Compliant Mechanisms

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Compliant Mechanisms

A compliant mechanism gains some or all of its motion from the deflection of flexible members
Low cost
Minimal assembly
Compact
High precision
Reduced wear
Harsh environments
Light weight
Tailored force response
Easily minaturized
One key thing to remember
Stiffness and strength are not the same thing
It is possible to make something both Flexible and Strong.
Pseudo-Rigid-Body Model

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Pseudo-Rigid-Body Model

- Models compliant mechanisms as rigid-body mechanisms
- Allows use of decades of research in mechanical systems
- Unifies compliant mechanism and rigid-body mechanism theories
Example
Example
PRBM:
Small-Length Flexural Pivot

\[ l \ll L \]

Pseudo-rigid joint

Torsional spring

Pseudo-rigid joint
Living Hinges

- Living hinge: extremely short and thin small-length flexural pivots
- PRBM is a pin joint at the center of the flexible segment.
- If other compliant elements are present, then can ignore spring for living hinge
PRBM: Fixed-Pinned

- Pseudo-rigid-body link
- Pseudo-rigid-body angle
- Torsional spring
- Characteristic pivot
- Characteristic radius

Undeﬂected position

\( l, EI \)

\( F \)

\( a \), \( b \), \( \gamma l \), \( nP \)
Practical Implementation

(a)

(b)

(c) Passive joint

(d) Living hinge

Rigid segment
Example
Exercise

(a) Sketch the PRBM
(b) Calculate the lengths of the links
(c) Write equations for spring constants symbolically
(d) Calculate numerical values of spring constants

Assume dimensions in mm and material is Aluminum (E=72 GPa)

\[ l = \frac{bh^3}{12} \]

Out-of-plane thickness = 2
PRBM: Pinned-pinned

(a) A

(b) deflected member
PRBM: Pinned-pinned

(a)

(b)
Other Pseudo-rigid-body Models

- Pure moment load
- Initially curved beam
- Other
Example: Bistable Switch

- **Stable equilibrium position**
- **Unstable equilibrium position**
- **Stable equilibrium position**
Example

Actuation lever
Living hinges
Contacts

Torsional spring

\[ r = \frac{L + l}{2} \]
Example

- The pseudo-rigid-body model is a four-bar mechanism.
- The potential energy is a function of the deflection of the torsional spring.
- PRBM provides simple model that allows the design of needed position and force control.
The lagging (crossed) form is determined by \(-\psi\) and \(-\lambda\), using the second solutions from the \(\cos^{-1}(\ )\) equations.
Parametric Models

- Powerful design tool
- Analyze many different designs quickly
- Integration with optimization tools
- Convert between different configurations
Example: Rocker Switch

- Same parametric models apply to move from a toggle switch to a rocker switch
PRBM with CAE tools

- Spreadsheets, Matlab, etc
  - Switch example
PRBM with CAE tools

- Multi-body dynamics tools (ADAMS, etc.)
  - Examples
    - folded-beam suspension
    - switch
This end connected to wafer gripper

Fixed to ground
Example: Switch

Applied force

Pinned to ground

Torsional spring
Rocker Switch
So why compliant mechanisms now?
Computational capabilities
Materials and processes
Design methods
and . . .
New needs

- High performance
  - weight
  - friction and wear
  - precision

- Size domains
  - meso
  - micro
  - nano

- Critical applications
  - biomedical
  - space
  - economic

- Cost
  - part count
  - assembly
  - manufacturing

- New motions
  - morphing
  - lamina emergent
  - adaptive
High performance
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21st Century Compliant Mechanisms
Biomedical Implants

FlexBAC
Biomedical Implants

FlexBAC

CROCKER
Spinal Technologies, Inc.
Microelectromechanical Systems (MEMS)
Engineering Tools of Scientific Discovery

The Grand Challenges of Engineering
Lamina Emergent Mechanisms
What do you think is next?

Hypercompact Mechanisms
Adaptive Morphing Systems
Disruptive Innovations
More Human-like Implants
Nanomachines
Advanced Materials
Human-Robot Interactions
Products using Local Materials
Resources

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Handbook of Compliant Mechanisms
Available soon
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