

KINEMATIC DESIGN

MCL747 DESIGN OF PRECISION MACHINES
DEPARTMENT OF MECHANICAL ENGINEERING
IIT DELHI

Kinematic Design

Maxwell describes *kinematic design* as:

'The pieces of our instrument are solid, but not rigid. If a solid piece is constrained in more than six ways it will be subject to internal stress, and will become strained or distorted, and this in a manner which, without the most exact micrometrical measurements, it would be impossible to specify' [Maxwell, 1890].

Kinematic Design

Kinematics evolved from mathematics and is hence somewhat 'idealised' in its components. e.g. rigid bodies, straight lines, perfect circles and 'point contacts' etc. Nevertheless it is a good starting point for mechanical design that is correct in principle.

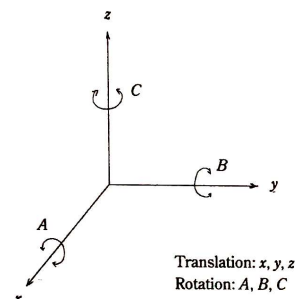
The basis for kinematic design is constraining the right number of degrees of freedom (d.o.f.), i.e. translations or rotations.

Kinematic Design

Kinematic design is a design principle for imparting the required movements to a body by means of constraints.

A rigid body possesses six degrees of freedom in motion.

Any unconstrained rigid body has six degrees of freedom.



Kinematic Design

Each time a constraint is imposed, the number of degrees of freedom is reduced by one.

- If a rigid body's movement in the z-direction is constrained, it will have five remaining degrees of freedom.

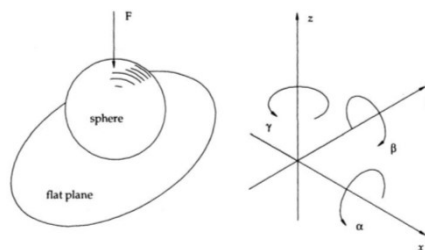
$$\text{Number of constraints} + \text{remaining degrees of freedom} = 6$$

Kinematic Design

Basic point constraints

- A simple single degree of freedom constraint may be envisaged as an infinitely rigid sphere pressed against an infinitely rigid flat, with a frictionless interface.

A point contact imposes a single constraint.



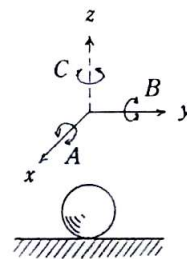
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The number of contact points between any two perfectly rigid bodies is equal to the number of their mutual constraints.

Models for predicting the motion of mechanisms can then be constructed in terms of the number of contact points, using the geometrical abstraction of spheres connected by rigid links.

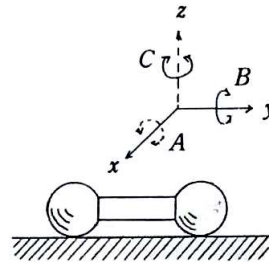
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The body has a single point of contact and only movement in the z-direction is constrained.



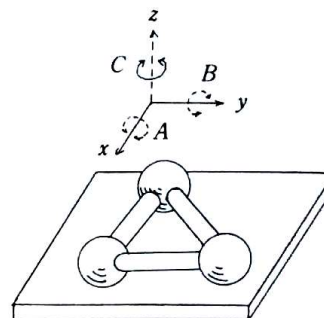
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A two degree of freedom constraint can be constructed from two spheres joined together to make a rigid body and placed onto a surface.



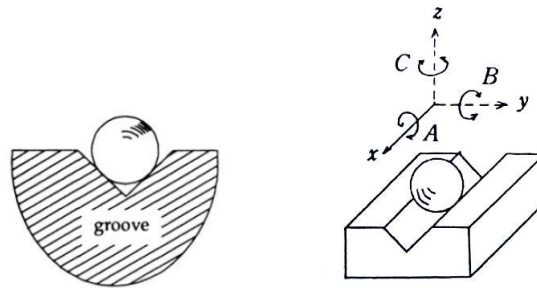
Kinematic Design

Three degree of freedom constraint



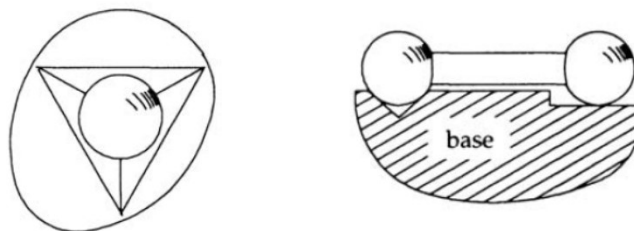
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Two degree of freedom constraint



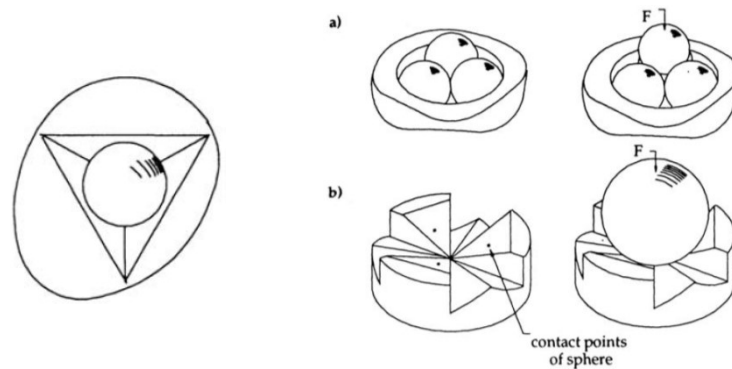
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Three degree of freedom constraint



Kinematic Design

Methods for achieving trihedral contacts



Kinematic Design

CONSTRAINTS

CONFIGURATION

- | | |
|---|---|
| 1 | Ball on flat |
| 2 | Link on flat |
| | Ball in groove |
| 3 | Ball in trihedral hole |
| | Link with one ball in groove and other on flat |
| | Three linked balls suitably distributed on a flat |

Kinematic Design

CONSTRAINTS

CONFIGURATION

- 4 Link with one ball in trihedral hole and the other on a flat
- Link with two balls both in a vee groove
- Link of three balls with two on a flat and one in a groove
- Link of four balls suitably distributed on two inclined flats

Kinematic Design

CONSTRAINTS

CONFIGURATION

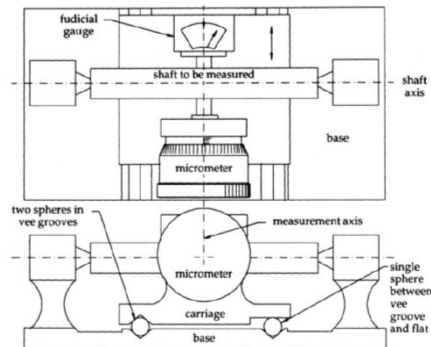
- 5 Link of two balls with one in a trihedral hole and the other in a vee groove
- Link of three balls with two in vee grooves and one on a flat
- Link of four balls with one in a vee groove and three on a flat
- Link of five balls suitably distributed on two inclined flats

This is because there are geometric singularities in the rules and simply counting the total contacts is not adequate.

Kinematic Design

Kinematic constraint can also be achieved through spheres that remain free floating between the two bodies.

two orthogonal views of a screw and diameter measuring instrument



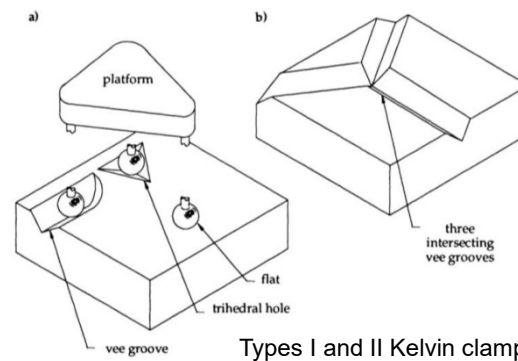
Kinematic Design

Kinematic clamps

- Constraint in all six degree of freedom between two rigid bodies
- Unable to move relative to each other and are considered 'clamped'
- An *ideal kinematic clamp* has six independent contact points

Kinematic Design

Kinematic clamps



Types I and II Kelvin clamp