


Mechanical Power Transmission

September 16, 2008

www.robojackets.org

## Goals

- Hand out kits to teams that don't have one.
- More physics concepts and terms
- Understanding key devices for transmitting power
  - Gears, Sprockets, Chain, Belts, Pulleys
- Purpose for bearings and which to use
- Making it all spin with your shaft

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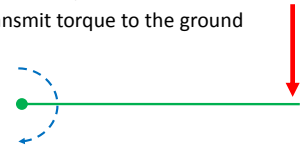
## Rotation

- Key to most machines and a moving robot
- Torque = Force acting at a distance
  - Motors transmit torque to gears
  - Gears transmit torque to wheels
  - Wheels transmit torque to the ground



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## Power

- Physics
  - Work / time
  - Torque x angular speed
  - Force x velocity
- Idea
  - Your robot in motion
  - Make your motors useful

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## Power (Cont)

- Factors
  - Force
  - Torque
  - Velocity
- Implications
  - Heat
  - Efficiencies
    - Noise = Bad vibrations

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## Work & Energy

**Work**

- Applied force x distance
- Δ Energy

A tugboat pulling a ship

**Energy**

- Mechanical
  - Kinetic
  - Potential
- Is conserved
- Losses to:
  - Efficiency issues
  - Friction
    - Sound
    - Heat

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*Pratt & Whitney R-4360

## MECHANISMS

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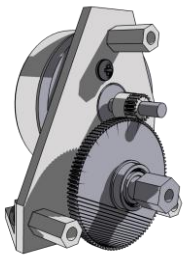
## Gears

- Types
  - *Spur*, Helical, Bevel, Internal
- How they work
  - Teeth
  - Pitch Diameter
    - Center line of meshing
  - Diametrial Pitch
    - Must have same size teeth



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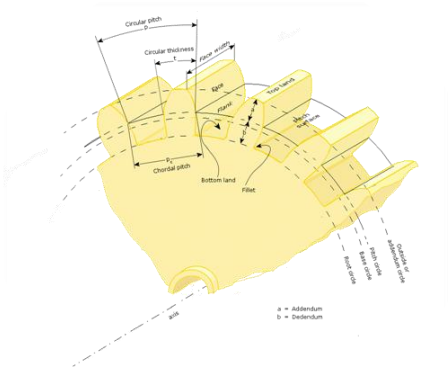


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## Gear Ratio

- Input : Output or input/output
- Gears and Sprockets
  - Teeth : teeth
- Pulleys and Belts
  - Diameter : Diameter
    - Can be used in all instances

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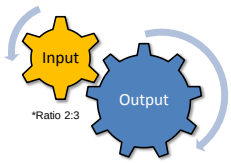
## Gear Ratio (Cont'd)

- Big Input : Small Output
  - Speed Faster
  - Torque Less
- Small Input : Big Output
  - Speed Slower
  - Torque More
- Same In and out
  - Direction Changes

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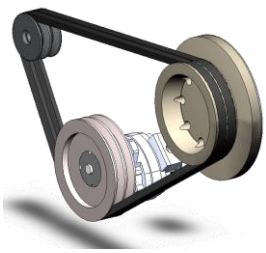
## Belts & Pulleys

- Types
  - V-Belts
  - Timing Belts
- How they work
  - V-Shaped Groove
  - Notches
  - Pitch diameter
    - (outside pulley)



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## Chains & Sprockets

- How they work
  - Links
  - Master Link
    - Connects ends / links (Full and half)
  - Chain Numbering
    - 35 Larger stronger, but less efficient
    - 25 Smaller, lighter, weaker, but more efficient.
  - Pitch diameter (chain centerline)
- Tools
  - Chain break (& chain puller)

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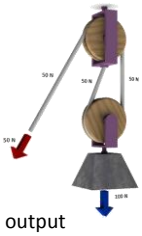
## Cable & Pulleys



- Note
  - Increase force
  - A potentially easy way to gain mechanical advantage
- Other
  - Need constant tension
  - Location – Motor can be far from output
  - Travel distance increase

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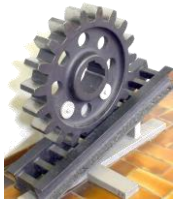
## Special Configurations

**Rack and Pinion**



**Worm and Worm Gear**

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## DESIGN CONSIDERATIONS

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## Gears

- Good
  - Easy to design with (no tensioning)
- Bad
  - Weight – You will be removing mass
  - Backlash
- Other
  - Location – Motor is close to output

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## Chains & Belts

- Good
  - Weight – Much less than gears
- Bad
  - Less efficient transfer compared to gears
- Other
  - Location - Motor can be far from output
  - Tensioning
    - Loose - could skip
    - Tight – Drains battery, moves slow, loads motors
  - Need to wrap around pulley / sprocket

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## Special Configurations

**Rack and Pinion**

- Maintaining alignment

**Worm and Worm Gear**

- Back drive impossible
  - unless failure occurs
  - If worm spiral allows
- High gear ratios (30:1)
  - Very slow output relative to input
  - One stage

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## BEARINGS

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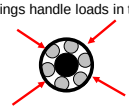
## Radial Bearings

**Radial Load bearings**

Radial bearings handle loads in the radial direction



Radial loads are applied from wheels to shaft

**Why even use bearings?**

Bearings are essential in rotating machines

Bearings reduce drag and handle forces

Without bearings, the shaft would heat up so much that it would swell and seize in its housing

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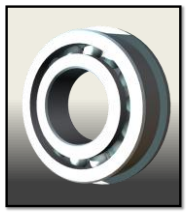
## Radial Bearings



- Types
  - Flanged or not flanged
  - Double shielded, unshielded
  - Packed with grease or oil
- Rating via ABEC 1 → 9
  - 1 ←→2 good for FIRST
  - Informs you how much it will / can wobble.
    - Higher number more efficient, but cost more.
    - As bearings get smaller they only come in higher ABEC #'s.
      - ISO's # are reverse

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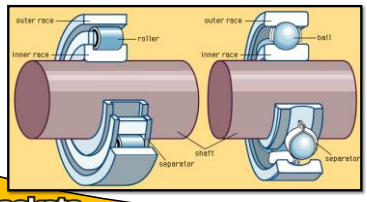
## Radial Bearing Types

**Roller**
- Higher radial loads

**Ball**
- Higher shaft speeds
- Common in FIRST

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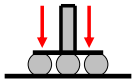
## Thrust Bearings

**Thrust Load bearings**

Thrust bearings handle loads in the axial direction



Radial loads are applied from shaft to housing or support

**Why even use bearings?**

Thrust bearings are good for supporting a rotating arm assembly…
Cars use combination radial/thrust bearings to handle cornering loads

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## Bushings

- What's the difference?
  - Act like bearings
  - No moving parts
  - Low speed apps
  - Less $$$$
  - For FIRST typically
    - Plastic
    - Brass
  - Below 1000 rpm

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## MATERIAL CONSIDERATIONS & USE

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## Wheel Setups

**Overhanging Loads**

**Analog to beam bending**

Wheels can be placed on the end of a shaft

Shaft **MUST** be supported in two places

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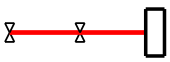
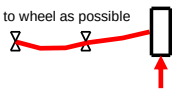
**Overhanging wheels:**



Put bearings as close to wheel as possible



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## Wheel Setups

**Centered Loads**

**Analog to beam bending**

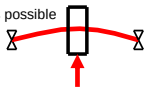
Wheels can be placed at the center of shaft

Shaft **MUST** be still supported in two places

Shaft is supported on both sides of wheel

**Centered wheels:**

Put bearings as close to wheel as possible



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## BattleBots

2007

2008

Note: Doing these things makes your design more compact and potentially saves room for other components.

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## Wheel Setups

**Wheels spinning on shaft**

- Advantages
  - Wheels are passive components
  - Useful for unpowered wheels
  - Simple for unpowered applications
- Thoughts
  - Wheels must have bearings inside hub

**Wheels spinning with shaft**

- Advantages
  - Wheels are actively driving the vehicle
  - Wheels can be mounted directly to gearbox
  - Or driven by chains or belts at a distance
- Thoughts
  - Wheels must be coupled to shaft
  - Keyed shafts are most effective way to couple

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## Shaft Restraints

**Reasons**

Shafts can still move axially within bearings

Solutions:

**Shoulders**

Prevents motion in one direction

**Snap Rings & E-Clips**

Clip onto grooves in shaft to prevent motion

**Shaft Collars**

Grip onto shaft by friction or set screws

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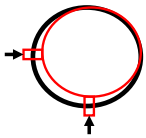
## Shaft Restraints

**Set Screws**

Set screws seize the shaft onto a hub

Set screws work best when applied at 90 degrees

**Application**



Even though the shaft is off-centered, the set screw clamping force is effective

Note: A shaft should have flats at any planned set screw contact.

**Pinning**

Pinning is simple but can shear

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## LUBRICANTS

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## Lubricants

- Uses
  - Smooth out motion
  - Keeps gear surface clean
  - Will tell you how something failed
  - Can catch small debris
  - Increase efficency

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**CLOSING**

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## What to expect

- Gear boxes
  - More than one stage
- Combinations
  - Mostly chain

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## Not just to move a robot!!

- Applications
  - Spinning a roller
  - Pivoting / rotating an arm
  - Opening / closing a gripper

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## Further Resources

- Wikipedia's Page on Gears
  - http://en.wikipedia.org/wiki/Gears
- WM Berg's pdf on gears, bearing, etc
  - http://wmberg.smartcats.com/pdf/techsessionpdf.pdf
- TIMKEN's presentation on bearings
  - http://www.timken.com/AntiFriction/player.html

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