Basic knowledge

Centrifugal pumps

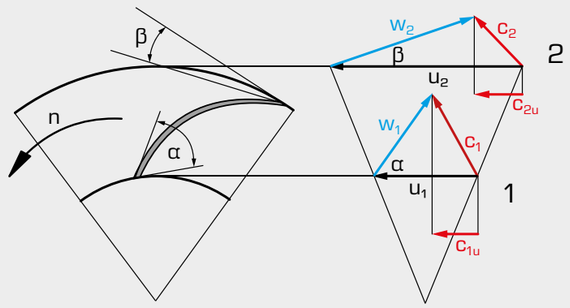
Fundamental principles of centrifugal pumps

In centrifugal pumps the energy is transferred hydrodynamically. This is in contrast to the hydrostatic transfer of energy in positive displacement pumps. In the hydrodynamic transfer of energy the fluid is accelerated by the impeller of the centrifugal pump. Therefore, the impeller of the centrifugal pump has to move with high velocity and thus a high rotational speed. The work Y_i transferred to the fluid is calculated from the velocities at the impeller.

$$Y_i = (c_{2u} \cdot u_2 - c_{1u} \cdot u_1)$$

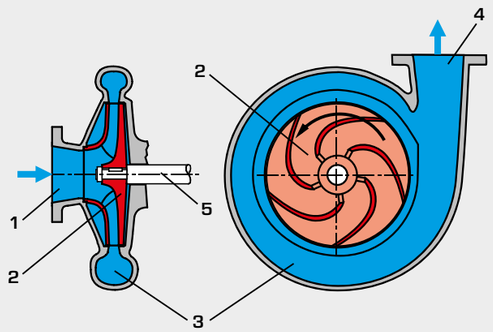
The specific work Y_i is independent of the fluid properties (density, viscosity). The flow rate **Q** and the density **ϱ** of the fluid together give the power P_i transferred from the impeller to the fluid.

$$P_i = \varrho \cdot Q (c_{2u} \cdot u_2 - c_{1u} \cdot u_1)$$



The velocities at the impeller inlet (1) and at the impeller outlet (2) can be clearly represented in velocity triangles.

1 entry of the flow, **2** outlet of the flow,
u peripheral speed, **w** relative speed of the fluid in the impeller,
c absolute velocity of the fluid,
c_{1u}/c_{2u} circumferential component of the absolute velocity,
a, b angle between the velocities, **Q** flow rate,
ϱ density, **n** rotational speed



The main components of a centrifugal pump

1 inlet, **2** impeller, **3** spiral housing, **4** outlet , **5** impeller shaft

Advantages of centrifugal pumps

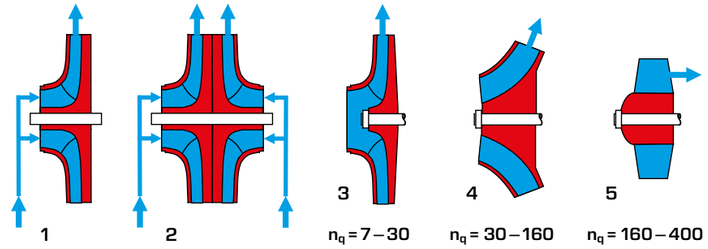
- simple design, few moving parts, long service life
- flow rate easily adjustable via valve at the outlet of the pump or via rotational speed
- high speed, direct drive via electric motor or turbine possible
- built-in pressure relief, no safety valve needed
- quiet running thanks to good mass balancing and lack of oscillating masses
- continuous, pulsation-free delivery
- solids may be carried along with the flow
- suitable for large powers
- high power concentration and smaller space

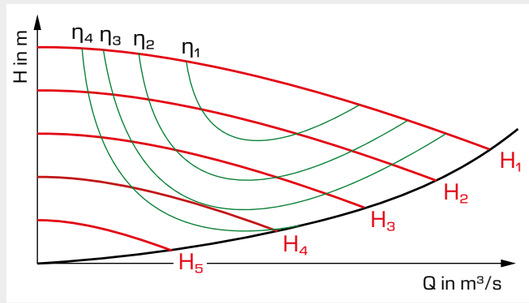
Disadvantages of centrifugal pumps

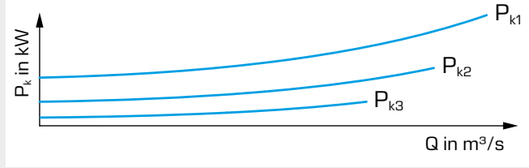
- not self-priming (special types such as side channel pumps may also be self-priming)
- risk of cavitation with warm water or low intake pressures
- flow rate is dependent on the delivery pressure
- several stages necessary at high delivery pressures

Design features of centrifugal pumps

- number of stages: single-stage, multi-stage
- open / closed impeller
- **1** single-suction / **2** double-suction impeller
- flow through the impeller
  3 radial, **4** diagonal, **5** axial







$H_1 \ldots H_5$ pump characteristics depending on the speed,
$\eta_1 \ldots \eta_5$ efficiency depending on the speed,
system characteristic;
$P_{k1} \ldots P_{k3}$ coupling power depending on the speed

Characteristic zone of centrifugal pumps

The characteristic values of a centrifugal pump are plotted in a characteristic zone over the flow rate **Q**. The main characteristic is the head **H** or the delivery pressure **p**.

The lines of equal efficiency **η** are also entered in the characteristic zone.

Another important representation is the plot of the coupling power P_K and the **NPSH** over the flow **Q**.

Important physical laws in centrifugal pumps:

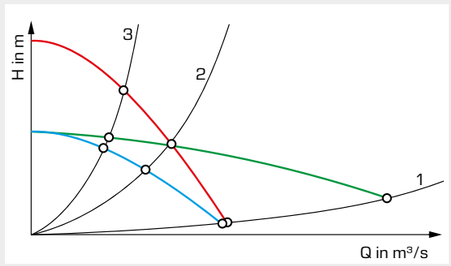
- the flow rate **Q** is linearly dependent on the speed **n**. $Q = f(n)$
- the head **H** is dependent on the square of the speed **n**. $H = f(n^2)$
- the power P_K is dependent on the third power of the speed **n**. $P_K = f(n^3)$

$$n_q = n \cdot \frac{Q^{1/2}}{H^{3/4}}$$

The similarity of different pumps is described by the dimensionless characteristic of the specific speed n_q.

Operating behaviour and operating points of centrifugal pumps

At the operating point the delivery pressure generated by the pump is in equilibrium with the resistance of the pipe network at a certain flow rate. The operating point is where the pump characteristic intersects the resistance characteristic of the pipe network.



Pump characteristics

single pump,
two pumps connected in series,
two pumps connected in parallel;

Pipe network characteristics

1 system with low resistance,
2 system with medium resistance,
3 system with large resistance