Hydraulic Cylinder MF4
(Cap Circular Flange/MF4 Mounting Type)

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1.Introduction to the Cap Circular Flange Hydraulic Cylinder

1.1 Duty and Operation of Hydraulic Cylinder

Hydraulic cylinders are mechanical devices that use the power of pressurized hydraulic fluid to produce linear force and motion. They play a crucial role in various industries, including manufacturing, construction, and automotive. These cylinders are commonly used to convert fluid power into mechanical force and motion. A hydraulic cylinder generally consists of a cylindrical barrel, a piston, and hydraulic fluid. When hydraulic fluid is pumped into the cylinder, it pushes against the piston, generating linear motion. The design and configuration of hydraulic cylinders can vary based on their intended application.

Actuators are hydraulic elements that convert hydraulic energy into mechanical energy and perform rectilinear movement in the process. It is particularly advantageous to use hydraulic cylinders for variable direction (back and forth) movements because there is no need to convert the rotary movement into a straight-line movement. The overall efficiency of the hydraulic cylinders is essentially the same as the hydromechanical efficiency, the mechanical losses are represented by the frictional resistance of the seals.

Hydraulic cylinders are often used in machine tools, agricultural and earthmoving machinery, loading and lifting machines, cranes, press and injection moulding machines, ships, locks, manipulators, and other purposes. Their field of application is made extremely wide by the various mounting versions: hinged, ball-jointed, pin, base, flanged, etc. connection solutions.

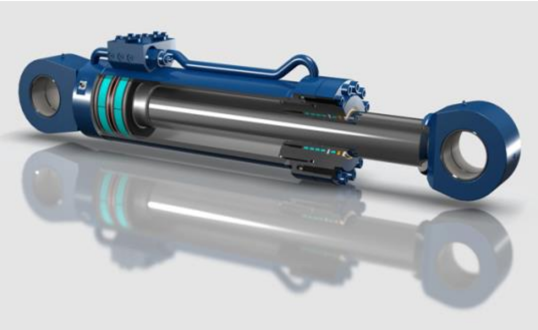


Fig. 1: The sample model of a hydraulic cylinder

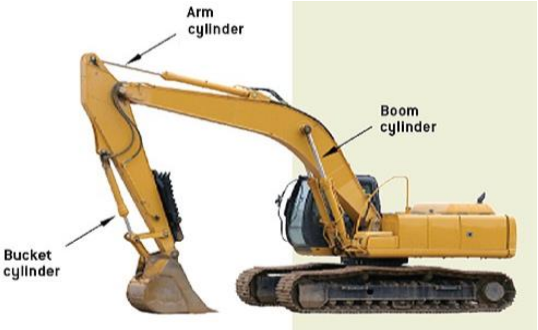


Fig. 2: The application of hydraulic cylinder in the construction machine

1.2 Design of the MF4 Hydraulic Cylinder

In hydraulic cylinders, mounting options are crucial as they determine how the cylinder will be attached to other components or structures. The cap circular flange mounting type (MF4) typically refers to a mounting configuration where the cylinder is attached using a circular flange on the cap end of the cylinder. Here are some key points related to the Cap circular flange mounting type (MF4):

- Mounting Configuration: The MF4 mounting type involves a circular flange on the cap end of the hydraulic cylinder. This flange provides a surface for attaching the cylinder to other components or structures.

- Flange Design: The circular flange is designed to distribute forces evenly and provide a secure connection. It often has bolt holes arranged in a circular pattern to facilitate attachment with bolts.
- Applications: Hydraulic cylinders with cap circular flange mounting (MF4) are commonly used in applications where a secure and rigid connection is required. This mounting type is suitable for various industrial applications, including those where the cylinder needs to be fixed or integrated into a larger system.
- Advantages: The MF4 mounting type provides a stable and reliable connection, preventing unwanted movement or misalignment. It allows for efficient force transmission from the cylinder to the connected components.
- Considerations: When selecting a hydraulic cylinder with cap circular flange mounting, it's essential to consider factors such as the load requirements, operating conditions, and compatibility with other components in the system.

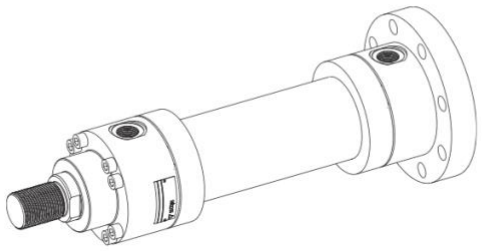


Fig. 3: The axonometric assembly model of the MF4 Hydraulic Cylinder

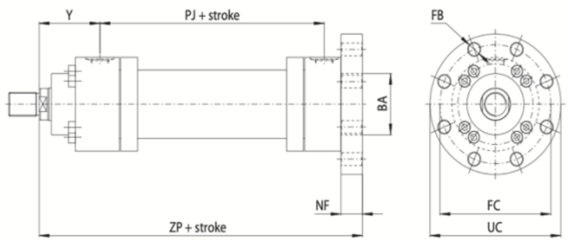
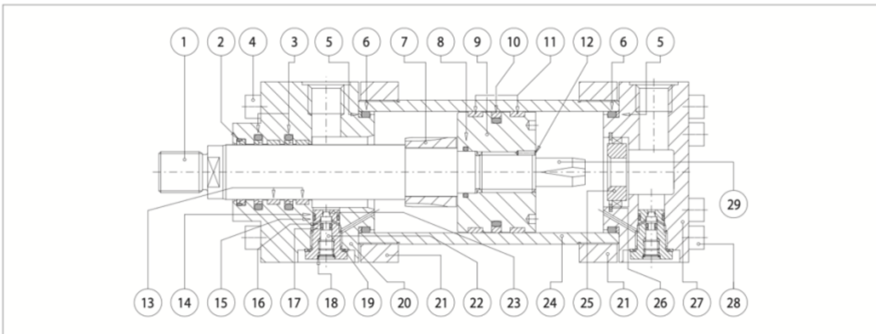


Fig. 4: The front and top view model of the MF4 Hydraulic Cylinder

1.3 Parts and Material Specification of the MF4 Hydraulic Cylinder

There are 29 parts that are connected in this type of a hydraulic cylinder, both in outside view and inside sections with a different mechanical function (purpose), and most of them are also made from various material technology with their own specification and standard. A table below provide information related to each part and their original manufactured material.



POS.	DESCRIPTION	MATERIAL	POS.	DESCRIPTION	MATERIAL	POS.	DESCRIPTION	MATERIAL
1	Rod	Chrome plated steel	11	Piston guide rings	PTFE	21	Counterflange	Steel
2	Wiper	NBR / FKM and PTFE	12	Screw stop pin	Steel	22	Cushioning adjustment screw	Steel
3	Rod seal	NBR / FKM and PTFE	13	Rod guide rings	Phenolic resin	23	Cushioning adjustment plug	Steel
4	Screw	Steel class 12.9	14	Anti-extrusion ring	PTFE	24	Cylinder housing	Steel
5	Anti-extrusion ring	PTFE	15	O-ring	FKM	25	Rear cushioning sleeve	Bronze
6	O-ring	NBR / FKM	16	O-ring	FKM	26	Toroidal ring	Steel
7	Front cushioning piston	Steel	17	Anti-extrusion ring	PTFE	27	Rear head	Steel / Cast iron
8	O-ring	NBR / FKM	18	Seeger	Steel	28	Screw	Steel class 12.9
9	Piston	Steel	19	Seal	FKM	29	Rear cushioning piston	Steel
10	Piston seal	NBR / FKM and PTFE	20	Front head	Steel / Cast iron			

Table. 1: List of parts and material specification for MF4 Hydraulic Cylinder

1.4 Material Selection for the MF4 Piston Rod

There are three given materials to manufacture the piston rod: CK45, 20MnV6, and 42CrMo4. Based on the mounting type and installation of a selected cylinder, the best material option is 42CrMo4. This is a *chromium-molybdenum* alloy steel known for its high strength and hardening. It's a good choice for applications where high strength is crucial. This material is a steel for quenching and tempering. The microstructure of larger dimensions is not fully martensite. Considering the high pressure of 10 MPa, the 42CrMo4 is the most suitable material among the other two materials due to its higher strength.

Characteristics of a 42CrMo4 material:

- Material: 42CrMo4 (EN 10083)
- Tolerance: ISO f7
- Length: 5500 – 6500 mm
- Surface roughness: Ra max. 0.20 μm
- Thickness of chromium layer: < Ø20 mm: min. 15 μm
- ≥ Ø20 mm: min. 20 μm Hardness of chromium layer: min. 900 HV (0.1)
- Straightness: ≤Ø16mm:max.0.3mm/1000mm > Ø16 mm: max. 0.2 mm / 1000 mm
- Mechanical properties: according to EN 10083 standard Corrosion resistance: < Ø20 mm: grade 9 after 120 hours (NSS) ≥ Ø20 mm: grade 9 after 120 hours (NSS)
- According to ISO 10289 / ISO 9227 standards

1.5 Constructed Drawing of the MF4 Hydraulic Cylinder

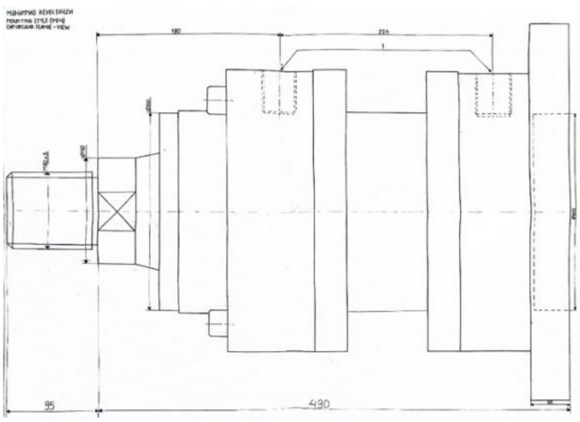


Fig. 5: Constructed Drawing of the MF4 Hydraulic Cylinder in the view perspective

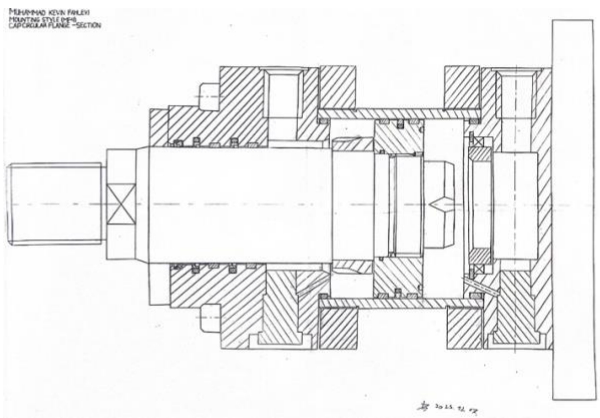


Fig. 6: Constructed Drawing of the MF4 Hydraulic Cylinder in the section perspective

2. Mechanical Calculations of the MF4 Hydraulic Cylinder

2.1 Installation Dimensions and Given Data of the Selected Mounting Type

To calculate strength, stress, force, and other mathematical calculations related to a Column Car Jack, the initial data of the material must be recognized. These data are useful as important properties for the further calculations.

- Nominal pressure of a cylinder : P = 10 [MPa] = 10,000,000 [Pa]
- Nominal diameter of a cylinder : D = [200 mm] = 0.2 [m]
- Cylinder stroke length : S = 125 [mm] = 0.125 [m]
- Piston rod length : R_L = 110 [mm] = 0.1 [m]
- Operating speed of the piston : v = 1 [m/s]
- Operating temperature : T = +20…+80 [K]
- Mass : m = 238.07 [Kg] + 22.66 [Kg]
  (stroke mass + mounting mass) = 260.73 [Kg]; Based on catalog
- Yield strength of the tube material : R_{EH} = 415 MPa
- Selected factor of safety : n_F = 2.0
- Cylinder length : l_C = 585 [mm]
- Modulus of elasticity : E = 210 [GPa] = 210,000 [MPa]

2.2 Determination of the Hydraulic Force and Dynamics Limit

Figure 5. shows the sketch of fluid mechanics properties inside of a cylinder. The mass, (m) acts for the moving component within a hydraulic cylinder. Density (ρ), velocity (v), and area (A) are the crucial properties for the volume flow rate (q_v) of fluid passing through the hydraulic system per unit of time. In a hydraulic cylinder, force (F) is the result of pressure applied to the hydraulic fluid, which then transmits that force to the piston inside the cylinder. This force is a fundamental concept in fluid mechanics and is governed by Pascal's Law.

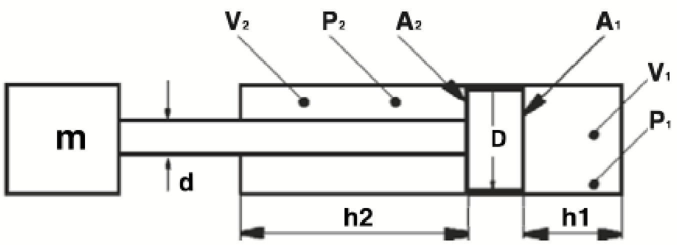


Fig. 7: The sketch of fluid mechanics properties of a cylinder

In case of constant oil flow by the pump is connected to the tap 1(h_1), there will exist a slow forward motion as results of A_1, v_1, and P_1. While fast backward motion is generated when the oil is connected to tap 2 (h_2) as consequences of A_2,v_2, and P_2.

Area ratio (φ_{area}) = A_1 / A_2 standardized = 1.25

$$\Phi = \frac{A1}{A2} = \frac{D^2\,\pi}{4} : \frac{(D^2 - d^2)\,\pi}{4} = 1.25 \quad d = 0.0894\ [m] = 0.09\ [m] = \ (rounded)$$

d: diameter of the piston rod

$$A1 = \frac{D^2\,\pi}{4} = 0.0314\ [m^2] \qquad A2 = \frac{(D^2 - d^2)\,\pi}{4} = 0.025\ [m^2]$$

P_1 and P_2 are having the same values. With the help of Bernoulli Equation, we can assume that operating speed of piston of v_1 and v_2 are also equal.

$$P1 + \rho\frac{v1^2}{2} = P2 + \rho\frac{v2^2}{2} \qquad v2 = v1 = v$$

Oil is connected to tap 1:

$$F1 = P\,A1 = 31400\ [N] \qquad qv = v\,A1 = 0.0314\ [m^3/\,s]$$

Oil is connected to tap 2:

$$F2 = P\,A2 = 31400\ [N] \qquad qv = v\,A2 = 0.025\ [m^3/\,s]$$

The calculation of the pulsing value ω_0 of the cylinder-mass system allows to describe the minimum acceleration/deceleration time (t_{min}), the maximum speed (v_{max}) and the minimum acceleration/deceleration space (S_{min}) in a diagram to not affect the functional stability of the system. Flexible piping or long distances between the directional valve and the cylinder may affect the stiffness of the system, thus the values may not be reliable.

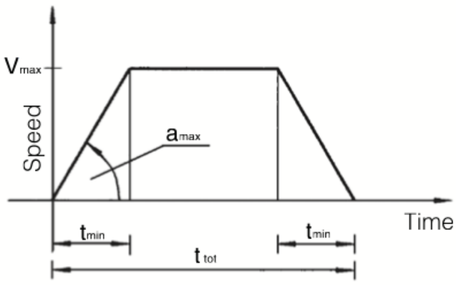


Fig. 8: Dynamics Limit Diagram of a general hydraulic cylinder

2.3 Dimensioning the Wall - Thickness and Piston Rod Size

The cylinder can be considered a thin-walled tube that must withstand the internal pressure. The required wall thickness of the pipe is written below:

$$s' = \frac{P\,D}{2\frac{ReH}{nF} - P} \qquad s' = 4.93\ [mm]$$

The minimum wall thickness of cylinder heads (cover) can be determined using the relation valid for flat covers and blind flanges:

$$h = 0.6\,D\,\sqrt{\frac{P}{\frac{ReH}{nF}}} \qquad h = 26.35\ [\text{mm}]$$

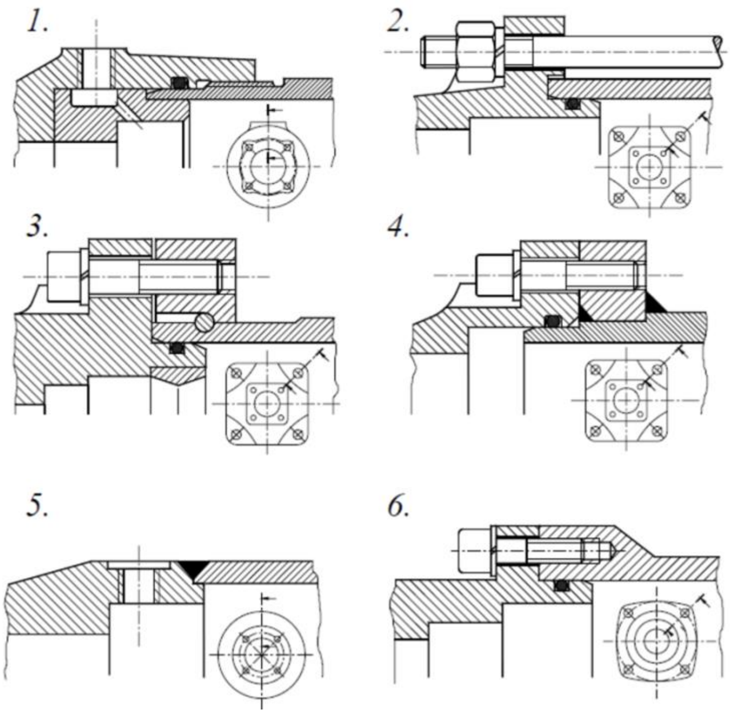


Fig. 9: CAD model for the connecting the cylinder
and cylinder head (cover)

The piston rod is subjected to tensile or compressive force. The magnitude of the pulling force (F_H) is attached below:

$$FH = \frac{(D^2 - d^2)\,\pi}{4} \,.\, P \qquad\qquad FH = 250{,}542\ [N] = 250.5\ [kN]$$

The magnitude of the compressive force (F_{Ny}):

$$FNy = \frac{D^2\,\pi}{4} \,.P \qquad\qquad FNy = 314{,}160\ [N] = 314.16\ [kN]$$

The ratio of both forces ($\varphi_{surfaces}$):

$$\varphi = \frac{FNY}{FH} = 1.25$$

2.4 Checking the Piston Rod for Buckling

Inspecting the piston rod for buckling in a hydraulic cylinder involves a visual check for external signs of bending and misalignment. Precision measuring tools, such as dial indicators, assess runout during rotation, while physical measurements confirm compliance with manufacturer specifications. Functional testing during operation helps identify abnormal vibrations or noises. Disassembly allows for a closer examination of wear or damage. Timely action, guided by manufacturer guidelines, is crucial if buckling is detected, possibly requiring repair or replacement. Regular preventive maintenance based on these procedures ensures reliable and safe hydraulic system performance, minimizing downtime and extending component lifespan.

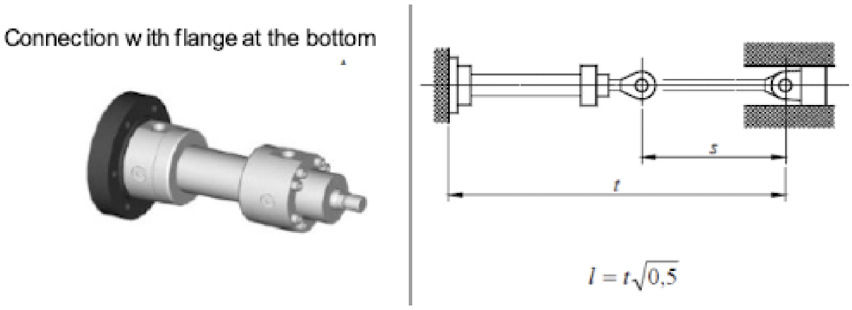


Fig. 10: The deflection (buckling) length for the MF4 clamping of the cylinder

The buckling length is calculated based on the cylinder length (l_C) and stroke length (S) of the given clamping. Sum both values will result in the overall length required.

$t = lc + S$ $\quad\quad\quad\quad$ $t = 710\ [mm]$

Thus, the buckling length (l) is calculated below:

$l = t\sqrt{0.5}$ $\quad\quad\quad\quad$ $l = 502\ [mm]$

In the buckling calculations, the hydraulic cylinder is modelled as a compressed support with cross-section and diameter (d). The slenderness of rod (λ):

$\lambda = \frac{4l}{d}$ $\quad\quad\quad\quad$ $\lambda = 22.31$

The limit slenderness:

$\lambda 0 = \pi \sqrt{\frac{E}{0.8\,ReH}}$ $\quad\quad\quad\quad$ $\lambda 0 = 79$

If $\lambda \geq \lambda 0$, then the critical (breaking) force causing buckling must be calculated using the long column theorem (Euler formula):

$Ft = \frac{\pi^2\, I\, E}{l^2}$ $\quad\quad\quad\quad$ I: The second-order moment of the cross section of the pistod rod

Since $\lambda < \lambda 0$, then the critical (breaking) force must be calculated with the Tetmajer line (the short column theorem):

$Ft = FNy\,.nF$ $\quad\quad\quad\quad$ $Ft =$ 628,320 [N] = 628.32 [kN]

References

- https://www.duttacontrol.com/unseries.html
- https://www.atos.com/marketing/EN/KTC19.pdf