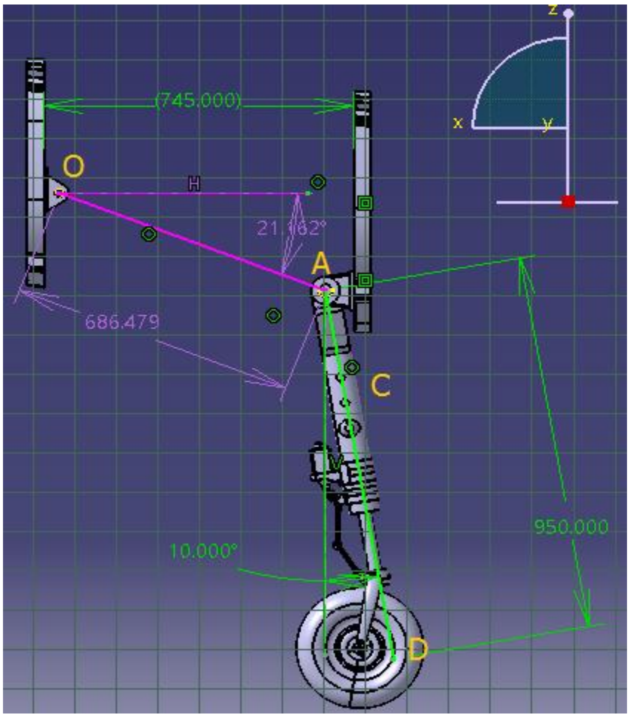

Figure 3 Design constrains and known parameters of Nose Landing Gear of MALE UAV

1.5. *Angle of Rotation Calculations:*

After finding the pivoting axis of landing gear, the next step is to find the retraction angleα. The angle αhas the value between 0 <α<α_{full}. For the calculation of α, it is compulsory to find the direction cosines of position vector V_1 and position vector V_2. Full rotatiuon angle is calculated by following equation.

$$Cos\alpha_{full} = l_1 l_2 + m_1 m_2 + n_1 n_2 \quad (5)$$

Where l_1, m_1, n_1 are the direction cosine of position vector V_1. l_2, m_2 and n_2 are the direction cosine of position vector V_2. Figure 4 is the 2D graphical representation of NLG that showing the fully extracted and fully retracted positions of landing gear along with rotation angle α. Deployed position is according to stable landing of UAV and retracted position is according to the place available in housing of NLG.

Table 1 Result of direction cosines and rotation angle

Parameter	Value	Parameter	Value
l_1	-0.1737	l_2	0.9962
m_1	0	m_2	0
n_1	-0.9848	n_2	0.0871
$Retraction\ Angle = \alpha_{full}$	105 degrees		

Table 1 is showing the result of direction cosines and angle of rotation of NLGwhich are calculated using equations (2-4).

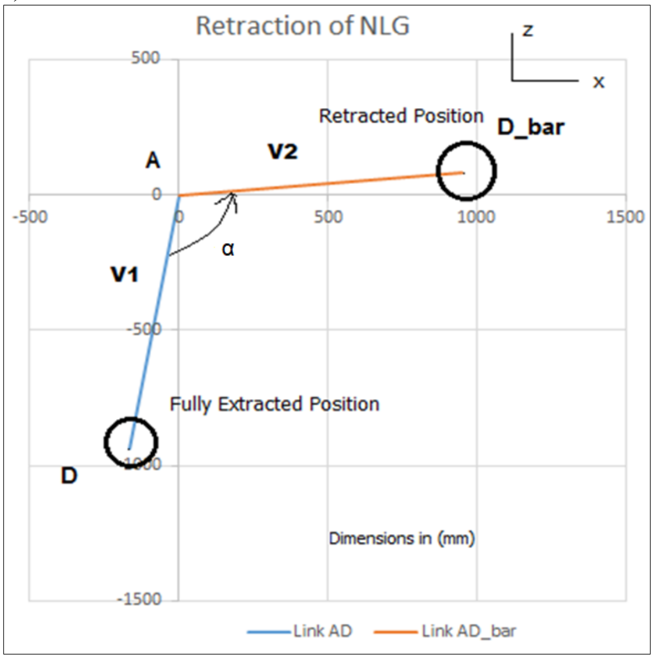

Figure 4Angle of rotation and position vectors of NLG

1.6. *Conditions for Actuator (OC & OC′) Sizing*

1. Fully retracted length of actuator (OC′)> stoke length of actuator
2. Fully extracted length of actuator (OC)< Link OA + Link AC
3. Angle of Link AD (Landing gear) with vertical Axis =10 degrees

Condition 1 is a constrain of manufacturing. It is impossible to have an actuator which fully extracted length is exactly equal to fully retracted length. Condition 2 is a constrain of mechanism, this mechanism is a triangular in nature where one length is variable, in a triangle sum of length of two sides cannot great than the length of third side of triangle. Condition 3 is the constrain that is provided by design of landing gear. 10 degrees angle with vertical line (z axis) calculated according to the stability and touch down requirements. (reference)

1.7. *Retracted Position of Pont C (denoted as C′)*

After finding the axis of rotation and path of rotation, position of the joint between actuator and landing gear is calculated by using the angle of rotation. This is an iterative process in which a point "**C**" is assumed on landing gear then its fully retracted position "**C′**" is calculated by using retraction angle$\boldsymbol{\alpha}_{\mathbf{full}}$about pivoting axis. For the selection of link AC length, above mention conditioned are to be considered.

- Assuming the length of link AC = 225 mm
- Angle of NLG with vertical Line = 10 degrees

$$\begin{bmatrix} X_C \\ Y_C \\ Z_C \end{bmatrix} = \begin{bmatrix} -\mathbf{AC} * \cos(\mathbf{10}) \\ -\mathbf{AC} * \sin(\mathbf{10}) \\ \mathbf{0} \end{bmatrix} \quad (6)$$

$$\begin{bmatrix} \mathbf{Xc'} \\ \mathbf{Yc'} \\ \mathbf{Zc'} \end{bmatrix} = \begin{bmatrix} \mathbf{AC} * \cos(\alpha_{\mathbf{full}} - (\mathbf{90} + \mathbf{10})) \\ \mathbf{AC} * \sin(\alpha_{\mathbf{full}} - (\mathbf{90} + \mathbf{10})) \\ \mathbf{0} \end{bmatrix} \quad (7)$$

Equations (6 & 7) give the coordinates of point C &C′ as shown in table 2

Table 2Coordinates of points of NLG

Name	Coordinates of point C	Coordinates of point C′	Coordinates of point O
x	-39.07	224.14	640.2
y	-221.58	19.61	247.83
z	0	0	0

1.8. *Actuator Stoke Length*

In Figure 6, actuator is place between point O and point C. Length of link OC is variable as the length of OC reduces the landing gear retract back. After the completion of stoke of actuator, landing gear retract back in the housing that is shown in the Figure 7.

For the calculation of stoke length, distance between point C and point O is calculated with help of distance formula(equation 8). OC is the length of actuator when actuator has completed itsstoke and landing gear is fully extracted. Similarly, length of OC′ calculated with help of distance formula.

It necessary to have reasonable dead length of actuator for appropriate working of NLG mechanism.

$$\boldsymbol{Distance} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2} \quad (8)$$

$$\boldsymbol{Stoke\ length} = \boldsymbol{Fully\ Extracted\ length\ of\ Actuator} - \boldsymbol{Fully\ Retracted\ length\ of\ Actuator} \quad (9)$$

1.9. *Dead Length*

It is impossible to have actuator whose fully retracted length is exactly half of fully extracted length, So, there will be an extra length in fully retracted position that is called dead length of actuator. It very important to include to calculate and include the dead length in design process otherwise there will be a mismatch during the placement of actuator between point O & C as mention in the Figure6. Dead length of actuator is difference between Fully retracted length and stoke length of actuator shown in Figure 5.

$$\boldsymbol{Dead\ Lenght\ of\ Actuator} = \boldsymbol{Fully\ Retracted\ length\ of\ Actuator} - \boldsymbol{Stoke\ lengh} \quad (10)$$

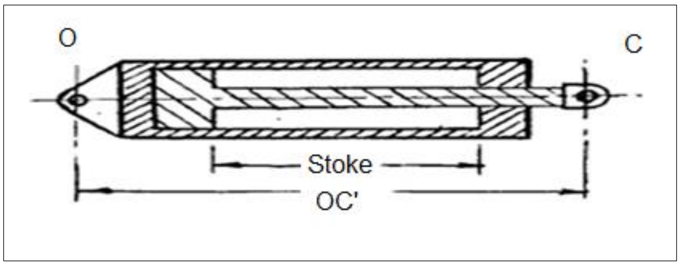

Figure 5 Schematic of dead length and stoke of actuator. Figure adapted from [1] and [3].

1.10. *Mechanism Links Parameters Calculations*

Landing gear retraction mechanism is planner and triangular in nature. One of the three lengths (OA shown in Figure 6& 7) is fixed by fixing the distance between bulkheads (design constrain as mentioned). Second length (AC shown in Figure 6&7) is calculated using iterative approach ensuring that the mentioned three conditions satisfied. Link OC (Actuator) is the driving component of mechanism with variable length. In retraction phase length of link OC reduces and at fully retracted

$$OC, Fully\ Extracted\ length\ of\ Actuator = \sqrt{(x_O - x_C)^2 + (y_O - y_C)^2 + (z_O - z_C)^2} = \boldsymbol{825\ mm}$$

$$OC', Fully\ Retracted\ length\ of\ Actuator = \sqrt{(x_O - x_C')^2 + (y_O - y_C')^2 + (z_O - z_C')^2} = \boldsymbol{475mm}$$

$$Stoke\ length = OC - OC' = 825 - 475 = \boldsymbol{350mm}$$

$$Dead\ Lenght\ of\ Actuator = OC' - Stoke\ length = 475 - 350 = \boldsymbol{125mm}$$

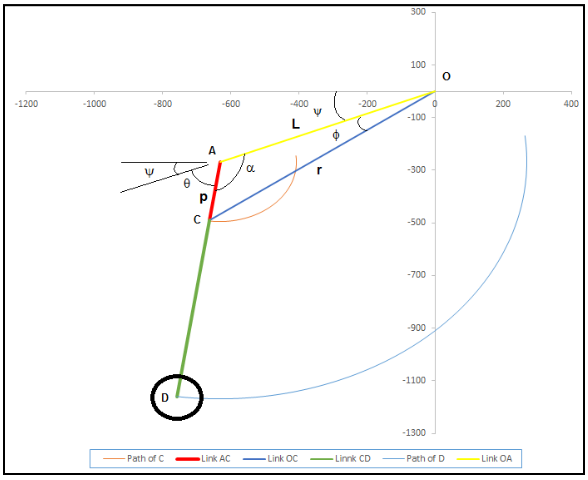

Figure 6 NLG at fully extended position (deployed position of landing gears)

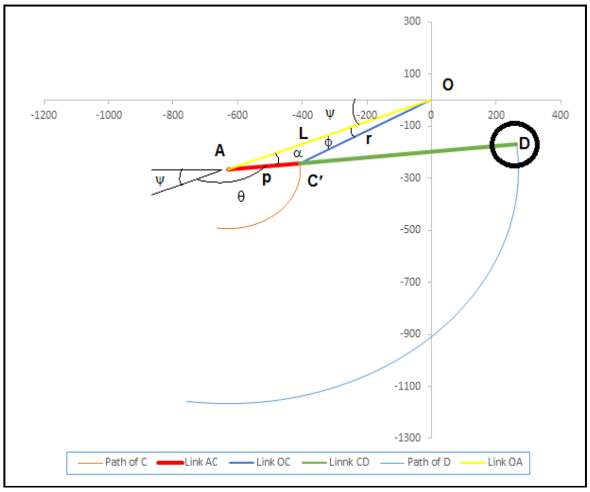

Figure 7NLG at fully retracted position. NLG is housed inside fuselage to reduce aerodynamic drag

NLG mechanism consist of three revolute joints and mechanism is driven with electric linear actuator. All the required parameters are labeled in Figure (6&7) with their retraction/ Extraction details. Mechanism parameters for NLG are mentioned in table 3.

Table 3NLG Mechanism parameters

Link	Length (mm)
Fixed Link OA (L)	686
Fixed Link AC (p)	225
Fully Retracted Length OC'(r)	825
Fully Extracted Length OC (r)	475
Stoke Length	350
Dead Length	125

III. DYNAMIC ANALYSIS OF JOINT A OF NLG

Dynamic analysis stated with drawing the free body diagram of NLG. Figure 8 showing all the forces actuation force, gravitational force and drag force along with their moment arms and placement on NLG. For analysis of NLG force are converted to moment about joint A.

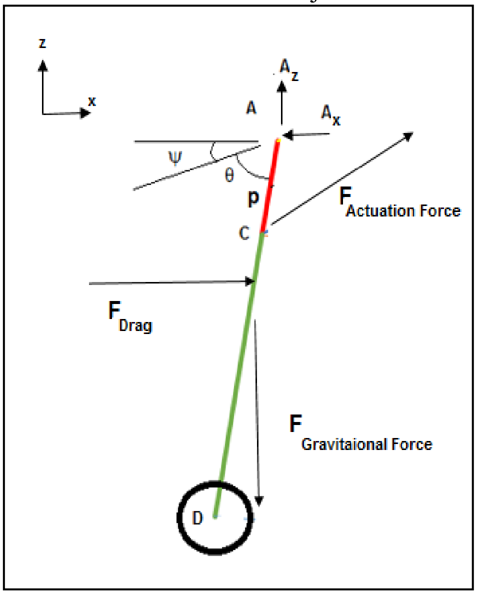

Figure 8 Free Body diagram for force representation

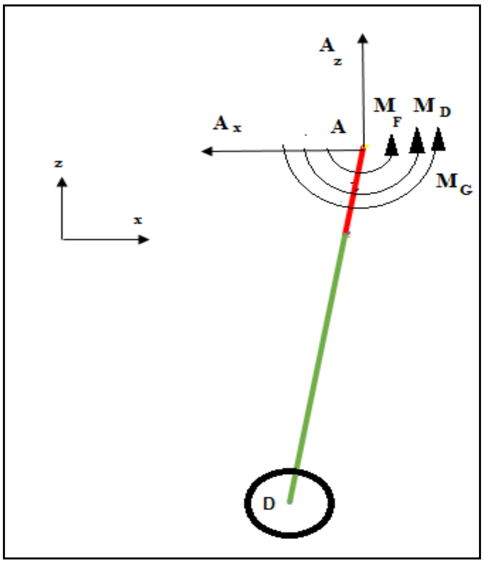

Figure 9 Free Body Diagram for moments representations

Actuation force depends upon the gravitational load, drag force and the inertial load as mentioned in equation 14.

$$-A_x + F_{A_x} + F_{D_X} = m_b a_x \quad (11)$$

$$A_z + F_{A_z} - F_{g_z} = m_b a_z \quad (12)$$

$$M_F + M_g + M_D = I\ddot{\theta} \quad (13)$$

$$F = \frac{I\ddot{\theta} - M_g - M_D}{p\sin(\theta+\phi)} \quad (14)$$

The value of force ultimately depends upon the actuation velocity of actuator, acceleration of actuator, material of NLG assembly, mass moment of inertia of NLG.

1.1. *Joint A Kinematic (Angular accelration)*

1.1.1. Loop closure equation

Loop closure equation is used to find out the position, velocity and acceleration kinematics of mechanism. The joint velocity vector $\dot{q}\equiv(\dot{r},\dot{\phi},\dot{\theta})^T$ and the joint acceleration vector $\ddot{q}\equiv(\ddot{r},\ddot{\phi},\ddot{\theta})^T$ are defined as function of the time derivatives of the joint variables. Equation 15 is loop closure equation for the mechanism which includes the lengths of links and the angles of mechanism. These parameters are mentioned in Figures (6 & 7).

$$re^{j\phi} - pe^{j\phi} - Le^{j\psi} = 0 \qquad (15)$$

$$\phi = 2Tan^{-1}\left(\mp\sqrt{\left(\frac{2rL+A}{2rL-A}\right)}\right) \qquad (16)$$

$$\theta = 2Tan^{-1}\left(\mp\sqrt{\left(\frac{2Lp+B}{2Lp-B}\right)}\right) \qquad (17)$$

Equation 16&17 provide the relation between length of mechanism with the angles of mechanism.

1.1.2. Velocity constraint equations

Joint rotation speed (angular speed) is affected by the velocity of actuator, equation (18&19) are showing how the effect of actuator velocity calculated.

$$\dot{\phi} = \frac{\dot{r}(L\cos\phi - r)}{Lr\sin\phi} \qquad (18)$$

$$\dot{\theta} = \frac{\dot{r}\sin\phi - r\dot{\phi}\cos\phi}{p\cos\theta} \qquad (19)$$

1.1.3. Acceleration equations

The ultimate goal of kinematic analysis was to find the actuation force and power required, so for that we have to find the angular acceleration of NLG joint (name as A in Figure 6 & 7). Equations15 to 21 are used for the calculations of angular acceleration of NLG.

$$\ddot{\phi} = \frac{\ddot{r}(L\cos\phi - r) - \dot{r}(\dot{r} + 2L\dot{\phi}\sin\phi) - Lr\dot{\phi}^2\cos\phi}{Lr\sin\phi} \qquad (20)$$

$$\ddot{\theta} = \frac{-(\ddot{r} - r\dot{\phi}^2)\cos\phi + (2\dot{r}\dot{\phi} + r\ddot{\phi})\sin\phi - \dot{\theta}^2 p\cos\theta}{p\sin\phi} \qquad (21)$$

where

$$A = p^2 - r^2 - L^2$$
$$B = p^2 + L^2 - r^2$$

Figure 10 shows the relation of positions, velocities and accelerations with respect to the time for motion. The of angular acceleration $\ddot{\theta}$ of joint A, calculated from analytical approach and ADAMS® software is compaired.

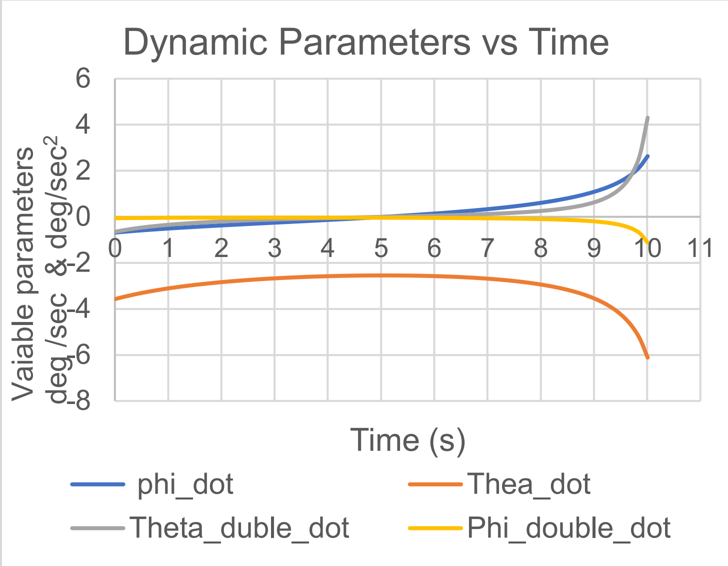

Figure 10 Dynamic parameters variation with time of retraction for Joint A of NLG

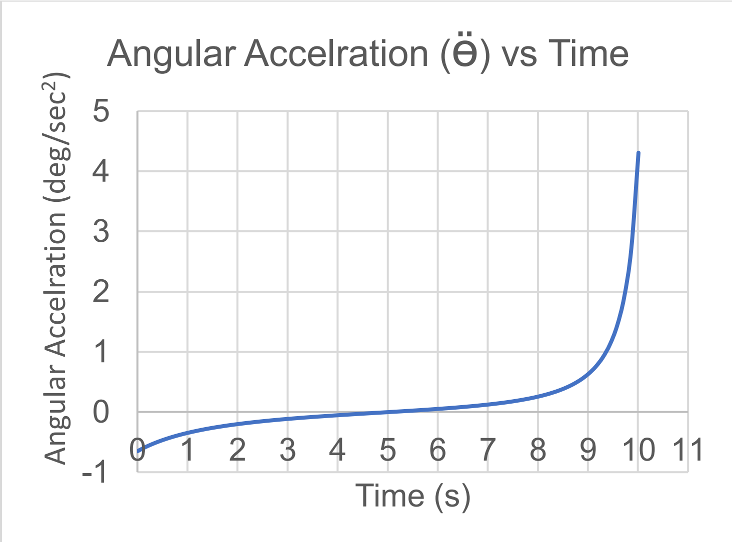

Figure 11 Angular acceleration variation with time for Joint A of NLG

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1.2. *Inertia Calculation*

Mass moment of inertia of NLG is calculated by assigning the Aluminum (Al) material to NLG assembly file. Figure 13 shows all the properties of NLG file.

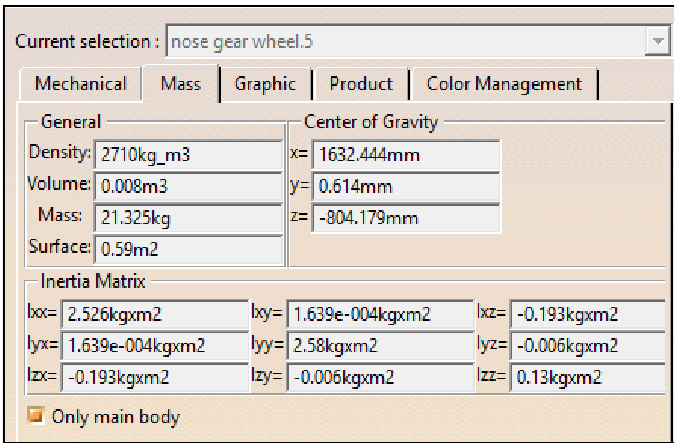

Figure 12 Inertia and mass of NLG. Figure taken from CATIA®

Value of mass moment of inertia (I_{yy}) from CATIA is taken about the Centre of Gravity of NLG assembly. But for this research, this mass moment of inertia was required at pivoting point A. So mass moment of inertia was shifted at point A by applying the parallel axis theorem.

$$I_A = I_{yy_{cg}} + m_b * d^2 \quad (22)$$

The results of mass, radius and shifted mass moment of inertia are mentioned in table 4.

Table 4 Mass moment of inertial properties of NLG

Parameter	Value
Mass	21.325Kg
Radius	0.037 m
$I_{yy_{cg}}$	**2.58 Kgm^2**
d	0.4 m
Moment of Inertia I_A	**6.37 Kgm^2**

1.3. *Drag Force*

As the landing gear retract back to the housing, the value of drag decreases. Drag depends upon the dynamic pressure, coefficient of drag and the frontal area of NLG. Resultant of drag is applied in the middle of projected area (frontal area) for moment calculations. During retraction frontal area and moment arm of NLG decreases as a result of that the value of drag and moment of drag both decrease. Every object of particular shape produces certain amount of drag when it placed in incoming flow. Researcher has found coefficient of drag for different shapes as mentioned in figure 14. Figure 14 showing the relation between C_D and Re number. At very low Re numbers the value of C_D is much higher.

$$D = \frac{1}{2}\rho V^2 S C_D \quad (23)$$

where

V=30m/s, ρ=1.225$\frac{Kg}{m^3}$, S= 0 – 0.0703 m^2

$C_D = 1.21$, μ=1.789 * 10^ − 5 kg/m·s

$$Re = \frac{\rho v D}{\mu} = \frac{1.225 * 30 * 0.074}{1.789 * 10^{\wedge} - 5} = \mathbf{152,012}$$

$$D = \frac{1}{2}\rho V^2 S C_D = \frac{1}{2} * 1.225 * (30)^2 * 0.0703 * 1.21 = \mathbf{46.31\ N}$$

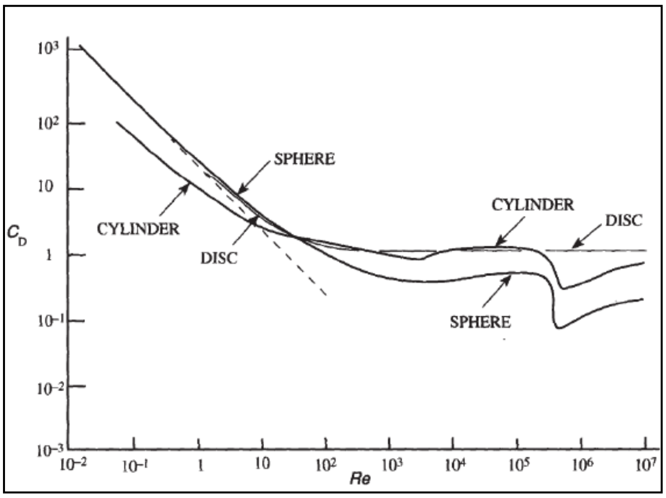

Figure 13 Coefficient of drag for various shapes versus Reynolds number. Figure adpated from [11].

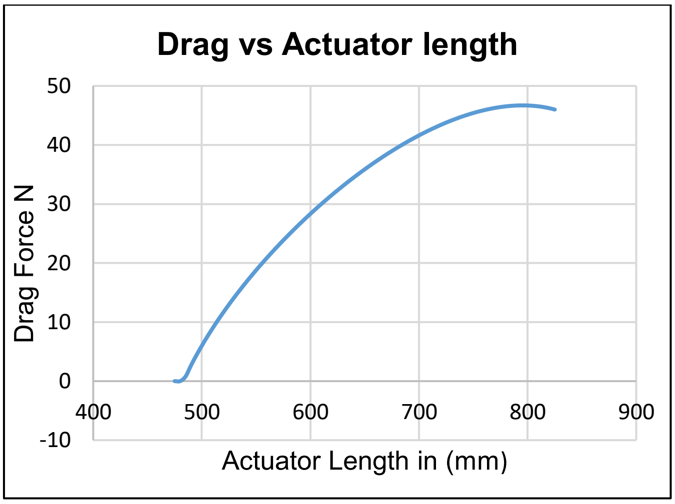

Figure 14 Drag Force vs Actuator Length

Figure (14) is the graph between actuator length and drag force produced. Drag force become zero after the completion of stoke. Maximum value of drag occurred when the gear is perpendicular to the incoming flow. The value of drag range in between 0 N to 46.2 N.

1.4. *Gravitational Force*

Gravity always acts down ward hence it produces moment accordingly. As landing gear makes angle of 10 degrees with vertical line or Z-axis, So, for the first 10 degrees of rotation angle $\beta$the direction of moment is Counter Clock Wise(CCW). For the reaming 95 degrees, the direction of rotation is clockwise (CW).

$$F_g = m_b * g = 21.32 * 9.81 = 209.15\ N$$

Gravitational force F_g remains constant during retraction and extraction but the direction of moment varies.

IV. Results and Comparisions

1.1. *Comparison of moment contribution*

The upper half portion of force vs actuator length shows the CCW moment value and the lower half portion shows the CW moment produced. Moment due to drag always produce in CCW direction. The maximum value of drag moment is 23 Nm which occurs when landing gear is in extracted position. Moment due to gravity is CCW for the first 10degrees rotation of landing gear then it becomes zero. Gravitational moment is CW for remaining 95 degrees. The maximum value of gravitational moment is 82Nm (CW) as mentioned in Figure 16. Similarly, the behavior of $I\ddot{\theta}$ can be seen in the Figure 16, $I\ddot{\theta}$ also changes its behavior. In retracted position $I\ddot{\theta}$ produces CW moment whereas in extracted position $I\ddot{\theta}$ produces CCW moment. Combine effect of total moment $M_F = M_t$, is shown in Figure 17. Summation of moment M_t is CCW in extracted position and M_t is CW in retracted position.

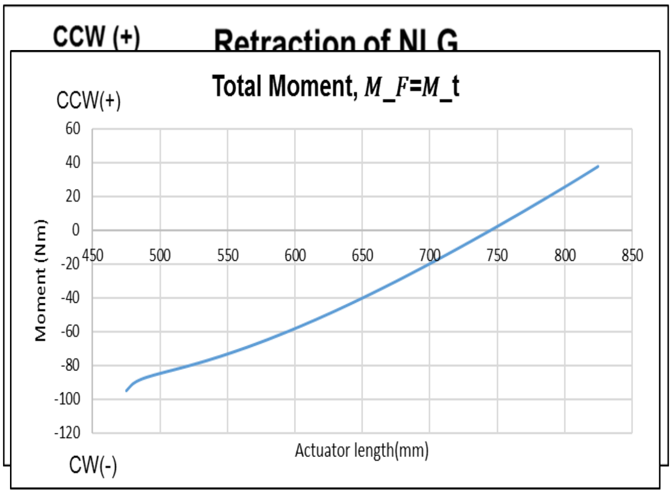

Figure 15 Moment vs Actuator length

Figure 16Total Moment $M_F = M_t$ vs Actuator length

1.2. *Actuation Force*

For the mechanism length of the links were calculated and then actuation force was made the function of r,ṙ,r̈, material (mass, cg), Aircraft speed (for drag), distance of cg to the local pivoting axis (moment arm for gravity) and gravitational acceleration g. For the mechanism calculation all the length and angle has been calculated, so positional kinematics is cover up till that point. In dynamic analysis the velocity of actuator is decided as 35mm/s and the acceleration of actuator is taken as zero.

Table 5 Input parameters for calculation of Actuation force

Input Parameters	Value	Units
r	475-825	mm
ṙ	35	mm/s
r̈	0	mm/s^2
I_A	6.37	Kgm^2
Aircraft velocity	30	m/s
C_D	1.2	

Table 6 reflects the input parameters for the calculation of drag force inertial force. For the calculation of this project $\dot{r} = 35mm/s$ and acceleration is taken as $\ddot{r} = 0\ mm/s$. Actuation force was calculated by dividing the M_t with moment arm of actuating force i.e. $F_A = M_t/psin(\theta + \phi)$.

Maximum actuation force was required at retracted position. Negative force in the Figure (18 and 19) reflected that the compressive force was produced. Negative potion was shown when the actuator was under compressive load for almost 2.6 seconds.

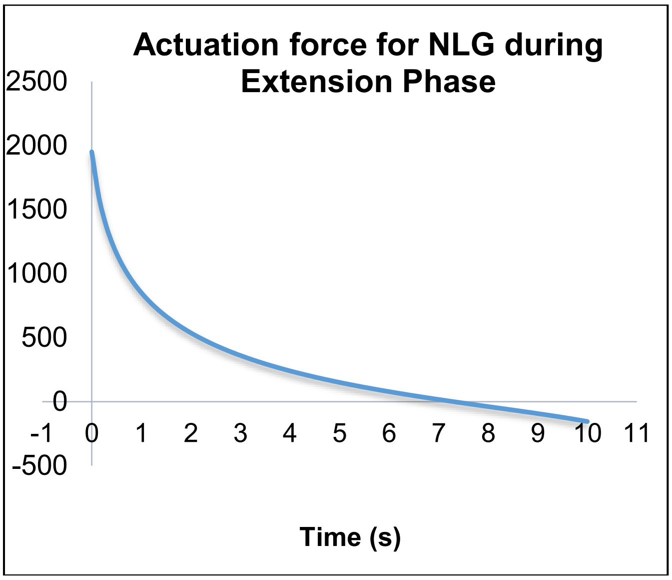

Figure 17a. Variation of force during extension of NLG (analytical solution). This figure shows that maximum force is required at the start of retraction cycle, then force requirement progressivly decreased.

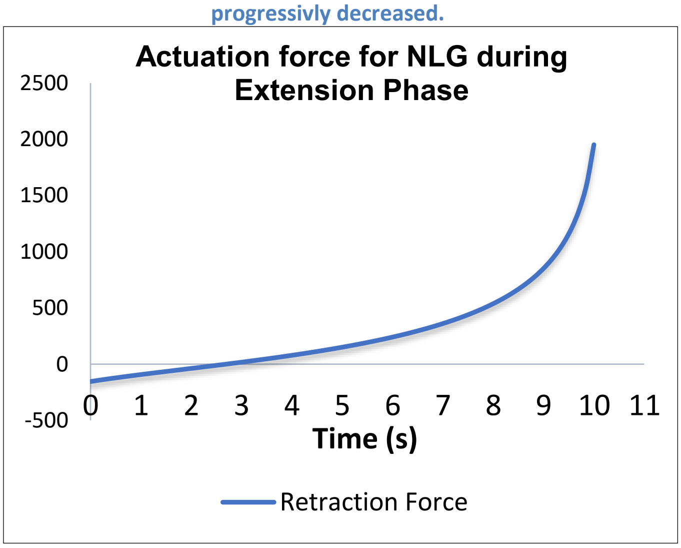

Figure 18b. Variation of force during extension of NLG (computational solution).

For compression of results same model was imported to ADAMS® software. In ADAMS® the drag force of NLG was added as single point force as a function of frontal area acting on mid-point of projected area. The trend of required actuation force was found in between analytical as well as computational (ADAMS®) solutions.

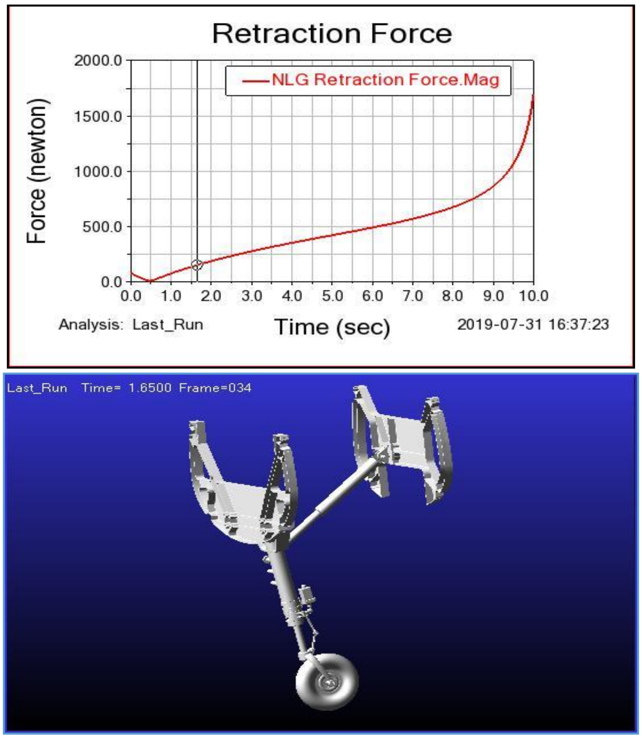

Figure 19 ADAMS® solution for NLG Retraction

In Figure 19, retraction force was mentioned against time. Analytical and ADAMS® software showed the similar trend. Major contributor for actuation force was mass and gravity force for these dimensions of mechanism. Similarly Figure 20 showed required extension force of NLG calculated by ADAMS® software.

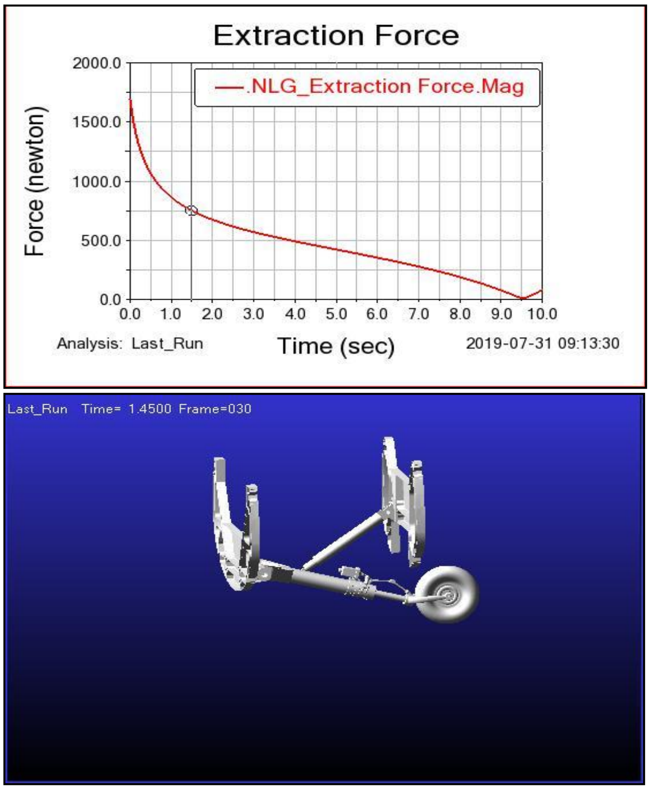

Figure 20 NLG extraction force as calculated by computational method (ADAMS® software)

1.3. *Material Variation Effect on Actuation Force*

It is observed that with variation of material the required actuation force changed. If material increased the mass of landing gear then the required force also increased and vice versa. Figure 21 showing the effect of changing material from Aluminum to steel. The required actuation force increased two and half times in steel as compared to Aluminum.

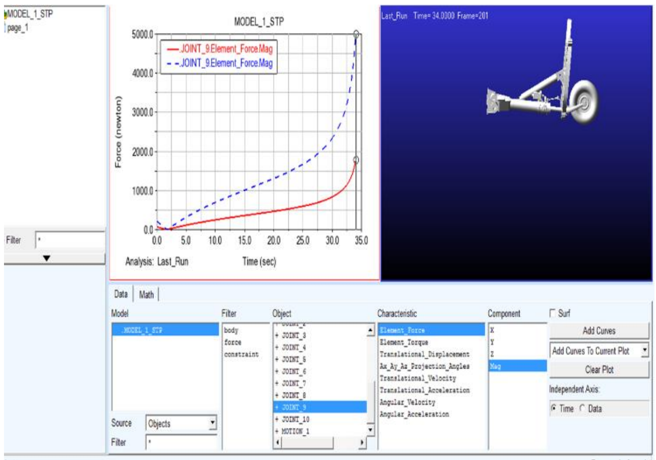

Figure 21 Effect of material on actuation force

V. Conclusion

In this paper planner triangular retraction mechanism of Nose Landing Gear actuated by electrical linear actuator has been researched upon. It is found that in case of MALE UAV retraction and extraction mechanism, the weight of NLG itself reflected a large contribution towards calculation of actuation force required to retract and extend it. The increased force requirement increased the power requirement for RLGS mechanism (Retractable Landing Gear System) to operate. Computational and analytical results for force required to extend / retract NLG come very close to each other thereby validating the methodology undertaken during this research. Further it was found that power requirement is inversely proportional to time required for complete rotation of retraction/extension cycle of NLG. Increasing

The research finally concluded that an increase in time for retraction/extraction sequence, power requirement of system increased and vice versa.

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