HI-SMART: HIGHER EDUCATION PACKAGE FOR NEARLY ZERO ENERGY AND SMART BUILDING DESIGN

MODULE #3

CHAPTER 3: PUMPING STRATEGIES

Co-funded by the Erasmus+ Programme of the European Union

3.3.1 BASICS OF THEORY

PUMPS

The main function of flow engineering machines is to transport liquid or gas in an open or closed system. The grouping of flow machines is shown in Figure 3.3.1.

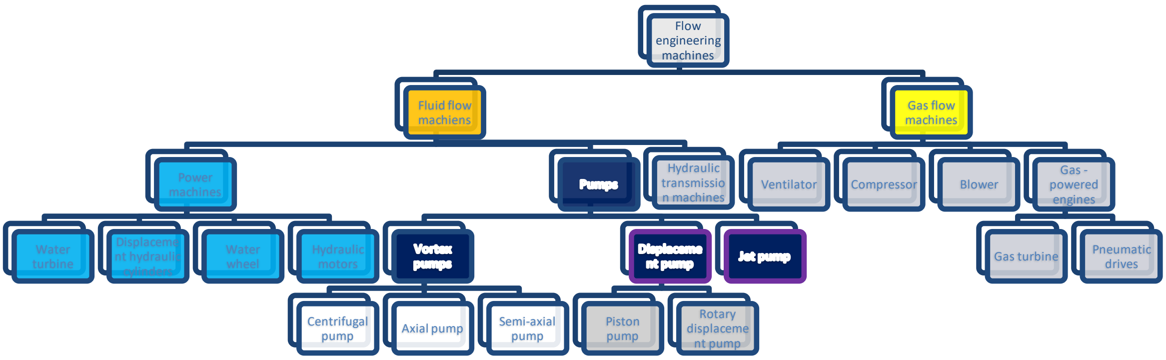

Figure 3.3.1 Flow engineering machines

In building engineering practice, we use pumps and, in the case of refrigeration equipment, a compressor. In the latter case, however, the compressor is housed in a prefabricated product. However, in the case of pumps, it is an engineering task to select the right machine for the job. In most cases, we use a vortex pump in buildings. In the following, we examine the devices belonging to this family of flow engineering machines.

USE OF PUMPS IN BUILDING SERVICES

As I mentioned, vortex pumps are typically used in building services practice. There are three main types of vortex pumps.

Centrifugal pumps: The basis of the operation of a centrifugal pump is the centrifugal force: its most important component is the turntable, the blades of which accelerate the liquid entering the pump housing by means of the centrifugal force. It is actually two parallel discs with curved or straight blades between them.

The increasing speed also results in increasing kinetic energy in the pump housing pressure converted into energy, it provides the right energy to move the fluid. In addition to the turntable, the shaft, auger housing, gland and suction and discharge port are important components of the centrifugal pump. In one type, a centrifugal pump with a radial flow impeller, the fluid at increasing speed is radially moves on the impeller blades. The most commonly used type in building services systems.

Axial, Semi-axial pumps: The axial pump is the most widely used equipment after the gear pump. They range from machine tools to impeller drives for agricultural machines. They are widely used due to their high operating pressure (45 MPa), favorable overall efficiency, long service life and excellent operational safety. Their defining characteristic is that the pistons forming the working space are most often located on the circumferential surface of a cylinder, less often on a cone with a half-opening angle of not more than 45 °. The construction of the pump and the hydraulic motor are basically the same. The axial piston pump can have a constant or variable displacement.

Pumps typically operating in buildings are centrifugal pumps. Pumps are most commonly used for three main types of tasks: heating and cooling systems; sewage and rainwater systems; pressure boosting, fire water networks.

Figure 3.3.1 Types of centrifugal pumps

3.3.2 OPERATION OF CENTRIFUGAL PUMPS

The basis of the operation of a centrifugal pump is the centrifugal force: its most important component is the turntable, the blades of which accelerate the liquid entering the pump housing by means of the centrifugal force. It is actually two parallel discs with curved or

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straight blades between them. Due to the increasing speed, also increasing kinetic energy in the pump housing is converted into pressure energy to provide the right energy to move the fluid. In addition to the turntable, an important part of the centrifugal pump is the shaft, worm housing, gland and suction and discharge port. In one type, a centrifugal pump with a radial flow impeller, the increasing velocity fluid moves radially through the impeller blades.

The liquid entering the intake manifold passes between the vanes and then accelerates into the conduit through the discharge manifold. As new liquid is constantly flowing in place of the outgoing liquid, the liquid is transported continuously. If the suction and discharge nozzles of the same diameter are connected to the centrifugal pump, the velocity of the suction and discharge liquid will be the same. The centrifugal pump is not self-priming; thus, the pump housing must be filled with liquid before starting.

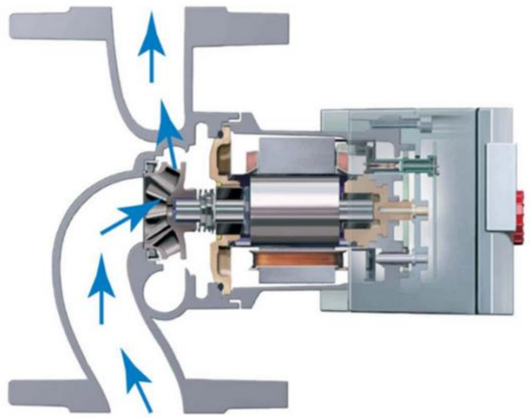


Figure 3.3.2 Centrifugal pump [wilo.com]

A vortex pump is a type of pump into which fluid enters the impeller axially. Pumps are needed to move fluids and overcome losses due to flow resistances in the piping system. In addition, geodetic height differences must be overcome for pump installations at different heights. Vortex pumps are hydraulic flow engineering machines according to their construction and method of energy conversion. Although there are many different pump designs, what all vortex pumps have in common is that the fluid enters the impeller axially. An electric motor drives the pump shaft on which the impeller sits. Water, which enters the impeller axially through the intake manifold and the intake manifold, is guided by the radial movement of the impeller blades. The centrifugal forces acting on the liquid particles increase the pressure as well as the velocity as it flows through the impellers. After leaving the impeller, the liquid collects in the pump housing. Due to deflections due to the construction of the housing, the flow rate decreases slightly again. The energy conversion further increases the pressure

TYPES OF CENTRIFUGAL PIPES

WET SHAFT PUMP:

By installing a wet shaft pump, either in the flow or return branch, the water can be moved quickly and intensively. In this case, a pipe with a smaller pipe cross-section can be used. The costs of the heating system will thus be lower. This will result in significantly less water in the heating system. The heating can react faster to temperature fluctuations and is more controllable. Features The vortex pump impeller is characterized by radial acceleration of the water. The impeller drive shaft is stainless steel. The bearings on this shaft are made of sintered carbon or ceramic. The motor on the shaft rotates in the transported medium. Water lubricates the bearing and cools the engine. The live stator of the motor is separated by a separation tube. It is made of non-magnetizable stainless steel or carbon fiber material with a wall thickness of 0.1 ... 0.3 mm. Constant speed motors are used for special purposes (e.g. in water supply systems). If the wet shaft pump is used in a heating system, i.e. to supply heat to radiators, it must be adapted to the changing heat demand of the house. Depending on the external temperature and the external heat source, different amounts of heating water are required. The volume flow is determined by thermostatic valves installed in front of the radiators. The motors of wet shaft pumps can therefore be switched to several speeds. This speed change can be performed manually, with switches or plugs. This can be automated with external switching or control systems that control as a function of time, pressure difference or temperature. Since 1988, there has been a design with built-in electronics that continuously regulates the speed. The electrical connection of wet shaft pumps is possible for 1 ~ 230 V single-phase or 3 ~ 400 V three-phase mains, depending on the size and the required pump power. Wet shaft pumps stand out for their very smooth running and, due to their design, do not have a shaft seal. Today's generation of wet shaft pumps are built on the building block principle. Each type is assembled variably according to the size and the required pump power. With this, any pump repairs that may be required can be carried out

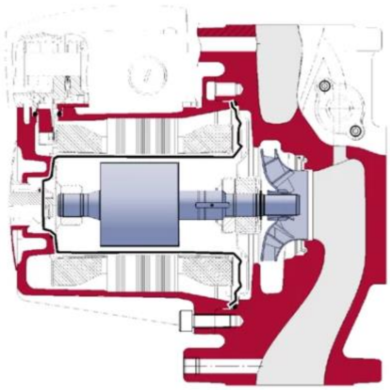


Figure 3.3.3 Wet shaft pump grundfos.com

easily by replacing parts. An important feature of this design is its ability to self-vent during commissioning.

STANDARD PUMP

Dry-shaft pumps are used to deliver higher volume flows. Dry shaft pumps are also more suitable for conveying cooling water or aggressive media. Unlike wet shaft pumps, the fluid transported here does not come into contact with the motor. A further difference from a wet shaft pump is the seal between the water deflecting pump housing and shaft and the atmosphere. This is done with a gland or mechanical seal. The motors of standard dry shaft pumps are normal three-phase motors with a given basic speed. They are usually controlled by an external electronic speed change. Today, there are dry-shaft pumps with built-in electronic speed control, which are available for increasing motor power as technology advances. The overall efficiency of dry shaft pumps is significantly better than that of wet shaft pumps. There are basically three different designs for dry shaft pumps: Inline pumps If the suction nozzle and the discharge nozzle are in the same shaft and have the same nominal diameter, they are called Inline (straight-line) pumps. Inline pumps have an air-cooled, flanged standard motor. In building services, this form has spread to higher performances. These pumps can be built directly into the pipeline. On the one hand, the pipeline can be held with brackets, or on the other hand, the pump can be mounted on a base or on its own bracket. Block pumps Block pumps are single-stage low-pressure vortex pumps in block design with air-cooled standard motor. On the screw housing, the suction nozzle is arranged axially and the discharge nozzle is radially arranged. The pumps are equipped with an elbow support or motor foot as standard. Standard pumps With these axial inlet vortex pumps, the pump, clutch and motor are mounted on a common base plate and can therefore only be installed on a foundation. They are equipped with a mechanical seal or gland seal, depending on the medium supplied and the operating conditions. The nominal size of the pump is determined by the vertical pressure port. The horizontal intake manifold is usually one nominal size larger.

Figure 3.3.4 Standard pump grundfos.com

3.3.3 PUMP SELECTION (CLOSED SYSTEM)

To select pumps, we need to know the two main parameters of the system to be supplied: the flow rate to be delivered and the required lift height.

To determine the required flow rate for heating and cooling systems, we need to know the heat demand and heat load of the room or building. From the heat demand and from the thermal gradient of the heat supply system, the flow rate to be delivered can be clearly determined. To determine the head, the hydraulic resistance of the distribution network and the system elements in the network must be determined. Knowing the flow rate and the head, the required pump operating point is calculated, which allows us to choose the most suitable pump from the various manufacturers.

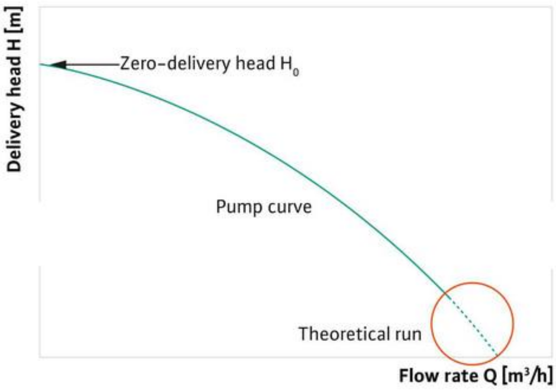


Figure 3.3.6 - Pump characteristic curve

The characteristic curve of each pump shows the lift head of the pump at a given flow rate (Figure 3.3.6). Figure 3.3.7 shows the characteristic curve of the same pump at different speeds.

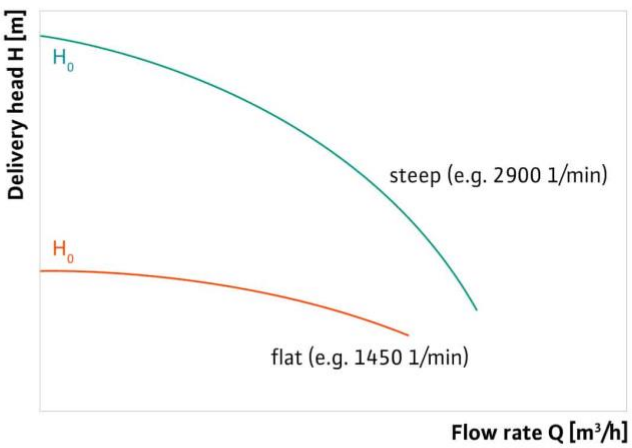


Figure 3.3.7 Pump characteristic curves at different speeds

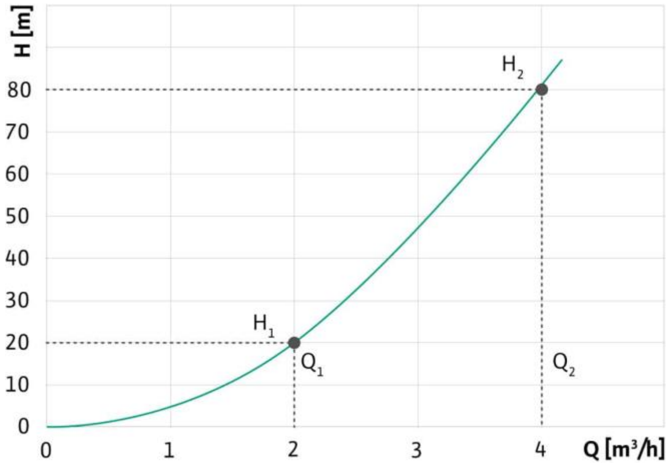


Figure 3.3.8 - System characteristic curve

Figure 3.3.8 shows the characteristic curve of a hydraulic system, which is an affine parabola. If the curve shown in Figure 3.3.8, i.e. the characteristic curve of the system, is combined with the characteristic curve of the pump, the duty point for the system with the selected pump is obtained. If you use a pump with a constant flow rate, then as you change the pressure in your hydraulic system (e.g. by closing valves), the duty point will move along the curve of the pump operating at the constant flow rate. Closing will, by definition, result in a larger pressure differential delta p at a lower flow rate. In this way we can set the desired flow rate, but the efficiency of our pump will be greatly reduced. Figure 3.3.9 shows an excellent example of this continuous control. You can see that in the upper case both thermostatic radiator valves are open. With this instantaneous setting, a

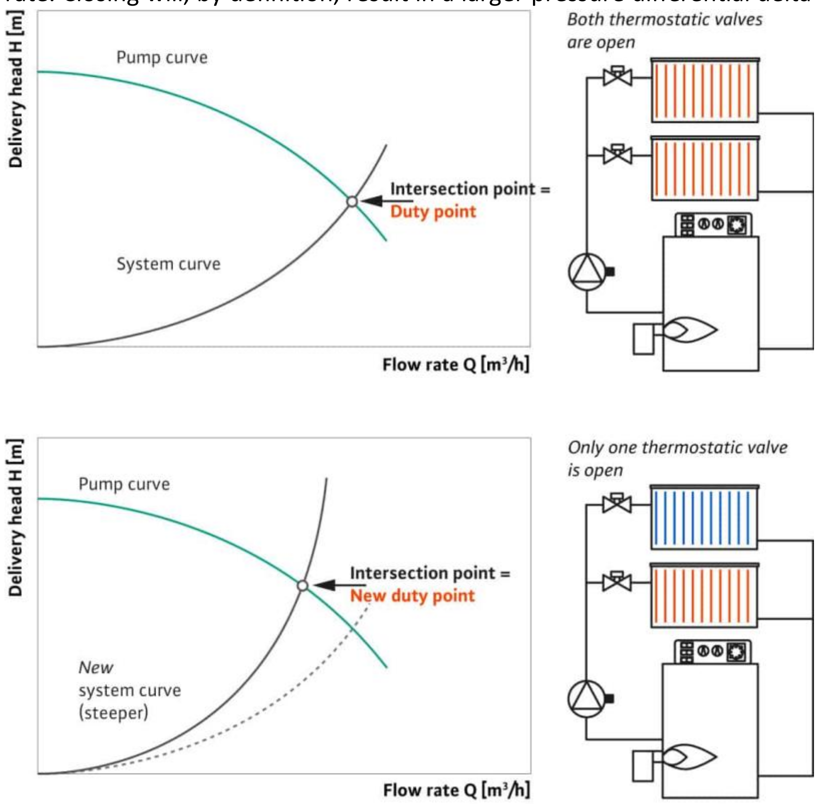


Figure 3.3.9 Duty point example

working point is formed at the intersection of the characteristic curve of our system and the pump. In the lower case, one of the valves closes, thus changing the characteristic curve of our system and forming a new intersection with the pump characteristic curve. This gives us a new working point.

PUMP REGULATION

The above example is not used today as a pump control mode because it has negative energy consequences. Nowadays, pumps with frequency inverter are used, which are able to reduce or increase the pump speed according to the current needs. In this case, as already shown in Figure 3.3.7, a different slope curve will be generated for the same pump, but the working point of our pump will shift along the affine parabola towards the lower or higher speed signal curve (Figure 3.3.10). In this case, the efficiency of our pump will remain within the theoretically well-dimensioned high range of the original working point.

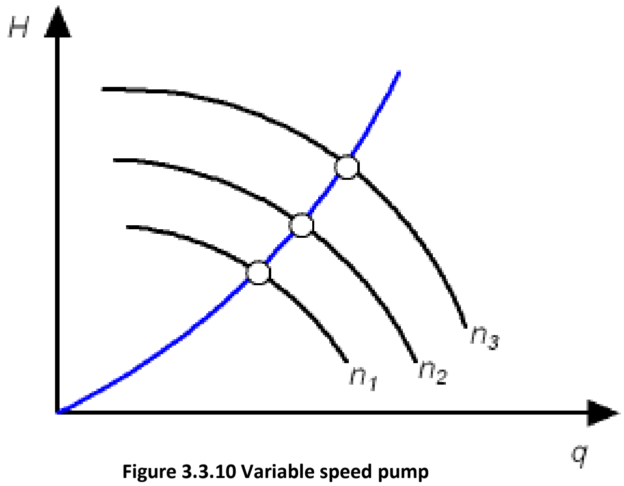


Figure 3.3.10 Variable speed pump

We also distinguish between constant differential pressure control, variable differential pressure control and constant/variable differential pressure control. In the constant case, the differential pressure established by the pump is maintained by the electronics at a constant value, the set differential pressure at the set differential pressure base signal, within the permissible range of the volumetric flow up to the maximum characteristic curve. In the case of a varying differential pressure, the electronics will vary the differential pressure baseline to be maintained by the pump, e.g. linearly between H and ½ H. The differential pressure H base signal increases or decreases with the flow rate. For constant/variable control In this case, the differential pressure established by the pump is kept constant by the electronics up to a certain flow rate (H 100 %). If the flow rate decreases further, the electronics change the differential pressure to be maintained by the pump, e.g. between H 100 % and H 75 %, in a linear fashion.

OPERATION EXAMPLES OF A PUMP IN A HEATING SYSTEM

In heating systems, and of course also in cooling systems, several pumps may be operating simultaneously. If we consider the relationship between the individual pumps, there are two basic cases. In the first case the pumps are connected in series, in the second case they are connected in parallel. In many cases, this may be a system design feature, which is avoided by design, e.g. by using manifold without differential pressure, or by separating the primary and secondary circuits by means of a hydraulic separator. In many cases, however, the two typical pump connections are deliberately used.

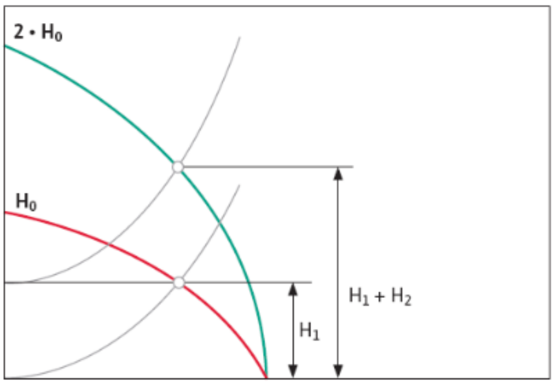


Figure 3.3.11. Pumps connected in series

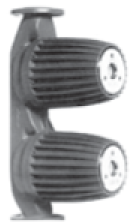


Figure 3.3.11 shows pumps connected in series. In this case, as can be seen in the system diagram, the lift of each pump is added together while the flow rate delivered remains constant. This can occur when there is not enough differential pressure in the system but the flow rate is sufficient. It is important to note that it is recommended to use only the same type of pumps to avoid adverse interactions between pumps. In many cases, this solution is referred to as a 'stimulating' pumping solution, which is typical of inadequately designed systems using the wrong specialist. Figure 3.3.12 shows parallel-coupled pumps, where the volume flows delivered add up to a constant value of lift height. This case is more common by design, especially for liquid chillers. It should not be confused with a stand-by pump, since in this case only one pump is in operation and the other is only a stand-by pump. In parallel operation, both pumps run simultaneously.

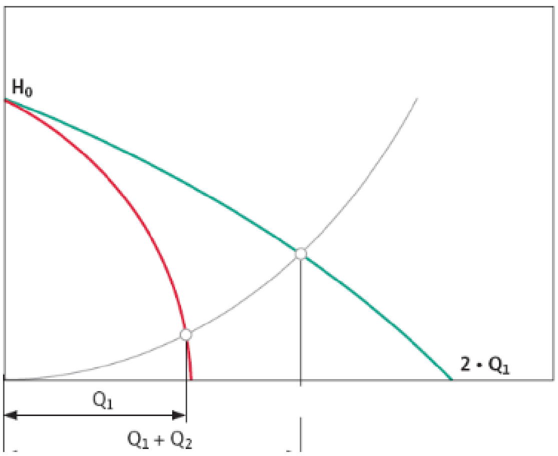
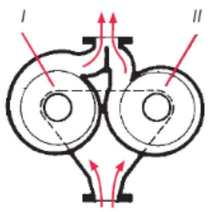


Figure 3.3.12 Pumps connected in parallel



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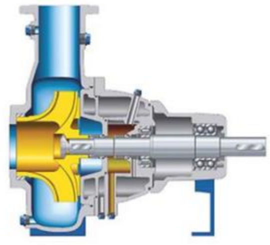
3.3.4 OTHER APPLICATIONS

Pumps are of course not only used in heating and cooling systems. In civil engineering, perhaps the other most important application of pumps is in wastewater pumping. Whenever possible, the waste water generated is discharged by gravity. However, in more extensive systems or in unfavourable terrain conditions, gravity drainage is not feasible and a pump must be used. Wastewater or rainwater is gravity-fed to the receiving manhole of the transfer pump, from where it is lifted from a lower ground level to a higher ground level. These systems are open systems with a variable quality and composition of the medium to be transported. As a result, these pumps are much more robust, stronger, more resistant and therefore more expensive than, for example, a heating pump of the same size. Figure 3.3.13 shows 1-1 examples of wastewater pumps of different designs.



Waste water pump: Horizontal waste water pump with channel impelle

Waste water pump: Submersible motor pump with single-vane impelle

Waste water pump: Submersible motor pump with guide wire arrangement

Figure 3.3.13 Waste water pumps

The other major area of pumping is pressure boosting. These systems occur in larger buildings where, for example, the high system pressure drop due to the height of the building means that the required pressure is not available above a certain level. For tower blocks this is a typical problem to be solved. Additional pressure boosting may be required, e.g. for internal fire-fighting networks, where the discharge pressure values set in the fire regulations of the country concerned must be maintained even for a wall hydrant in the most unfavourable location, or for sprinkler networks. For such pumps or groups of pumps, in most

Pressure booster system: Package system with four variable speed pumps, ready for installation

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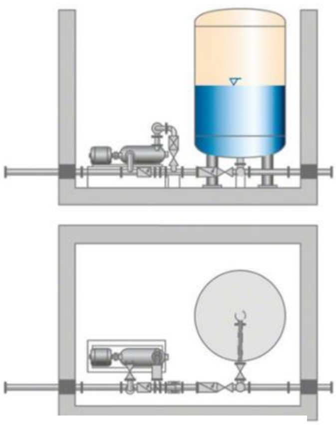

Figure 3.3.14 Pressure booster and fire protection pumps

cases an additional equalising tank is required to maintain constant pressure values. Figure 3.3.14 shows an example of these.

3.3.5 REFERENCES

Wilo, Grundfos and other manufacturer's brochure, and products