Pinned couplings.

The calculation is intended for the geometric design and strength check of couplings using pins and clevis pins. The program is used to solve the following tasks:

1. Design of pin for spring attachment.
2. Design of couplings with securing pins.
3. Design of cross pin in rod and sleeve.
4. Design of radial pin for shaft-hub connection.
5. Design of longitudinal pin for shaft-hub connection.
6. Design of clevis pin for rotating rod-clevis connection.
7. Strength check of designed couplings.
8. The program includes dimensional tables for pins and clevis pins according to ANSI, ISO, DIN, BS, JIS and CSN.
9. Support for 2D CAD systems.

The calculation is based on data, procedures and algorithms from specialized literature and standards ANSI, ISO, DIN and others.

List of standards: ANSI B18.8.1, ANSI B18.8.2, ISO 2338, ISO 2339, ISO 2340, ISO 2341, ISO 8733, ISO 8734, ISO 8735, ISO 8739, ISO 8740, ISO 8741, ISO 8742, ISO 8743, ISO 8744, ISO 8745, ISO 8746, DIN 1, DIN 7, DIN 1443, DIN 1444, DIN 1470, DIN 1471, DIN 1472, DIN 1473, DIN 1474, DIN 1475, DIN 1476, JIS B 1352, JIS B 1354, JIS B 1355, BS EN 22339, BS EN 22340, BS EN 22341, CSN EN 22339, CSN EN 22340, CSN EN 22341

Control, structure and syntax of calculations.

Information on the syntax and control of the calculation can be found in the document "Control, structure and syntax of calculations".

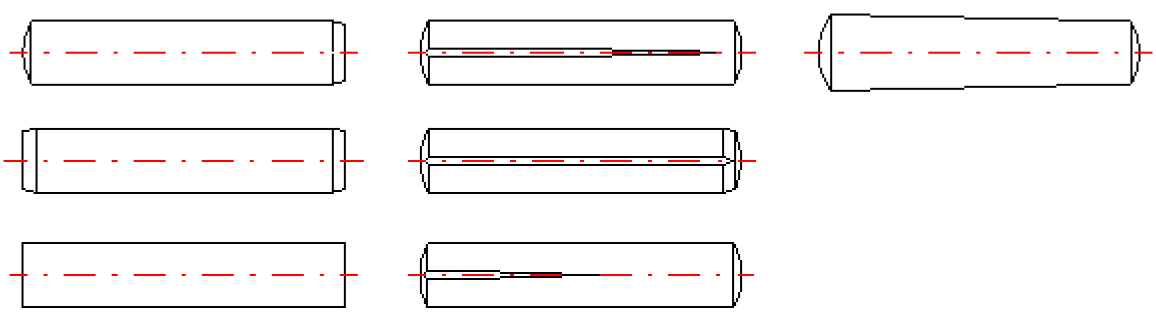
Information on the project.

Information on the purpose, use and control of the paragraph "Information on the project" can be found in the document "Information on the project".

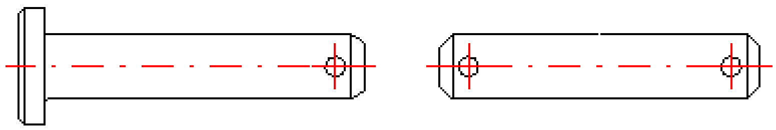
Theory - Fundamentals.

Connecting pins serve to make strong, detachable connections between two mechanical parts, to secure their positions accurately, and to eliminate transversal shifting forces. As a rule, standardized pins manufactured in a wide range of dimensions and designs are used. Pre-stress in the connection between parts is achieved either by means of pin allowance against the hole or the use of conical pins. Conical pins are self-locking and have taper ratio 1: 50. Cylindrical pins are produced as either plain or grooved.

- Holes for fitted cylindrical pins are drilled or reamed; the common fitting methods are H7/n6, H7/m6, H7/p6.
- Grooved pins do not require precise hole fitting and are more resistant to release. On the other hand, they are not suitable for connections that are dismantled frequently, or for connecting aluminium parts. The loading capacity of connections with grooved pins is approximately 20-30% lower. The H11/h11, H12/h11 fitting methods are most frequently used.
- Conical pins provide highly accurate and strong connections. They guarantee that the precise position of the parts being connected is maintained even after repeated connection disassembly. They are not suitable for connections subject to vibration and shocks. Holes for conical pins must be reamed in both parts simultaneously; the common fitting methods are H11/h10, H12/h11.

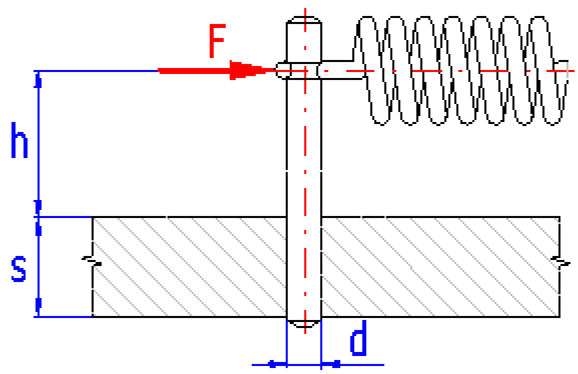


Clevis pins are used for detachable, rotating connections of mechanical parts. As a rule, these connections transfer only transversal forces acting perpendicularly on the clevis pin axis. Clevis pins are generally fitted with a clearance to form coupled connections (rod-clevis couplings). Clevis pins can also be used for short axles of pulleys, travel wheels, etc. The H11/h11, H10/h8, H8/f8, H8/h8, D11/h11, D9/h8 fitting methods are most frequently used. Connecting clevis pins should be secured against axial movement by means of cotter pins, flexible safety rings, nuts, adjusting rings, etc. Standardized clevis pins are produced in versions with or without heads, in which case they are provided with holes for cotter pins.



Pinned couplings are sized, under simplified assumptions, without allowing for the pressing effect and with reasonably reduced allowable stress. Connected parts are checked for deformation of contact surfaces on the hole face. Pins and clevis pins, depending on the connection type, are checked for shearing or bending stresses. As a rule, an additional check for shaft torsional stress is done in torque-loaded shaft-hub connections.

Pin for spring attachment.



Loading with transversal bending force. The connection is checked for contact surface deformation and pin bending.

Pin bending stress:

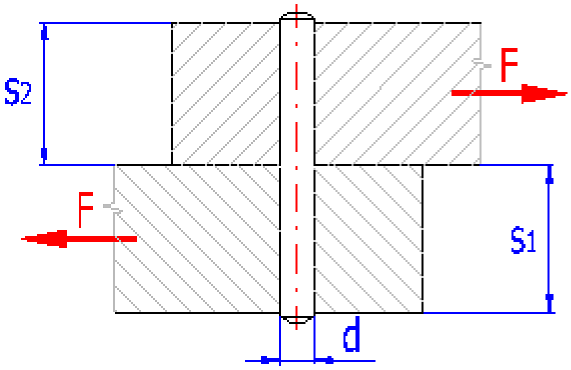
$$\sigma = K_{Sb} \cdot \frac{M_b}{W_b} = K_{Sb} \cdot \frac{32 \cdot F \cdot h}{\pi \cdot d^3} \quad [MPa, psi]$$

Contact pressure:

$$p_{max} = K_{Sp} \cdot (p_b + p_p) = K_{Sb} \cdot \left(\frac{6 \cdot F \cdot \left(h + {}^{s}\!/_{2}\right)}{d \cdot s^2} + \frac{F}{d \cdot s} \right) \quad [MPa, psi]$$

where:
- M_b ... bending moment [Nmm, lb in]
- W_b ... section modulus in bending [mm^3, in^3]
- P_b ... bending deformation [MPa, psi]
- P_p ... pressure deformation [MPa, psi]
- F .... acting force [N, lb]
- s .... thickness of board [mm, in]
- h .... arm of force [mm, in]
- d .... pin diameter [mm, in]
- K_{Sb}, K_{Sp} ... service factor (see details in [2.7, 2.8])

Securing pin.



Loading with transversal shearing force. Connection is checked for contact surface deformation and pin shearing.

Pin shearing stress:

$$\tau = K_{Sb} \cdot \frac{4 \cdot F}{K_L \cdot i \cdot \pi \cdot d^2} \quad [MPa, psi]$$

Pressure on bottom board:

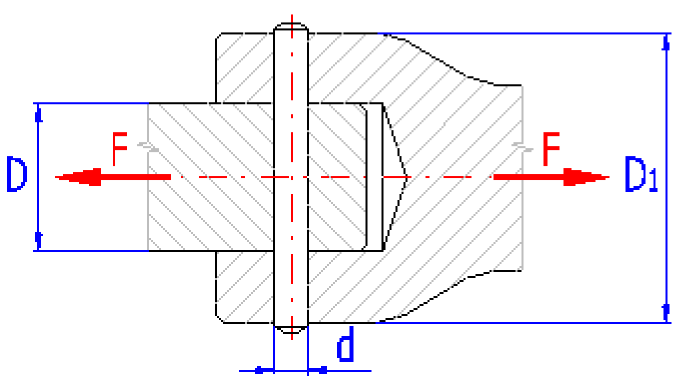
$$p_1 = K_{Sp} \cdot \frac{F}{K_L \cdot i \cdot d \cdot s_1} \quad [MPa, psi]$$

Pressure on top board:

$$p_2 = K_{Sp} \cdot \frac{F}{K_L \cdot i \cdot d \cdot s_2} \quad [MPa, psi]$$

where:
F .... acting force [N, lb]
s_1 ... thickness of bottom board [mm, in]
s_2 ... thickness of top board [mm, in]
d .... pin diameter [mm, in]
i ..... number of pins
K_L ... load distribution factor (see details in [2.6])
K_{Sb}, K_{Sp} ... service factor (see details in [2.7, 2.8])

Cross pin in rod and sleeve.



Loading with transversal shearing force. The connection is checked for contact surface deformation and pin shearing.

Recommended coupling dimensions:

d » (0.2 .. 0.3) D
D » (1.5 .. 2) D - for steel hub

1
D_1 » (2.5) D - for cast-iron hub

Pin shearing stress:

$$\tau = K_{Sb} \cdot \frac{2 \cdot F}{K_L \cdot i \cdot \pi \cdot d^2} \quad [MPa, psi]$$

Pressure on rod:

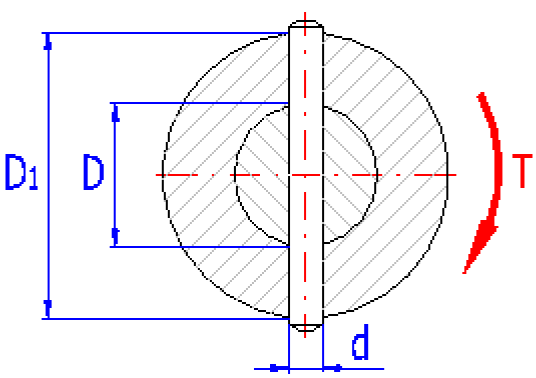
$$p_1 = K_{Sp} \cdot \frac{F}{K_L \cdot i \cdot d \cdot D} \quad [MPa, psi]$$

Pressure on sleeve:

$$p_2 = K_{Sp} \cdot \frac{F}{K_L \cdot i \cdot d \cdot (D_1 - D)} \quad [MPa, psi]$$

where:
F .... acting force [N, lb]
D .... rod diameter [mm, in]
D_1 ... sleeve diameter [mm, in]
d .... pin diameter [mm, in]
i ..... number of pins
K_L ... load distribution factor (see details in [2.6])
K_{Sb}, K_{Sp} ... service factor (see details in [2.7, 2.8])

Radial pin for shaft-hub connection.



Loading with torsional moment. The connection is checked for contact surface deformation, pin shearing and shaft twisting.

Recommended coupling dimensions:
d » (0.2 .. 0.3) D
D_1 » (1.5 .. 2) D - for steel hub
D_1 » (2.5) D - for cast-iron hub

Pin shearing stress:

$$\tau = K_{Sb} \cdot \frac{4 \cdot T}{\pi \cdot d^2 \cdot D} \quad [MPa, psi]$$

Pressure on shaft:

$$p_1 = K_{Sp} \cdot \frac{6 \cdot T}{d \cdot D^2} \quad [MPa, psi]$$

Pressure on hub:

$$p_2 = K_{Sp} \cdot \frac{4 \cdot T}{d \cdot (D_1^2 - D^2)} \quad [MPa, psi]$$

Shaft torsional stress:

$$\tau = K_{Sb} \cdot \frac{16 \cdot T}{\pi \cdot D^3 \cdot \left(1 - 0.9\frac{d}{D}\right)} \quad [MPa, psi]$$

where:

T .... torque [Nmm, lb in]

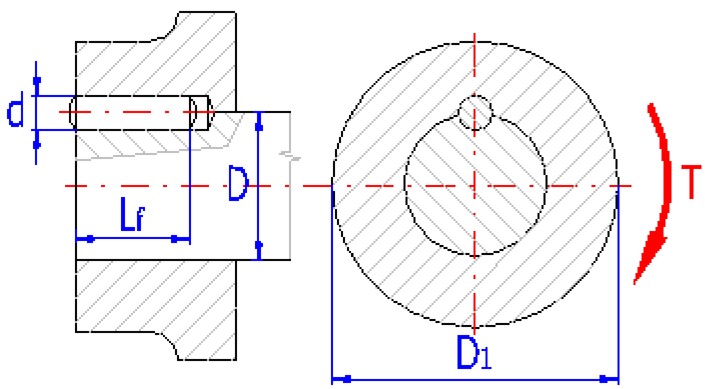
D .... shaft diameter [mm, in]

D_1 ... hub diameter [mm, in]

d .... pin diameter [mm, in]

K_{Sb}, K_{Sp} ... service factor (see details in [2.7, 2.8])

Longitudinal pin for shaft-hub connection.



Loading with torsional moment. The connection is checked for contact surface deformation, pin shearing and shaft twisting.

Recommended coupling dimensions:

d » (0.125 .. 0.2) D

L_f » (1 .. 1.5) D

D_1 » (1.5 .. 2) D - for steel hub

D_1 » (2.5) D - for cast-iron hub

Pin shearing stress:

$$\tau = K_{Sb} \cdot \frac{2 \cdot T}{K_L \cdot i \cdot d \cdot D \cdot L_f} \quad [MPa, psi]$$

Pressure on shaft and hub:

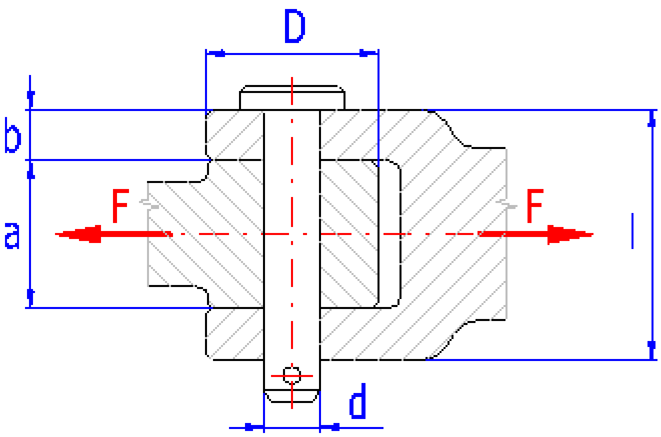
$$p_1 = p_2 = K_{Sp} \cdot \frac{4 \cdot T}{K_L \cdot i \cdot d \cdot D \cdot L_f} \quad [MPa, psi]$$

Shaft torsional stress:

$$\tau = K_{Sb} \cdot \frac{16 \cdot T}{\pi \cdot \left(D - i \cdot \frac{d}{2}\right)^3} \quad [MPa, psi]$$

where:
T .... torque [Nmm, lb in]
D .... shaft diameter [mm, in]
D_1 ... hub diameter [mm, in]
d .... pin diameter [mm, in]
L_f ... functional length of pin [mm, in]
i ..... number of pins
K_L ... load distribution factor (see details in [2.6])
K_{Sb}, K_{Sp} ... service factor (see details in [2.7, 2.8])

Clevis pin for rotating rod-clevis connection.



Loading with transversal bending force. The connection is checked for contact surface deformation, pin bending and shearing.

Recommended coupling dimensions:

a » (1.5 .. 1.7) d
b » (0.3 .. 0.5) a
l » (2 .. 2.5) d
D » (2.5) d - for steel
D » (3.5) d - for cast-iron

Pin bending stress:

$$\sigma = K_{Sb} \cdot \frac{M_b}{W_b} = K_{Sb} \cdot \frac{4 \cdot F \cdot (a + 2 \cdot b)}{\pi \cdot d^3} \quad [MPa, psi]$$

Pin shearing stress:

$$\tau = K_{Sb} \cdot \frac{2 \cdot F}{\pi \cdot d^2} \quad [MPa, psi]$$

Pressure on rod:

$$p_1 = K_{Sp} \cdot \frac{F}{d \cdot a} \quad [MPa, psi]$$

Pressure on clevis:

$$p_2 = K_{Sp} \cdot \frac{F}{2 \cdot d \cdot b} \quad [MPa, psi]$$

where:
M_b ... bending moment [Nmm, lb in]
W_b ... section modulus in bending [mm^3, in^3]
F .... acting force [N, lb]
a .... rod width [mm, in]

b .... clevis width [mm, in]
d .... pin diameter [mm, in]
K_{Sb}, K_{Sp} ... service factor (see details in [2.7, 2.8])

Process of calculation.

The typical connection calculation / design includes the following steps:

1. Set the required calculation units (SI / Imperial). [1.1]
2. Select the required connection type [1.2].
3. Enter the connection load (transferred output, speed, acting force) [1.4, 1.5, 1.7].
4. Set the connection service and assembly parameters [1.8].
5. Select the material of the parts to be connected [1.13, 1.18].
6. Select the required pin type [2.2].
7. Define the applicable service coefficient [2.5].
8. Select the pin material [2.9].
9. Enter the dimensions of the parts to be connected [2.17, 2.18].
10. Propose a suitable pin diameter and length [2.21, 2.23]. You can use the function of automatic search for a suitable pin when designing this [2.20].
11. Check the results of the designed pin strength checks [3].
12. Save the file with the acceptable solution under a new name.

Loading and basic parameters of the coupling. [1]

In this section, it is necessary to enter the basic initial parameters which characterize the method, mode and magnitude of load, connection design and materials of parts to be connected.

1.1 Calculation units.

In the selection list, choose the desired calculation unit system. All values will be recalculated immediately after switching to other units.

1.2 Coupling type.

Select the required connection type by clicking the switch by the pertinent picture.

1.4 Transferred power.

Enter the power which will be transferred by the shaft.

1.5 Shaft speed.

Enter the shaft speed.

1.6 Torque.

The transferred power and speed provide a torsional moment, which is the basic input value for the design of the coupling.

1.7 Acting force.

Enter the maximum transversal force loading the connection.

1.9 Type of loading.

Select such loading method which best suits your specification.

Note: In repeated and alternating loads, connection loading capacity is reduced by approximately 30% and 50% respectively.

1.10 Type of pin.

Select the required pin type from the list. Grooved pins do not require precise hole fitting and are more resistant to release. On the other hand, they are not suitable for connections that are dismantled frequently, or for connecting aluminium parts.

Note: In grooved pins, the connection loading capacity for contact surface deformation decreases by approximately 30%. Pin loading capacity for shearing and/or bending is approximately 20% lower than in plain pins.

1.11 Type of fit.

Select the required pin fitting method from the list. In running fitting methods there are considerably lower values of allowable pressures in materials used (see [1.13, 1.18, 2.9]).

Note: This parameter is only relevant in rotating rod-clevis connections.

1.12 Desired safety.

With regards to accuracy and credibility of input information, importance of the coupling, quality of production and accuracy of the calculation, it is usually chosen in a range from 1.5 to 3.

Orientation values for choice of safety:

- 1.3 to 1.5 - Very accurate input information, perfect knowledge of material characteristics, high quality and exact following of production technology; insignificant couplings, damage to which does not cause any serious consequences.
- 1.5 to 1.8 - Less accurate calculation without any experimental verification, lower accuracy in production technology, couplings of lower importance.
- 1.8 to 2.5 - Decreased accuracy of calculations, approximate determination of material characteristics, inaccurate knowledge of actual effects of external loading; large diameters of shafts, very important couplings, damage to which

could jeopardize human life or bring about high material losses.

Note: Even higher levels of safety are used in case of couplings working in a corrosive environment or at high temperatures.

Hint: General procedures of determination of safety coefficients can be found in the document "Coefficients of safety".

1.13, 1.18 Material of parts to be connected.

From the list, select the type of material from which the connected parts will be produced. The value in brackets shows the minimum tensile strength [MPa/ksi] of the given material group. In case the checkbox to the right of the selection list is enabled, the necessary strength parameters for the chosen material are determined automatically. Otherwise, fill in the material characteristics manually. The permitted pressure values [1.16, 1.21] are used to check contact surfaces for deformation in fixed connections. In rotating connections, the permitted pressures [1.17, 1.22] are considerably lower (by up to 80%). In connections stressed with torsional moment, the permitted torsional stress data [1.23] serves to check the shaft strength for torsion.

Warning: The material strength parameters are set empirically for still (static) load and reflect the minimum values valid for the whole group of materials. Although these obtained values are close to the values obtained using measurement of particular materials, it is recommended in cases of final calculations to use parameters of material according to the material sheet or specifications of the producer.

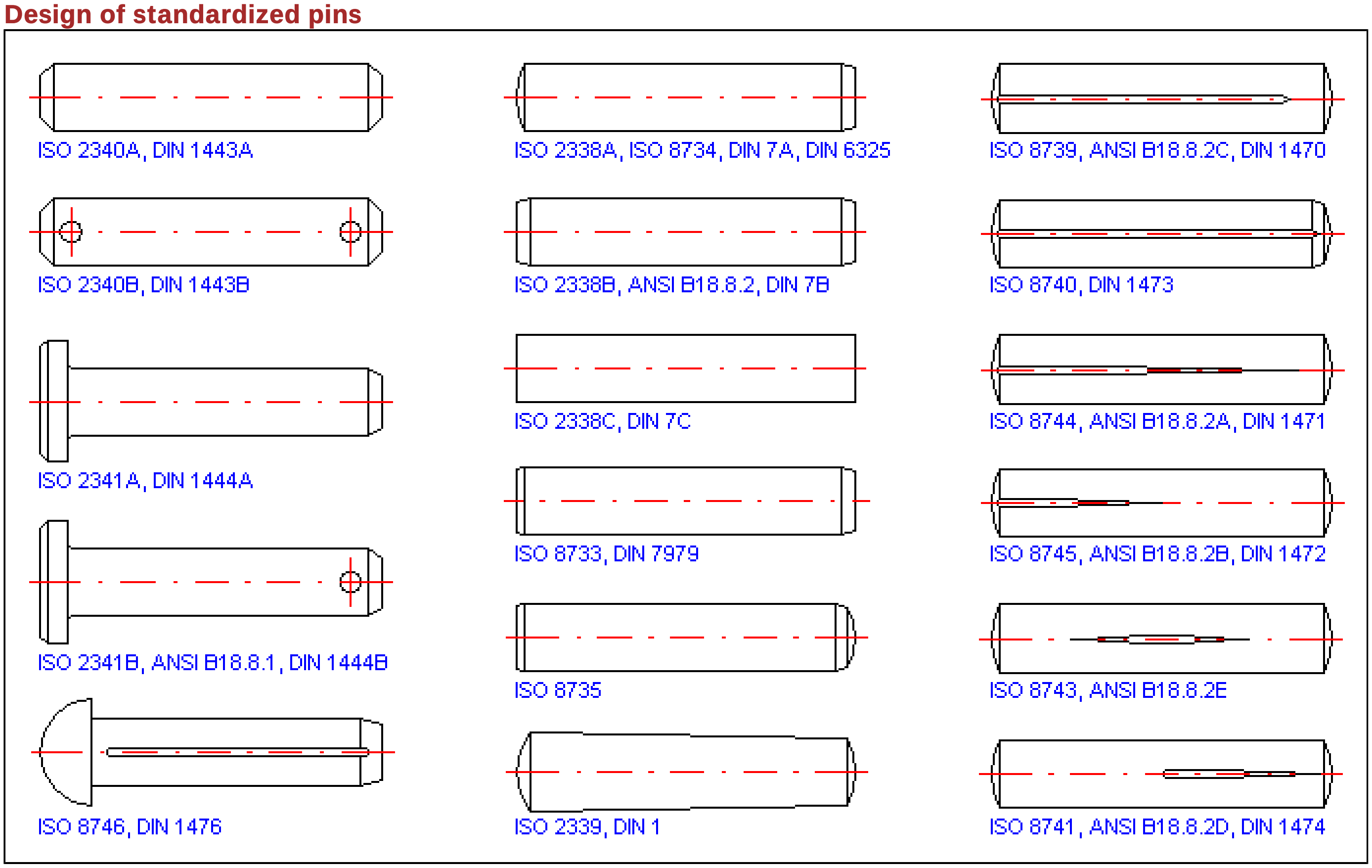
Design of coupling dimensions. [2]

This section serves to select a suitable pin and to propose connection dimensions.

2.2 Pin selection.

Select the pin design (standard) from the list. Standardized pins have precise diameters and lengths prescribed in the standard. Pin dimensions according to ANSI are defined in the standard in [in]; dimensions of other pin types are defined in [mm].

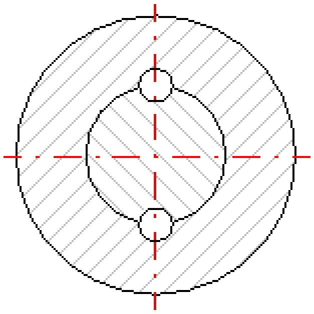
Design of standardized pins



Hint: If the range of prescribed dimensions is not sufficient in the offered (standardized) pins, choose the item "**User pin**" in the list. The program then makes it possible to define a pin of any dimensions.

2.4 Number of pins.

More pins can be used to transfer higher loads. Their arrangement will depend on the general connection design and/or load character. A symmetrical arrangement (shifted by 180°) is usually used in longitudinal pins on shafts.



Note: This parameter is only applicable in those connections where using more pins is technically possible.

2.6 Load distribution factor.

Due to manufacturing and assembly inaccuracies, uniform load distribution among pins may not always be achieved in connections with more pins. The actual connection bearing area is then lower than that set theoretically. The ratio between the theoretical and actual load bearing surface of the coupling is defined by the coefficient of distribution of the loading. In consideration of the connection design and pin fitting accuracy and number, the coefficient value is given from 0.5 to 1.

Hint: When the check button in line [2.5] is activated, the coefficient will be proposed automatically on condition of common manufacturing and assembly inaccuracies.

Warning: Uniform load distribution can be expected in connections with tightly fitted pins (free of clearances) where the pin holes have been drilled simultaneously with the connection assembly. A coefficient equal to 1 is then used for such connections.

Note: This parameter is only applicable in those connections where using more pins is technically possible. In connections with one pin, the coefficient always equals 1.

2.7 Service factor (pressure).

This refers to the overall effect of manufacturing and operational parameters upon connection loading capacity reduction in terms of allowable deformation of contact surfaces. Its value depends on the pin type and connection loading character. With regards to the mentioned parameters, the literature gives values of the coefficient in a range from 1 to 3.

Hint: For easier choice of coefficient, the application is provided with automatic design. When the check button in line [2.5] is activated, the coefficient is determined automatically and based on parameters of the coupling defined in paragraph [1.8].

2.8 Service factor (bending, shearing).

This refers to the overall effect of manufacturing and operational parameters upon reduction of the loading capacity of a pin loaded with shearing or bending stress. Its value depends on the pin type and connection loading character. With regards to the mentioned parameters, the literature gives values of the coefficient in a range from 1 to 3.

Hint: For easier choice of coefficient, the application is provided with automatic design. When the check button in line [2.5] is activated, the coefficient is determined automatically and based on parameters of the coupling defined in paragraph [1.8].

2.9 Pin material.

From the list, select the type of material from which the pin will be produced. The value in brackets shows the minimum tensile strength [MPa/ksi] of the given material group. In case the checkbox to the right of the selection list is enabled, the necessary strength parameters for the chosen material are determined automatically. Otherwise, fill in the material characteristics manually. The value of the permitted pressure [2.12] is used to check the pin for deformation in fixed connections. In rotating connections, the permitted pressure [2.13] is considerably lower (by up to 80%).

Warning: The material strength parameters are set empirically for still (static) load and reflect the minimum values valid for the whole group of materials. Although these obtained values are close to the values obtained using measurement of particular materials, it is recommended in cases of final calculations to use parameters of material according to the material sheet or specifications of the producer.

2.16 Coupling dimensions.

This section serves to propose connection dimensions. When designing the connection, first enter the dimensions of the parts to be connected [2.17, 2.18] and select a suitable pin diameter from the list [2.21]. For such designed connection, the minimum functional pin length is calculated in line [2.24]. Finish the connection design by selecting the actual pin length in line [2.23]. Select length from the standardized range [2.22] so that the functional length [2.25] is greater than the minimum length [2.24].

Hint 1: Recommended values for mutual proportions of individual connection dimensions are provided in the theoretical part of Help.

Hint 2: To facilitate design preparation, the program is equipped with the function of automatic selection of a suitable pin [2.20]. After pressing the "**Search**" button, the program selects a suitable pin of minimum dimensions.

2.20 Searching for a suitable pin.

To facilitate design preparation, the program is equipped with the function of automatic selection of a suitable pin. After pressing the "**Search**" button, the program selects a suitable pin of minimum dimensions. The buttons "**<**", "**>**" serve to quickly change (select) pins within the standardized dimensional line of diameters. After selecting the pin diameter, the program automatically sets its optimum length.

2.21 Pin diameter.

Select the pin diameter from the standardized dimensional line of diameters. The selection of a suitable diameter can be facilitated by the recommended values [2.19] set empirically on the basis of the dimension [2.17].

Hint: If the range of prescribed dimensions is not sufficient in the offered (standardized) pins, choose the item "**User pin**" in the list [2.2]. The program then makes it possible to define a pin of any dimensions.

2.22 Allowable range of pin lengths.

The minimum and maximum allowable lengths of the selected pin prescribed in the standard.

Hint: If the range of prescribed dimensions is not sufficient in the offered (standardized) pins, choose the item "**User pin**" in the list [2.2]. The program then makes it possible to define a pin of any dimensions.

2.23 Pin length.

Select pin length from the standardized range [2.22] so that the functional length [2.25] is greater than the minimum length [2.24].

Hint: If the range of prescribed dimensions is not sufficient in the offered (standardized) pins, choose the item "**User pin**" in the list [2.2]. The program then makes it possible to define a pin of any dimensions.

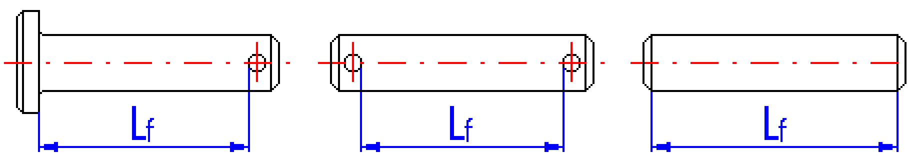
2.24 Minimum functional length of pin.

In connections with longitudinal pins, this parameter gives the minimum functional length of the selected pin necessary for safe transfer of the entered torsional moment. In other types of pinned couplings, the minimum length is given by the connection design and by the dimensions of the parts to be connected [2.17, 2.18].

Warning: If the minimum pin length is greater than the upper limit of the standardized range of lengths [2.22], it is necessary to repeat the process for a pin of greater diameter or use a non-standardized pin.

2.25 Functional length of pin.

The functional length of the pin is the total length reduced by the pin end chamfer or round-off. In clevis pins, the active length is the distance between the clevis pin head and the cotter pin hole.



Strength checks of the coupling. [3]

Pinned couplings are sized, under simplified assumptions, without allowing for the pressing effect and with reasonably reduced allowable stress. Connected parts are checked for deformation of contact surfaces on the hole face. Pins and clevis pins, depending on the connection type, are checked for shearing or bending stresses. As a rule, an additional check for shaft torsional stress is done in torque-loaded shaft-hub connections.

Hint: Detailed information about sizing and checks of individual types of pinned couplings can be found in the theoretical part of help.

3.1 Pin check for shearing.

The resulting connection safety [3.4] is given by the ratio between the permitted pin material shearing stress and the calculated comparative stress. If the coupling is to be sufficient, the calculated safety must be higher than the required one [1.12].

Note: If the check result is not satisfactory, design a connection with a greater pin diameter.

3.5 Pin check for bending.

The resulting connection safety [3.8] is given by the ratio between the permitted pin material bending stress and the calculated comparative stress. If the coupling is to be sufficient, the calculated safety must be higher than the required one [1.12].

Note: If the check result is not satisfactory, design a connection with a greater pin diameter.

3.9, 3.13 Check of contact pressure.

The check for deformation is carried out separately for every part being connected. The resulting safety [3.12, 3.16] is given by the ratio between the permitted pressure of the lower quality material (of the pair pin – the part being connected) and the calculated comparative pressure acting on the given connection part. If the coupling is to be sufficient, the calculated safety must be higher than the required one [1.12].

Note: If the check result is not satisfactory, design a connection with a greater pin diameter and/or greater dimensions of parts to be connected.

3.17 Check of shaft for torsion.

The resulting connection safety [3.20] is given by the ratio between the permitted torsional stress of the shaft material and the calculated comparative stress. If the coupling is to be sufficient, the calculated safety must be higher than the required one [1.12].

Note: If the check result is not satisfactory, design a connection with a smaller pin diameter or greater shaft diameter.

Graphic output, CAD systems.

Information on options of 2D and 3D graphic outputs and information on cooperation with 2D and 3D CAD systems can be found in the document "Graphic output, CAD systems".

Setting calculations, change the language.

Information on setting of calculation parameters and setting of the language can be found in the document "Setting calculations, change the language".

Workbook modifications (calculation).

General information on how to modify and extend calculation workbooks is mentioned in the document "Workbook (calculation) modifications".