Chapter 7:

The pneumatic cylinder – part 1

HAFNER pneumatik

In the earlier chapters we looked at the basic design of a pneumatic system and its most important elements:

- Air preparation
- Control valves
- Flow-regulators
- Actuators / cylinders
- Tubes and fittings

In this chapter we will be looking at **pneumatic cylinders**. **Cylinders are the most important means of actuation in pneumatics.** The cylinder transfers the energy that is stored in the compressed air into movement.

They can be classified by:

- **Design**
  - Cylinders with piston rods
  - Rodless cylinders
  - Diaphragm cylinders
  - Rotary cylinders
- **Movement**
  - Linear
  - Rotary = turning
- **Function**
  - Single-acting
  - Double-acting
  - 3- or 4-positions
- **Cushioning**
  - Adjustable, pneumatic cushioning
  - Flexible cushioning
  - Without cushioning

There is a very wide variety of pneumatic cylinders. In this training we will only focus the most common ones.

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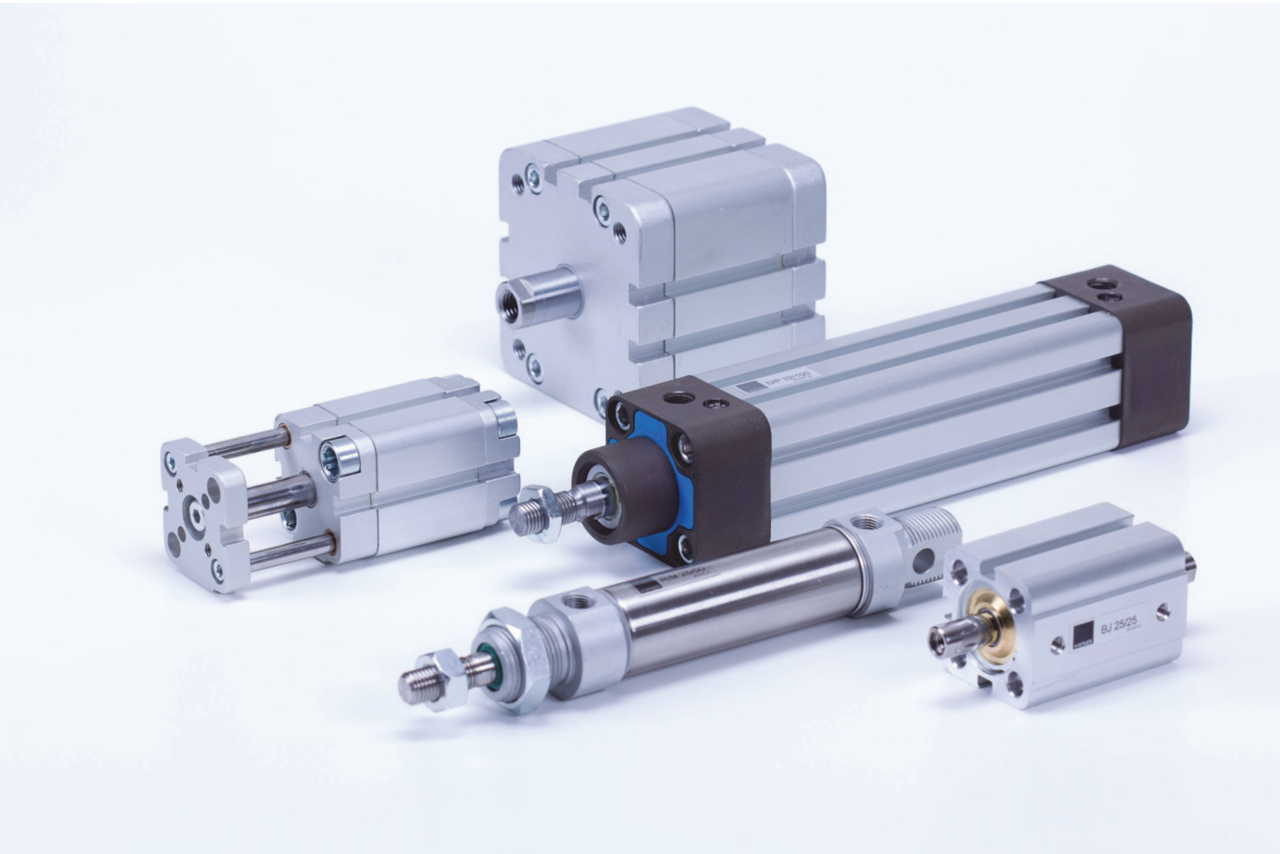
Cylinders with piston rods

Cylinders are available in different types and follow different international standards. Besides the ones that follow standards there are also “non-standardized cylinders”. Especially before the standardization into DIN/ ISO norms 6431 and 6432, there were numerous cylinder-types offered by different manufacturers.

Common standard cylinders are:

- Mini cartridge cylinders
- Round cylinders | DIN ISO 6432
- Profile cylinders | ISO 15552 | VDMA 24562 | (old norm: DIN ISO 6431)
- Compact cylinders | ISO 21287 | UNITOP
- Short stroke cylinders
- Tie rod cylinders | ISO 15552



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We will look at the following characteristics:

1. Design
2. Diameter and stroke
3. Movement
4. Number of positions
5. ISO symbols
6. Cushioning → chapter 8
7. Detection of cylinder position (magnetic) → chapter 8
8. Speed control → chapter 8

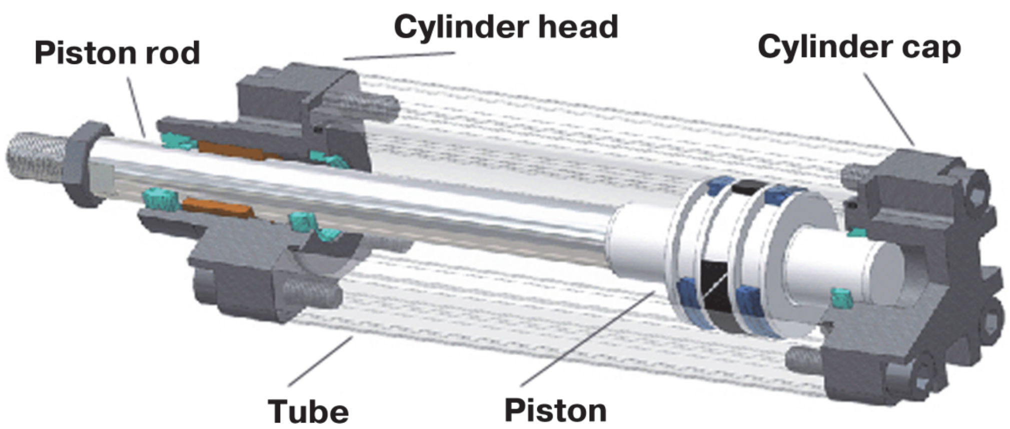
1. Design of a cylinder

Most of the cylinders with a piston rod contain the following parts: **a tube** that is closed **on both ends with a cap and head.** Inside the tube seen below a piston rod moves with a drive piston.

The movement of the piston is triggered by compressed air, controlled by a directional valve. The **direction** is defined by the chamber into which compressed air is allowed to flow inside the cylinder.

The force is transferred by the piston rod.

Components of a piston rod cylinder:



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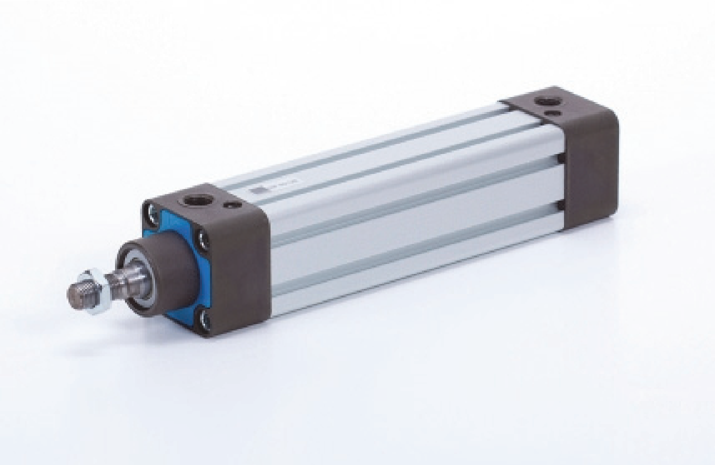
2. Diameter and stroke

Diameter and stroke are the most important attributes of a cylinder.

e.g. HAFNER Cylinder DIP: **DIP 40/320**



Type numbering system:

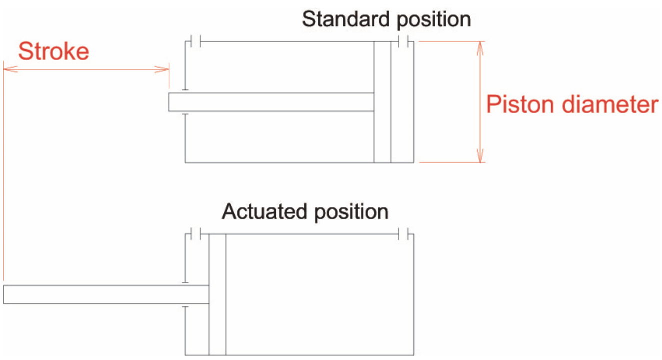
- **DIP** – type of cylinder / design

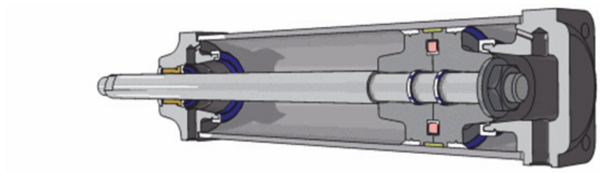
  (*DIP = ISO 15552 standard – double-acting cylinder – adjustable cushioning – magnetic piston*)

- **40** – diameter of the piston [mm]
- **320** – stroke of the cylinder [mm]

The **diameter** is actually the diameter of the piston. The diameter of the cylinder defines its force relative to the air-pressure.

The **stroke** tells us how many millimetres the piston and therefore the piston rod can travel.





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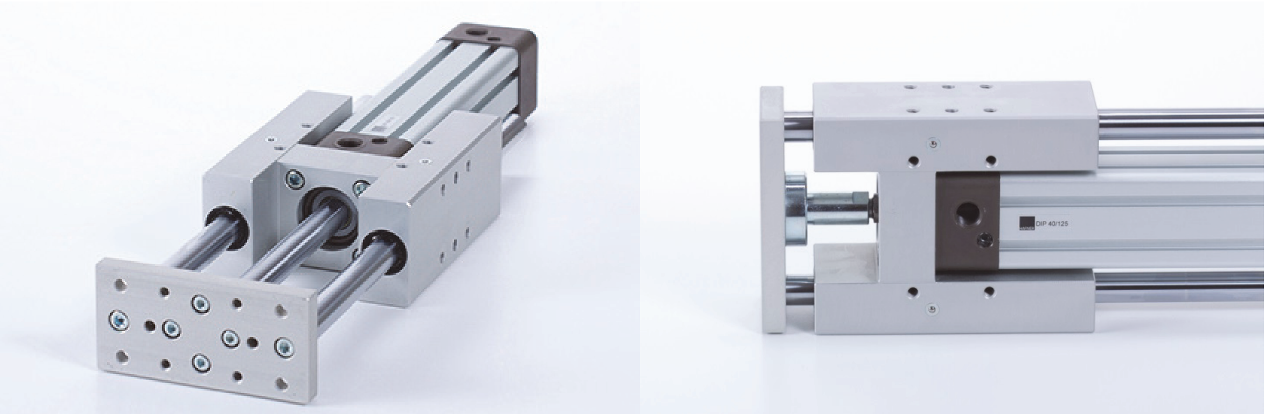
If the stroke is long, the forces on the bearing between head and piston rod are high. In order to avoid a defect we recommend to select a larger diameter (cylinders with larger piston diameters also offer larger piston rod diameters).

In case of very long strokes or radial forces we recommend the use of a guide unit.



Pictures: DIP cylinder with assembled guide unit

Diameters and strokes are standardized, the most common values are:

Piston diameters [mm]:
| ⌀8 | ⌀10 | ⌀12 | ⌀16 | ⌀20 | ⌀25 | ⌀32 | ⌀40 | ⌀50 | ⌀63 | ⌀80 | ⌀100 | ⌀125 | ⌀160 | ⌀200 | ⌀250 | ⌀320 |

Stroke lengths [mm]:
| 5 | 10 | 15 | 20 | 25 | 30 | 40 | 50 | 60 | 80 | 100 | 125 | 160 | 200 | 250 | 320 | 400 | 500 | ...

The available diameters depend on, and are limited by, the type / standard. The availability of strokes on the other hand is less limited.

The maximum force generated by a cylinder depends on:

- **Operating pressure**
- **Diameter of the piston**
- **Friction of the inner parts**

As an example we calculate the force of a cylinder DIL 40/320 at 6 bar.

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Piston diameter:

$$d = 40 \text{ mm}$$

Surface of drive piston:

$$A = \frac{d^2 \cdot \pi}{4} = \frac{40(\text{mm})^2 \cdot 3{,}14}{4} = 1256 \text{ mm}^2$$

Operating pressure:

$$p = 6 \text{ bar} = 0{,}6 \frac{\text{N}}{\text{mm}^2}$$

Calculation of the force:

$$F = p \cdot A = 0{,}6 \left(\frac{\text{N}}{\text{mm}^2}\right) \cdot 1256 \left(\text{mm}^2\right) = 753{,}6 \text{ N}$$

Thus we have a theoretical force of 753,6 N.

As a rule of thumb we can deduct 5% for friction. Therefore a cylinder with a piston diameter of 40 mm, and an operating pressure of 6 bar, **can exert a force of approx. 716 N**.

$$\frac{716 \left(\frac{\text{kg} \cdot \text{m}}{\text{s}^2}\right)}{9{,}81 \left(\frac{\text{m}}{\text{s}^2}\right)} = 72{,}98 \text{ kg}$$

If we divide the force by gravity (9,81 m/s^2), we find - in practice - that our cylinder can hold a mass of about 73 kg.

CAUTION! We can only hold the weight with this force, we cannot move it yet!

If we want to move a weight we have to (again) take gravity into consideration. Only then our cylinder is not only able to hold a weight but to perform work.

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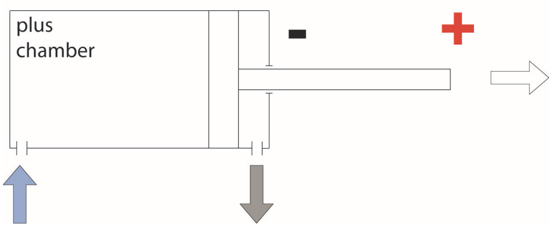
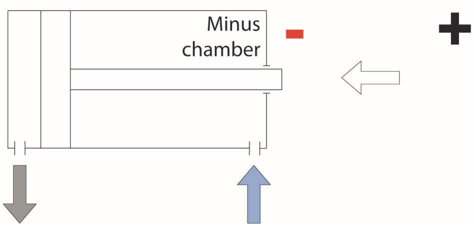
3. The Movement of a cylinder

We call the two end-positions of a cylinder **positive** / **plus** and **negative** / **minus** positions.

Therefore we also call the two chambers inside the cylinder the plus and the minus chamber.



Positive movement



Negative movement

The position where the piston rod is out of the cylinder the furthest possible is called the **plus end-position**. In order to reach it, the **plus chamber** needs to be inflated.

The **minus end-position** is positioned on the opposite side; **the minus chamber** needs to be inflated.

The cylinder cannot reach an end-position if the opposite chamber is not fully exhausted!

4. Stable positions of a cylinder

We distinguish between **single-acting and double-acting** cylinders.

In **single-acting cylinders** only one chamber is inflated with compressed air. Therefore work is performed only in one direction by compressed air. For the movement into the opposite direction a **mechanic spring** is the source of energy. The stroke is limited by the length of the spring. In general single-acting cylinders offer a relatively short stroke.

Two different types of single-acting cylinders are available:

Single-acting cylinder **with base position minus** (*spring between head and piston*)

Single-acting cylinder **with base position plus** (*spring between cap and piston*)

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Double-acting cylinders are driven in both directions by compressed air. They are always used when work has to be performed in both directions **or** when the required stroke is longer than the available springs.

There are different designs for different applications:

- **Double-acting cylinder**
  (*standard design*)

- **Double-acting cylinder with through piston rod**

  (*Cylinder has a piston rod on both ends*)

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- **Double-acting cylinder, guided / non-rotating rod**

  (integrated guide unit for higher radial forces)

- **Cylinders with non-rotating piston rods**

  (*If the application does not allow a rotation of the piston rod, either a rod that does not have circular cross section or a double piston-rod is in use)*

- **Multi-position cylinders**

  (*Two cylinders are assembled back to back. Thus 4 different strokes with different lengths are possible.)*

- **Tandem cylinder**

  (*Target: Higher force of the cylinder without increasing its diameter. In order to achieve this, two or more cylinders are connected to each other so that their piston rods are connected as well and working in line. In other words several pistons use the same piston rod. Thus the force adds up.)*

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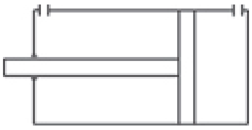
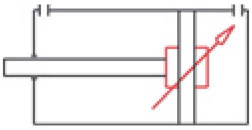
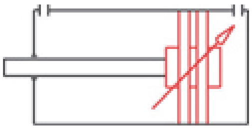
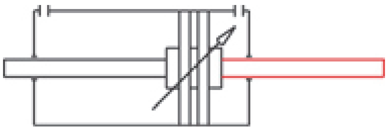
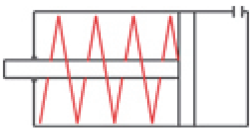
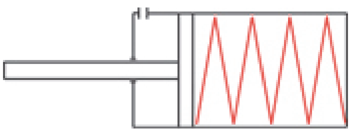
5. ISO symbols

In order to distinguish between cylinders, there are also well defined ISO symbols and schemes indicating their different functions. These do not however indicate their size, diameter, stroke, ISO-standard etc.

Double-acting cylinder („**standard design**“)		
Double-acting cylinder with **magnetic piston**		*The piston is different from figure 1, indicating the magnetic piston.*
Double-acting cylinder with **adjustable cushioning**		*Cushioning symbolized by two rectangular objects; arrow for „adjustable“.*
Double-acting cylinder with **adjustable cushioning and magnetic piston**		*Combination of figure 2 and 3.*
Double-acting cylinder with **through piston rod, adjustable cushioning and magnetic piston**		*The through piston rod is added.*
Single-acting cylinder (**MINUS**)		*Single-acting cylinder with spring in minus chamber*
Single-acting cylinder (**PLUS**)		*Single-acting cylinder with spring in Plus chamber*

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We introduced the following expressions:

- Cushioning
- Magnetic piston

Their explanation will follow in the next chapter. Just to give you a short insight:

- The **adjustable cushioning** slows the cylinder down when the piston is entering either head or cap. The idea is to avoid a hard shock when the piston hits these elements.
- The **magnetic piston** is required if we want to check the positon of the piston with a REED-switch. The switch is added onto the outside of the cylinder. When the piston travels by, the switch sends a signal.

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