5. Other mechanisms and landing gear

Design 2

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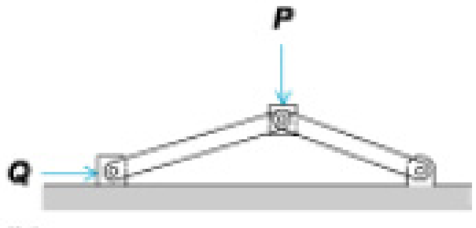
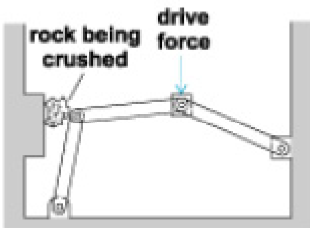
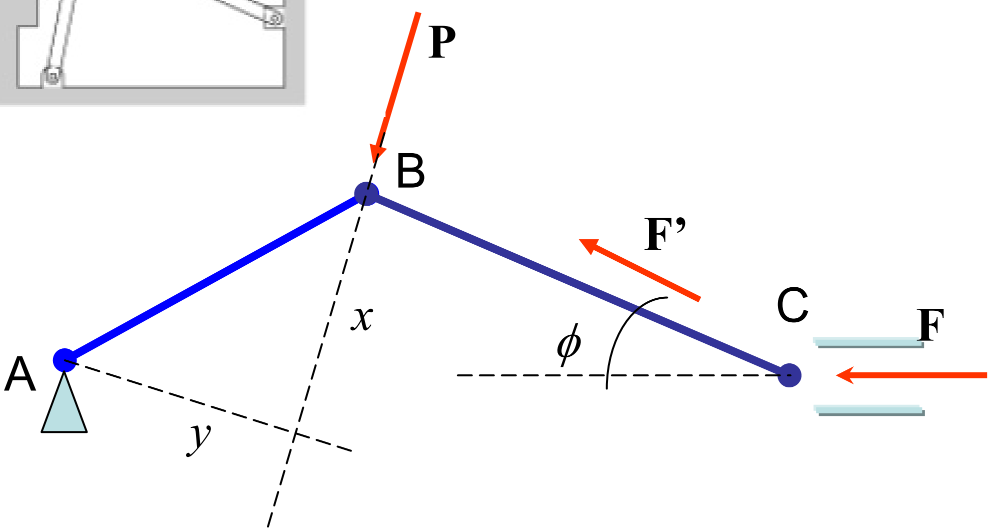
5.1 Toggle Mechanisms



- Consists of 2 hinged columns joined end to end but not in line → a force applied to the knee that tends to straighten the links will result in endwise pressure at the ends of the columns
- Significant mechanical advantage
- Locking system





Toggle mechanism can be made self-locking by permitting B to go below dead centre

$$F'x = Py$$

$$F' = \frac{F}{\cos\phi}$$

$$\boxed{\frac{F}{P} = \frac{y}{x}\cos\phi}$$

If AB = BC and **P** ⊥ **F**:

$$\frac{F}{P} = \frac{1}{\tan\phi}$$

5.1 Toggle Mechanisms

- Large mechanical advantage (output forces → 0 as ϕ increases)
- High efficiency – principal losses are due to pivot friction (using low friction bearings)
- Load bearing members (columns & tension members) easily designed and fabricated
- Output force increases as the follower approaches the end of its stroke
- Can be made self-locking

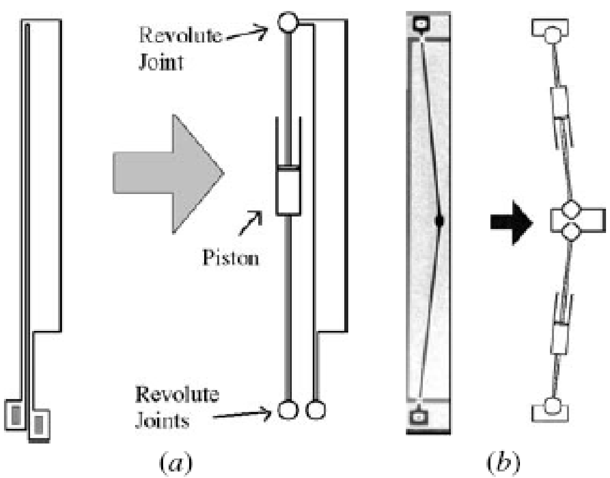


Figure 1. Thermal actuators and their rigid link models: (*a*) folded toggle (STA) and (*b*) open toggle (chevron).

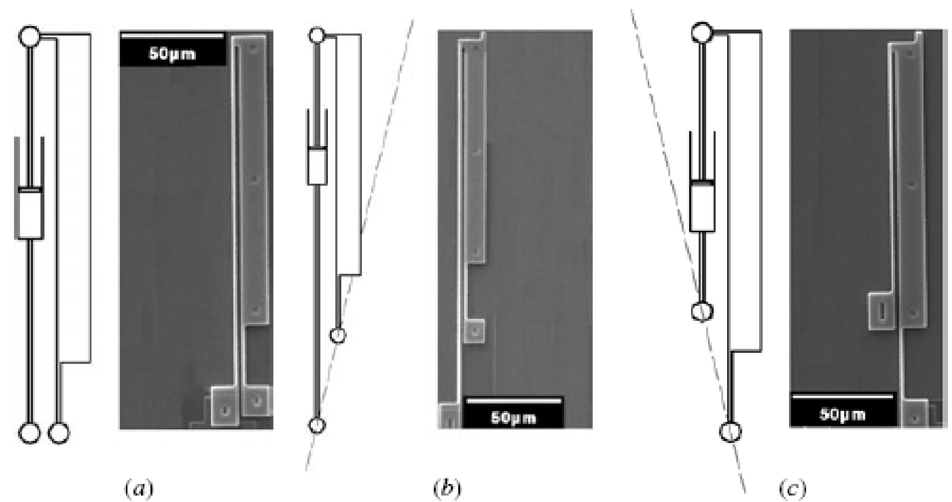
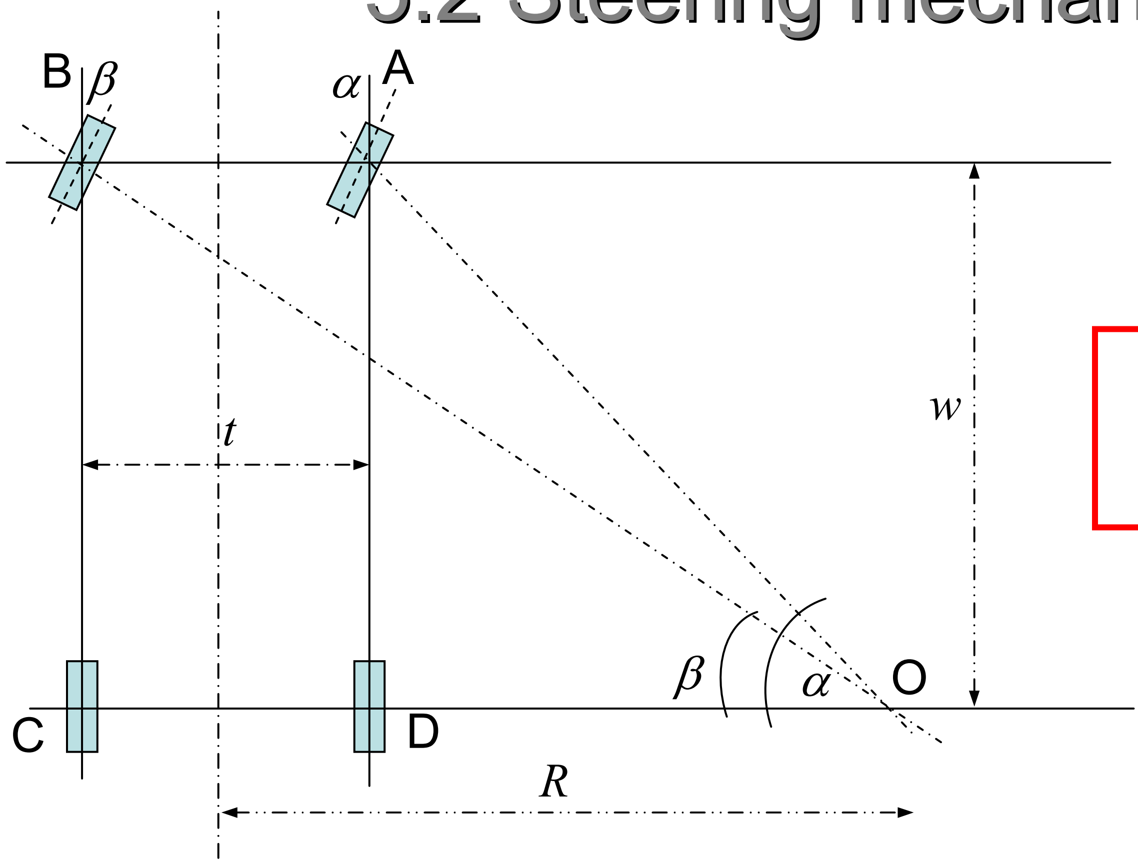


Figure 3. (*a*) Standard TA, (*b*) TA moving into toggle and (*c*) TA moving out of toggle.

Lai *et al*, *J. Micromechanics and Microengineering*, **14** (2004), 49-56

5.2 Steering mechanism



t = track
w = wheel distance
A, B = wheel pivots

O must lie on line CD otherwise rear wheels will skid

$$w \cot \beta = t + w \cot \alpha$$

$$\boxed{\cot \beta = \frac{t}{w} + \cot \alpha}$$

Typical: t/w = 0.4

α	0	10	20	30
β	0	9.35	17.6	25.1
R [m]	Inf	17.6	8.8	5.8

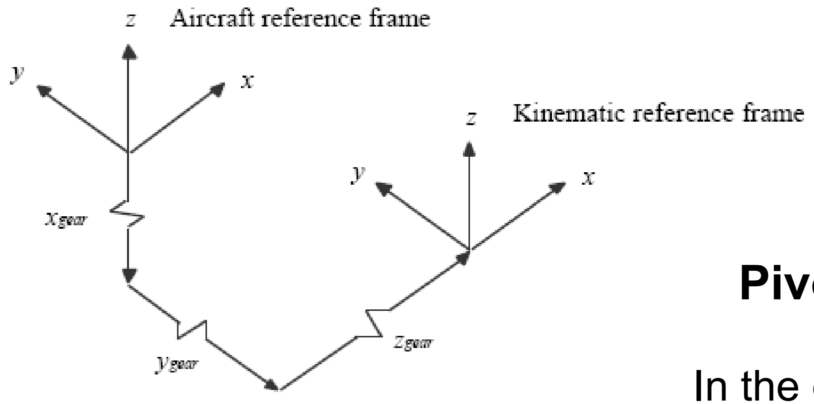
5.3 Concepts of kinematics for landing gears

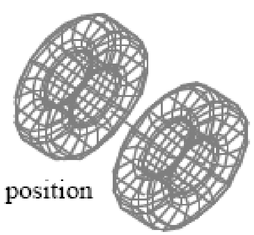
•Design objectives are for simple deployment/retraction schemes that takes up the least amount of stowage volume, while at the same time avoiding interference between the landing gear and surrounding structures.
•From operational experience, **complexity**, in the forms of increased part-count and maintenance down-time, drives up the overall cost faster than weight
•Interference problems may lead to a more complex system to retract and store the gear within the allocated stowage volume.

Considerations for retraction schemes

✓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 uplocks, the gravity and air drag would be utilized to deploy and down-lock the assembly and thus avoid a wheels-up landing
✓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.

5.3 Concepts of kinematics for landing gears





Tires in the deployed position

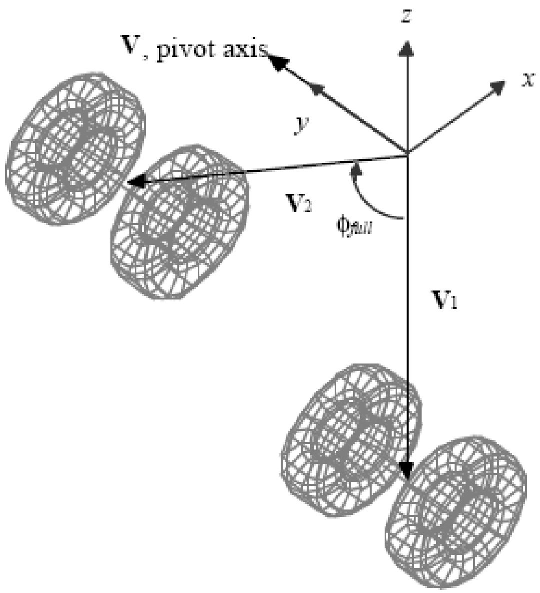
origin is located at the respective landing gear attachment locations with the axes aligned with the aircraft reference frame.

Pivot axis and directions cosines

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

5.3 Concepts of kinematics for landing gears

Example – fuselage mounted assembly



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:

$$\mathbf{V} = \mathbf{V}_1 \times \mathbf{V}_2$$

Direction cosines of fuselage-mounted assembly:

$$l = \frac{X}{\sqrt{X^2 + Y^2 + Z^2}} \qquad m = \frac{Y}{\sqrt{X^2 + Y^2 + Z^2}} \qquad n = \frac{Z}{\sqrt{X^2 + Y^2 + Z^2}}$$

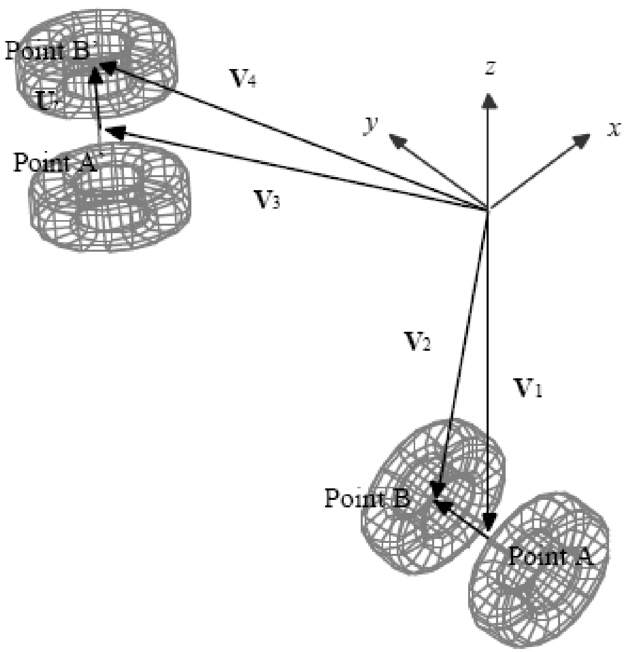
Angle of retraction:

$$\cos\phi_{full} = l_1 l_2 + m_1 m_2 + n_1 n_2$$

l_i, m_i, and n_i are the respective direction cosines of the deployed and retracted space vectors.

5.3 Concepts of kinematics for landing gears

Example – wing mounted assembly



We have to bring the line segment between the two points from its deployed position to its retracted position

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. The retracted positions of the first and second points are given as point A' and B', respectively.

$$\mathbf{V}_2 = \mathbf{V}_1 + \hat{j}$$

1,2: deployed positions of A and B

$$\mathbf{V}_4 = \mathbf{V}_3 + \mathbf{U}_r \qquad \text{(a)}$$

3,4: retracted positions of A and B

$\mathbf{U}_r$: defines orientation of unit vector in retracted position (unknown)

5.3 Concepts of kinematics for landing gears

Example – wing mounted assembly

If no devices are used to shorten the length of the strut during the retraction process, *i.e.*, that the magnitudes of $\mathbf{V}_2$ and $\mathbf{V}_4$ remain constant:

$$X_1^2 + (Y_1 + 1)^2 + Z_1^2 = (X_3 + X_U)^2 + (Y_3 + Y_U)^2 + (Z_3 + Z_U)^2 \qquad \text{(b)}$$

And the magnitude of the retracted unit vector remains at unity:

$$X_U^2 + Y_U^2 + Z_U^2 = 1 \qquad \text{(c)}$$

The angle of inclination (θ) of $\mathbf{U}r$ 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 by:

$$\tan\theta = \frac{Y_U}{Z_U} \qquad \text{(d)}$$

The vector components of $\mathbf{U}r$, and subsequently $\mathbf{V}_4$, can then be determined by solving Eqs (b), (c), and (d) simultaneously

5.3 Concepts of kinematics for landing gears

Example – wing mounted assembly

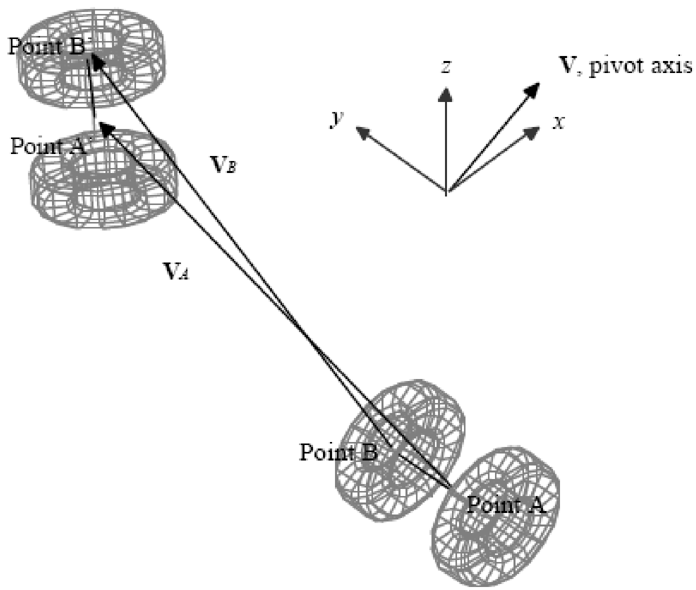
Pivot axis defined by:

$$\boxed{\mathbf{V} = \mathbf{V}_B \times \mathbf{V}_A}$$

Where:

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

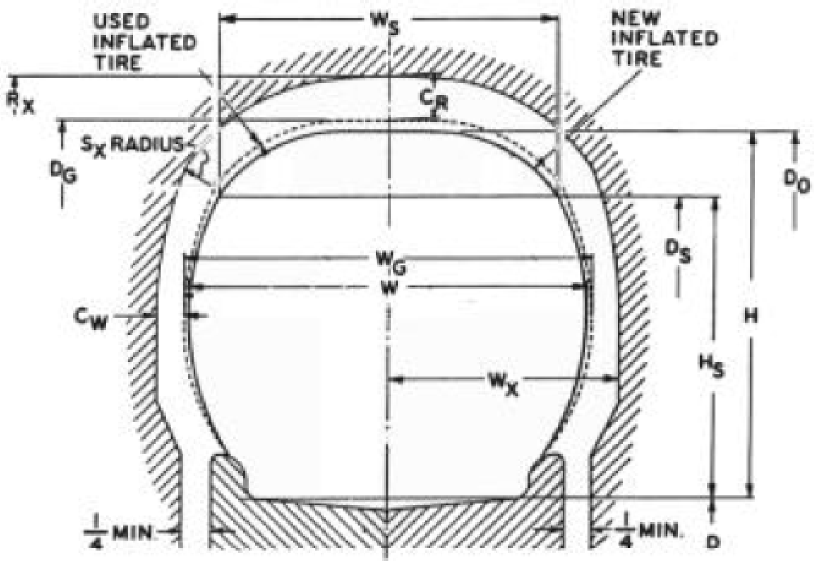
$$\mathbf{V}_B = (X_4 - X_2)\hat{i} + (Y_4 - Y_2)\hat{j} + (Z_4 - Z_2)\hat{k}$$



Directions cosines can be determined as per fuselage mounted assembly

5.3 Concepts of kinematics for landing gears

Example – Truck assembly clearance envelope



Clearances are provided to prevent unintended contact between the tire and the adjacent parts of the aircraft during operation, particularly in the case when the tire is damaged and continues to spin when stowed. Typical formulas:

$$D_G = D + 2(1.115 - 0.074\,AR)H \qquad AR = \frac{H}{D}$$

$$W_G = 1.04\,W$$

D = specified rim diameter, H = maximum section height, W = maximum section width

$$C_R = \begin{bmatrix} 0.073 \\ 0.060 \\ 0.047 \\ 0.037 \\ 0.029 \end{bmatrix} W_G + 0.4 \qquad at \begin{Bmatrix} 250\,MPH \\ 225\,MPH \\ 210\,MPH \\ 190\,MPH \\ 160\,MPH \end{Bmatrix}$$

$$C_W = 0.019 W_G + 0.23$$

<u>Radial and lateral clearance</u>