

ABOUT THE ANALYTICAL KINEMATICS ANALISYS OF THE LANDING GEAR

Marian BOBE*, Doru LUCULESCU*

*Air Force Academy “Henri Coandă”

Abstract: *The landing gear is one of the basic aircraft systems which has a significant effect on aircraft performance and economy. The tasks of aircraft landing gears are complex and lead to a number of sometimes-contradictory requirements. In this paper is presented a kinematics analysis for the landing gear assembly.*

Keywords: *retraction scheme, mathematical kinematics analysis, forward-retracting scheme, assembly clearance envelope, retraction path, pivot axis and angle of retraction.*

1. INTRODUCTION

Kinematics is the term applied to the design and analyses of those parts used to retract and extend the gear [2]. Particular attention is given to the determination of the geometry of the deployed and retracted positions of the landing gear, as well as the swept volume taken up during deployment/retraction. The objective is to develop as deployment/retraction scheme that takes up the least amount of stowage volume, while at the same time avoiding interference between the landing gear and surrounding structures.

The simplicity requirement arises primarily from economic considerations. As shown from operational experience, complexity, in the forms of increased part-count and maintenance downtime, drives up the overall cost faster than weight [5]. However, interference problems may lead to a more complex system to retract and store the gear within the allocated stowage volume.

For safety reasons, a forward-retracting scheme is preferable for the fuselage-mounted assemblies. In a complete hydraulic failure situation, with the manual release of up locks, the gravity and air drag would be utilized to deploy and down-lock the assembly and thus avoid a wheels-up landing [2]. As for wing-

mounted assemblies, current practice calls for an inboard-retraction scheme, which stows the assembly in the space directly behind the rear wing-spar. The bogie undercarriage may have an extra degree of freedom available in that the truck assembly can rotate about the bogie pivot point, thus requiring a minimum of space when retracted. As will be illustrated in the following section, deployed/retracted position of the landing gear, as well as possible interference between the landing gear and surrounding structures, can easily be identified using the mathematical kinematics analysis.

2. THE KINEMATIC ANALYSIS OF THE LANDING GEAR

A kinematics analysis, which is more effective and accurate than the graphical technique, was selected to determine the axis of rotation that will, in one articulation, move the landing gear assembly from a given deployed position to a given retracted position. As shown in fig. 1, a new coordinate system, termed the kinematics reference frame here, is defined such that the origin is located at the respective landing gear attachment locations with the axes aligned with the aircraft reference frame.

The aircraft coordinate system-based origin permits constraints established in the

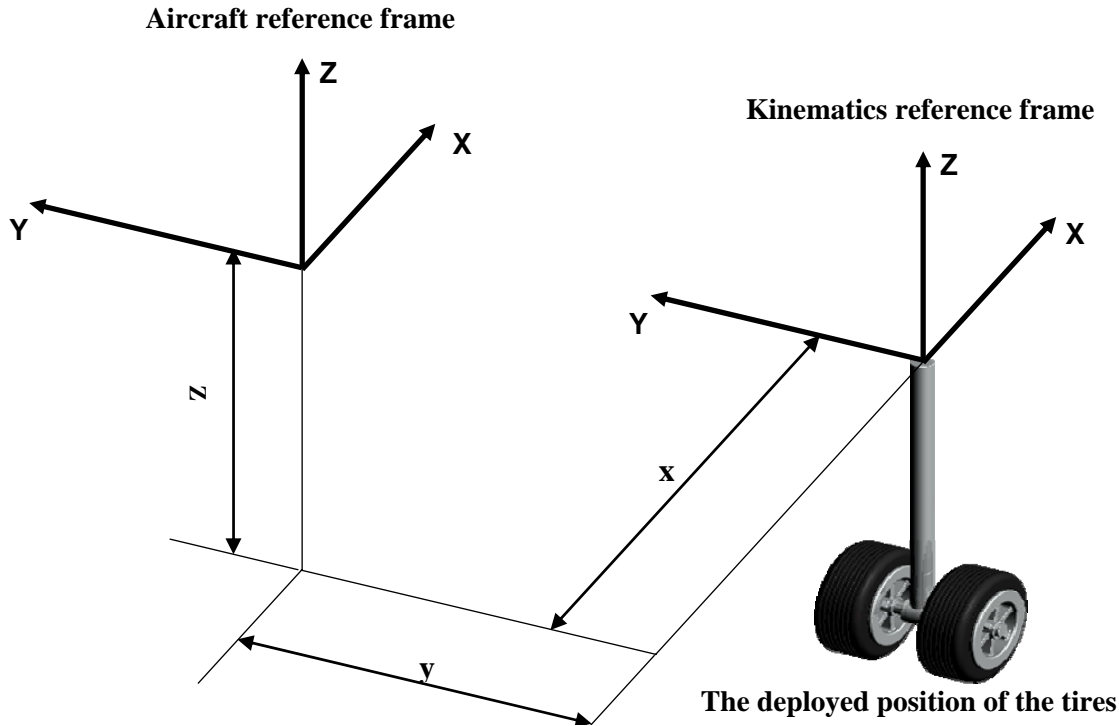


Fig. 1 The connexion between the aircraft and the kinematics reference frames

kinematics reference frame, *e.g.*, assembly clearance envelope, retraction path, and swept volume, be translated into the aircraft reference frame and checked for interference with surrounding structures.

In the determination of the alignment of the landing gear pivot axis, it is assumed that the axle/piston centerline intersection is brought from its deployed position to a given location within the stowage volume.

For wing-mounted assemblies, the retracted position of axle/piston centerline intersection is assumed to coincide with the center of the stowage volume.

In the case of fuselage-mounted assemblies with a forward-retracting scheme, the retracted position is assumed to be at the center of the cross-sectional plane located at the forward third of the stowage length.

For fuselage-mounted assemblies with a forward retracting-scheme, the pivot axis is defined by the cross product of the space vectors corresponding to the deployed and retracted position of a point location on the truck assembly. As shown in fig. 2, the cross product of two vectors (\vec{v}_1 and \vec{v}_2) representing the deployed and retracted positions of a given point location, here taken as the axle/piston centerline intersection, is

orthogonal to both vectors, *i.e.*, in the direction of the pivot axis.

Thus,

$$\vec{V} = \vec{V}_1 \times \vec{V}_2 \quad (1)$$

From standard vector operation, the direction cosines of the fuselage-mounted assembly is given as:

$$\begin{aligned} t &= \frac{X}{\sqrt{X^2 + Y^2 + Z^2}} \\ u &= \frac{Y}{\sqrt{X^2 + Y^2 + Z^2}} \\ v &= \frac{Z}{\sqrt{X^2 + Y^2 + Z^2}} \end{aligned} \quad (2)$$

and the angle between the two vectors, the angle of retraction (Δ) in this case, is calculated using the expression:

$$\cos \Delta = t_1 t_2 + u_1 u_2 + v_1 v_2 \quad (3)$$

where $t_{1,2}$, $u_{1,2}$ and $v_{1,2}$ are the direction cosines of the deep and retracted space vectors.

The determination of the wing-mounted assembly pivot axis involves the deployed and retracted positions of two points on the assembly.

Essentially, the problem consists of bringing the line segment between the two

points from its deployed position to its retracted position.

For ease of visualization, a twin-wheel configuration is used here to illustrate the procedure involved in determining the alignment of the desired pivot axis. Identical procedure is used for other configurations as well.

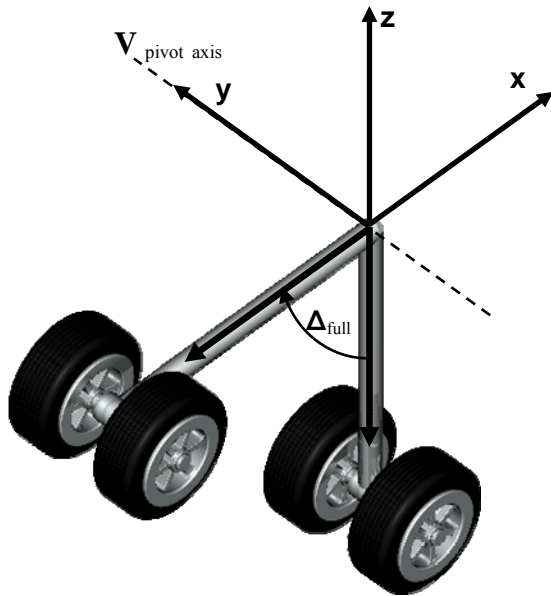


Fig. 2 The alignment of fuselage-mounted assembly

In fig. 3, the axle/piston centerline intersection is selected as the first point (point A), while the second point (point B) is conveniently located at a unit distance along the axle, inboard from the first point location. Retracted positions of the first and second points are given as point A' and B', respectively.

Of the four point positions required in the analysis, the positions of point A and A' are readily determined from the geometry of the landing gear and the stowage volume, respectively.

From simple vector algebra:

$$\vec{V}_2 = \vec{V}_1 \times \vec{m} \quad (4)$$

where subscripts 1 and 2 denote the space vector corresponding to the deployed positions of points A and B, respectively.

Similarly,

$$\vec{V}_4 = \vec{V}_3 \times \vec{n} \quad (5)$$

where subscript 3 and 4 denote the retracted positions of point A and B, respectively, and

\vec{n} defines the orientation of the unit vector in its retracted position and is unknown.

To solve for \vec{n} , it is assumed that no devices are used to shorten the length of the strut during the retraction process, that the magnitudes of \vec{V}_2 and \vec{V}_4 remain constant,

$$\begin{aligned} \vec{V}_1 &= X_1 \cdot \vec{i} + Y_1 \cdot \vec{j} + Z_1 \cdot \vec{k} \\ \vec{V}_2 &= X_2 \cdot \vec{i} + Y_2 \cdot \vec{j} + Z_2 \cdot \vec{k} \\ \vec{V}_3 &= X_3 \cdot \vec{i} + Y_3 \cdot \vec{j} + Z_3 \cdot \vec{k} \end{aligned} \quad (6)$$

$$\begin{aligned} \vec{V}_4 &= X_4 \cdot \vec{i} + Y_4 \cdot \vec{j} + Z_4 \cdot \vec{k} \\ X_1^2 + (Y_1 + 1)^2 &= (X_3 + X_n)^2 + \\ &+ (Y_3 + Y_n)^2 + (Z_3 + Z_n)^2 \end{aligned} \quad (7)$$

and that the magnitude of the retracted unit vector remains at unity:

$$X_n^2 + Y_n^2 + Z_n^2 = 1 \quad (8)$$

The angle of inclination ϕ of \vec{n} in the yz-plane, which is one of the design variables that can be used to position the retracted truck assembly to fit into the available stowage space, is given as:

$$\text{tg}\phi = \frac{Y_n}{Z_n} \quad (9)$$

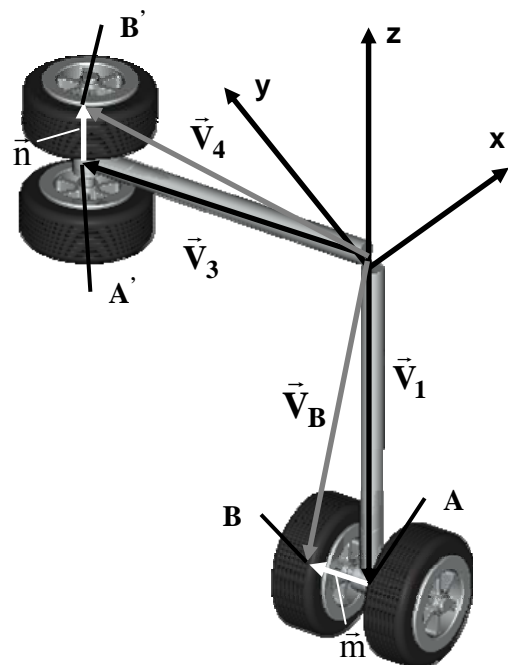


Fig. 3 The wing-mounted landing gear vector

We can determined the vector components of \vec{n} , and subsequently \vec{V}_4 , then by solving the system:

$$\begin{cases} X_1^2 + (Y_1 + 1)^2 - (X_3 + X_n)^2 + \\ + (Y_3 + Y_n)^2 + (Z_3 + Z_n)^2 = 0 \\ X_n^2 + Y_n^2 + Z_n^2 = 1 \\ Y_n - Z_n \operatorname{tg} \varphi = 0 \end{cases} \quad (10)$$

As shown in fig. 4, the pivot axis that will permit the achievement of the desired motion is defined by the cross product of the space vectors between the deployed and retracted positions of the two point locations, in this case points A and B,

$$\vec{V} = \vec{V}_A \times \vec{V}_B \quad (11)$$

where:

$$\vec{V}_A = (X_3 - X_1)\vec{i} + (Y_3 - Y_1)\vec{j} + (Z_3 - Z_1)\vec{k} \quad (12)$$

and

$$\vec{V}_B = (X_4 - X_2)\vec{i} + (Y_4 - Y_2)\vec{j} + (Z_4 - Z_2)\vec{k} \quad (13)$$

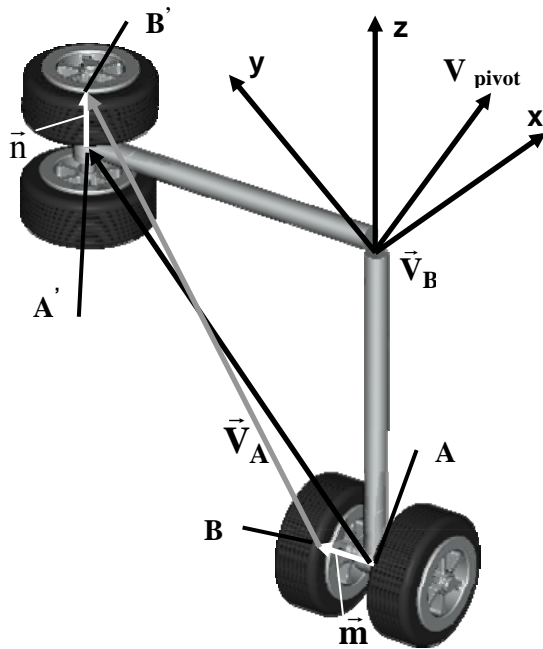


Fig. 4 Wing-mounted assembly pivot axis alignment

The direction cosines of the wing-mounted assembly and the angle of rotation can be determined using equations (2) and (3), respectively.

To determining the required pivot axis and angle of retraction, the analytic method is used to establish the retraction path and the stowed position of the landing gear assembly.

Note that the drag and side struts are excluded in the analysis since the retraction of these items involves additional articulation, folding and swiveling, that cannot be modeled by the analysis.

Define point A as an arbitrary point location on the landing gear assembly. Given the angle of rotation and the direction cosines of the pivot axis as determined above, the retracted position of point A, denoted here as A', can be determined by solving the following system:

$$\begin{cases} X_A + (uZ_A - vY_A)\sin\Delta + \\ + [t(X_A + uY_A + vZ_A) - X_A](1 - \cos\Delta) = X_{A'} \\ Y_A + (vX_A - tZ_A)\sin\Delta + \\ + [u(tX_A + uY_A + vZ_A) - Y_A](1 - \cos\Delta) = Y_{A'} \\ Z_A + (tY_A - uX_A)\sin\Delta + \\ + [v(tX_A + uY_A + vZ_A) - Z_A](1 - \cos\Delta) = Z_{A'} \end{cases} \quad (14)$$

Similarly, the retraction path and swept volume of the assembly, can be established by calculating several intermediate transit positions at a given interval of degrees.

The above information can then be used to identify possible interference between the landing gear and surrounding structures during deployment / retraction.

REFERENCES

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