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Kinematics

- Kinematics: develop various means of transforming motion to achieve a specific task needed in applications
- ensure the functionality of the mechanism
 Mechanism?
 - Dynamics: behavior of a given machine or mechanism when subjected to dynamic forces
 - verify the acceptability of induced forces in parts

Example : cam operating valve



Kinematical analysis : satisfy functional requirements for valve displacements.

Dynamic analysis : compute forces in the system as a function of time.

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Choice of coordinates



(Cartesian coordinates)

(Lagrangian coordinates)

 ϕ_3

Relative coordinates



- Absolute vs relative
- Choice is not unique
- How many coordinates ?
 (Efficiency vs simplicity)
- How many constraints?

What is the best choice ?

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Coordinates and constraints

- N = number of DOFs: minimum number of coordinates required to fully describe the configuration of a system
- Number of coordinates: $q \ge N$

→ We have to find p=q-N relationships



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Coordinates and constraints

$$\begin{array}{c}
\underline{Option 2}: q = 7: \\
\theta_1, \theta_2, \theta_3, x_{G2}, y_{G2}, x_{G3}, y_{G3} \longrightarrow p = 7 - 2 = 5 \\
\end{array}$$

$$\begin{array}{c}
1) l \cos \theta_1 = x_2 - \frac{l}{2} \cos \theta_2 \\
2) l \sin \theta_1 = y_2 - \frac{l}{2} \sin \theta_2 \\
\end{array}$$

$$\begin{array}{c}
A_1 = A_2 \\
A_1 = A_2 \\
3) x_2 + \frac{l}{2} \cos \theta_2 = x_3 - \frac{l}{2} \cos \theta_3 \\
4) y_2 + \frac{l}{2} \sin \theta_2 = y_3 - \frac{l}{2} \sin \theta_3 \\
\end{array}$$

$$\begin{array}{c}
B_2 = B_3 \\
B_2 = B_3 \\
5) y_3 + \frac{l}{2} \sin \theta_3 = 0 \\
\end{array}$$

$$\begin{array}{c}
B_2 = B_3 \\
B_2 = B_3 \\
B_3 = B_3 \\
B_4 = B_3 \\
B_5 = B_5 \\$$

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Number of DOFS



Number of DOFS









 $b = 0 (l = 2, n = 2) \qquad b = 1 (l = 4, n = 3) \qquad b = 2 (l = 7, n = 5)$





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Redundant constraints



A constraint that can be removed without changing the kinematics is called redundant.

Not taken into account in the calculation of the number of DOFs.



Constraint equations : single body revolute joint



Constraint equations : two bodies revolute joint



$$\overline{r}_G^1 + A_1 \overline{s}_P^1 = \overline{r}_G^2 + A_2 \overline{s}_P^2$$



Constraint equations : translation joint



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Constraint equations : revolute-revolute joint

Constant distance between P and Q



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Constraint equations : revolute-translation joint



Rotation around S and translation

CDM - VIB - Kinematics

Constraint equations : spur gears

$$\overrightarrow{v_P} \underbrace{v_P^2}_{P} \underbrace{v_P^2}_{P}$$

$$\overrightarrow{v_P} \underbrace{\overrightarrow{v_P}}_{P}$$

$$\overrightarrow{v_P} = \overrightarrow{v_P}^2$$

$$\overrightarrow{v_P} = R_1 \dot{\theta}_1 = R_2 \dot{\theta}_2$$



Constraint equations : rack and pinion





Constraint equations : universal joints



https://www.youtube.com/watch?v=LCMZz6YhbOQ

Universal joint equations



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Universal joint equations

$$\tan \phi = \cos \beta \tan \theta \qquad \text{Differentiation:} \quad \frac{1}{\cos^2 \phi} \dot{\phi} = \frac{\cos \beta}{\cos^2 \theta} \dot{\theta}$$
$$\frac{1}{\cos^2 \phi} = 1 + \tan^2 \phi = 1 + \cos^2 \beta \tan^2 \theta$$
$$\omega_2 = \frac{\omega_1 \cos \beta}{1 - \sin^2 \beta \sin^2 \theta} \qquad \beta << \qquad \text{Transmission is not}$$
uniform unless the two axles are aligned
$$\dot{\omega}_2 = \frac{\omega_1^2 \sin^2 \beta \cos \beta \sin 2\theta}{\left(1 - \sin^2 \beta \sin^2 \theta\right)^2}$$

Universal joint equations

