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A large market segment is the water and waste water treatment by means of dissolved air flotation where the multiphase pumps provide the task of air saturation without the use of compressed air.

Multiphase pumps for energy-efficient water and wastewater treatment

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Multiphase pumps are unique products with outstanding features compared to conventional centrifugal pumps. The approach consists of using the pumps not only for transport of liquids but also for partial gas supply and as dynamic mixer for gas enrichment. Therefore this novel pump conception barely has something in common with a standard pump. Even the mode of operation does no longer comply with the common doctrine: the multiphase pumps are slightly throttled at the inlet side, in order to get automatically sucked in gas contents.
With standard centrifugal pumps this inevitably would result in cavitation.
Multiphase pumps are suitable for many processes. Gassing liquids that also need to be handled by pumps occur in many applications. A large market segment is the water and waste water treatment by means of dissolved air flotation where the multiphase pumps provide the task of air saturation without the use of compressed air.

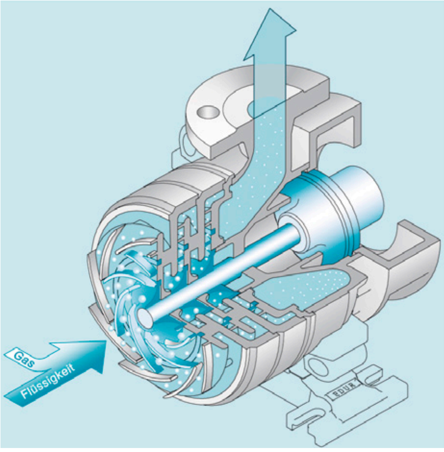

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Fig. 1: Sectional drawing of the pump hydraulics

Multiphase pumps are dynamic mixers performing two functions. On the one hand liquids are being enriched with gases, on the other hand these liquid-gas mixtures are being transported. At the same time during the pressure generation in the pump a blending and an excellent gas saturation occurs. By means of following retention lines this gas saturation can be further enhanced.

The multiphase pump only is required for the gas enrichment. Static mixers are omitted. The gas is supplied directly into the suction pipe line or into the inlet flange of the pump. The pump hydraulics itself then brings the gas contents into solution (Fig. 1).

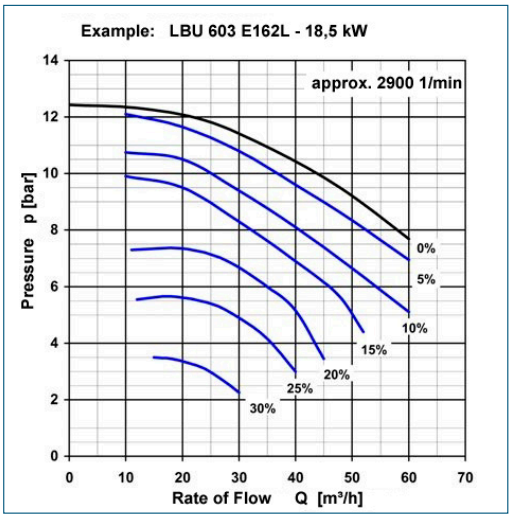

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Fig. 2: Characteristic curves of a multiphase pump – 18.5 kW

Some typical applications are:

- Dissolved air flotation with a pressure saturation system corresponding to VDMA Specification 24430 Edition March 2010
- Aeration (Bioreactors)
- Ozonation
- Oil-water separation
- Elimination of lime in the paper industry
- Mineral processing (like copper extraction)

The use of multiphase pumps provides a lot of advantages:

- The reduction of the system components and the simplification of the system design results in lower investment costs and higher operational reliability. Compared to conventional system designs compressors, pressure tanks and complex control are no longer required.
- The high efficiency improves the energy balance and reduces operating costs.
- High degrees of solution in terms of the utilised gases improve the yield of recyclable fractions.
- Good control characteristics and a wide range of application of the multiphase pumps lead to an operation that meets the requirements and avoids uneconomical method of operation.
- Process reliability is significantly increased.

Consequently the new pump conception amortises within a short period of time means that it is not only of interest for new plants but also for the retrofitting of existing plants.

Operating limits of centrifugal pumps

The usual purpose of centrifugal pumps is the transport of clean liquids. Unfortunately this ideal typical utilisation is rare under real operating conditions. It is frequently the case that the pumps also need to handle undissolved gases or vapours. On one hand the reasons may be internal to the plant, e.g. leaks in the suction pipe lines, insufficient coverage of the suction pipe line with liquid in open systems etc. On the other hand process-related requirements must also be taken into consideration. In many processing applications it is often the case that multiple phases of various media that need to be handled are present simultaneously.

Typically liquids need to be enriched with gases, liquid-gas mixtures are to be transported or gassing liquids are to be handled safely. Under such requirements the well-known non-selfpriming centrifugal pumps either fail or do not enable safe operation. Basically the failures here are caused by the design of the impeller. During increase of gas contents an increasingly more stable stationary gas area is formed in the area of the impeller hub that finally blocks the impeller inlet and interrupts the transport. The characteristic curve is no longer stable, even at low gas contents. Consequently such standard pumps are not suitable for meeting the before mentioned operating conditions. The process automation in particular requires a controlled and trouble-free pump operation.

Gas contents influence

The pump hydraulics of a modern multiphase pump is designed also for safe handling of gases. Furthermore in case of separate supply of liquids and gases a good mixing of the two phases resp. a high degree of dispersion is achieved.

The pump characteristic is essentially determined by the gas contents in the pumped liquid. The gas contents influences the flow rate, the pressure and the required pump power input. Increasing gas contents tend to decreasing flow rates and pump pressures but also to decreasing pump power input (Fig. 2).

Gas handling percentages of up to 30% are achieved without that the pumps are stopping operation. With regard to the process it is of advantage that the entire pump characteristic curves can be run with stable operating conditions.

Operation as a dynamic mixer

By doing so multiphase pumps provide the gas enrichment of liquids. The gas is supplied into the suction pipe line or directly into the inlet flange of the pump. If the pressure of the available gas is below that of the separate available liquid, the pump only has to be throttled at the suction side.

Increase of gas pressure is omitted. The pump operates as dynamic mixer as due to the rota-

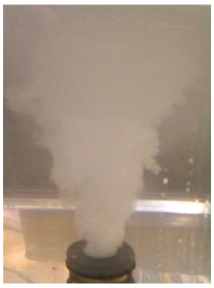


Photo: EDUR

Fig. 3: White water

tion of the special impellers, the gas content is passed into a solution depending on the adopted operating conditions.

During the pressure build-up in the pump a mixture and excellent air saturation takes place. This air saturation effect can be increased even more by downstream solution lines.

Multiphase pumps can not only be used for the transport of liquids, they can also be used for the transport of liquids with gases and gas enrichment.

Multiphase pumps cannot only be used for transport of liquids but also for partial gas supply and as dynamic mixer for gas enrichment.

Waste water treatment by means of dissolved air flotation

Dissolved air flotation (DAF) is a proven and well recognised procedure for the treatment of water and waste water and for the recovery of recyclables as well. It serves to simply separate substances that are suspended or emulsified in liquids. In doing so saturated water is released to atmospheric pressure with highly pressurised air and guided into the waste water tank. The micro bubbles that become free during pressure release do settle on the suspended materials and float them to the liquid surface. From here they are removed by skimming devices. Consequently, the particle stream is the opposite of known sedimentation process.

The cleaning result is significantly determined by two influence factors: the size of the micro bubbles and the amount of gas.

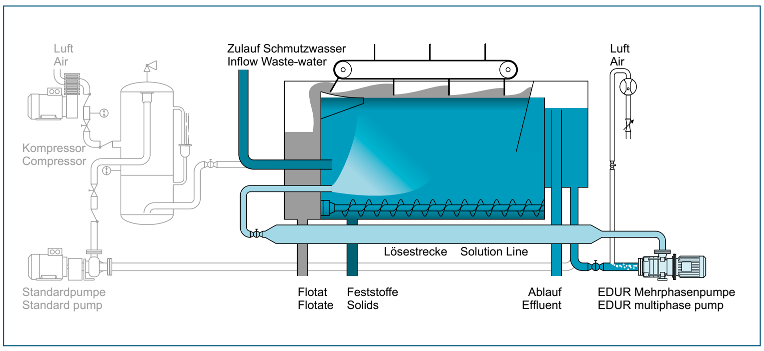
Fine and homogeneously dispensed micro bubbles must be created in order to collect as much floating substances as possible. Depending on the waste water quality and the saturation pressure, dispersions with bubble sizes of between 30 and 50 µm successfully achieve an ideal cleaning result. Smaller bubbles do reduce the rising speed too much whereas larger bubbles do disturb the formation of flotate (Fig. 3).

The maximum solubility of air in water essentially depends on the saturation pressure, the water temperature and the water quality. In combination with the other system components the degree of solubility of the supplied air amounts up to a maximum of 100%. The operating performance of the pump also remains stable even in case of changing flow rates and air contents enabling an exact pump control and adjustment to the regarding process.

Various gases with their specific characteristics are used depending on the particular application. For the correct pump selection the solubility of the gas in the regarding liquid is of utmost importance. As a result the solubility and therefore the level of gas feeding of air or oxygen is far below the values of carbon dioxide.

The special design of the multiphase pumps enables a direct gas input into the suction pipe line. As a result system components like compressors, pressure tanks, pumps, control devices and valves are not necessary compared to conventional systems (Fig. 4).

Typical fields of application include the treatment of oil/water emulsions, fat separation, phosphate precipitation and heavy metal precipitations as well as secondary clarifications in biological purification plants. Multistage flotation systems are also well-known for the treatment of special waste. Many plant manufacturers report that by the use of multiphase pumps savings are not only made with regard to investment volumes but also for the continuous operating costs that on average amount to between 30% and 40% compared to conventional systems depending on the plant type.



Source: EDUR

Fig. 4: System design

New construction and retrofitting of existing plants

Slaughter house waste water:

In addition to improved effluent values and a reduced utilisation of chemicals, users report of significant energy savings following the retrofitting of existing plants. For example by replacing two side-channel pumps by an optimised multiphase pump energy costs of the flotation plant installed in an abattoir have significantly been reduced.

The installed motor power was more than halved. Originally two side-channel pumps each with 7.5 kW motors for an operating point of 9 m3/h against 6.7 bar with 8.3% air contents each were in operation. The aim of these pumps was to separate fat and other contaminations from abattoir waste water that had already been pre-cleaned mechanically (pH value 7). Here the customer complained about an insufficient flotation effect (formation of bubbles) and an insufficient pump service life of two months only.

These pumps have now been replaced by one multiphase pump with a 5.5 kW motor for an operation point of 17 m3/h against 5 bar with approx. 15% air contents. Due to the improved formation of bubbles the effluent results have dramatically been improved. Furthermore the flotate is significantly more compact (Fig. 5). Additionally less flocculants are required. The pump service life instead of formerly 2 months now is prolonged to actually more than three years. The energy balance has also significantly improved (from a total of 2 x 7.5 kW = 15 kW previously to only 5.5 kW now). For 220 working days and a 16 hour operating period per day, this equates to savings of more than 3,500 € per year (at 0.10 € / kWh) on energy costs only. Consequently the retrofitting did amortise after only six weeks.

Municipal waste water treatment:

Since 1929 waste water from the city of Kiel and the connected surrounding communities has been pumped through long sewage outfall


Photo: EDUR

Fig. 5: Flotate

channels to the Bülk waste water treatment plant where it is treated and finally pumped into the Baltic Sea .

Each year approximately 20 million cubic meters of untreated waste water is pumped to the waste water treatment plant which corresponds to a connected value of approx. 310,000 inhabitants and 65,000 inhabitant equivalents (industrial and commercial).

During a retrofitting in 2011/2012 the downstream flotation that is used to treat the cleaning water of the cloth filters consisting of the conventional system with dispersion pumps, compressors and pressure tanks was modified to the redeveloped system. Four standard pumps were installed as dispersion pumps, each with 15 kW of motor power that feed the pressure tanks with recycling water at approx. 8 bar for air saturation. In order to perform the air saturation of the recycling water a pressure tank, two dissolving tanks and two compressors with 4 kW power were installed.


Photo: EDUR

Fig. 6: Municipal waste water treatment plant Bülk, Germany

The dispersion pumps, pressure tanks and compressors were replaced by three of the successful multiphase pumps, each with 5 kW of motor power whereby one of the three pumps serves as a standby pump (Fig. 6). All three components (dispersion pumps, pressure tanks and compressors) were replaced by multiphase pumps during the described retrofitting.

By throttling the pumps down to approx. –0,2 to –0,3 bar artificial vacuum at the suction side, the pumps suck the required air into the pumped liquid. The pumps simultaneously operate as dynamic mixer and, due to the increase of pressure to approx. 8 bar, achieve an excellent solution. This causes a fine-bubble dispersion of the pumped liquid during the pressure release which leads to an excellent flotation result.
By operating in three shift system during assumed 220 working days, the energy savings only amount to more than 100,000 € (at 0.10 € / kWh) annually.

Many municipal waste water treatment systems worldwide have been retrofitting to the new multiphase system (Fig. 7). All users report of similar savings.

Other projects

Limy circulation water in the paper industry:

In the paper industry calcareous deposits from the circulation water in pipes, cooling systems, heat exchangers, etc. are avoided by the use of lime traps. As a result the freshwater demand is significantly reduced and a sustainable improvement of the process reliability is achieved. The costs associated with repair and maintenance of the systems are also significantly reduced. Originally in a paper factory a partial flow of approx. 288 m^3/h was saturated with compressed air in a pressure reactor.

The fed quantity of compressed air was adjusted to approx. 400-500 l/min. For the flotation aeration a standard pump with 75 kW motor power (QN 288 m3/h, HN 6.5 bar, pump power input at QN approx. 68 kW) as well as a 7.5 kW compressor, a pressure reactor for the preparation of the air-water mixtures and a compressed air tank were conventionally installed.

Under the same operating conditions two multiphase pumps each 18.5 kW with air input in front of the pumps were installed. The results indicated a perfect operation of the lime traps at a flow rate of 45 m^3/h and a flow amount of 4 bar incl. approx. 20 % air as well as a pump power input of approx. 13 kW per pump. A total of 75.5 kW (motor and compressor) was required in the conventional system. In contrast no compressor is required since the multiphase pumps have been used. The pump power input of the two pumps amounts to 26 kW only.

Consequently the total motor power is reduced by 49 kW or remarkable 65.6%. At an energy price of 0.10 € / kWh and an annual operating time of 8,000 hours (three shift system), the annual energy savings amount to approx. 39,600 €. The energy-efficient reconstruction of the plant was amortised after approx. 5 months.

Renewable energy:
In the processing of regenerative energy carriers – such as biofuel, wood, waste fractions with high heat value, or animal meal – the inert CO_2 has to be washed out of the synthesic gas. A compressor forwards the gas into an absorption cell, where it flows ascendingly through a support medium aggregate. This aggregate is being sprayed from above with water that is conveyed by a multiphase pump. During this process the water is enriched with the CO_2 out of the synthesis gas. Afterwards the water is led into a desorption tank, in which most of the CO_2 will outgas. As this water is still saturated for 100 %, gas bubbles occur during priming, that however are soluted again by the multiphase pump – the circuit starts again.

Raw materials production:
It is historically proven that the flotation technology began with the production of raw materials. Most copper mining depends on crude ore


Photo: EDUR

Fig. 7: Municipal waste water treatment plant Ohio, USA

that is cracked, grinded in rock crushers and subsequently supplied towards the flotation. Fine air bubbles transport the small mineral particles to the water surface and keep them in the flotate. By means of the water-air mixture and adding of flotation additives at the same time the copper ore is separated from other ores. The ore concentrate subsequently is smelt in the following process.

Supreme process reliability, energy efficiency, the simplification of the plant concept and the associated reduction of plant components that are susceptible to problems and are maintenance-intensive result in a wide acceptance of the innovative multiphase concept.

Ammonia stripping plant:
Downstream the fertilizer production process a stripping system is installed and serves for reducing the ammonia nitrogen content and also the chemical oxygen demand (COD) in the process waste water to the standard values. Initially the waste water is fed into the tank near ground level. From there it is conducted into the multiphase pump where air is aspired along with the water and brought into solution under pressure. After pressure release the generated water-air mixture is delivered back into the tank through nozzles from above. Due to this sprinkling the ammonia releases gaseous from the waste water. It can be conveyed by a gas pipe to the fertilizer production process again.

Cooling water treatment by ozone:
The innovative conception of the multiphase pumps did lead to participation at seventh frame programme of the EC for research and technological development. Marine bio-fouling is a major problem for materials in constant contact with seawater. Accumulation of marine organisms has impact on the proper functioning of engines and further appliances on board that need constant und proper cooling, and on the safety of the vessels. The project comprises the development of a system for avoiding bio-fouling, by means of ozone improving the quality of the seawater for cooling the ship's engines and by this avoiding considerable maintenance costs and at the same time assuring a reliable operation of the seagoing vessels.

Crude oil-water separation:
Instead of hydro cyclones the separation of the mixture can also be performed using flotation technology and multiphase pumps. There is generally a significant amount of oil-water mixture when conveying crude oil. Flotation plants equipped with multiphase pumps separate the oil and water. The recovered oil is further processed and the water is sent back to the drill holes. However, in contrast to industrial applications, the multiphase pumps must be designed as super-duplex pumps for resistance reasons. The shaft sealing is executed according to the so-called API plan (API 682 / ISO 21049). Essentially, methane is used in place of ambient air in order to achieve separation.

Result

Supreme process reliability, energy efficiency, the simplification of the plant concept and the associated reduction of plant components that are susceptible to problems and are maintenance-intensive result in a wide acceptance of the innovative multiphase concept. Both the immense savings and the significantly lower running costs compared to the previous plant structure lead to extremely short amortisation times. Even the retrofitting of existing plants paid for itself after a short period of time.

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