Chain Drives

Introduction
Bush Roller Chains
Chain Drive Design
Chain Types
Transmission Chain Selection
Chain Failures

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Introduction

- Chain drives are a means of transmitting power like gears, shafts and belt drives

- Characteristics
  - High axial stiffness
  - Low bending stiffness
  - High efficiency
  - Relatively cheap
## Introduction

- **Performance of different transmission types**

<table>
<thead>
<tr>
<th></th>
<th>Shaft</th>
<th>Belt</th>
<th>Chain</th>
<th>Gear</th>
<th>Hydraulic</th>
<th>Electric</th>
</tr>
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<tbody>
<tr>
<td>Required alignment accuracy</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Positive drive</td>
<td>Yes</td>
<td>No (except toothed)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Efficiency</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Variable</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Stiffness</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>N/A</td>
</tr>
<tr>
<td>Strength</td>
<td>Medium</td>
<td>Low-medium</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>N/A</td>
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<tr>
<td>Ability to span large distances</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
<td>Very high</td>
<td>Very high</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Cost</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
</tr>
</tbody>
</table>
Introduction

- History and development
  - First belt drives: China c100 BC
  - First chain drives: Roman c200 AD

Roman chain link

Roman chain device for lifting water
Introduction

• Leonardo DaVinci: sketch of leaf type chain c1500 AD – many similarities to modern chains

• Galle chains: 19th century - first mass produced roller chains (no bushes)

• Hans Renold (Switzerland) 1880 – invented modern bush roller chain
Bush Roller Chains

- Parts of a bush roller chain

Side elevation

Section A-A

Exploded section

- Pin
- Bush
- Roller
- Side plate
Bush Roller Chains

- **Terminology**

  Sprocket teeth mesh with rollers

  Pitch
Bush Roller Chains

- **Manufacture**
  - Bushes and pins: cold drawn, cropped, turned/ground, case hardened, ground again and shot peened
  - Side-plates are stamped from plate

- **Assembly**
  - Pins and bushes are press-fitted into appropriate side plates
Chain Drive Design

- Chain length and centre distance
  - Chain must contain even integer number of links
  - Hence cannot pick an arbitrary centre distance and chain pitch
  - Nearest chain lengths (in pitches) for a contemplated centre distance, $C_C$, are calculated by empirical formulae like (for a two sprocket system):

$$L = \frac{N_1 + N_2}{2} + \frac{2C_C}{P} + \frac{(N_2 - N_1)^2 P}{4\pi^2 C_C}$$

where $N_1$ and $N_2$ are the numbers of teeth on sprockets and $P$ is the chain pitch

- The result of which should be ROUNDED UP to the next even number to calculate the actual centre separation, $C_A$:

$$C_A = \frac{P}{8} \left\{ 2L - (N_1 + N_2) + \sqrt\left[ 2L - (N_1 + N_2) \right]^2 - \frac{\pi}{3.88} (N_2 - N_1)^2 \right\}$$
Chain Drive Design

- Inertial force in chain
  - In addition to the tension required to transmit power, chain tension also provides centripetal force to move links around sprockets
  - The extra inertial force, $F_{cf}$, is given by:

$$F_{cf} = mr^2 \omega^2$$
Chain Drive Design

- **Vibrations**
  - Chain between sprockets can vibrate like a string

- Basic equation for natural frequency, $f_n$, of taught string

$$f_n = \frac{k \sqrt{\frac{F}{m}}}{2L}$$

where $F$ is the tension, $m$ is the mass per unit length, $L$ is the length, and $k$ is the mode number
Chain Drive Design

- For tight side of chain there are typically ranges of resonant frequencies given by:

\[ f_{\text{range}} = (1.1 \rightarrow 1.2) \sqrt{\frac{k \sqrt{F_c + F_{cf}}}{m}} \]

where \( F_c \) is the tight span tension (excluding inertial contribution)

### Avoiding vibration

- To avoid the chain resonating, need to avoid having sources of excitation with frequencies near possible resonant frequencies
- Obvious source is impact of sprocket teeth on chain
- Frequency of these occurs at:

\[ f_{\text{exc}} = \frac{\omega N}{2\pi} \]

where \( \omega \) is the sprocket rotation speed and \( N \) is the number of teeth
Chain Types

- Transmission chains
  - Chains to transmit rotary power between shafts
  - Bush roller chains are transmission chains

- For more power capacity, multi-strand transmission chains are used

![Chain Examples]

**DUPLEX CHAIN**

**TRIPLEX CHAIN**
Chain Types

- Conveyor chain
  - Rollers sit proud of links and can roll along supporting surface
  - Can be used for transporting materials, as rollers can support weight
  - Can also be used just to support weight of chain if transmitting power over long distances
Chain Types

- Inverted tooth (or silent) chain
  - Sprocket teeth mesh with shaped links instead of rollers on chain
  - Joints between links use rolling rather than sliding contact
  - Profile of links are more like involute gear teeth
  - Overall effect is to reduce noise
Chain Types

- **Leaf (or lifting) chain**
  - Designed for lifting rather (than power transmission)
  - Do not have to mesh with sprockets, hence no rollers
  - Therefore can narrower than roller chain with equivalent strength
  - Example: fork-lift truck
Chain Types

- Heavy duty chain
Transmission Chain Selection

- Currently performed using selection charts

For selection of drives to the right of this line, consult Renold Engineers to obtain information on optimum drive performance.
Transmission Chain Selection

- Limiting criteria
  - Fatigue strength of link plates
  - Bush and roller fatigue
  - Pin galling (damage due to lubricant breakdown at high loads)
Chain Failures

- Failures caused by poor selection
  - Overload
  - Failure of side plates due to cyclic load fatigue
  - Failure of bush or roller due to impact fatigue

- Above failures can still occur due to poor installation or maintenance
  - Misalignment
  - Incorrect or failed lubrication system

- If correct chain is selected, installed and maintained the overall life is determined by wear
Chain Failures

- Causes and effects of chain wear
  - Caused by material removal as chain components slide relative to each other
  - Effect of wear is to cause the chain to gradually elongate
  - As pitch increases, chain sits at larger and large radius on sprockets
  - Limit is when chain jumps over sprocket teeth
  - Empirical extension limits are
    - 2 % for sprockets with less than 200 teeth
    - 200/N % for sprockets with more than 200 teeth

Even space between rollers on new chain

Extension of space between alternate rollers due to pin wear
Chain Failures

- **Wear life**
  - Typically 15,000 hours for any power, chain or sprocket size if correctly selected, installed and maintained
  - Typical elongation curve:

![Elongation Curve Diagram]

- **Wear Characteristics**
  - Bedding in. Adjust tension
  - Initial wear
  - Steady state wear
  - Projected life 15,000 hours

Elapsed Time (hours)