



Mechanics and Machines, Lecture 3

Types of drives: kinematics, where to find other info

Drives: friction, belts, chains, gears, universal, geneva, ballscrew



Goal of the lecture

Make an overview of typical drives.

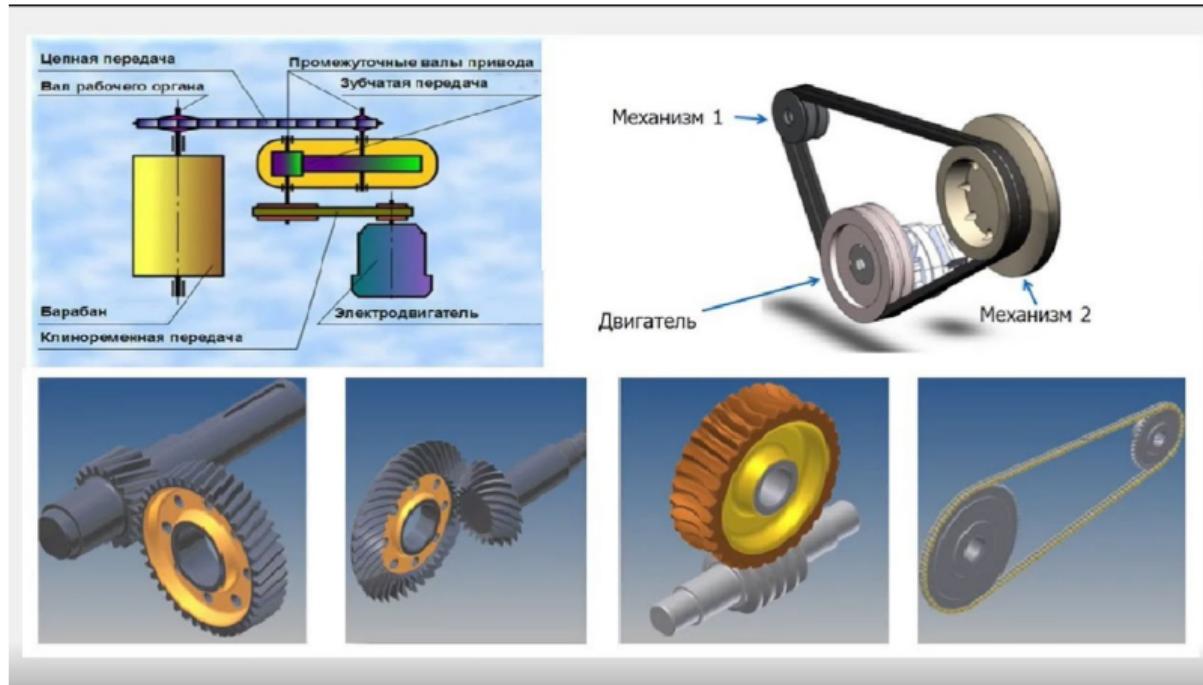
Give a hint how to work with it.

Explain how to find information about particular drive.



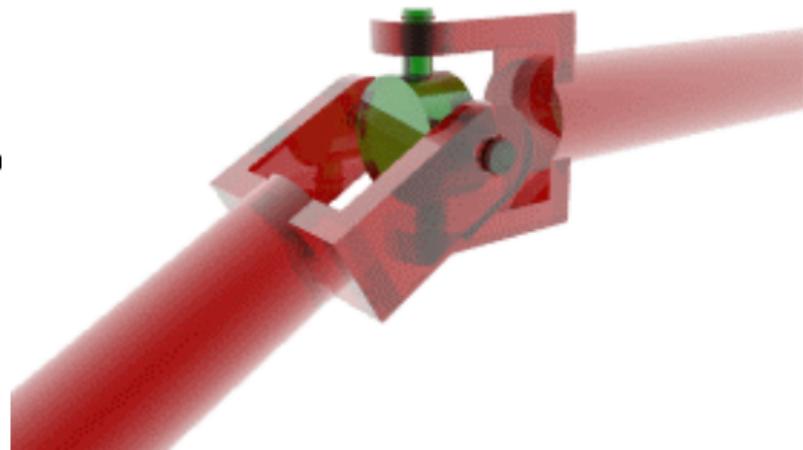
General info about drives

Video



Universal Joint

Visualisation



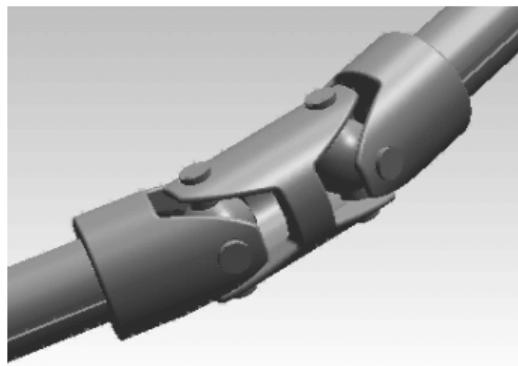


Universal Joint

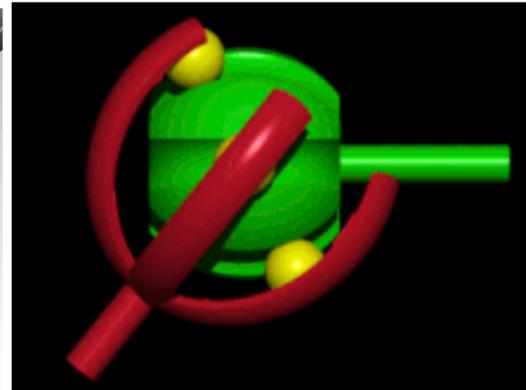
Types of universal joint



Cardan



Double cardan joint



Constant-velocity universal ball joint

Universal Joint

Drive kinematics

Angle relationship — $\tan(\psi) = \tan(\psi') \cos(\beta)$

Angular velocities relationship —

$$\omega \cos(\beta) = \omega' (\sin^2(\psi) + \cos^2(\psi) \cos^2(\beta))$$





Universal Joint

Features and facts

- It's effective tool for transferring a torque for max 30 degrees.
- Constant-velocity universal ball joint (шпyc) is not a small device and it's not easy to find it (it can be found as a car detail).



Universal Joint

What can be interesting to find (queries)

1. Correlation between velocities and angle between links in Universal joint
2. Cardan dynamics



Universal Joint

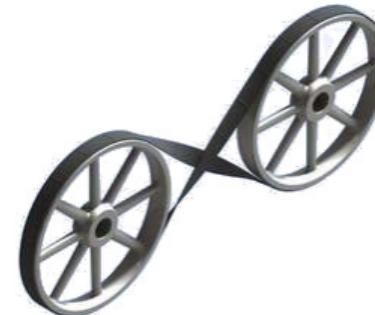
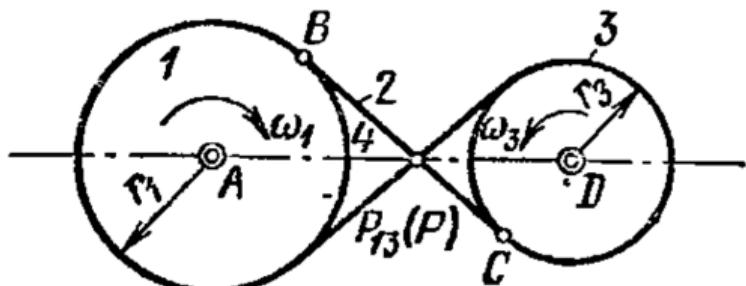
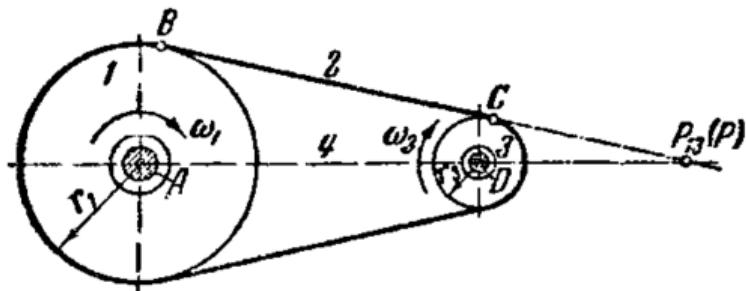
Reference material

1. **Other names:** cardan joint, Hooke's joint, кардан, универсальный шарнир
2. [Universal joint \(wiki\)](#)
3. "Теория механизмов и машин" Артоболевский И. И. 1988, pdf pages 168-172
4. Find U-joint parameters using quaternions
5. Dynamics of universal joints



Belt

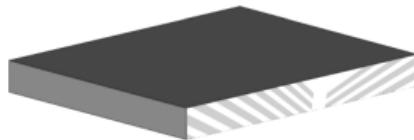
Visualisation



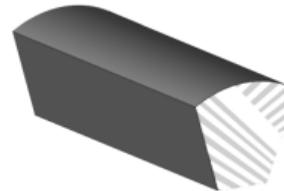


Belt

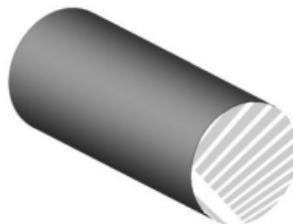
Types of belts



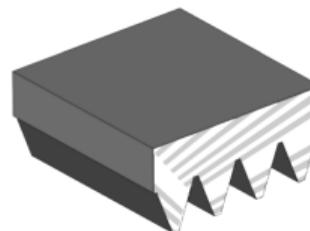
a



б



в



г

а) flat (плоская), б) vee belt (клиновидная), в) round (круглая), г) timing (toothed, зубчатый)



Belt

Drive kinematics

- Linear velocity of a pulley — $v_1 = \omega_1 \frac{d_1}{2}$, d — diameter of a pulley (шкив)
- Length of a belt — $I = 2a + \frac{\pi}{2}(d_1 + d_2) + \frac{(d_2 - d_1)^2}{4a}$, where a — distance between center of pulleys.



Belt

What can be interesting to find (queries)

- How to find the appropriate diameter of a pulley
- Min and max distance between pulleys
- Appropriate angle of covering the pulley



Belt

Features and facts

- Simple design and operation, relatively low cost.
- Smooth and quiet operation due to elasticity belt.
- Possibility to transfer power over long distances (with V-belts up to 15 m) at speed up to 100 m/s.
- Softening of vibrations and shocks due to elasticity of the belt.
- Possibility to protect machines from overloading due to elastic belt tension and slippage
- Reduced requirements for axle alignment shafts.



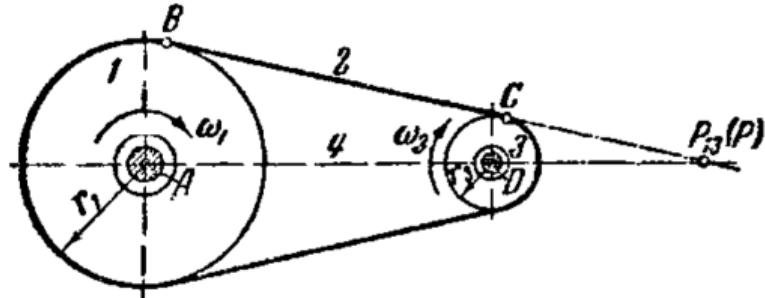
Belt

Reference material

1. Other names: ременная передача
2. Belt drive (wiki)
3. "Теория механизмов и машин" Артоболевский И. И. 1988, pdf pages 166–168
4. Детали машин. 9 лекция
5. Belt formulas
6. Ременная передача (видео)
7. Types of belt drive, Belt drive arrangement (video)

Chain

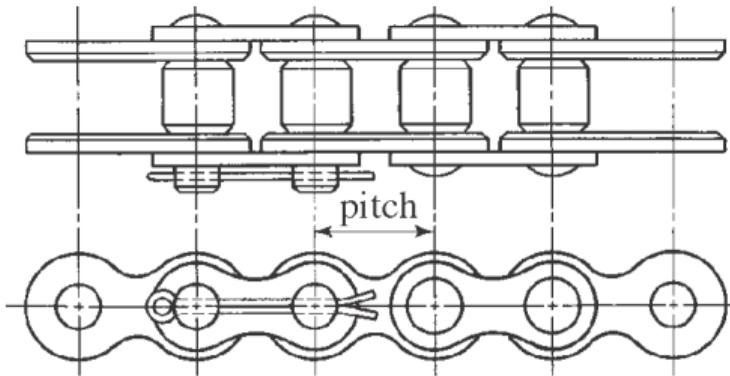
Visualisation



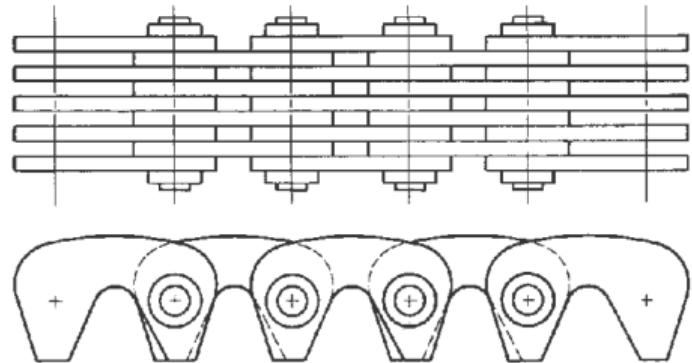


Chain

Types of chain transmissions



(a) Roller chain



(b) Inverted-tooth or silent chain



Chain

Drive kinematics

Almost the same as in belt. The main difference, that max angle of sprocket covering by chain is 120° .

Distance between centers can be found $a = (30 - 50)P$, where P — chain pitch.



Chain

What can be interesting to find (queries)

- Amount of tooth in sprockets.
- How to find a length of the chain



Chain

Features and facts

- Compared to gears, chain transmissions can transmit motion between shafts at large center distance (up to 5 m)
- Compared to belt drives, chain transmissions are more compact, transmit more power, can be used within a considerable range of axle spacing, ensure constant transmission ratio (no slipping);
- can transmit motion with one chain to several sprockets.
- Irregularity of sprocket rotation.
- The necessity of a high accuracy of the transmission assembly.



Chain

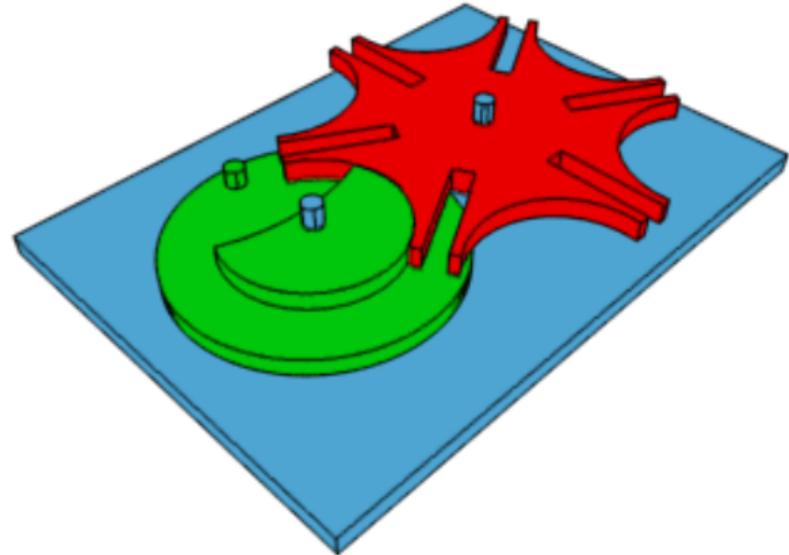
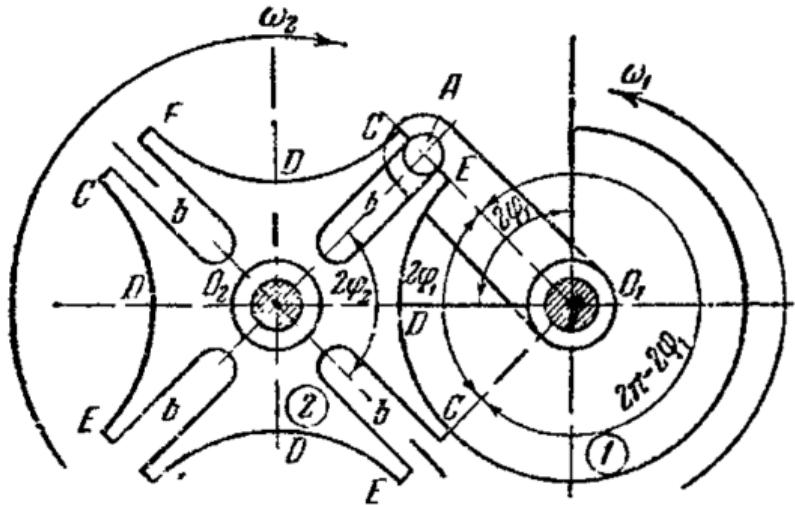
Reference material

1. **Other names:** цепная передача
2. [Roller chain \(wiki\)](#)
3. "Теория механизмов и машин" Артоболевский И. И. 1988, pdf pages 166-168
4. [Детали машин. 10 лекция](#)
5. [Sprockets & Chains For Engineers](#)
6. [Расчет цепной передачи](#)
7. [Цепная передача \(видео\)](#)



Geneva drive

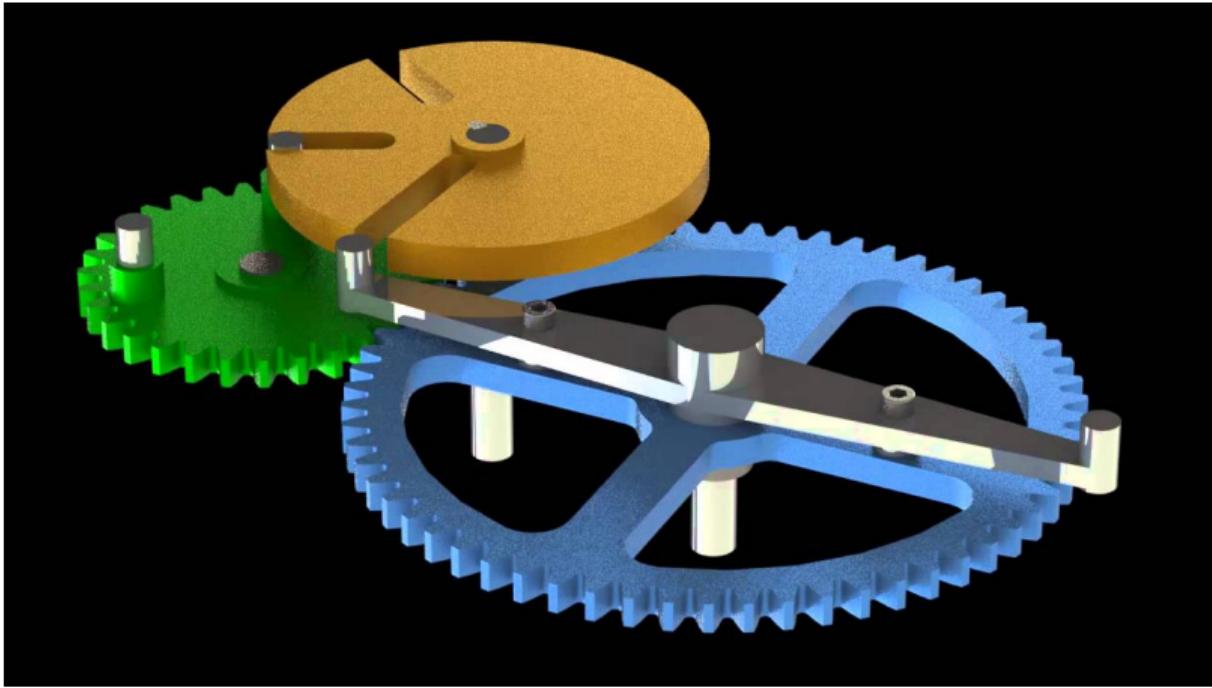
Visualisation





Geneva drive

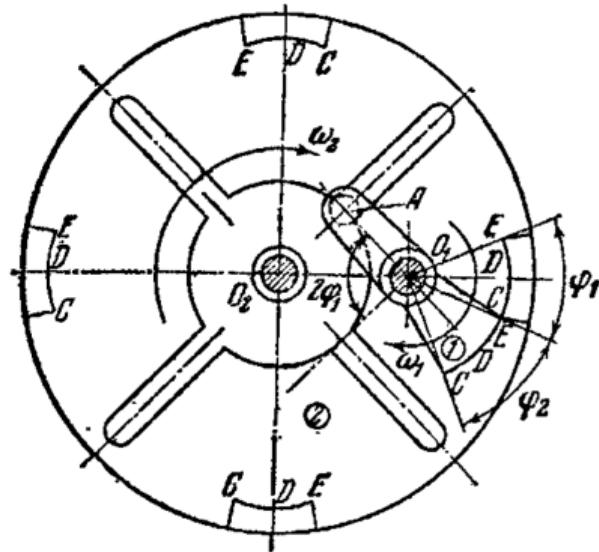
Example of geneva drive



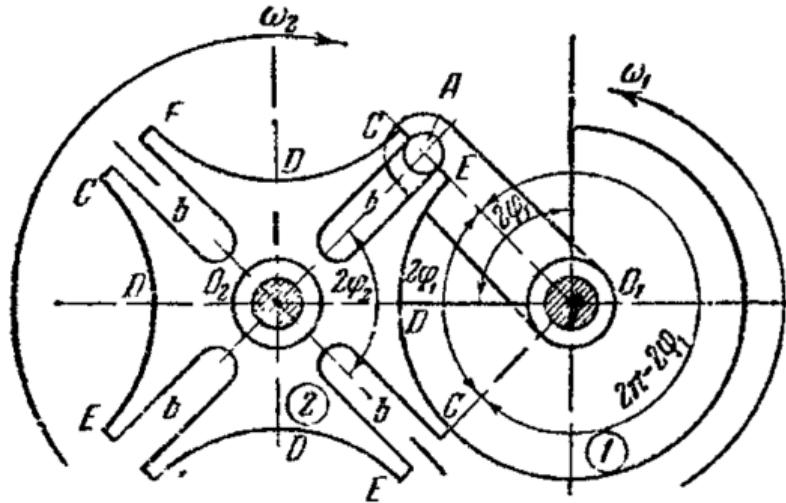


Geneva drive

Types of geneva drive



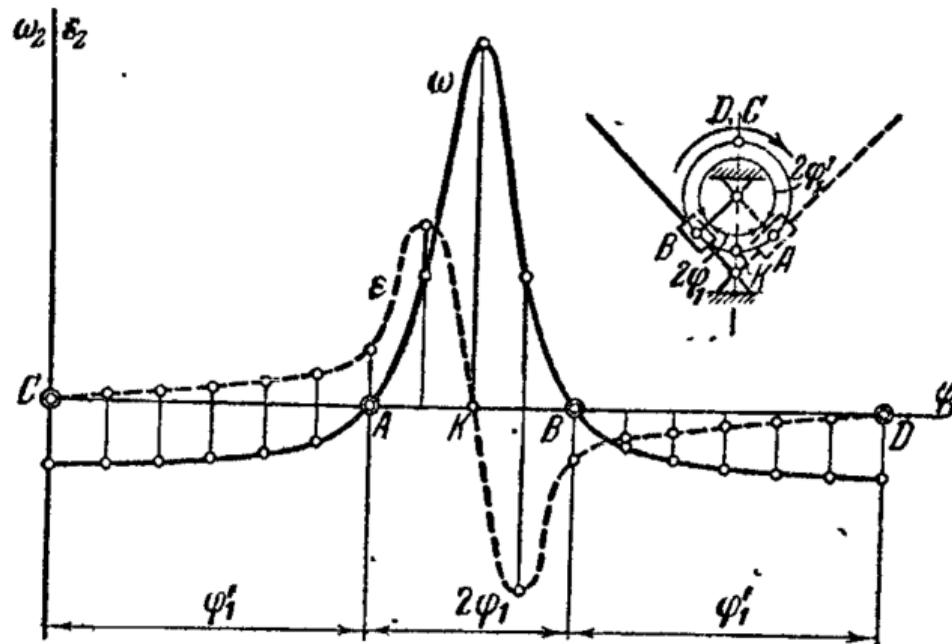
Inner connection



Outer connection



Geneva drive



Angular velocity and acc diagram of output link



Geneva drive

Features and facts

- The best application — when you want to have a constant velocity in input link and some fancy behavior with stopping — on output link.



Geneva drive

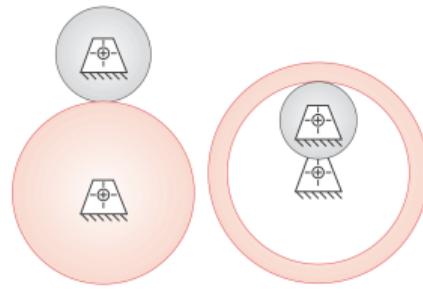
Reference material

1. **Other names:** мальтийский крест
2. [Geneva drive \(wiki\)](#)
3. "Теория механизмов и машин" Артоболевский И. И. 1988, pdf pages 172-174
4. [How to draw a geneva drive](#)
5. [Make a geneva wheels of any size](#)
6. [Structural synthesis of geneva wheels \(rus\)](#)



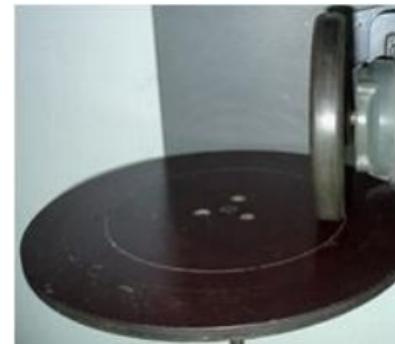
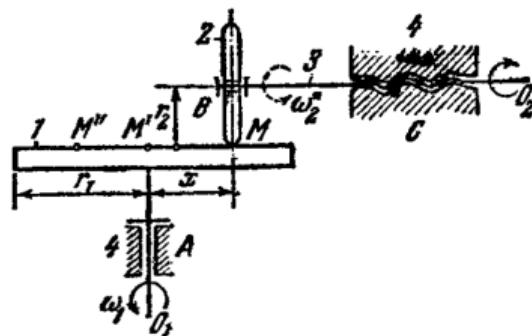
Friction drive

Visualisation



(a) External set

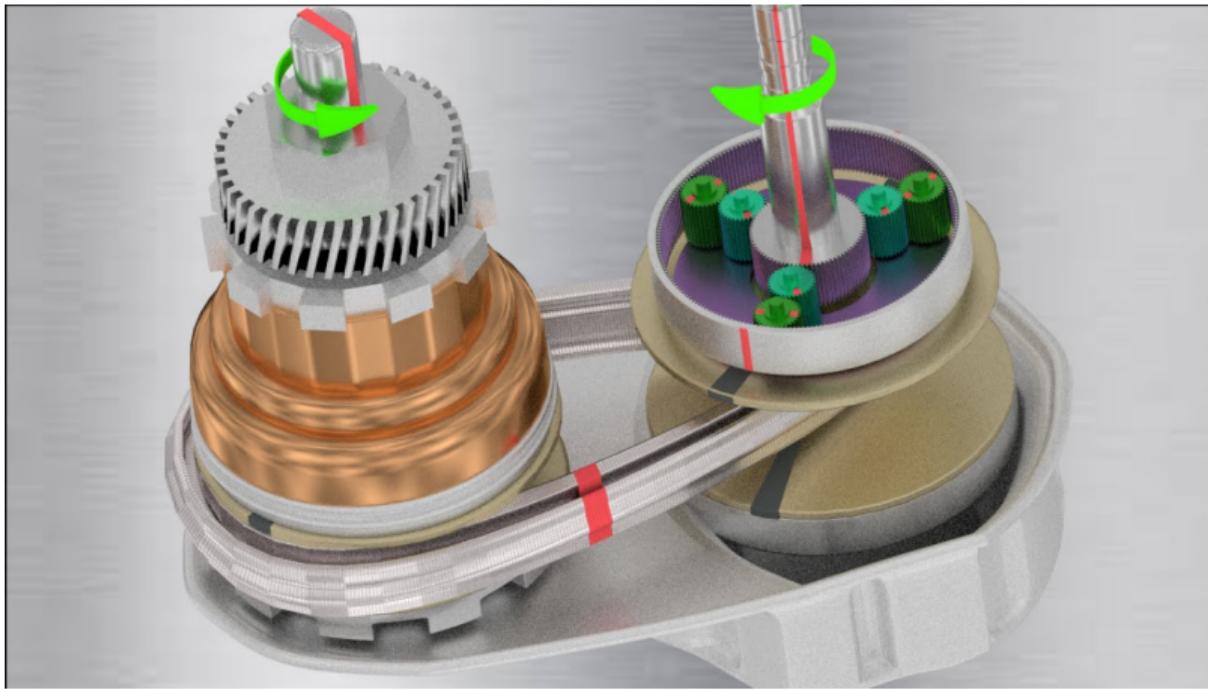
(b) Internal set





Friction drive

Continuously Variable Transmission (CVT) Video





Friction drive

Features and facts

- Simple design and maintenance.
- Smooth motion transmission and noiseless operation.
- Large kinematic capabilities (conversion of rotary motion into translational motion, stepless speed change, reversing on the fly, gear engagement and disengagement on the fly without stopping)
- Gear ratio varies due to slippage.
- Necessity of using specially designed shaft supports with clamping devices.



Friction drive

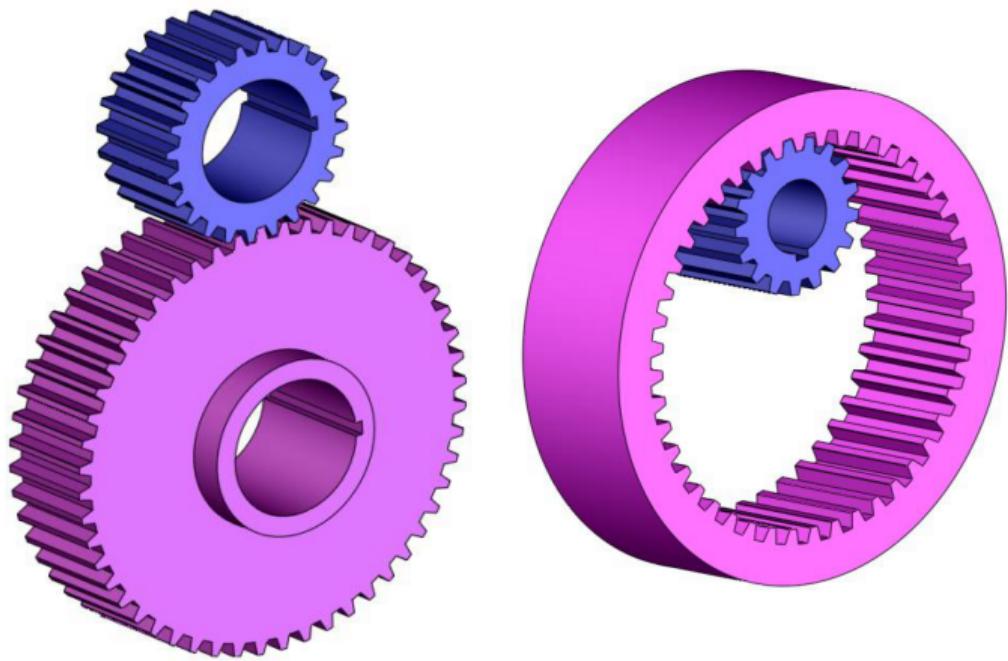
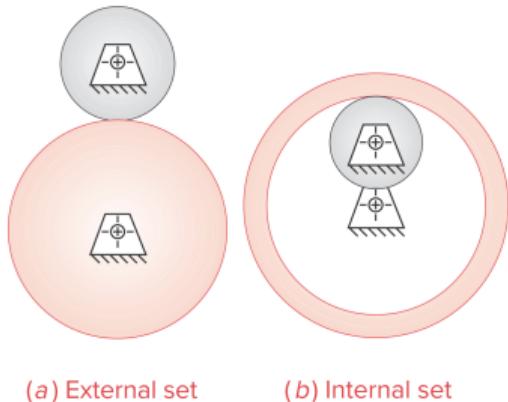
Reference material

1. **Other names:** фрикционная передача
2. [Friction drive \(wiki\)](#)
3. "Теория механизмов и машин" Артоболевский И. И. 1988, pdf pages 141-146
4. [Детали машин. 22 лекция, 2 страница](#)
5. [CVT — how it works](#)
6. [Фрикционная передача](#)



Gears

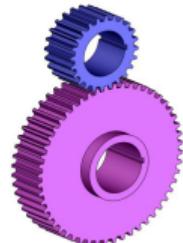
Visualisation



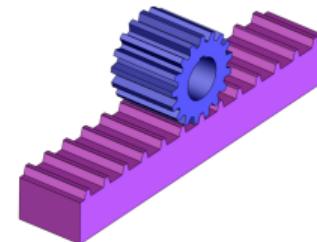


Gears

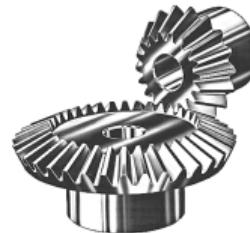
Types of Gears



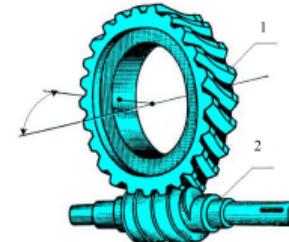
(a) Spur and helical gears



(b) Rack and pinion



(c) bevel gear

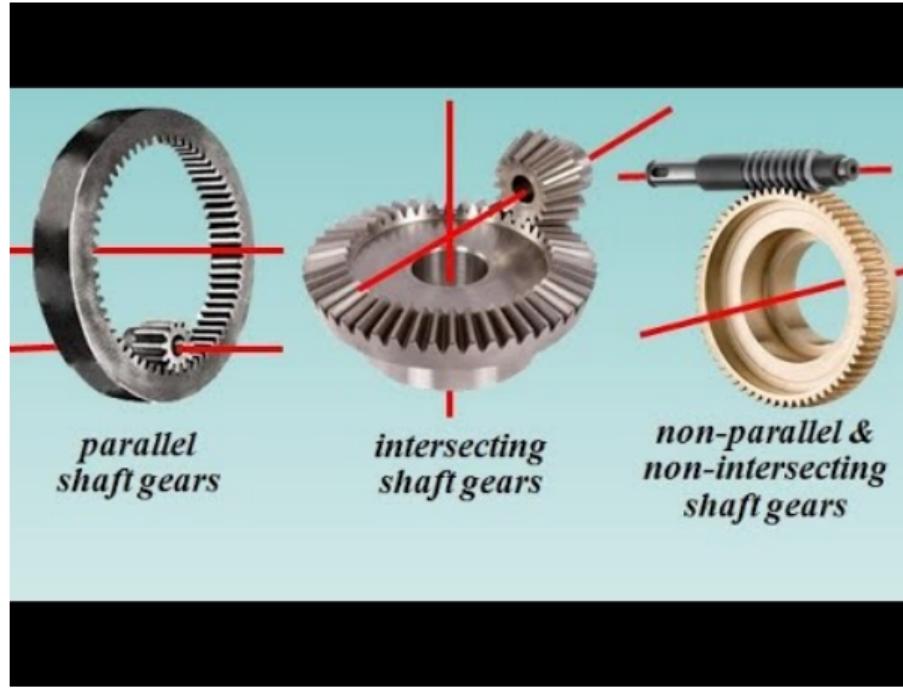


(d) worm gear



Gears

Gear classification (Video)





Gears

Gear ratio calculation methods

1. Common one, when you have a simple gear train. (Artobolevskii, pdf page 150)
2. When you have a planetary gearset, fundamental formula of the planetary gear train (Формула Виллиса для дифференциалов). (Artobolevskii, pdf page 154 – 166)
3. When you have a planetary gearset, tabular method (Norton R., pdf page 550 – 551)



Gears

Features and facts

- Consistency of transmission ratio.
- Reliability and durability of operation.
- Large range of transferable speeds.
- High efficiency.
- The need for high accuracy of fabrication and assembly



Gears

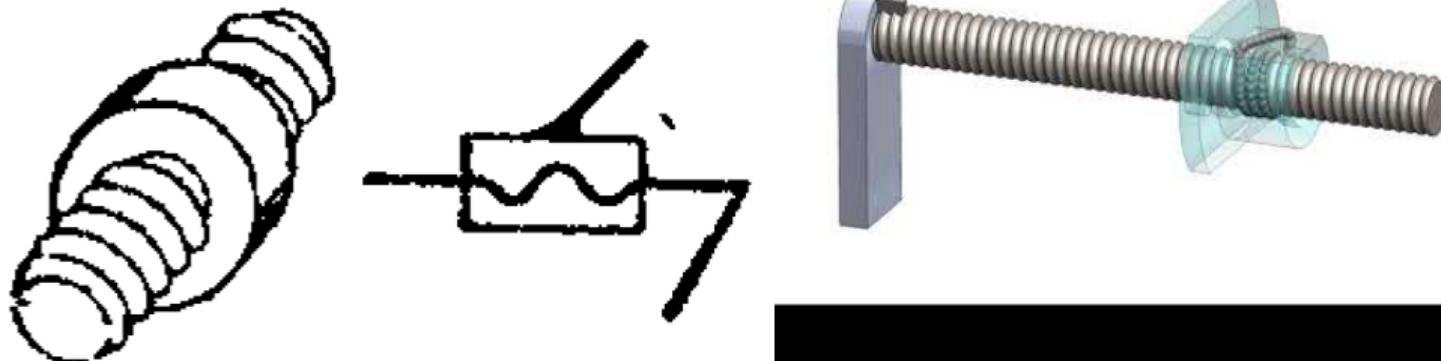
Reference material

1. **Other names:** зубчатая передача
2. [Gears \(wiki\)](#)
3. "Теория механизмов и машин" Артоболевский И. И. 1988, pdf pages 145–166
4. [Детали машин. 5-8 лекции](#)
5. "Design of machinery" Robert L. Norton, pdf pages 517–557 2.0 — 2.11
6. [Зубчатая передача \(видео\)](#)



Ballscrew

Visualisation





Ballscrew

Types of ballscrew (Video)





Ballscrew

Drive kinematics (1)

[Helical gear kinematics \(rus\)](#)

Artobolevskii, pdf page 27



Ballscrew

Features and facts

- Conversion of fast rotational motion of the master element into slow rectilinear motion of the slave element.
- Conversion of a small torque at the leading element into a significant force at the moving linear element.
- Realization of the self-locking phenomenon.
- Simplicity of design, compactness, reliability.



Ballscrew

Reference material

1. **Other names:** шарико-винтовая передача, передача винт-гайка
2. [Ball screw \(wiki\)](#)
3. "Теория механизмов и машин" Артоболевский И. И. 1988, pdf pages 166–168
4. [Детали машин. 10 лекция](#)
5. [Передача винт-гайка \(видео\)](#)



How to use provided materials

Guideline

Live Demo

Deserve “A” grade!

– Oleg Bulichev

✉ o.bulichev@innopolis.ru

↗ @Lupasic

🚪 Room 105 (Underground robotics lab)