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 \( W \) transferred to the fluid is calculated from the velocities at the impeller:

\[
W = \rho \cdot Q \cdot (c_2u_2 - c_1u_1)
\]

The specific work \( W \) is independent of the fluid properties (density, viscosity). The flow rate \( Q \) and the density \( \rho \) of the fluid together give the power \( P \) transferred from the impeller to the fluid:

\[
P = \rho \cdot Q \cdot (c_2u_2 - c_1u_1)
\]

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

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 \( \eta \) 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 \( n \).
- The head \( H \) is dependent on the square of the speed \( n \).
- The power \( P_k \) is dependent on the third power of the speed \( n \).

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

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.