

Use of Double Hose-Diaphragm Pumps in the 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, red mud and lime milk. 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 the double hose-diaphragm 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 characterized 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 a 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. Beyond process technology improvements to energy consumption, 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 positions within the system. Positive displacement pumps are typically employed to pump the bauxite slurry into the digesters under high pressure.

2. Digester Feed Pumps and Double Hose-Diaphragm 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 create significant man power and cost for cleaning and subsequent repair of pump and gearbox.

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 strong 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 favors the flow behavior 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.

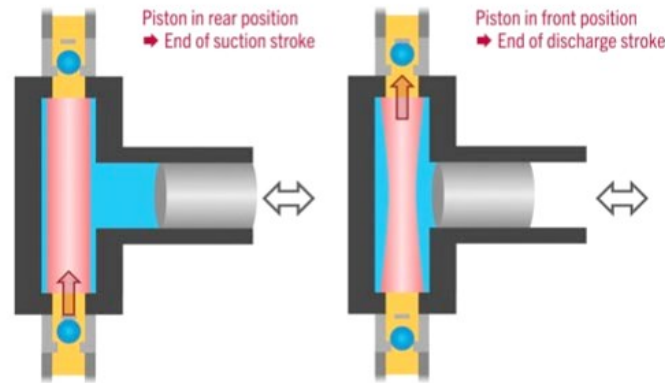


Figure 3. Working principle of double hose-diaphragm pumps.

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. Efficiency and Availability

Availability and reliability are of utmost importance for owners and operators. Hence, the pumps should 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 consistent against the pumpage (see Figure 4). Moreover, they are more economical to manufacture.

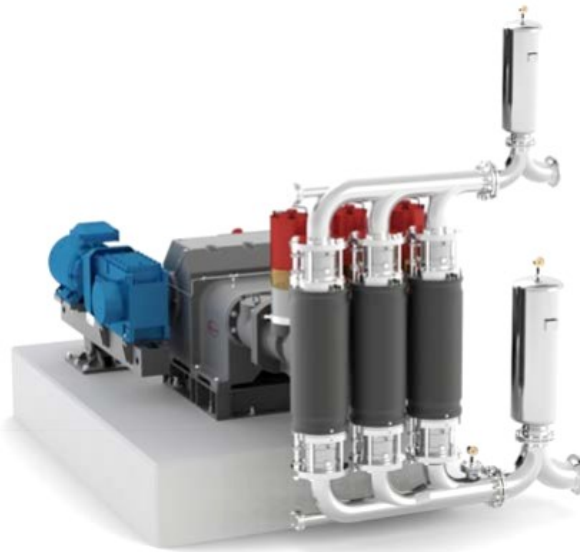


Figure 4: Triplex configuration of double hose-diaphragm pump.

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

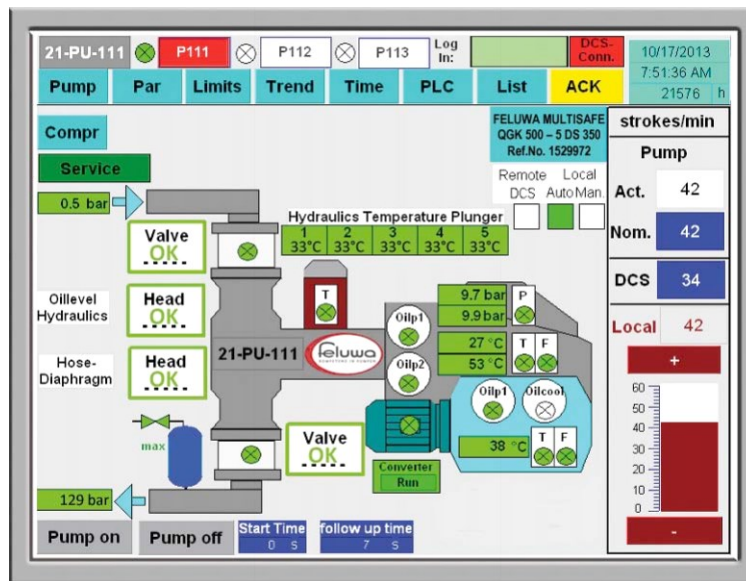


Figure 5. Touch panel for overall diagnostics, control and web-based service of two pump sets.

One of the criteria of condition monitoring is to recognize even the merest 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 into the process as appropriate, in order to avoid unscheduled shutdown of the system.

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 of well-directed advance planning of 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 because any decrease in output resulting from valve wear, is usually automatically compensated by the variable speed drive through the necessity of increased pump speed. From the exemplified calculation of Figure 6 it is evident that an assumptive loss of flow of 20 % as a result of valve wear is equated with a loss of power of 500 kW per hour, when looking at a pump with a flow rate of 300 m³/h and a pressure of 10 MPa. Based on a rate of 0.07 USD per kilowatt-hour, this equals an amount of 35 USD per hour, 840 USD per day, 5,880 USD per week, 25,200 USD per month, and 306,600 USD per year. Extrapolated on an estimated lifespan of 30 years, the loss of 20 % would even come to 9,198,000 USD.

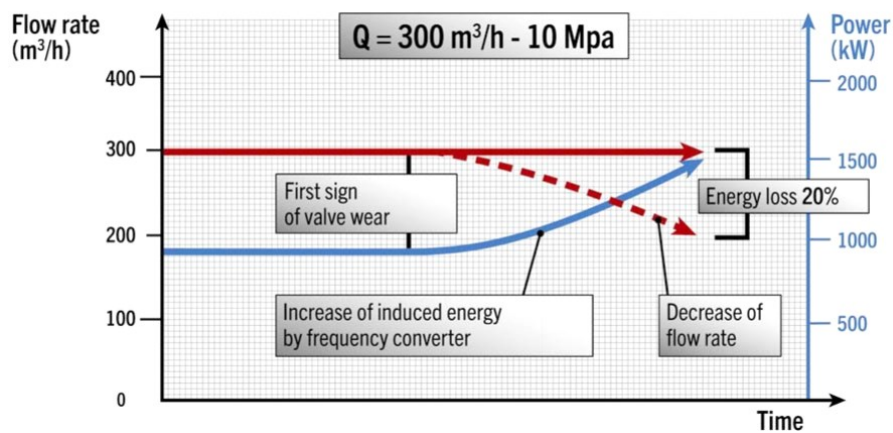


Figure 6. Influence of Valve Wear on OPEX (Operating Expense).

2.2. Check Valves

As for aluminium industry applications, especially the check valves of the pump play a decisive role. It is essential to take precautions in terms of minimization of 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).

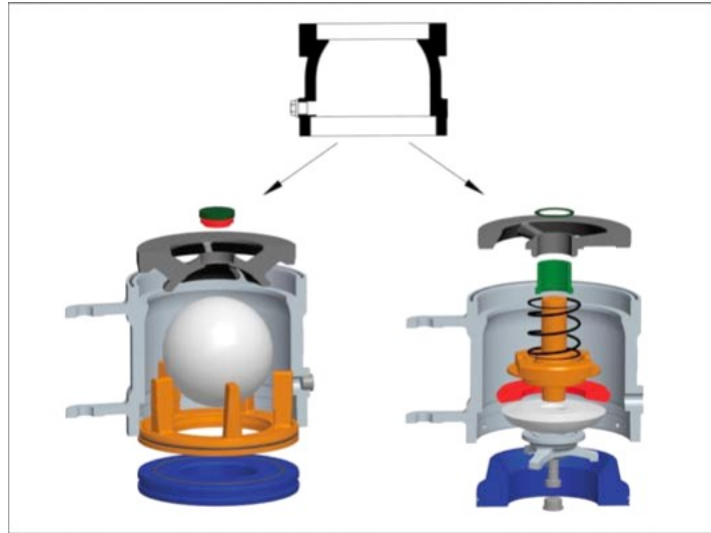


Figure 7. Common valve casing for variable valve trims.

All check valves of double hose-diaphragm pumps are individually customized in terms of choice of material, flow velocity, flow geometry and weight of the valve body, in order 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 the 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 (instead of cone valves), provided that 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 favorable 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 within the twinkling of an eye.

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.

2.3. 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 realization 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 % of single-acting four cylinder pumps. Special pulsation dampeners (Pulsorber) allow for the reduction of the residual pulsation to 0.5 % from peak to peak.

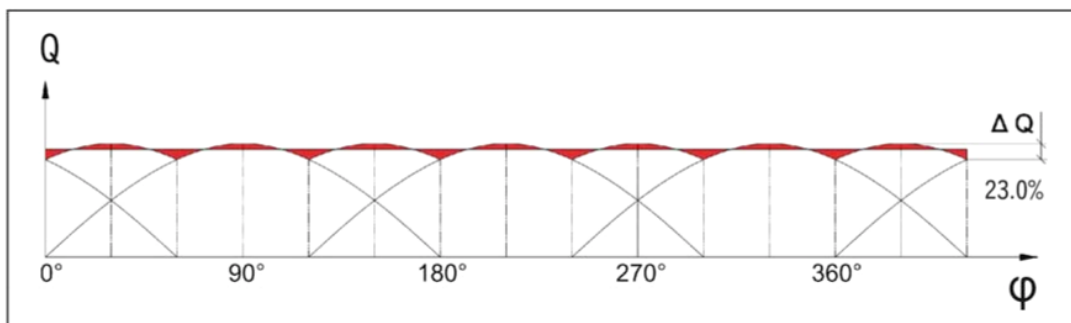


Figure 9. Kinematic irregularity of single-acting triplex pumps.

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.

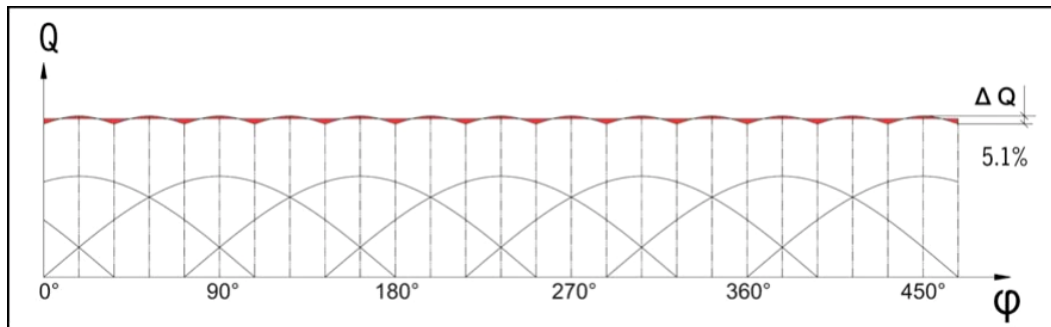


Figure 10. Kinematic irregularity of single-acting five cylinder pumps.

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 1000 m³/hr.

2.4. 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.

In accordance with their design, double hose-diaphragm pumps generate pulsating discharge curves. They usually do not cause problems in piping systems of process industry, 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 possible fluid system dynamics. To utilize 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

Beyond process technology developments to reduce energy consumption, additional improvement is achieved by the implementation of energy-efficient equipment, such as digester feed pumps, which rank among the highest energy consuming equipment of alumina facilities. 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 sedimentations 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 the necessity of increased pump speed. Single-acting quintuplex configuration provides lowest pulsation by means of five plungers actuated by a common crankshaft. This pump can handle up to 1000 m³/h. The pumps are equipped with the latest Condition Monitoring System, especially designed to monitor smallest valve leakage, temperatures and diaphragm condition. Where several pumps operate in parallel and discharge at independent speeds into a common pipe, pump synchronization controls phase shift and eliminates excitation of resonances significantly.