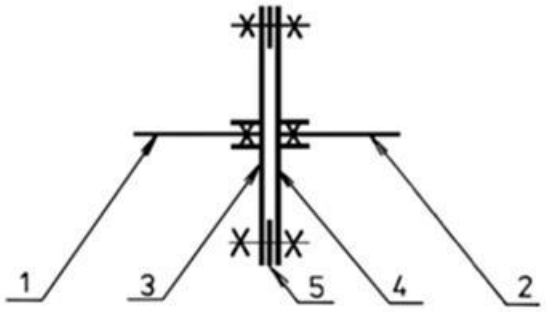
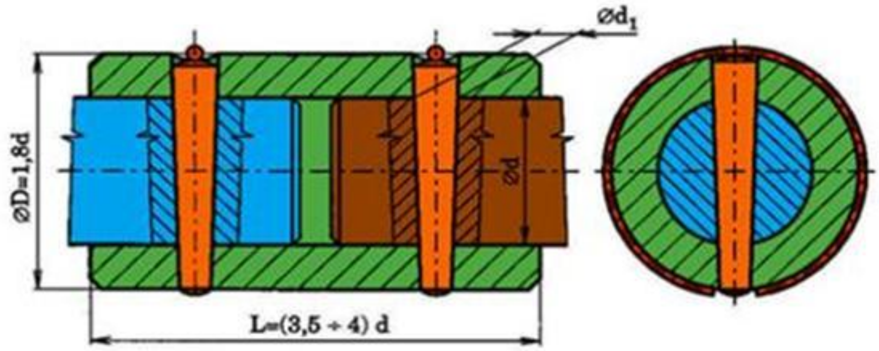
Design of Clutches and Shaft Couplings

References of fig:
Homišin J. a kol: Základy konštruovania
https://slideplayer.cz/slide/14790846/
https://slideplayer.cz/slide/4870564/
https://slideplayer.cz/slide/4873415/
https://slideplayer.cz/slide/2961688/

The basic design of the shaft couplings consists of the drive and driven part of the coupling or also referred to as the primary and secondary part of the couplings, (Fig .: 1- drive shaft, 2-driven shaft, 3 - drive part, 4-driven part, 5-coupling element couplings). Between these two parts is usually located a third part - the connecting, which fulfills the so-called. "other" role. The construction of couplings itself then focuses on the calculation, design and control of the main connecting - third part of the coupling.



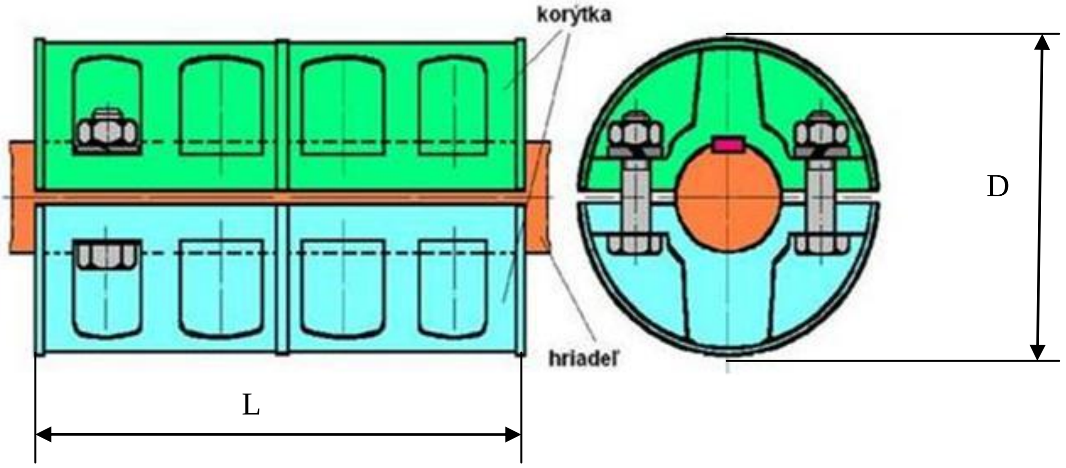
Rigid coupling – Pipe coupling with pin
The pipe coupling belongs to the rigid couplings, the task of which is to firmly connect the shafts of the device. The main part is the tube which is connected to the shafts by transverse pins fig.



Tube and pins are checking on shear strain:

Split – Muff coupling

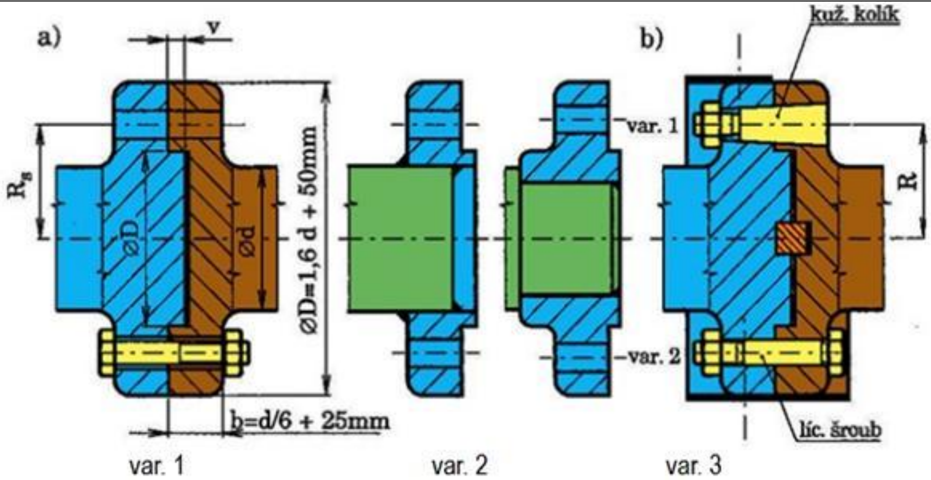
The Split – Muff coupling is a two-part rigid coupling. This two-part coupling is intended to facilitate its assembly. Both parts of the coupling are connected by screws on both sides of fig.



The design of the coupling can be compared to a combination of a claim joint and a shaft-hub connection with a key. Transmitted torque by the:

Flange coupling

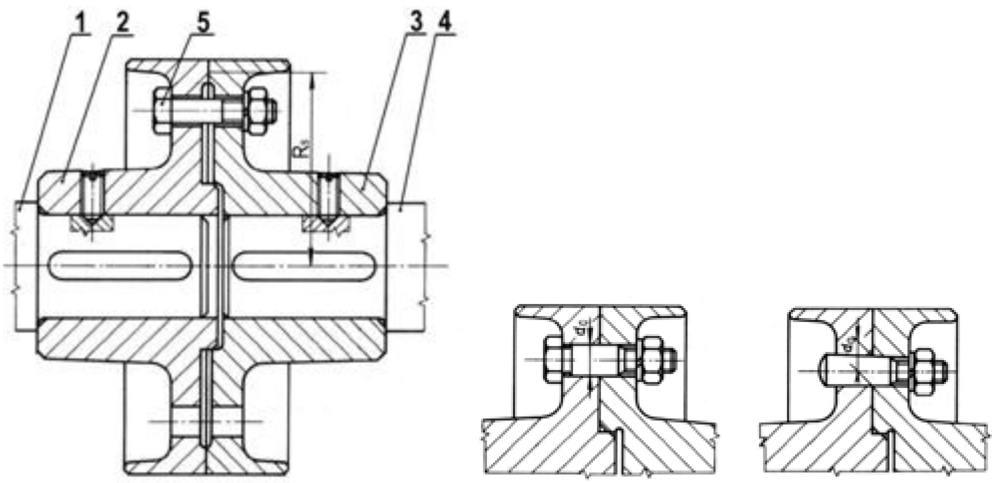
Flange coupling belongs to rigid couplings. Connecting flanges are part of the connected shafts. The flanges are made as forgings - in the case of forged shafts, or as welds, resp. pressed flanges on shafts. The flange coupling can be designed as a flange connection by friction, or a flange connection by means of a shear pin, or a screw stressed on the shear of FIG.



If friction principle, load torque of coupling:

Disc coupling

The disc coupling is one of the most widely used rigid clutches. The clutch discs are attached to the shaft by a shaped element (key, etc.) or by pressing. The discs are screwed together.

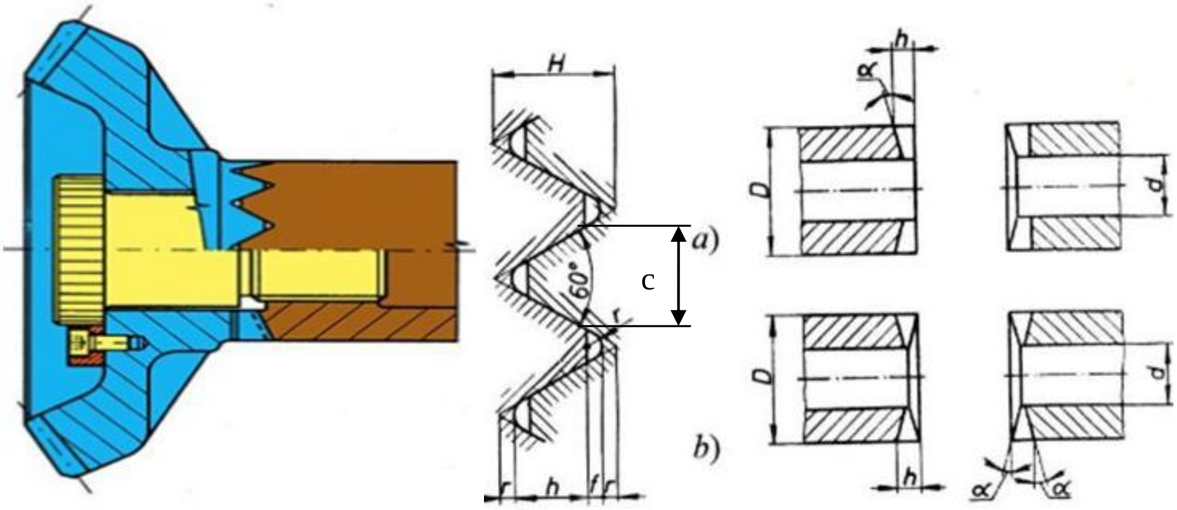


By screwing on the discs, it is possible to create friction at the contact surfaces and then the load transfer will be by frictional force. If friction transmission:

Another possibility is to use a mating screw or a shear pin and the determination of the transmitted power is similar to that of a flange coupling.

Hirth coupling

Hirth coupling belongs to the group of jaw couplings. It is a coupling of simple construction. The teeth are formed on the faces of the connected parts, which are usually pipes or hollow shafts. The number of teeth of the Hirth clutch must always be chosen so that it is divisible by 12 value.

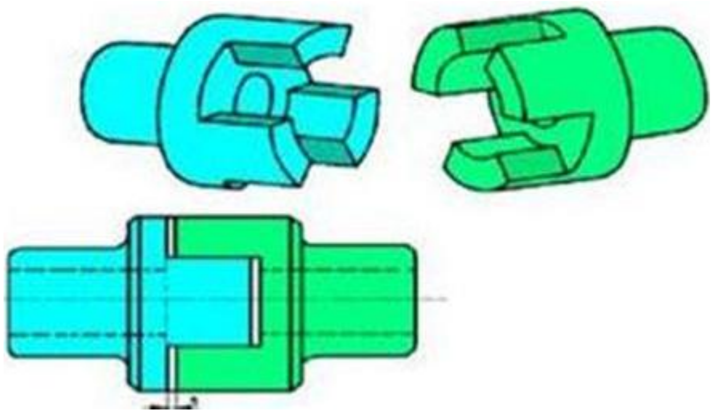


The design of the dimensions of the coupling and the determination of its load-capacity are based on the following relations:

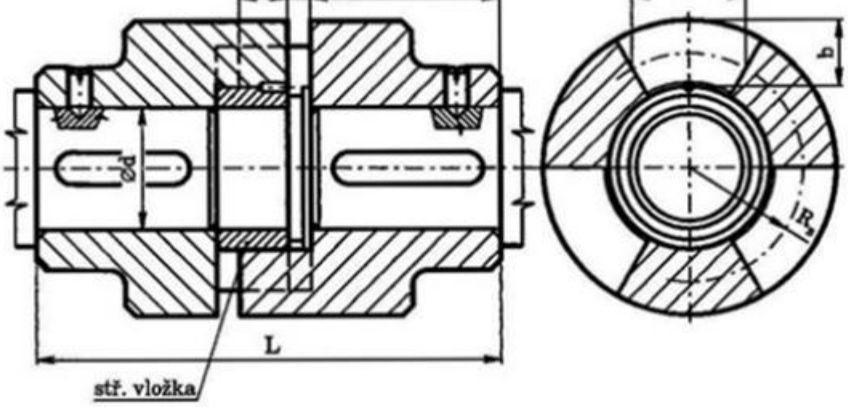
Stress between the teeth

Jaw misaligned coupling

The main function of misaligned coupling is to eliminate misaligned of the connected shafts. These are mainly misaligned, radial, axial and angular. The Jaw misaligned coupling is of a very simple construction in the figure, which, however, allows the elimination of only axial misaligned.



The calculation and dimensional model of the coupling is shown in the following figure. we can determine the stress in the teeth of the transmitted coupling.

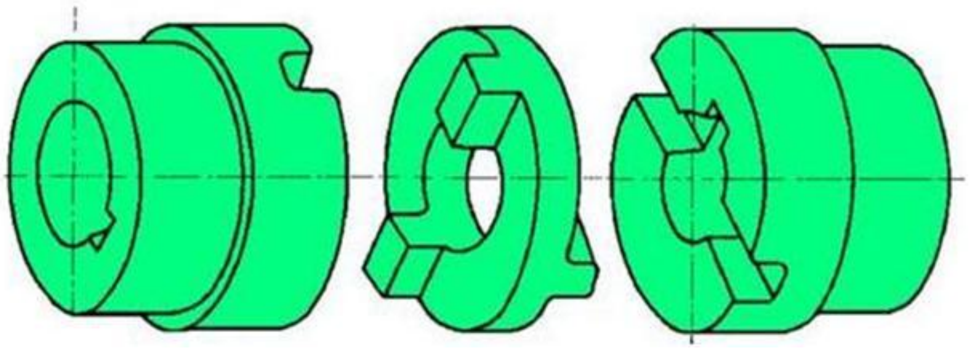


Stress between teeth

Due to the fact that the coupling parts will move axially one after the other, it is necessary that the allowed value of p_D is not more than 10MPa. The allowable bending stress should be in the range of 15 to 30 MPa.

Oldham coupling

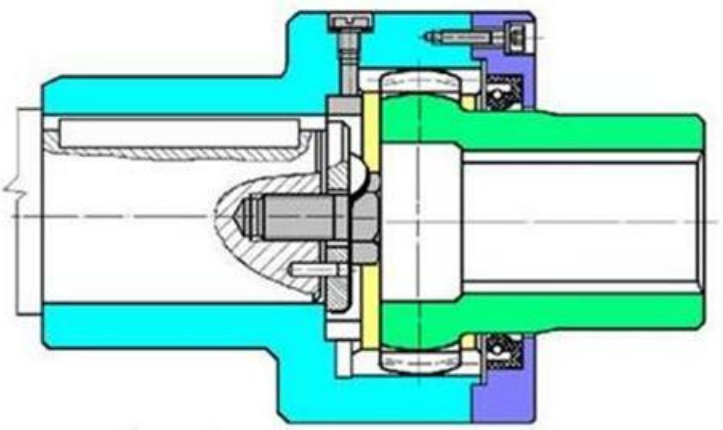
The Oldham coupling, or also called the cross disc coupling, is an misaligned coupling that effectively eliminates radial misaligned of the connected shafts. The disadvantage is that when the radial misaligned is eliminated, the middle part is pushed out of the axis of rotation, which causes an imbalance of the system. Due to the fact that during the rotation the middle part shifts, it wears out and there are losses on the transmitted power.



Compression stress between parts:

Gear coupling

Gear coupling its suitable construction (from the point of view of balancing), the gear swivel coupling belongs to the often applied misaligned couplings. This type of coupling is able to eliminate small axial misaligned and angular misaligned. In the form of a double toothed coupling, it can also be used to eliminate small radial misaligned. The base of the clutch is formed by gears with the same number of teeth, one of which is internal gearing and the other with external gearing. FIG.

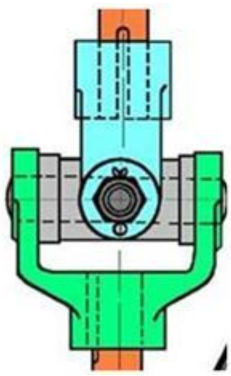


Stress of teeth
Bending stress:

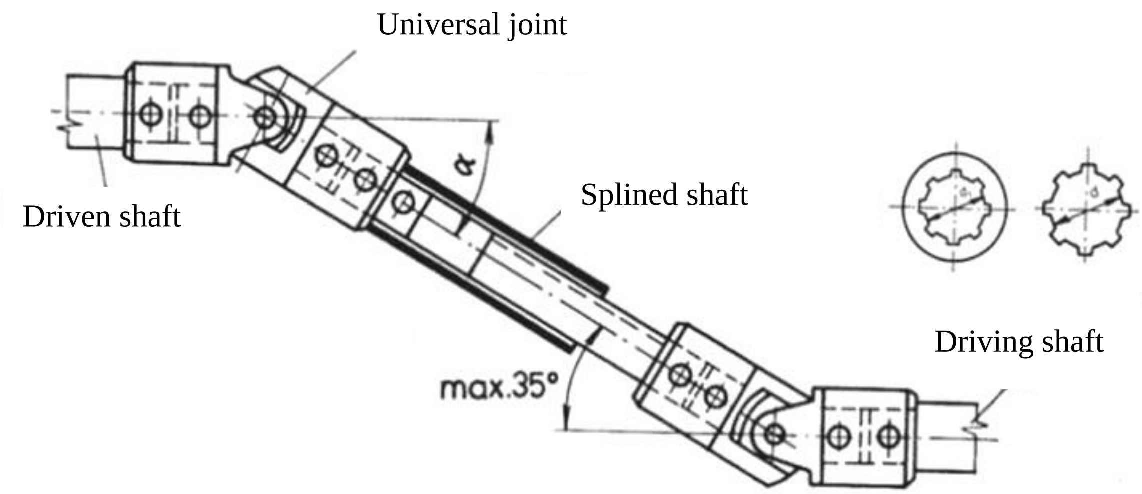
m- modulus of teeth
R – radius of working circles
z – number of teeth
b- width of toth
s_p – tooth thickness
ρ – tooth radius

Universal coupling - Universal joint

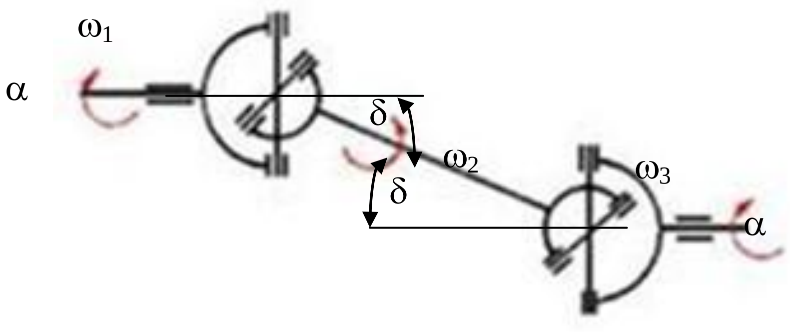
Universal couplings are very effective misaligned couplings, which by a suitable combination and suitable arrangement are able to eliminate radial, axial but also angular misaligned joints. The design of the Universal coupling can be formed by various types of joints, see fig. block 9. One of the most commonly used joints is the Universal joint fig.



However, the universal joint is a producer of fluctuations rotational movement and it is therefore necessary that the universal joints are arranged in a double of fig.



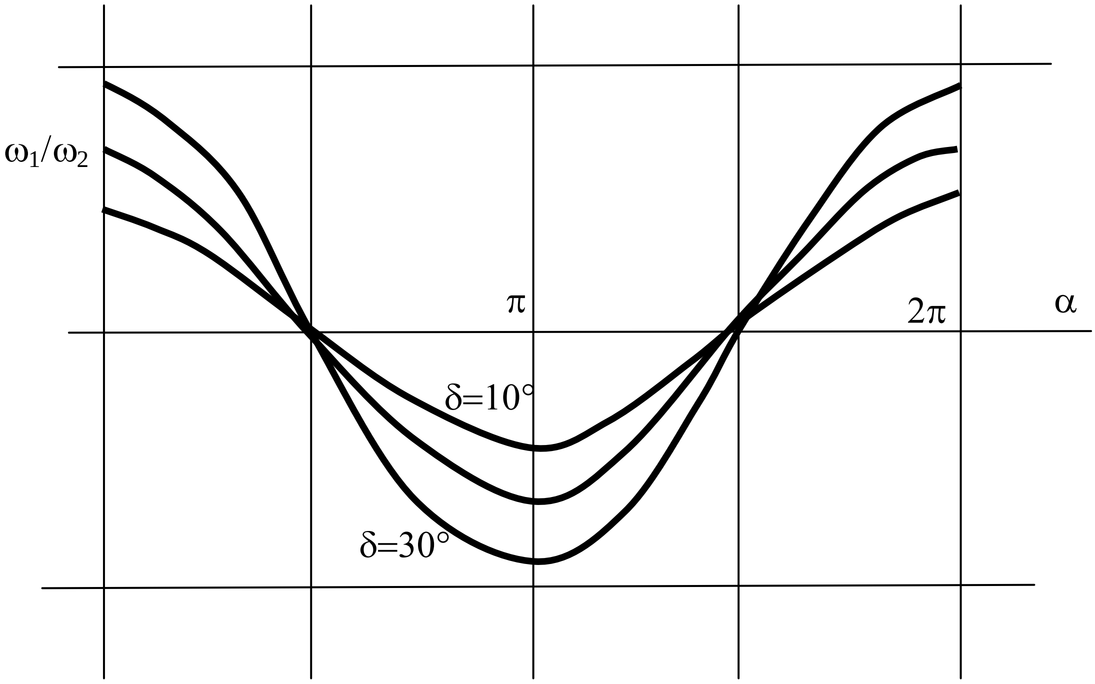
Starting from the scheme in fig., we define the angular velocities of the coupling parts.



Ratio of angular velocity

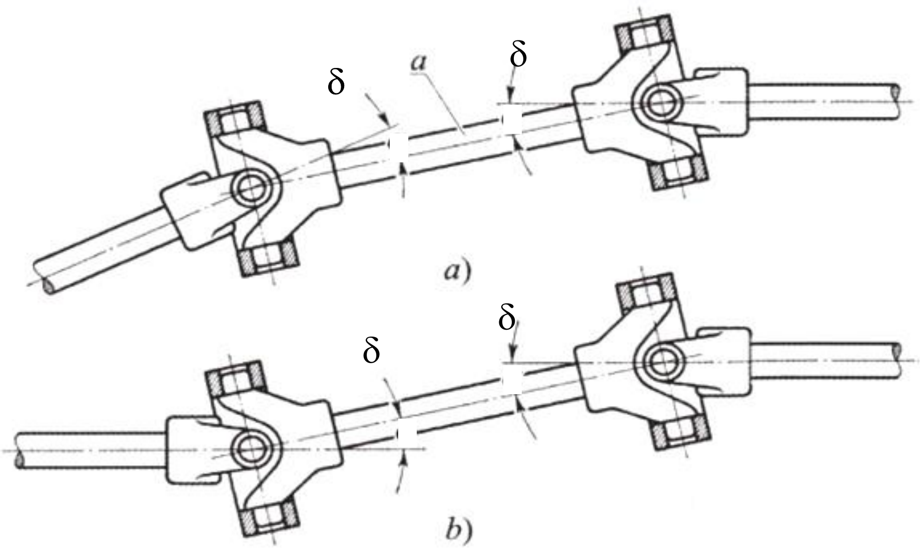
It will be fulfilled if : $\delta_1=\delta_3$

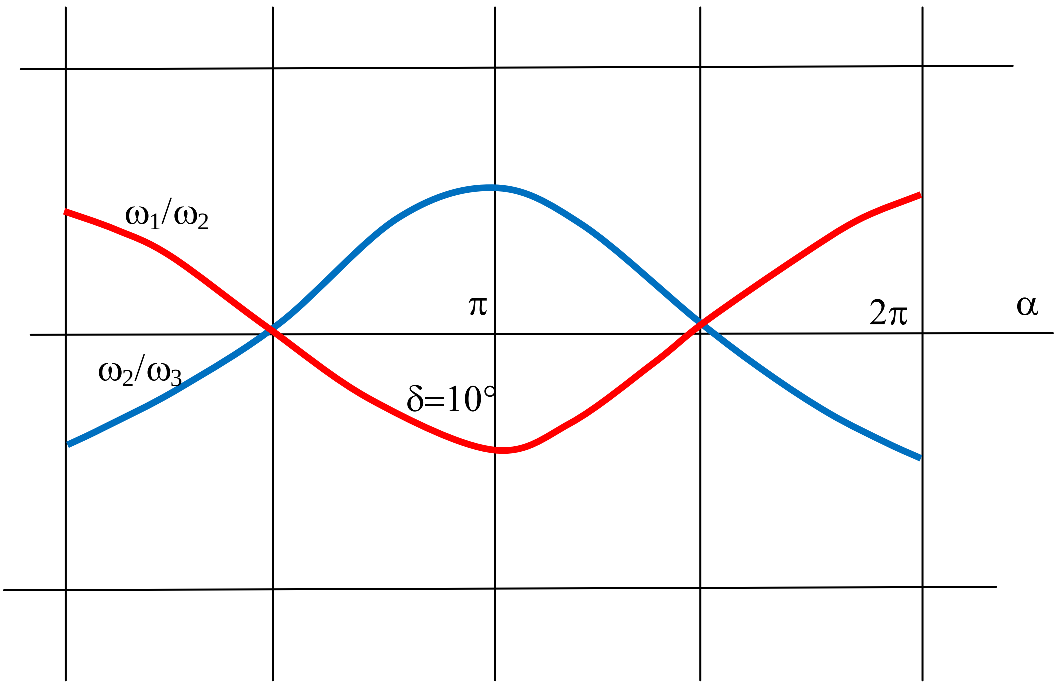
<u>Ratio Graph of angular velocity</u>



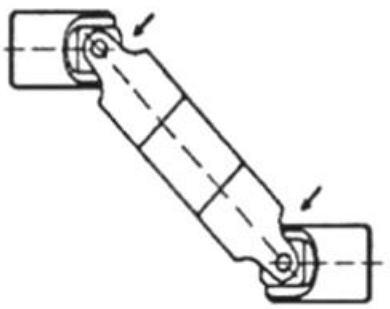
As can be seen from the formulas and graphs above, it is necessary to follow the basic design rules for the use of universal couplings, these rules are summarized in the following figures.

A. The slope angle of the input and output shafts must be the same. It is then possible to create a coupling arrangement in the shape of the letter "Z" or "U".

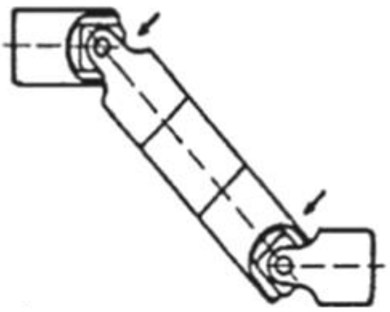




B.

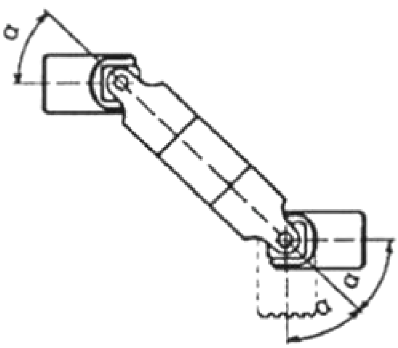


Appropriate arrangement of the joint forks.

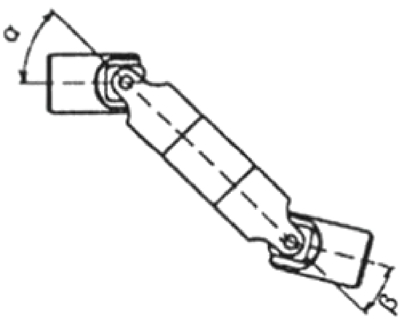


Improper arrangement of joint forks
- shifted about 90°

C

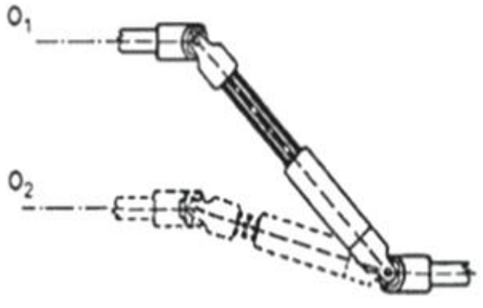


Suitable joint slope.

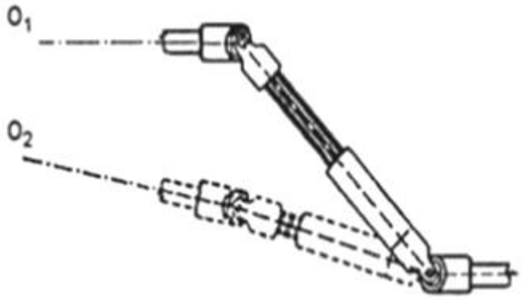


Unsuitable joint slope.

D.



Suitable solution: axis of joints are paralel



Unsuitable solution: axis are not paralel

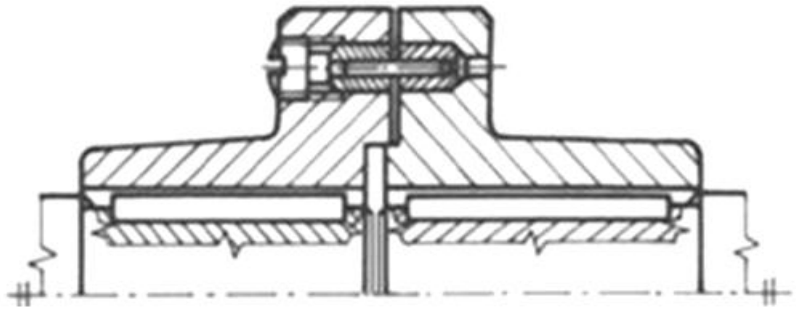
Application examples of suitable and unsuitable solutions

Unsuitable

Suitable

Safety clutch - pins

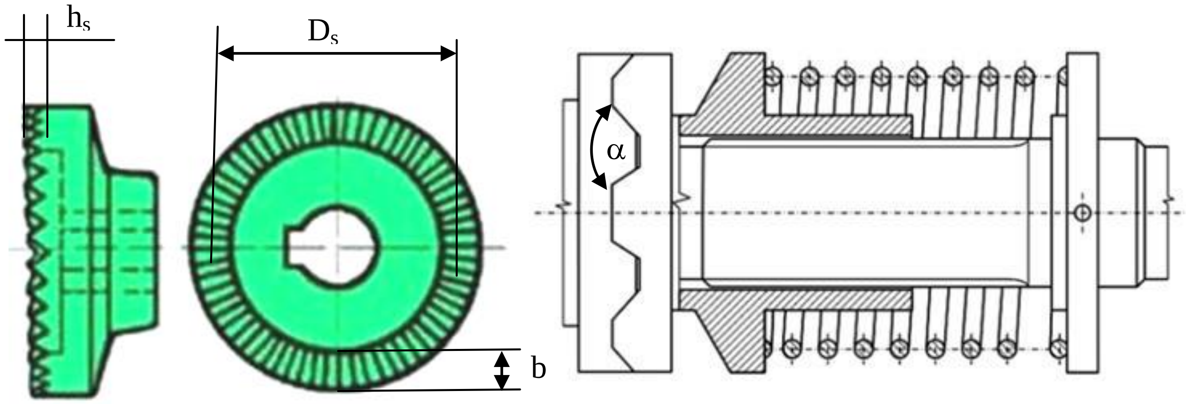
Safety clutches are an essential part of such systems in which it is necessary to protect the individual often from excessive load stress. The pin safety coupling belongs to the category of safety couplings with a destructive member (elements).



The maximum torque with which the clutch can be loaded depends on the destructive member - shear pin:

Safety clutch - jaws

This safety clutch works on the principle of jumping (skipping) the jaws (teeth) of the clutch from overload and thus to disconnect its individual parts. Disconnection of the parts of the toothed coupling occurs at the moment if the axial force in the teeth is greater than the pressing force of the spring.



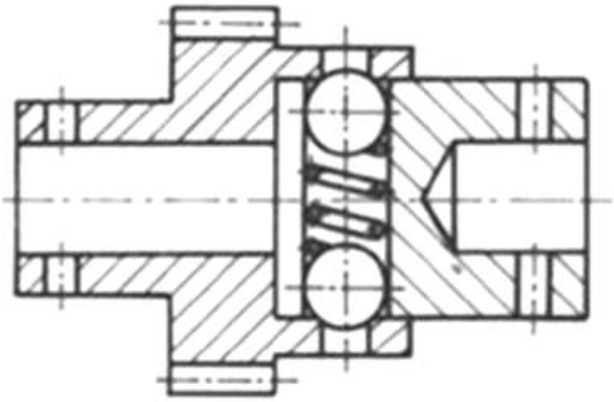
Forces analyze:

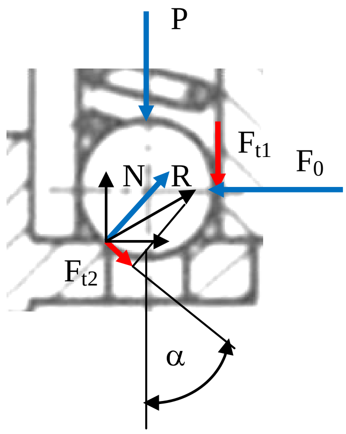
In application practice, usually the shape of the teeth is chosen to apply: $Fa \approx 0{,}8.F$

Compression of tooth:

Safety clutch – ball rollers

The function of this clutch is similar to that in the case of a toothed safety clutch, only instead of teeth balls are used, which can be structurally arranged as axial or radial, see fig. in block 9.

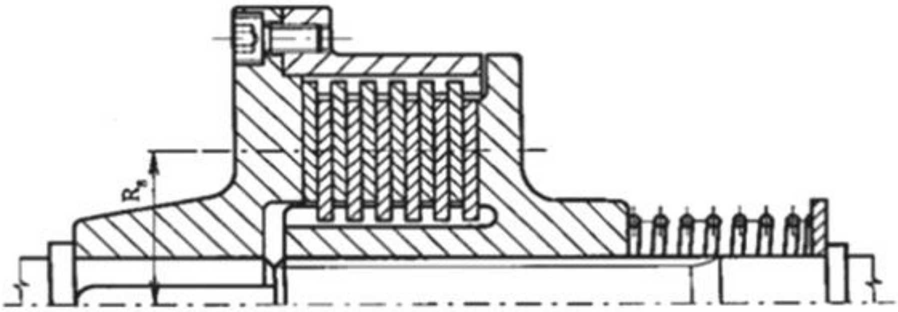




Force in clutch:

Safety clutch – friction

The safety friction clutch can be designed as a single-disc or multi-discs. The slats are pressed together by the force of the springs. The friction force between the discs ensures the transmission of the load. In the event of an overload, the slats will start to slide one after the other. When the slats slide, they heat up, which can subsequently cause damage to them.

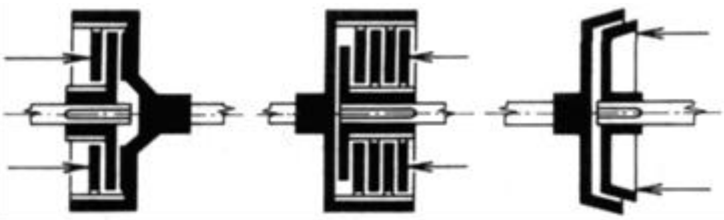


Transmitted torque by the clutch - The friction moment is expressed as with friction clutches:

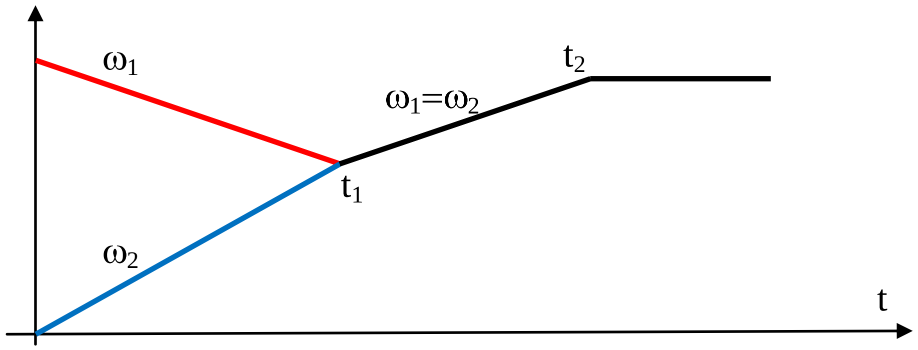
After overcoming the friction torque, the clutch shifts. Warning! - there is a risk of the clutch overheating.

Friction clutch – controlled shift

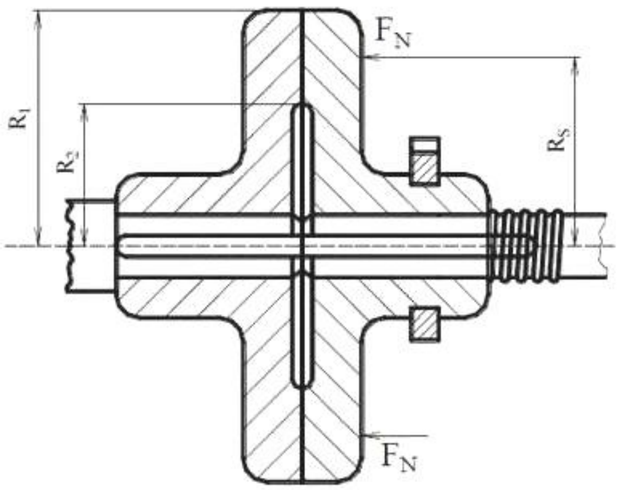
Friction clutch can be designed as with one friction surface - single-disc, multi-disc or conical fig. An important functional feature is, in particular, the way in which these clutch are engaged or disengaged.



As can be seen in the following graph, the friction clutches can be used to suitably control the engagement of the drive and driven shafts so as to achieve the desired shaft speed compensation at a certain point in time t_1. From this moment, the shafts accelerate together until the moment t_2, when they reach the working speed.



Friction clutch - single-disc

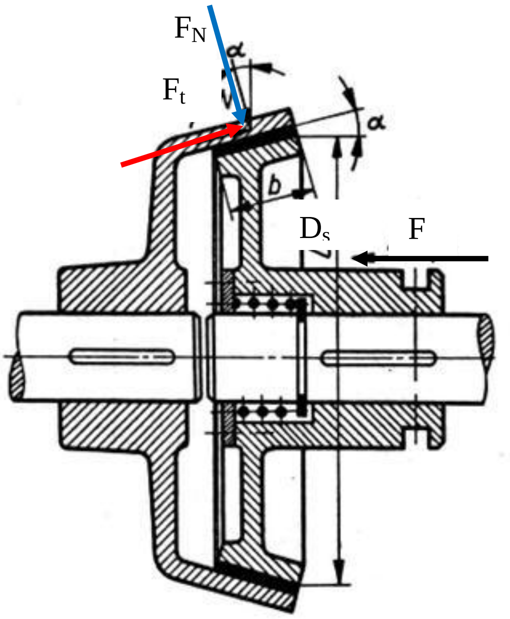


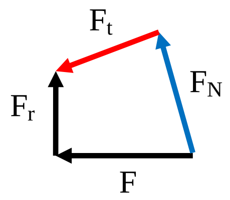
Transmitted torque by the clutch at one friction surface:

c_i – coefficient of the number of contact surfaces - characterizes the uneven load of the discs. If number to i=3 is c_i =1, then this factor decreases, for i=11 is c_i = 0,76.

Friction clutch – conical

In the case of the application of conical friction clutch, it is necessary to achieve a very precise coaxiality between the connected shafts. These clutchs are suitable for small and medium loads. The conicity must not be too large (from 12 ° to 20 ° depending on the type of friction material), as it could limit the disengagement of the clutch. For this reason, it is necessary to check the self-locking of the clutch according to the condition: **tan φ < tan α**



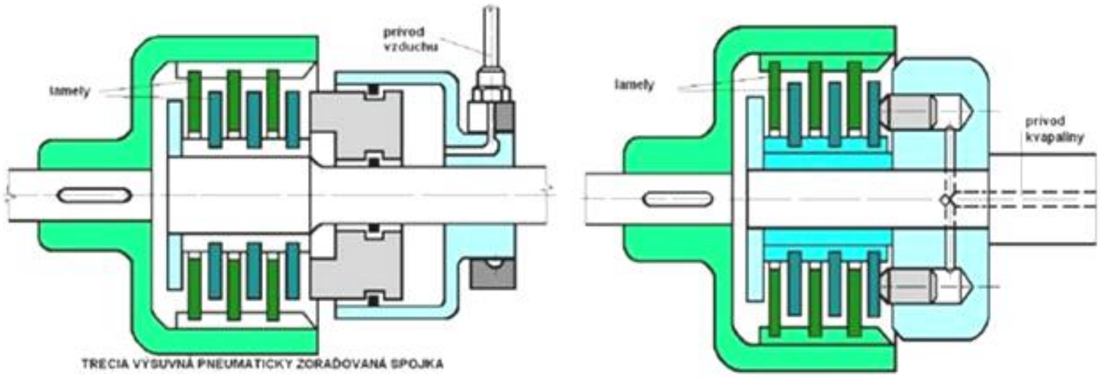


F_t – friction force
F – pressing force
F_N – normal force
F_r – radial force

Pressing force:

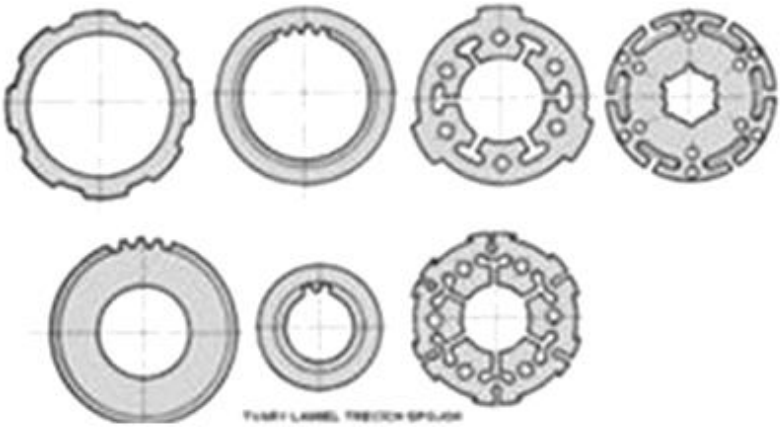
Friction clutch – multi discs

Disc clutches are suitable for a wide range of torques. They consist of a combination of inner and outer discs (plates), which are pressed together by a pressing force.



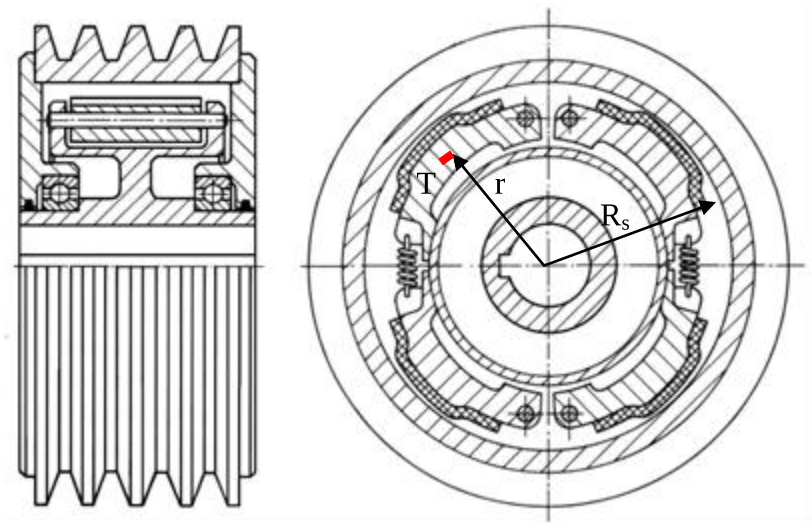
Transmission torque:

Basic types of inner discs and outer discs



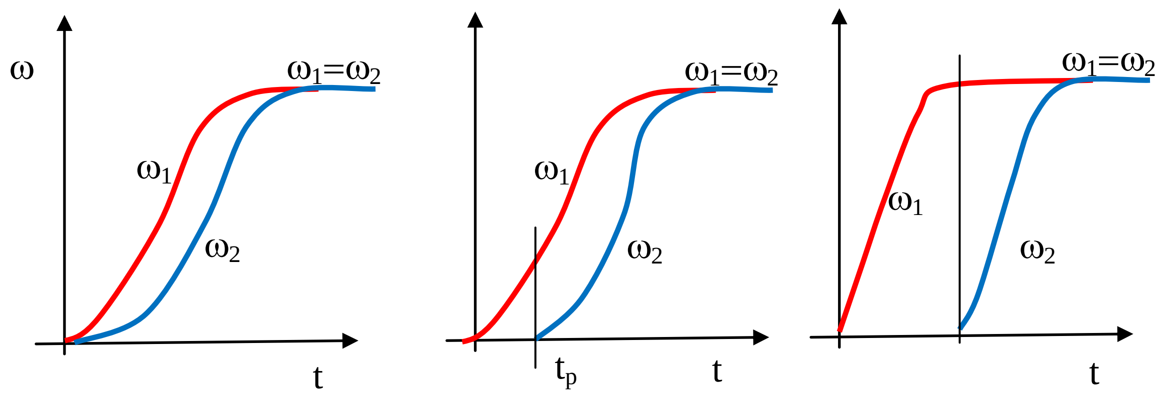
Centrifugal clutch

Centrifugal - Starting clutches should ensure automatic engagement of the drive and driven parts. The control of the moment of switching on is done by means of centrifugal force. By designing the starting clutch, it is possible to achieve accurate closing timing depending on the drive speed of the shaft.



The centrifugal clutch is designed as a friction clutch and therefore the friction torque of the clutch can be calculated as follows:

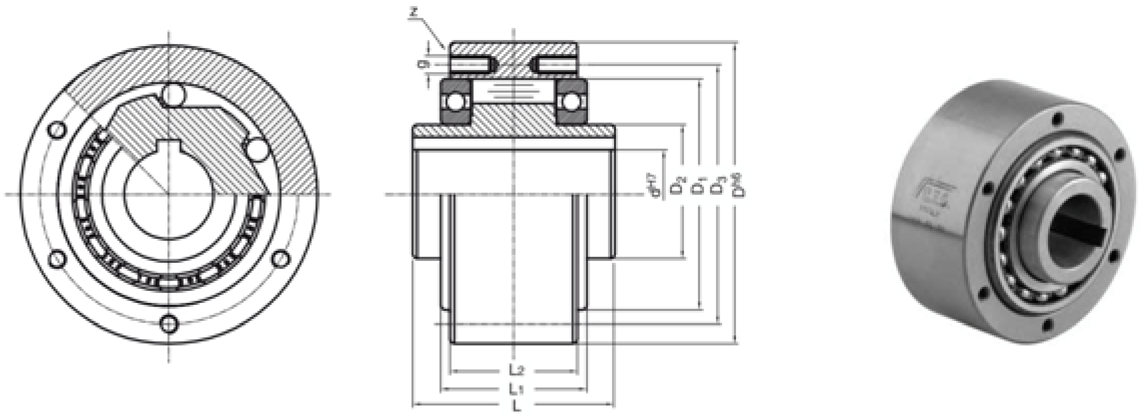
r- distance of centre of gravity between element and axis clutch
ω- angular velocity

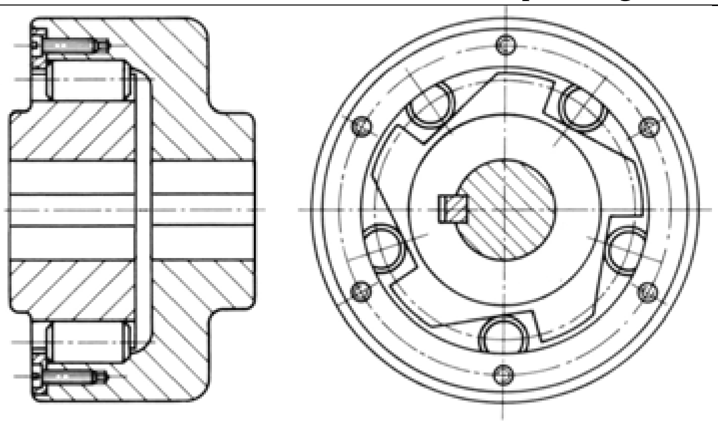


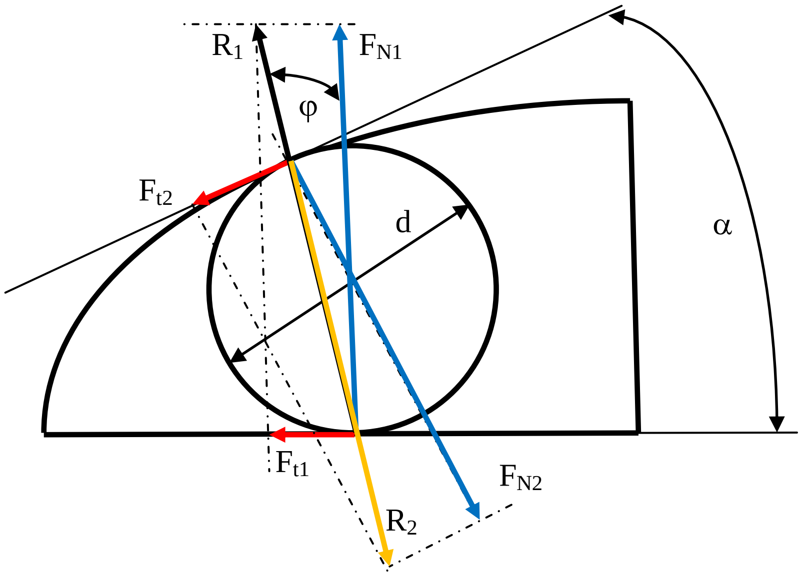
In the previous courses, three possible characteristics of closing the starting clutch are indicated. The first case is the characteristic of a starting clutch with uncontrolled engagement. This means that along with the primary part, the secondary part of the clutch also starts to run.
The second case is a spring-controlled clutch characteristic. The primary part of the clutch rotates according to characteristic ω_1, the secondary part of the clutch is stationary. At the moment, the force of the springs is overcome and the centrifugal force engages the clutch and the secondary part of the clutch also starts to rotate.
The third case is the clutch characteristic with delay. The primary part of the clutch rotates according to characteristic ω_1, the secondary part of the clutch is stationary. The primary part of the clutch reaches the operating speed and then the secondary part of the clutch starts to engage according to characteristic ω_2.

One-way clutch

One - way clutches transmit torque in only one direction of rotation. If the secondary part begins to overtake the primary part, the contact between these parts is automatically cut and the clutch disconnect.







The roller is subjected to reactions R_1 and R_2 which decompose into components of normal forces F_n and components of frictional forces F_t. In terms of the law of action and reaction, it follows that the resulting reactions of R_2 and R_1 must lie on one line but with opposite orientations.

For safe torque transmission, the clamping angle must be $\varphi > \alpha / 2$.
Transmission torque:

The rollers are stressed to push, it is necessary to check the Hertz pressures.
Contact of the roller and the inner cylindrical surface:

If:
l- length of roller
E – Young´s modul
p_D- limit of Hertz press, for steel of hardness HRC 62 je p_D= 1500 až 2000MPa

Chain coupling

Chain couplings are used to connect the shafts in such cases where a quick disengagement of the shafts is required. Chain couplings consist of a pair of flanges terminated by a sprocket, which are connected by a double-row chain. It is necessary that the number of teeth of the wheels is even in order to be able to use a standardized chain. The chain link is oriented with the closed part in the direction of rotation of the flanges.

Diameter of chain wheel: