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Successful operation of ceramic rotary valves at Karsdorf cement plants

Erfolgreicher Einsatz von Keramik-Zellenradschleusen im Zementwerk Karsdorf

M. Dikty, L. N. Lüth, KREISEL Engineering GmbH & Co. KG, Hamburg,
A. Akdag, OPTERRA Zement GmbH, Sötenich,
P. Kühn, OPTERRA Zement GmbH, Karsdorf, Germany

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M. Dikty, L. N. Lüth, KREISEL Engineering GmbH & Co. KG, Hamburg,
A. Akdag, OPTERRA Zement GmbH, Sötenich,
P. Kühn, OPTERRA Zement GmbH, Karsdorf, Germany

SUMMARY

For many decades screw pumps and discontinuous pressure vessel systems were the only means of introducing abrasive bulk materials into pneumatic conveying systems. These two input systems are familiar for their specific power consumption and sensitivity to changes in the properties of the material being conveyed. Also worth mentioning is the high cost of maintenance, especially for the widely used screw pump. Because of the nature of the system it has to be operated at high rotational speeds and is therefore exposed to excessive wear. Thanks to the progress in the field of industrial ceramics Kreisel GmbH & Co. KG from Krauschwitz has succeeded in introducing a rotary valve to the market with gap widths between the rotating cellular rotor and the surface of the housing of less than 0.1 to 0.2 mm. This provides an effective seal and its wear surfaces are protected by a ceramic coating. For reasons of sustainability and energy efficiency Opterra GmbH, a subsidiary of the CRH Group, therefore decided in close co-operation with Kreisel GmbH & Co. KG to use ceramic rotary valves to replace the screw pumps that were previously used in the Karsdorf cement plant in Germany for the pneumatic transport of cement raw meal, bypass dust and electrostatic precipitator dust. After the pneumatic transport of bypass dust to the cement grinding plants had been successfully implemented using ceramic rotary valves in 2015 this was followed in 2016 by the project for pneumatic feeding of each of the two-string preheater towers of two dry-process kiln lines with raw meal. By the end of March 2019 ceramic rotary valves were also in use for pneumatic conveying of electrostatic precipitator dust. Two ceramic rotary valves were used for feeding each of the two preheater towers in the project realized in 2016. The valves are each driven by a motor with an installed rating of 5.5 kW while the screw pumps that had been replaced were each equipped with 160 kW drive motors. After this project had been implemented the Karsdorf cement plant was able to reduce its annual energy and maintenance costs by € 345000.

(Translation by Robin B.C. Baker)

ZUSAMMENFASSUNG

Für das Einschleusen von abrasivem Schüttgut in eine pneumatische Förderanlage standen über Jahrzehnte bislang nur die Schneckenpumpe und das diskontinuierlich arbeitende Druckgefäßsystem zur Verfügung. Diese beiden Einschleussysteme sind wegen ihres spezifischen Energiebedarfs sowie ihrer Empfindlichkeit gegenüber Eigenschaftsveränderungen des zu fördernden Materials hinreichend bekannt. Erwähnenswert ist auch der hohe Wartungsaufwand speziell bei den weit verbreiteten Schneckenpumpen, die systembedingt mit hohen Drehzahlen betrieben werden müssen und deshalb einem überproportional hohem Verschleiß ausgesetzt sind. Dank der Fortschritte im Bereich der industriellen Keramik ist es der Kreisel GmbH & Co. KG aus Krauschwitz gelungen, eine Zellenradschleuse auf den Markt zu bringen, die mit Spaltweiten < 0,1 bis 0,2 mm zwischen dem rotierenden Zellenrad und den Gehäuseflächen eine hohe Dichtheit besitzt und deren Verschleißflächen durch eine Keramikbeschichtung geschützt sind. Aus Gründen der Nachhaltigkeit und Energieeffizienz entschied sich deshalb die Opterra GmbH als Tochterunternehmen des CRH-Konzerns in enger Zusammenarbeit mit der Kreisel GmbH & Co. KG im deutschen Zementwerk Karsdorf die bislang beim pneumatischen Transport von Zementrohmehl, Bypass-Staub und EGR-Staub eingesetzten Schneckenpumpen durch Keramik-Zellenradschleusen zu ersetzen. Nachdem im Jahr 2015 der pneumatische Transport von Bypass-Staub zu den Zementmahlanlagen unter Einsatz von Keramik-Zellenradschleusen erfolgreich realisiert wurde, folgte 2016 das Projekt zur pneumatischen Beaufschlagung der jeweils zweisträngig ausgeführten Vorwärmertürme von zwei Ofenlinien nach dem Trockenverfahren mit Zementrohmehl und Ende März 2019 der Einsatz von Keramik-Zellenradschleusen bei der pneumatischen Förderung von Elektrofilterstäuben. Bei dem 2016 realisierten Projekt kamen bei der Beaufschlagung der beiden Vorwärmertürme je zwei Keramik-Zellenradschleusen zum Einsatz, die durch Motoren mit einer installierten Leistung von jeweils 5,5 kW angetrieben werden, während die ausgetauschten Schneckenpumpen jeweils mit 160-kW-Antriebsmotoren ausgerüstet sind. Durch die Realisierung dieses Projekts konnte das Zementwerk Karsdorf seine jährlichen Energie- und Wartungskosten um 345000 € senken.

Successful operation of ceramic rotary valves at Karsdorf cement plant

Erfolgreicher Einsatz von Keramik-Zellenradschleusen im Zementwerk Karsdorf

1 Introduction

In a period when sustainability and energy efficiency are becoming ever more important the producers of building materials are finding themselves increasingly faced by the challenge of appropriate optimization their production plants. It is well known that this continuous change is also supported by DIN EN ISO 50001.

One company that has faced this challenge is Opterra GmbH, which is a subsidiary of the CRH Group and one of the leading producers of building materials, both nationally and internationally. In addition to high-grade cements Opterra also offers its customers special products with material compositions that are adapted to the customer's requirements. In order to operate its cement production in a way that conserves the environment and resources Opterra has in the past implemented various projects with Kreisel GmbH & Co. KG at the Karsdorf cement plant.

Figure 1: Metering and conveying system from Kreisel

2 Description of the projects

In addition to reducing the energy consumption the emphasis has also been on raising the plant availability. Three projects that have been implemented are described in detail below.

2.1 Pneumatic transport of bypass dust

A project for metering and pneumatic conveying of bypass dust was implemented in 2015. Bypass dust is produced during clinker burning in a rotary kiln and is normally co-processed in very precisely metered quantities during cement grinding. Not only the sharply fluctuating quality but also the tendency of the bypass dust to agglomerate and form coatings cause problems during the metering and conveying of the dust. As a rule these properties are caused by the chloride content in the bypass dust and meant that the screw pumps previously used in the pneumatic conveying systems for feeding the bypass dust into the conveying lines had to be cleaned manually every two weeks. The metering and feeding system shown in ❱ Fig. 1 was implemented by Kreisel to ensure uniform and trouble-free metering and conveying. The Kreisel self-cleaning rotary valves are fitted with counter-rotating scrapers that free each chamber reliably from residual material (❱ Fig. 2).

With the aid of a differential weigher with stirrer in the feed hopper positioned upstream of the self-cleaning rotary valve it is possible to achieve a metering accuracy of 1 %, even under conditions of frequently changing properties of the material being conveyed. In addition to significantly higher plant availability the cement plant is also profiting from the fact that each rotary valve requires only one drive motor with an installed rating of 1.1 kW while a motor with a rating of 15 kW was required for driving each screw pump.

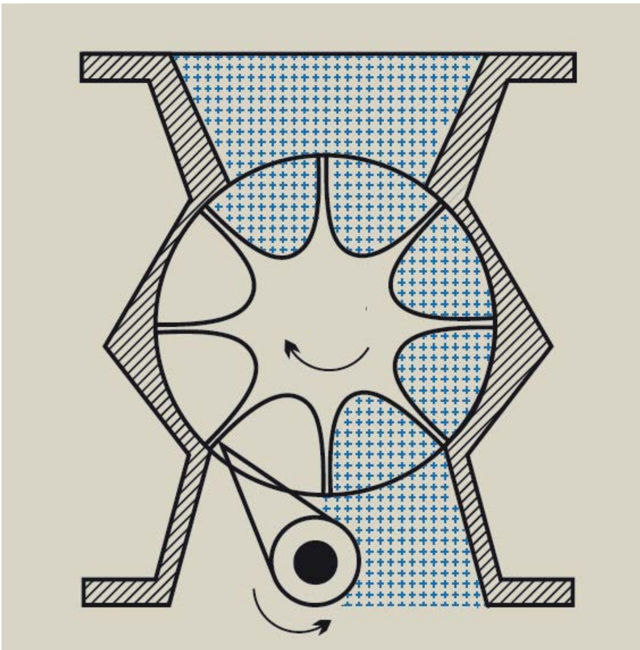

Figure 2: Mode of operation of a self-cleaning rotary valve

Figure 3: The old screw pump

The rotary valves are also provided with ceramic wear protection. No wear has been detected so far on the rotary valves and the cost of maintenance has also dropped to a minimum.

2.2 Pneumatic transport of raw meal

The Karsdorf cement plant operates two dry-process kiln lines for which the raw meal for feeding the two-string preheaters has to be transported over a distance of 180 m. The two preheaters used to be fed pneumatically with raw meal using a total of four screw pumps (❱ Fig. 3).

In 2016 Opterra decided to replace the screw pumps by the energy-efficient ceramic rotary valves from Kreisel. The four existing screw pumps were each replaced by a ZSVH 630 x 630 rotary valve with a conveying capacity of 100 t/h (❱ Fig. 4).

Figure 4: The new Kreisel rotary valve

The existing screw pumps had each been driven by a motor with a rating of 160 kW while a rotary valve from Kreisel only needs a drive rating of 5.5 kW, which leads to substantial energy savings. This means that the Karsdorf cement plant not only operates with greater environmental conservation but has also reduced the annual energy and maintenance costs by about € 345 000.

2.3 Pneumatic conveying of electrostatic precipitator dust

The project for re-routing the precipitator dust entered the planning phase in 2018 and was completed with the hot commissioning at the end of March 2019. In this project it is basically possible to differentiate between two areas.

In the first area the kiln precipitator dust is conveyed mechanically by horizontal screw conveyors to a ceramic rotary valve from Kreisel that feeds the dust into a conveying line that is under pressure. The hot precipitator dust at up to 200 °C is transported by two conveying systems to a new storage silo with a capacity of 300 m^3.

In a second section of the plant the precipitator dust then passes through flow control rollers into a metering hopper from where it is metered gravimetrically and fed by the Kreisel rotary valve into a conveying line that is under pressure. It is transported pneumatically to the preheater tower where it is collected by a cyclone separator and then mixed with bypass dust to improve its transport characteristics.

3 Conveying systems

There are various possible ways of transporting powdered bulk materials. Bulk materials in powder form are usually conveyed pneumatically using compressed air. The familiar systems for introducing the bulk material into the conveying line are described and compared below.

3.1 Screw pump

The screw pump that was very widely used in the past is an feeding system that operates continuously. ❱ Fig. 5 shows the functioning principle of a screw pump. The material drops through the inlet (1) into the top-mounted pump hopper (2) during which the air can escape through a second opening (right). The material then passes from the top-mounted pump hopper into the conveying screw operating at a rotational speed of about 1 000 rpm that conveys the bulk material towards the outlet. During the transport through the conveying screw (3) and non-return valve (4) the bulk material is heavily compressed. It arrives at the outlet in the form of a plug of material, drops into the chamber (6), is picked up by the air jet from the accelerating nozzle (9) and transported into the conveying line (8). The nozzles produce a pressure loss of about 0.3 bar.

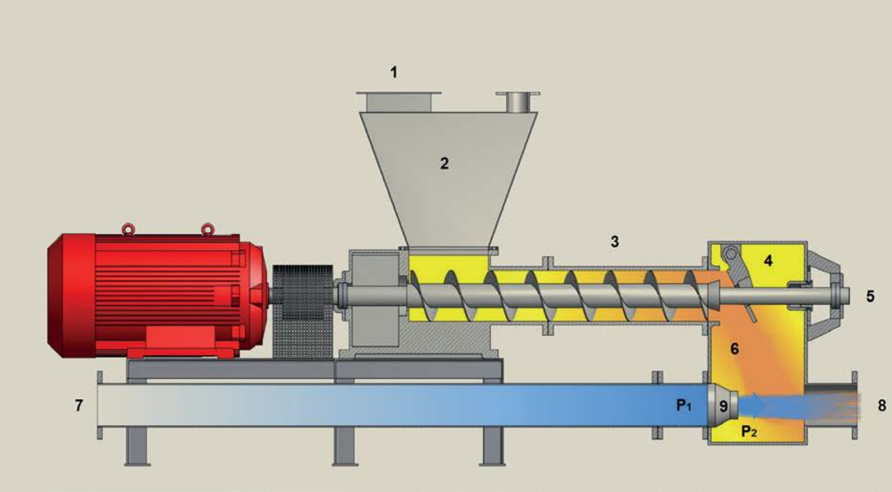

Figure 5: Functioning principle of a screw pump [1]

3.2 Pressure vessel system

The pressure vessel compresses and depressurizes the air in order to transport the material. The air flow consists of two subsidiary flows. One subsidiary flow is fed directly into the conveying line and the other into the pressure vessel. After the container has been filled the pressure level in the container is increased further. The conveying line is at a lower pressure level than in the pressure vessel so that the air flows into the conveying line during which the material product is entrained and transported. The cycle is repeated after the system has been completely depressurized. This mode operation of the pressure system is characterized by discontinuous conveying.

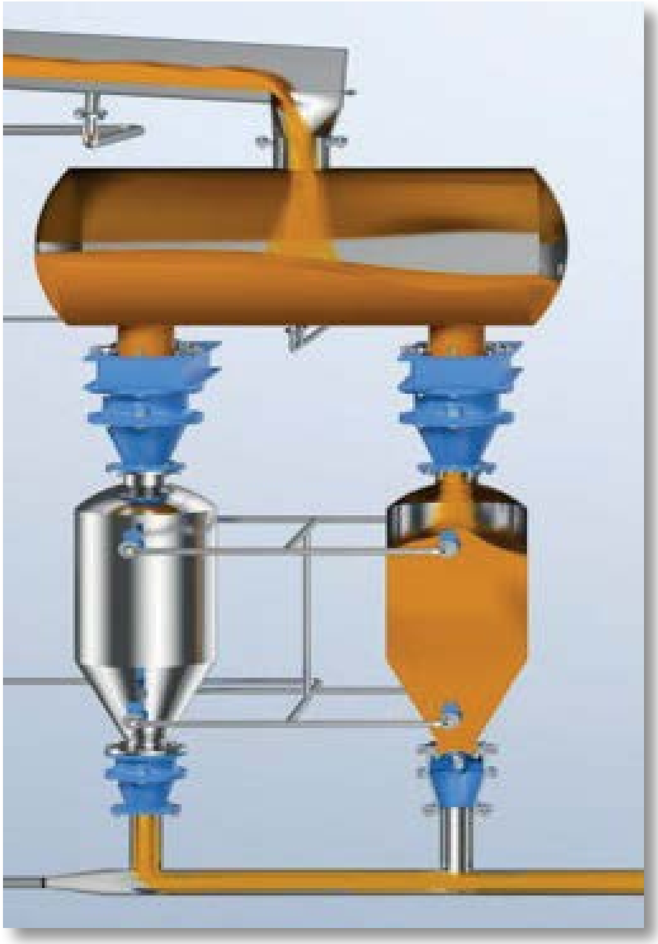

Figure 6: Interconnection of several pressure vessels for quasi-continuous conveying

Only part of the cycle time is utilized for active conveying so the conveying rate in this phase must be set higher than the average conveying rate for the entire cycle. Quasi-continuous conveying can be achieved by interconnecting several pressure vessels (❱ Fig. 6).

Increased safety requirements and regular checks in accordance with the pressure equipment directive (PED) are required because of the high pressure level used in the containers for this conveying system.

3.3 Rotary valve

The functioning principle of a rotary valve is as simple as it is efficient. The material drops vertically into one of the chambers of the rotating cellular rotor (❱ Fig. 7). Underneath the cellular rotor it passes into the conveying line that is under pressure. The volume of each chamber and the continuous rotational speed (about 30 rpm) mean that a uniform mass flow is metered and conveyed. Due to the highly accurate manufacture it is now possible to minimize the gap widths between cellular rotor and housing to < 0.1 mm, which reduces material or air from escaping through the gaps to a minimum.

In the past rotary valves had suffered from the disadvantage that the wear with mineral bulk materials was very severe. This disadvantage can now be almost completely eliminated by employing an industrial ceramic coating. Kreisel makes use of this new potential of ceramic coating in its rotary valves (Fig. 7).

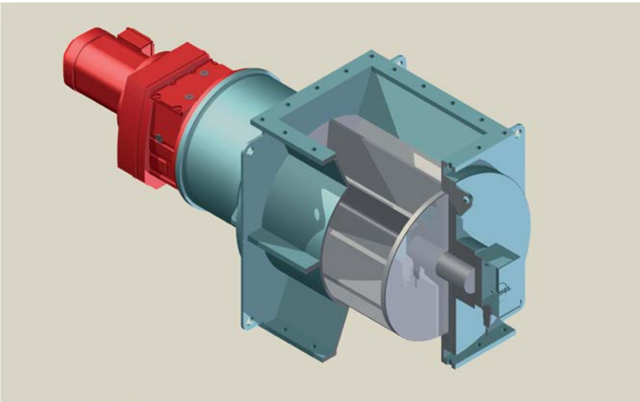

Figure 7: Ceramic rotary valve from Kreisel

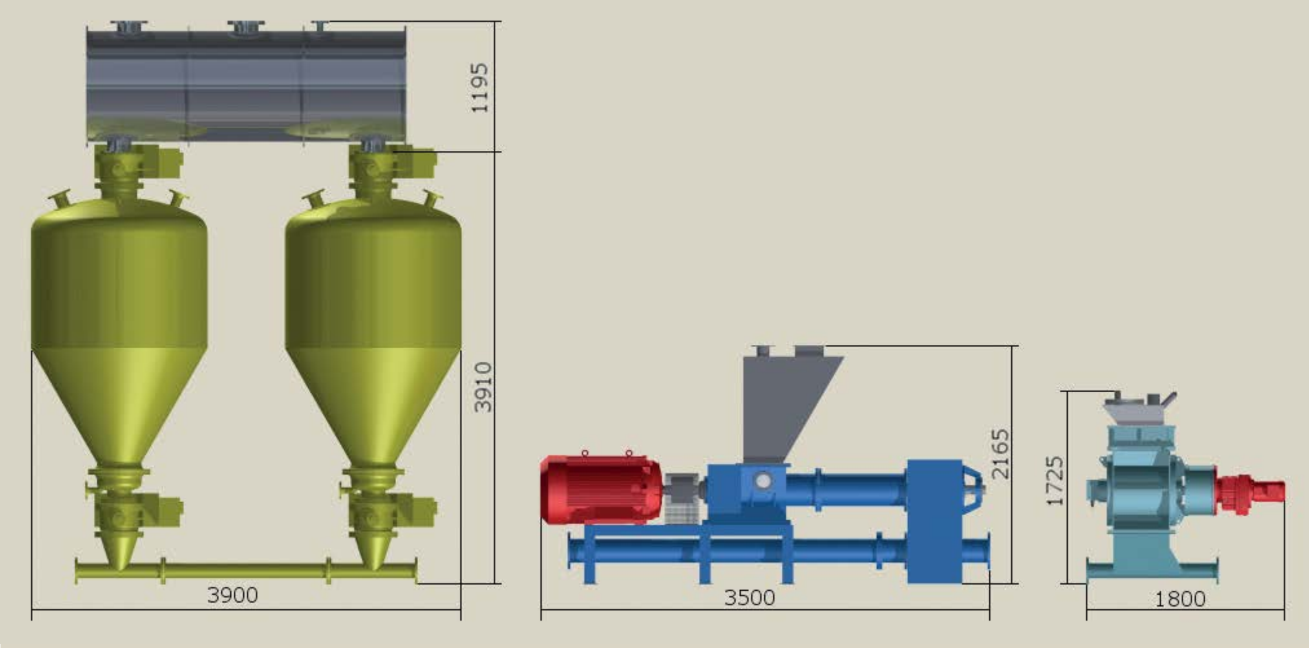

Figure 8: Comparison of the geometries of a pressure vessel system, a screw pump and a rotary valve using the example of cement conveying [1] at a conveying rate of 50 t/h

3.4 Comparison

Each of the three input systems described has advantages and disadvantages for the operator. The most important criteria are listed and evaluated below.

3.4.1 Space requirements / overall height

Different space requirements arise because of the different geometries required by the respective input systems (❱ Fig. 8). The space-saving design of the rotary valve means that its space requirement is impressive. The rotary valve can be used even in surroundings with severe spatial restrictions.

The screw pump requires more space, especially in the horizontal direction, bearing in mind the requisite dismantling length for the compression screw during maintenance. However, of the three input systems the pressure vessel system has the significantly largest space requirement. It has a high overall height requirement and needs a large area if several pressure vessels have to be interconnected.

3.4.2 Weight requirement

The weight of an input system also plays a part in its integration into a production plant as the foundation and the surrounding structure have to be able to take the machine. Because of the high pressures a pressure vessel system needs to have a massive structure and the container has to be filled almost completely with bulk material. This means that a pressure vessel system has about ten times the weight of a rotary valve or a screw pump.

3.4.3 Energy efficiency

Various aspects have to be considered for the energy efficiency of the input systems. In particular, the required motor rating and the pressure drop and gas loss in the conveying system are crucial for the energy efficiency. Auxiliary systems for possible drying and cooling of the compressed air must also be taken into account where applicable.

3.4.3.1 Motor rating

The motor rating required by the input system has a significant influence on the operating and capital costs. Unlike the screw pump, which has to be operated at speeds of up to 1 000 rpm, a rotary valve runs at speeds of only about 30 rpm. This reduces the required motor rating.

The back pressure does not affect the drive rating of a rotary valve but with the screw pump the motor rating increases virtually linearly with the conveying line pressure. For pneumatic raw meal conveying the screw pump used previously had to be driven with a motor with a rating of 160 kW while a ceramic rotary valve needs a drive rating of about 1 kW in operation. The pressure vessel does not have any motorized drives with appreciable ratings.

3.4.3.2 Pressure loss

Pressure losses, which demand additional energy, occur as the flow passes through pipelines because of friction and lifting work (vertical sections). As a rule the screw pump and the rotary valve operate in a pressure range from 0.3 to 1.5 bar. From the flow technology aspect this is referred to a lean-phase conveying. With fine-grained products such as cement, raw meal or fly ash the material is transported through the pipeline in the form of strands.

With pressure vessel input the conveying gas velocity is reduced further with the result that the loading increases. If the loading limit is exceeded this can lead to deposits and the formation of strands [2]. Dunes and balls are formed if the conveying gas velocity falls still further. This increases the pressure losses with a simultaneous reduction of the amount of conveying gas required. The energy demand falls below that of lean-phase conveying. However, additional pressure losses due to the discontinuous operation and compressed air processing system (cooler and dryer) raise the total energy consumption again.

The pressure level of a pressure vessel system, which normally operates at pressures of 4 to 8 bar, is therefore higher than that of the screw pump of 1.5 bar plus about 0.3 bar through the pressure loss of the nozzle. The rotary valve, which requires neither a nozzle nor a compressed air processing system, has the lowest pressure level.

3.4.3.3 Gas losses

As a rule air is used as the conveying gas for pneumatic conveying. The rotary valve has a gap between the rotor and the fixed housing of about 0.1 to 0.2 mm. The conveying pressure that is established provides for a gas leakage flow through the rotary valve that amounts to 1 to 20 % of the conveying gas flow, depending on the plant. The screw pump, on the other hand, requires sealing gas and in some cases has reverse flow losses through the conveying screw. The order of magnitude of the gas losses is usually somewhat lower than that of the rotary valve. With the pressure vessel system the residual pressure at the end of the conveying cycle has to be passed to a filter through the de-dusting line, which leads to gas losses. These losses are of an order of magnitude that is comparable with that of a screw pump. The total energy consumption of the compressed air generation system is most favourable with pressure vessel systems, followed by the rotary valve.

3.4.4 Influence of changes in the bulk material properties

It is not possible to ensure that the material properties in every production process will always remain constant. Being able to deal with these fluctuations is one of the requirements of a conveying system. All the conveying systems described are bulk volume conveyors so fluctuations in bulk density inevitably lead to a varying mass flow. These variations can, where necessary, be offset by changes in the operating parameters. However, the screw pump is also dependent on other bulk material properties. The throughput of a screw pump can be affected not only by the bulk density but also by fluctuations in the moisture content, particle size distribution and fineness. Rapid changes in these parameters can lead to loss of capacity, motor overloads and sealing problems with the screw pump.

3.4.5 Flexibility in the mode of operation

The mass flow cannot be directly increased with a screw pump but it can be reduced. However, the energy consumption remains virtually the same as the back-pressure p_2 falls with reduced throughput. This raises the operating volume flow and with it the velocity within the nozzle, which leads to a virtually constant pressure before the screw pump. When a pressure vessel system is used it is not possible to increase the throughput but it can be lowered with a simultaneous reduction in energy consumption. With a rotary valve the throughput can be adjusted very easily through the rotational speed .The rotary valve is therefore the most flexible of the input systems described. The rotational speed can be adjusted by means of frequency converters.

3.4.6 Capital costs (including electrical engineering)

The capital costs of a pneumatic conveyor system are made up as follows:

- Compressed air generation (fan, compressor, dryer, cooler)
- Input system (pressure vessel, screw pump, rotary valve, dedusting system)
- Structural steelwork
- Dedusting unit at the end of the conveying line
- Conveying line
- Installation (electrical/mechanical)
- MCC
- PLC

Table 1: Relative evaluation of capital costs

	Screw pump	Pressure vessel system	Rotary valve
Compressed air generation	=	-	+
Input system	=	-/=	=
Structural steelwork	+	-	+
Dedusting unit	=	+	=
Conveying line	-	+	-
Installation	+	-	+
MCC (incl. compressed air generation)	-	=	=
PLC	+	-	+

+ low = medium - high

Table 1 contains a qualitative evaluation of the capital costs. As can be seen from the table a pneumatic conveying system with input by rotary valve has the lowest capital cost.

3.4.7 Reliability

To operate a production plant consistently it is important that the components are as reliable as possible. If the mass flow of the feed material is uneven during operation it is important to know how the existing system will react. For example, the intake could be overfilled as the result of an increased mass flow. With a screw pump [2] the air is separate from the bulk material at the intake (Fig. 5). If this intake is overfilled the air can no longer escape through the inlet and is transported through the screw pump. If the plug of bulk material needed to provide the seal is loosened then the seal is impaired and the conveying capacity is reduced.

In the inlet area of the Kreisel rotary valve the special designed leakage air collector avoids any influence of the feeded bulk material by leakage air. An overfilling is due to the leakage air collector not possible. Experiences show a positive effect of overfilling. The mass flow will be increased. Fluctuations in the supply have absolutely no effect on the operation with a pressure vessel system. Conveying only starts when the pressure vessel is full. The more complex a system is the more liable it is to faults and stoppages. While a pressure vessel system has a large number of fittings, flaps, sophisticated controls and signals the rotary valve is impressive because of its simple structure. Changes in the supply (bulk material properties such as particle size distribution, particle size, bulk density and overfilling) have the greatest effect on screw pumps and pressure vessel systems. The rotary valve reacts primarily only to changes in bulk density.

3.4.8 Use as a metering unit

In the majority of process sequences the material has to be metered as well as conveyed. In this case the rotary valve has the great advantage that it can also be used as a metering system. The conveying rate can be changed to any

Table 2: Decision matrix for choosing the most suitable conveying and metering system

	Screw pump	Pressure vessel system	Rotary valve
Space requirements	++	--	++
Weight	+	--	++
Energy efficiency	=	++	+
Influence of change in bulk material properties	-	-	+
Flexibility	-	+	++
Capital costs (including electrical installation)	=	--	+
Reliability	=	+	+
Use as metering unit	--	-	++
Mode of operation	Continuous	Discontinuous/Quasi-continuous	Continuous

++ very good + good = moderate/ adequate - poor
-- very poor

required level by changing the rotational speed. In contrast, a screw pump always needs a separate metering device as a change in the rotational speed is not permissible. The high rotational speed of the screw shaft is needed to build up the plug of material to form the seal. A pressure vessel system could be used for metering but the requisite control technology is very expensive. For this type of application it would be necessary to construct a double-deck pressure vessel plant. There are some applications, such as feeding blastfurnaces in the steel industry with coal, where only pressure vessel systems can be used because of the high internal pressures in the furnaces of up to 4 bar.

3.4.9 Type of operation

The rotary valve and the screw pump convey the bulk material in a continuous operation. On the other hand, the pressure vessel system operates discontinuously. Quasi-continuous systems are possible in individual cases by interconnecting several pressure vessels.

3.4.10 Decision matrix

The process engineering and economic aspects of the criteria that have been described are evaluated in ❱ Table 2 and are shown in the form of a decision matrix.

4 Final comment

New potential applications have opened up for rotary valves through progress in the field of industrial ceramics. Opterra GmbH, which now also operates the Karsdorf cement plant, has recognized this potential and, with the aid of the energy-efficient, low-wear, ceramic rotary valves from Kreisel, has optimized its pneumatic conveying processes and thereby made a contribution to environmental and climate protection in accordance with DIN EN ISO 50001. The use of ceramic rotary valves in the operation of pneumatic conveying systems in the cement plant has proved to be an outstandingly energy-efficient and environment-conserving solution.

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