Overview of Assemblies: Rigid and Articulating Joints

24-370 - Spring 2011

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Reminders and Announcements

- Rev 2 and Addendum due now…
  - Please bring up your plastic boxes
  - Parts look much improved!
- Testing of Rev 2 parts Monday
- AutoDesk info session today 4:30 SH 224
  - Free pizza and drinks…
- HW4 assigned today: materials and assemblies
- Project 2 assigned today…

Project 2 Overview

- The Swinging Gripper!
  - Team project (groups online)
  - Sketch Description…
- Deadlines:
  - Rev 1 Prototype testing March 21st (5 weeks)
  - Rev 2 Prototype and Group Report due April 4th
  - No conflicts, to my knowledge

Assemblies, continued

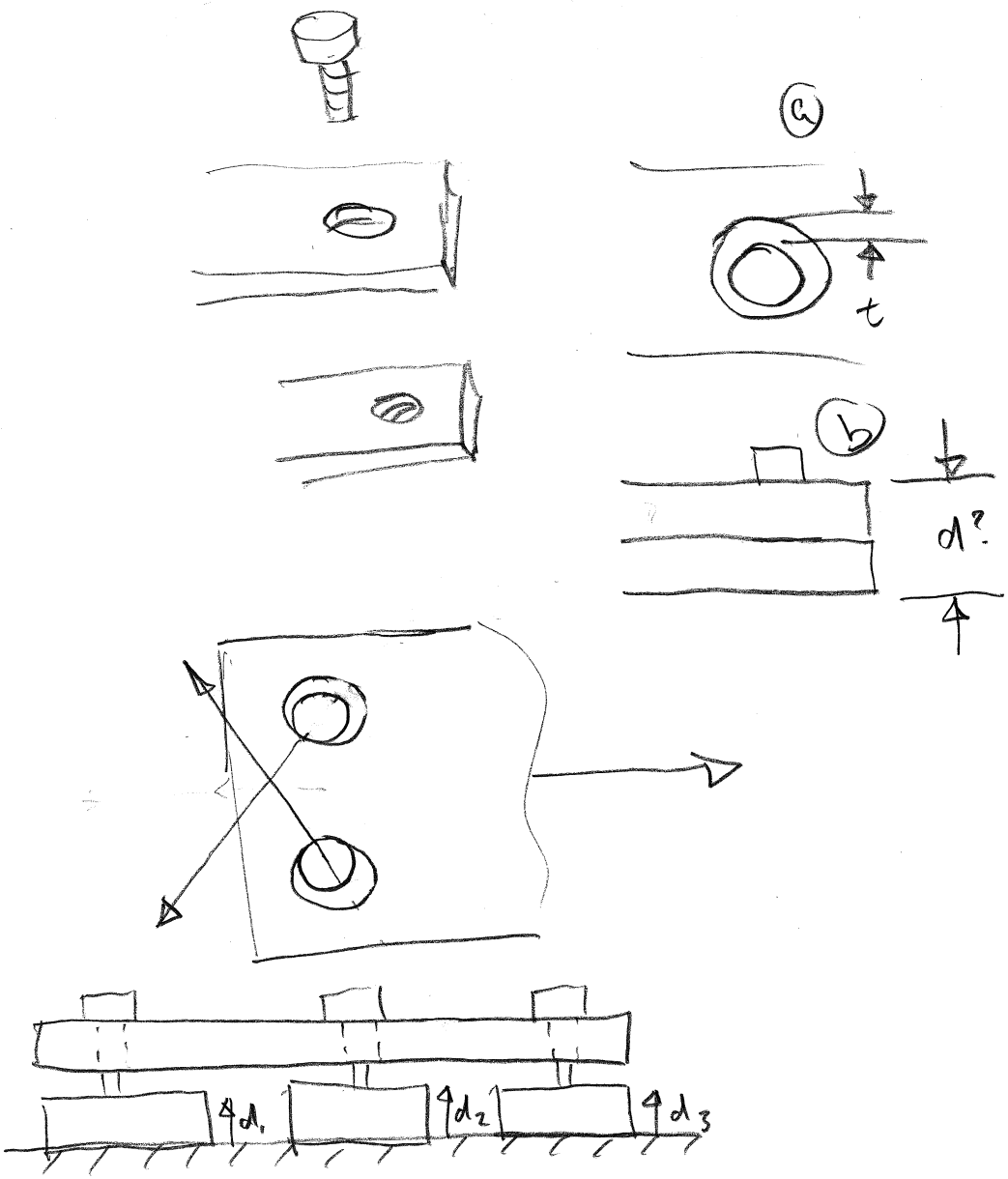
- Review:
  - Allow movement, manufacturing, separability
  - Can add complexity, reduce strength and accuracy
  - Loading implications: keep attachment forces low
- Tolerances
- Constraints
- Overview of joint types
- Rigid joints
- Articulating elements

Assemblies and Tolerances

- What are tolerances?
  - From possible errors in parts
  - From uncertainty in connections
  - Other types of “slop”
- Stacking
- Geometry of attachments very important
  - Displacement errors affected by geometry, stacking
- Some examples and exercises
  - Mounting a shaft
  - A high-precision gear-box frame

Assemblies and Constraint

- Engineering materials are stiff
  - Small displacements can cause large forces
- Over-constraint can increase stress
  - Inducing bending
  - Less-desirable element taking stress
  - Unforeseen force multipliers
- Some examples and exercises
  - Billy-Bob’s Miller sign, revisited
  - Perfectly-constrained cantilevered beam
  - Perfect constraint using indexing surfaces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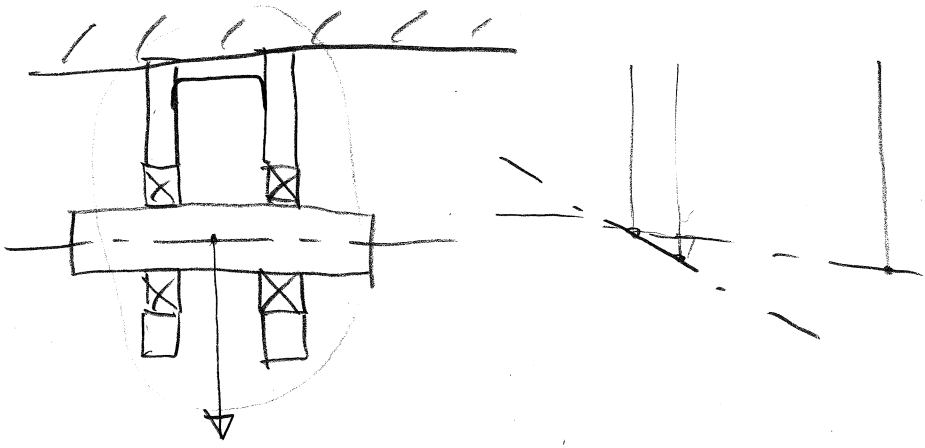

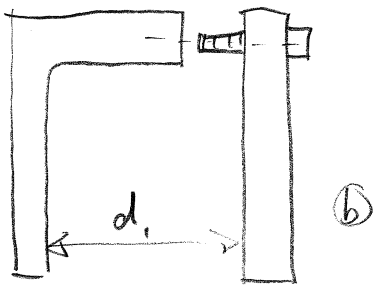
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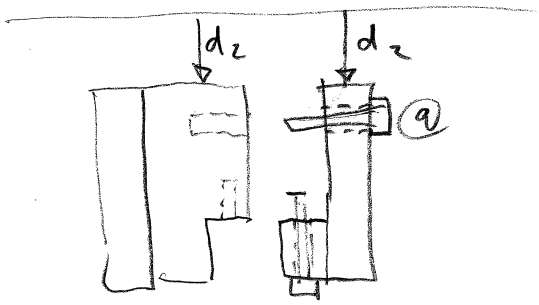
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Overview of Rigid Joints

- Common methods
  - Machine screws, bolts, nuts, setscrews, rivets, retaining rings, pins, keys, welds, adhesives
- Modes of connection
  - Normal (tensile or compressive) load transfer
    - Best, where possible
  - Shear load transfer
    - Usually to be avoided
  - Friction load transfer
    - Better than shear where normal impossible

Overview of Articulating Joints

- Common methods
  - Bearings, springs
- Degrees of freedom
  - One rotational d.o.f., i.e. hinge joint
    - Usually best, where possible
  - One linear d.o.f., e.g. linear slide
    - Usually to be avoided due to bulk
  - Multiple rotational d.o.f., e.g. ball joint
    - Usually to be avoided due to control difficulties
  - Multiple linear d.o.f., e.g. gantry… oh no!

Nuts and Bolts of Rigid Joints

- Threads
  - Pitch - distance between adjacent threads (or inv.)
  - Major Diameter - outer diameter
  - Tap or Die Diameter - pre-threaded diameter
  - Typically single-threaded, right-handed
  - Standardized, e.g. UNS
- Common Choices
  - Socket cap screws (machine screws) with hex drive
  - Also, flat or button head
  - e.g. 4-40, 6-32, 8-32, 10-32, ¼-20

Nuts vs. Threaded Holes

- Threaded holes usually better in robotics apps
  - Fewer parts
  - Better tolerances
  - Lower mass
- Nuts and bolts better in some applications
  - Cost
  - Manufacturing
  - Careful reusing nuts - built to yield
- Rule of thumb for threaded holes:
  - 3 full threads - min
  - 2 diameter's depth - best for alignment

Socket Cap Screws

- Strength
  - Simple model of screw in tension?
    - $\sigma = F A^{-1}$, A = tensile stress area
  - Stress concentrations: fatigue; F.O.S.
  - See, e.g., Shigley pp. 419 for detailed estimates
- Tension and torque in screws
  - Think of as a vise or jack, model as a wedge
  - Relate torque to force using pitch and friction
  - See, e.g., Shigley pp. 437 for equations

Rigid Shaft Clamping

- Setscrews - screw pushing on side of shaft
  - simple, but weak and self-loosening
- Pins - radial hole and cylinder
  - more complex, small shear area
- Keyways - slots and rectangular key
  - complex, hard to get good fit
- Split-hub clamps - one-sided slot and screw
  - high-torque, low-slop, robust, but big
- Retaining ring - springy ring in groove
  - axial only, adds complexity to shaft

Detail Design of Articulating Joints

- Rotational joints
  - Plain bearings
    - Low-friction, low-wear material, often polymer
    - Cheap, strong, small, light, and easy
    - Still, higher friction and less precision
  - Ball bearings
    - Small rolling balls between inner and outer race
    - Very low friction, high precision, high speed
    - Low load, high mass and size
  - Needle roller bearings
    - Like ball, but higher load, lower precision, mass and size

Detail Design of Articulating Joints

- Linear joints
  - Same types of elements
    - Plain, ball, needle roller
  - Also have rotationally-constraining tracks
    - Two rails
    - Square rails with features
  - Did I mention I don't like linear bearings?

Capturing Articulating Elements

- Don't want to interfere with desirable motion
- Securing, e.g., outer race
  - Press fit - careful with induced stresses
  - Slip fit and glue - careful with glue
- Securing, e.g., inner race
  - To be avoided, unless using angular contact bearing
- Securing against, e.g., axial shaft motion
  - Use normal contact and (thrust) washer
  - Commonly: retaining ring or gear face pushes against plain thrust bearing or needle bearing

Accompanying Readings

- Shigley Chapter 8 - Fasteners
- Shigley 7-7 - Shaft clamping

HW4

- Assigned today
- Due in class next Wednesday, February 23rd
- Covers:
  - Material selection
  - Assembly geometry, strength and tolerances
  - Common joining elements and constraints