Use of double hose-diaphragm pumps in Bayer process for alumina production

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Abstract

In alumina production processes, highly caustic bauxite slurries are pumped at high pressure into tubes or autoclaves for digestion at high temperature. Even today, production of alumina is based on the conventional Bayer process. Within this process, MULTISAFE double hose-diaphragm pumps are involved at several stages and reliably pump bauxite slurry (i.e. in plants of Russian aluminium giant Rusal), red mud and lime milk (i.e. as just ordered for the Emirates Global Aluminium (EGA) alumina refinery Al Taweelah). FELUWA pumps provide for environmentally friendly transportation of critical media at solids concentrations of up to 70 % with associated high efficiency as well as low wear and tear. The special design of MULTISAFE pumps offers decisive advantages compared to traditional diaphragm pumps. At the heart of MULTISAFE pumps are two hose-diaphragms which are arranged one inside the other. They fully enclose the product and provide double hermetic sealing from the hydraulic drive end. Thus, the slurry is in contact with the inside of the hose-diaphragm and check valves only, so that the heavy pump casings can be made from standard materials, which means considerable cost savings.

Keywords: Hose-diaphragms; energy efficiency; bauxite slurry; red mud disposal; alumina production

1. Introduction

Whereas bauxite mining is generally characterised by relatively low energy consumption, the further processes for transforming bauxite into alumina and further to aluminium are associated with a considerably higher energy demand. Nevertheless, the alumina industry has succeeded in an almost 10 % improvement in global refining energy efficiency in the course of the past years. The saving of energy is consequence of the implementation of advanced technologies and equipment with improved energy efficiency.

The actual energy requirement of the Bayer process is to a great extent dependent on the quality of the feedstock. It uses a recirculating volume of concentrated caustic solution to dissolve the alumina minerals, separate them from still solid impurities, and then re-precipitate alumina tri-hydrate. Calcining completes the transformation of the tri-hydrate to alumina. In this Bayer refining process of high temperature bauxites (typically those bauxites requiring a digestion temperature of 250 °C or greater), there is a process variant known as sweetening. It involves injecting an extra ~ 25 % of low temperature (gibbsitic) bauxite slurry into the flash down where the heated slurry is cooled to 105 °C (and the pressure reduced back to atmospheric) by allowing steam evaporation or flashing in a cascade of vessels. The alumina in the gibbsitic bauxite slurry dissolves rapidly in the high temperature stream, allowing the concentration of dissolved alumina in the liquor to be significantly higher than could otherwise be achieved by processing high temperature bauxite alone. In this way “sweetening” allows extra alumina to be produced from an existing high temperature plant for only a very small capital and operating cost increase (pro rata, far less than the alumina produced). [1].

Whereas sweetening digestion contributes to a noticeable saving of energy in terms of process technology, additional improvement is achieved by the implementation of energy-efficient equipment. Given that up to 30 % of the electricity consumption of alumina processing facilities is used by the high-pressure digestion pumping system and by motors of the ball mills, energy-efficient equipment is indispensable for such key applications. Positive displacement pumps are typically employed to pump the bauxite slurry into the digesters under high pressure.

2. Digester feed pumps

Hydraulically actuated piston diaphragm pumps are typically applied for digester feeding. However, the suitability of traditional piston diaphragm pumps is limited when it comes to the handling of aggressive or abrasive products, because not only the diaphragms but also entire pump chambers are in contact with the product. Aggressive fluid pumping, for example, requires wet ends made of high grade stainless or even duplex steels. Solids, which are carried by fluids, tend to settle in the lower pump area between diaphragm and clamping ring and often lead to premature diaphragm failure. In the event of a diaphragm failure with such pump types, the product automatically contaminates the hydraulic system, where it comes in contact with the sliding seals and cylinder surface. This can lead to considerable destruction and consequential damage and require significant man power and cost for cleaning and subsequent repair of pump and gearbox.

2.1. Double hose-diaphragm pumps

Combined hose diaphragm piston pumps offer substantial advantages compared to traditional piston diaphragm pumps. MULTISAFE double hose-diaphragm pumps (see Figure 1) represent the highest level of diaphragm pump technology with numerous advantageous features.

Figure 1. Seven sets of double hose-diaphragm pumps.

At the heart of MULTISAFE pumps are two hose-diaphragms which are arranged one inside the other (see Figure 2) and fully enclose the linear flow path of the conveyed fluid.

Simultaneously, they create a double hermetic sealing from the hydraulic drive end of the unit. Both hose diaphragms are actuated by the piston by means of hydraulic fluid. In step with the piston stroke, they are subject to pulsing action, comparable with that of a human vein. The cylindrical shape of the diaphragm favours the flow behaviour and avoids the settling of solids.

Figure 2. Arrangement of double hose-diaphragms.

Similar to the traditional piston diaphragm pump, double hose-diaphragms are likewise actuated by a hydraulic fluid and provide for the displacement action. One of the major advantages of this design is its linear flow path, so that it is especially beneficial to the handling of aggressive, abrasive and solids carrying fluids and slurries, even at high viscosity. Unlike traditional diaphragm pumps, hose-diaphragms do not require a clamping ring that leads to settling of solids. Figure 3 illustrates the principle of the hose-diaphragm pumps: As per the left side graph, the hose-diaphragm assumes a cylindrical shape at the end of the suction stroke, when it is completely filled with slurry, whereas it is subject to slight hydraulic compression during the discharge stroke, as illustrated in the right graph.

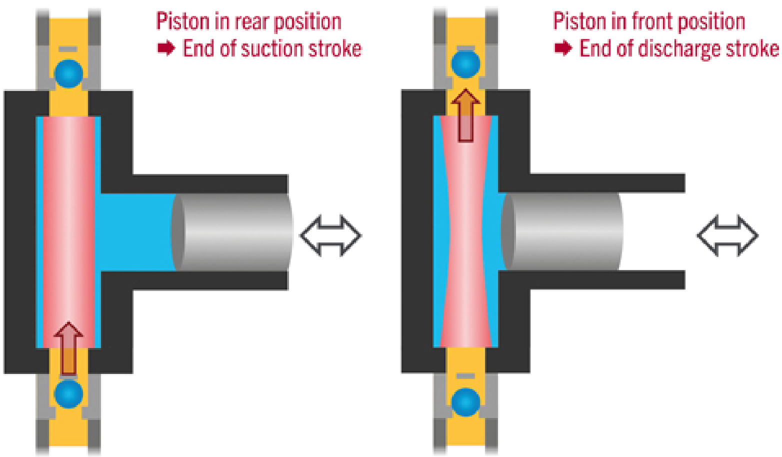

Figure 3. Working principle of double hose-diaphragm pumps.
Since inside and outside pressures of hose-diaphragms are identical, they are subject to hydrostatic load only. For this reason, hose-diaphragms are not considered as wearing parts.

2.1.1. Efficiency and availability

Availability and reliability are of utmost importance for owners and operators. Hence, the pumps should support and contribute to the continuous operation of the plant. Consequently, the plant operation should schedule shutdowns instead of inadequate equipment causing unplanned shutdowns.

Hose-diaphragm pumps ensure a high hydraulic efficiency of 97 % and provide for unique operating reliability. Even in the event that one of the hose-diaphragms fails, the second one reliably prevents leakage of fluids. No matter whether it is the inner or the outer diaphragm that is breached, the product neither comes in contact with the pump casing nor with the hydraulic drive area or the environment. This allows for a considerable reduction of wet end parts, and the pump casing has no need to be manufactured from expensive special materials that are resistant to the pumped materials (see Figure 4), and moreover, are more economical to manufacture.

Figure 4. Triplex configuration of double hose-diaphragm pump.

Double hose-diaphragm pumps are designed to avoid sudden deviance from admissible working conditions and unplanned downtime. They utilise an overall diagnostic system for permanent condition monitoring of essential components and parameters (see Figure 5).

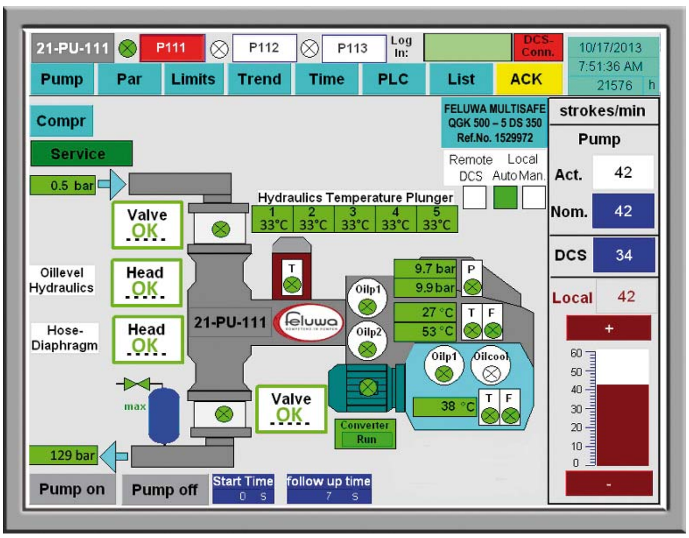

Figure 5. Touch panel for overall diagnostics, control and web-based service of two pump sets.

One of the criteria for condition monitoring is to recognise even the slightest indication of wear or any other variance from set-points early enough to permit the operator to closely monitor any further developments. This allows the opportunity to introduce preventative maintenance as appropriate to avoid unscheduled shutdown of the production line.

Since the leak-free sealing of check valves plays a decisive role, an innovative system for the early detection of wear in check valves has been developed for double hose-diaphragm pumps. The measuring principle of these purpose-built sensors is based on the analysis of solid-borne sound and is capable of detecting leaks between valve seat and ball or cone respectively, at a time when the loss of flow is still less than 1.5 %. Multiple options are available for the transmission of the measured results by means of a dry contact (such as Internet or Intranet). Intrinsically, this provides the operator the opportunity for well-directed advance planning of any required maintenance or repair action, as well as the precise determination of "mean time between repair" (MTBR)-values. As a decisive advantage, permanent condition monitoring of check valves avoids loss of energy. Any decrease in output resulting from valve wear is usually automatically compensated by the variable speed drive through increased pump speed. From the example calculation in Figure 6, it is evident that an assumed flow loss of 10 % as a result of valve wear equates to a loss of 250 kW per hour, for a pump with a flow rate of 300 m^3/h and a pressure of 10 MPa. Based on a rate of 0.07 USD per kilowatt-hour, this equals 420 USD per day.

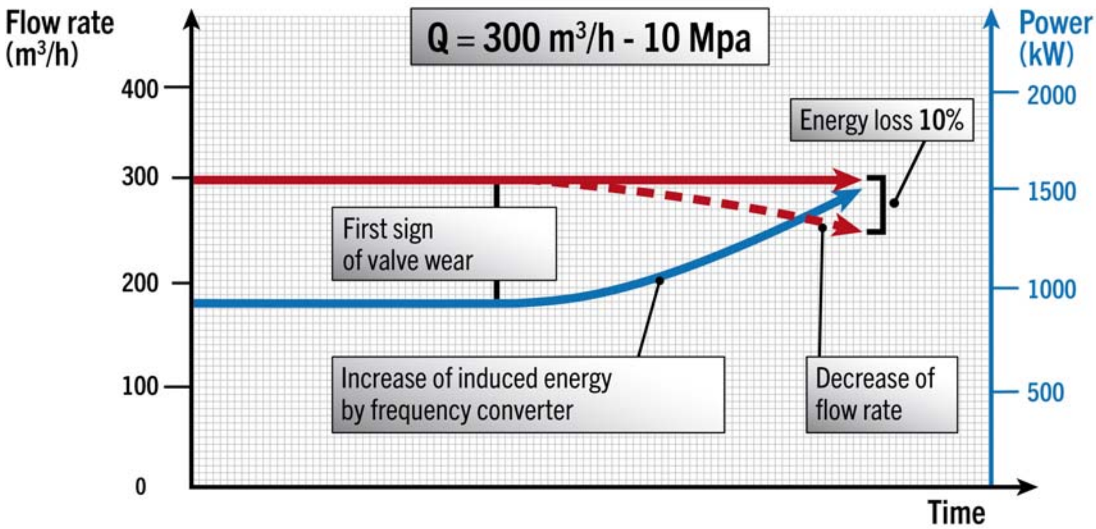

Figure 6. Influence of valve wear on OPEX (Operating expense).

2.1.2. Check valves

For alumina industry applications, the check valves of the pump play an especially decisive role. It is essential to take precautions to minimise valve wear and to avoid valve blockage by means of sedimentation. Check valves are considered the sole real wearing parts of double hose-diaphragm pumps. These are of easily removable top entry wafer design and, dependent on the pump duty, either specified as single or double ball or cone valves. Valve casings are suitable for a great variety of valve trims (see Figure 7)

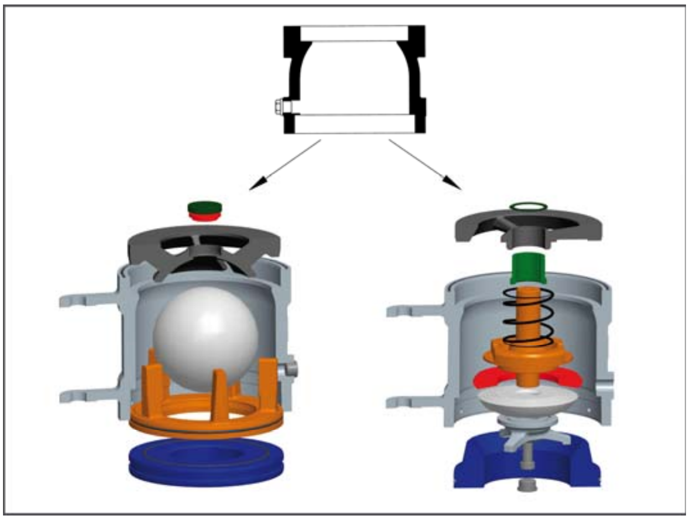

Figure 7. Common valve casing for variable valve trims.

All check valves of double hose-diaphragm pumps are individually customised in terms of choice of material, flow velocity, flow geometry and weight of the valve body to ensure sufficient lifting of the valve body from the sealing face (dependent on the particle size). In any case, the achievement of utmost lifetime is paramount when designing these valves. Valve balls have a considerably higher lifespan than valve cones, because they are continuously rotating and thus changing the sealing area against the valve seat. Operators therefore prefer ball valves over cone valves, provided they are feasible from a dimensional point of view. Ball valves are available with ball diameters up to 300 mm and pressures up to 400 bar. They have favourable flow characteristics, are self-cleaning and distinguished by almost optimum drag coefficient values. Ball valves are preferably used where media with high solid concentrations or viscosities are to be pumped. The cassettes are hinge-mounted so that the complete valve unit is removable within a very short time without prior dismantling of piping and valve trims. Valve seats and balls, for example, are easily replaceable by swiveling of the valve casing. Large size units are additionally provided with the most efficient hydraulically activated Quick Change system (see Figure 8).

Figure 8. Hydraulic Quick Change system tightens and relieves valve casings rapidly.

Double valve configuration is recommended for media with high levels of impurities and applications which require a particularly high continuous flow. If, in the short term, a particle gets jammed between the ball or cone and the valve seat resulting in valve leakage, the second valve ensures effective sealing, thus preventing medium backflow and a resulting volume loss.

2.1.3. Pump configuration

The delivery characteristic of a single-cylinder pump is approximately sinusoidal. When comparing single- and double-acting single and multiple cylinder pumps, it is obvious that the kinematic irregularity coefficient is considerably smaller in case of an uneven number of cylinders than for an even number. Preference is therefore given to the realisation of pumps with an uneven number of cylinders. For this reason, the majority of hose-diaphragm pumps are of single-acting triplex design.

For triplex pumps, the kinematic irregularity amounts to 23.0 % (see Figure 9), as compared to 32.5 % for single-acting four cylinder pumps. Special pulsation dampeners (Pulsorber) allow for the reduction of the residual pulsation to 0.5 % from peak to peak.

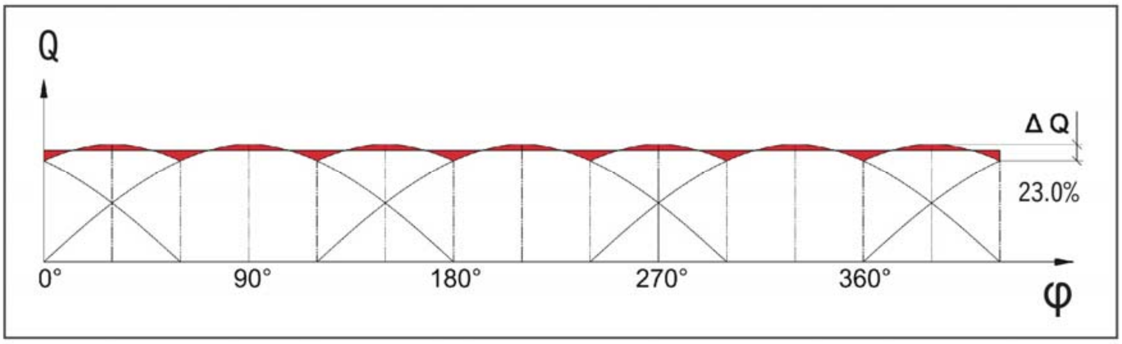

Figure 9. Kinematic irregularity of single-acting triplex pumps.

For duties with high flow rates, by far the highest efficiency and lowest irregularity is achieved by means of single-acting five cylinder pumps (see Figure 10).

Quintuplex configuration (see Figure 11) not only allows for uniformities comparable with that of centrifugal pumps, but also contributes to a noticeable reduction of valve wear. Even without pulsation dampening, the irregularity of single-acting quintuplex reciprocating pumps is reduced to 5.1 % vs. 23.0 % of single-acting three cylinder pumps and 32.5 % of single-acting four cylinder pumps.

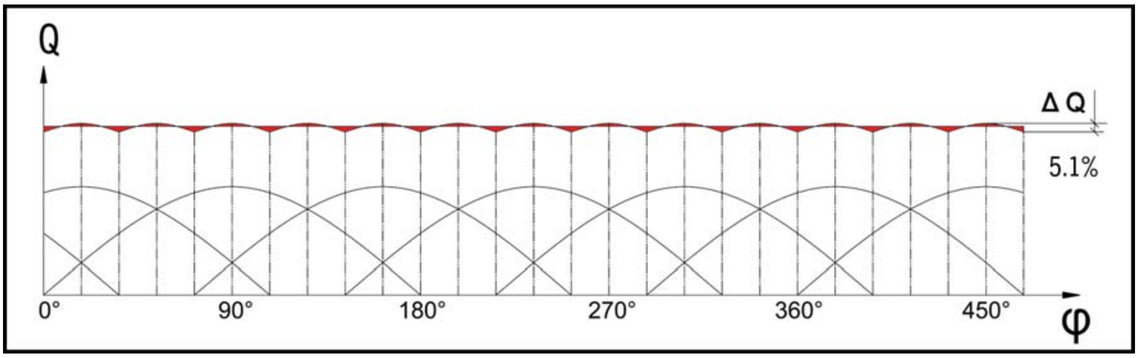

Figure 10. Kinematic irregularity of single-acting five cylinder pumps.

The irregularity of 5.1 % is to be considered as a theoretical value, which does not yet make allowance for additional compensation as a result of gas content included in the hydraulic oil and the slurry.

Redundancy of pulsation dampening equipment is advantageous due to the avoidance of manually or automatically operated dampening devices, which are usually mandatorily employed when operating at variable discharge pressures.

Figure 11. MULTISAFE double hose-diaphragm pump in quintuplex design with a maximum flow rate 1 000 m³/h.

2.1.4. Avoiding pulsations and resonance forces in hydraulic systems

Where several pumps operate in parallel and discharge at independent speeds into a common pipe, phase synchronism frequently occurs that may result in pressure maxima and temporary resonance conditions. As is generally known, machines with an unbalanced mass interact in terms of vibration, if they are set up on the same floor or in the same building. After a certain period of time, this results in a consolidated rhythm and an accordingly increased pulsation rate. This phenomenon can be counteracted by means of the included PLC (programmable logic control) with the latest Multiple Pump Control System [2].

In accordance with their design, double hose-diaphragm pumps generate pulsating discharge curves. They usually do not cause problems in piping systems of process industries, provided that efficient pulsation dampeners are applied or minimum pulsation is ensured by the pump design, such as quintuplex configuration. The encoder provides for out-of-phase operation with angular synchronism and reduces the risk of damage to components or problems in associated processes due to fluid system dynamics. To utilise this system each of the driving motors has to be provided with an encoder. Single units discharging into a piping system do not require encoders, since the direct torque control (DTC) is capable of determining the nominal torque of the driving motor with a high degree of accuracy. However, the provision of an encoder does not only ensure out-of-phase operation of multiple pumps discharging into common piping. The reduced residual pulsation likewise contributes to an accordingly reduced wear rate of the check valves for the benefit of "mean time between repairs" (MTBR) and "mean time between failures" (MTBF) figures.

3. Conclusions

Sweetening digestion contributes to a noticeable saving of energy in terms of process technology. Additional improvement is achieved by the implementation of energy-efficient equipment, such as digester feed pumps, which rank among the key equipment in alumina refineries. Double hose-diaphragm pumps are especially conducive to handle aggressive, abrasive and highly viscous fluids as used in the Bayer process. The redundant hose-diaphragm provides for a linear flow path without sedimentation and ensures double hermetic sealing from the drive end. Check valves are considered the sole real wearing parts of double hose-diaphragm pumps. Ball valves are preferable, because valve balls have a considerably higher lifespan than valve cones. Valve balls are continuously rotating and thus changing the sealing area against the valve seat. Permanent condition monitoring of check valves avoids loss of energy, because any decrease in output resulting from valve wear is usually automatically compensated by the variable speed drive through increased pump speed. Single-acting quintuplex configuration provides the lowest pulsation by means of five plungers actuated by a common crankshaft. This pump can handle up to 1 000 m^3/h. The pumps are equipped with the latest Condition Monitoring System, especially designed to monitor the smallest valve leakage, temperatures and diaphragm condition. Where several pumps operate in parallel and discharge at independent speeds into a common pipe, pump synchronisation controls phase shift and eliminates excitation of resonances significantly.

4. References

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