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SUMMARY

For the pneumatic transport of bulk materials in the cement industry, pressure vessels, screw pumps, rotary valves or injectors are used as infeed systems. Depending on the respective requirements, such as bulk material properties, transport distance, size of the mass flow, continuous or discontinuous mode of operation, one of the above-mentioned infeed systems is used. For the transport of cement, lime, gypsum, fly ash, clinker dust and cement raw meal, the use of highly wear-resistant rotary valves from Kreisel GmbH & Co. KG with its headquarters in Krauschwitz, Upper Lusatia, has increased in the last decade. Depending on its chlorine and sulphur content, the bypass dust produced during the combustion of alternative fuels leads to more or less severe problems with the infeed systems. In the past, caking and sticking were among the most frequent causes of failure and led to unplanned plant shutdowns. The self-cleaning rotary valve developed by Kreisel more than 40 years ago solves these operating problems. The self-cleaning rotary valve, originally developed for mill feed, designed for conveying capacities of up to 1 000 m³/h, was developed with the high-pressure rotary valve with ceramic armouring, which has already been successful for more than a decade, as an infeed and metering device for handling particularly difficult bulk materials such as bypass dusts or hydrated lime for pneumatic transport. The rotary valve, which is extended by means of a scraper wheel, is used for pressures of up to 1.5 bar (gauge pressure) and temperatures of up to 200 °C. The sticky bulk solids can be fed into the rotary valve by means of a ceramic plating. The sticky bulk material that does not fall out of the rotor of the rotary valve on its own is discharged from the rotary valve chamber by a scraper wheel. The more than a dozen rotary valves in operation in Germany have so far proven to be very reliable in operation. Three examples are given below to illustrate the possible applications. At present, perhaps only about 1 % of the approx. 4 500 cement plants worldwide have to deal with particularly high chlorine and sulphur concentrations in the bypass dust. But already in the coming years, almost every cement plant will have to be equipped with a bypass system due to the increasing firing of alternative fuels. In order to be able to reliably and efficiently pneumatically transport the abrasive and sticky bypass dust, an ideal infeed and metering system is available in the form of the Kreisel self-cleaning rotary valve. .

ZUSAMMENFASSUNG

Beim pneumatischen Transport von Schüttgütern in der Zementindustrie werden als Einschleussysteme, Druckgefäße, Schneckenpumpen, Zellenradschleusen oder Injektoren eingesetzt. Entsprechend den jeweiligen Anforderungen, wie Schüttguteigenschaften, Transportentfernung, Größe des Massestroms, kontinuierliche oder diskontinuierliche Betriebsweise, gelangt eines der oben genannten Einschleussysteme zum Einsatz. Für den Transport von Zement, Kalk, Gips, Flugasche, Klinkerstaub und Zementrohmehl wurde im letzten Jahrzehnt vermehrt auf den Einsatz von hochverschleißfesten Zellenradschleusen der Kreisel GmbH & Co. KG mit Ihrem Hauptsitz in Krauschwitz, Oberlausitz, gesetzt. Der bei der Verfeuerung alternativer Brennstoffe anfallende Bypass-Staub führt, je nach seinem Chlor- und Schwefelgehalt, zu mehr oder minder starken Problemen bei den Einschleussystemen. Anbackungen und Verklebungen zählten in der Vergangenheit zu den häufigsten Ausfallursachen und sorgten für ungeplante Anlagenstillstände. Die von Kreisel vor mehr als 40 Jahren entwickelte Räum-Zelleradschleuse löst diese Betriebsprobleme. Die ursprünglich für die Mühlenbeschickung entwickelte Räum-Zellenradschleuse, ausgelegt für Förderleistungen von bis zu 1 000 m³/h, wurde mit der bereits seit mehr als einem Jahrzehnt erfolgreichen Hochdruck-Zellenradschleuse mit Keramikpanzerung als Einschleus-und Dosiervorrichtung zum Handling von besonders schwierigen Schüttgütern wie Bypass-Stäuben oder Kalkhydraten für den pneumatischen Transport entwickelt. Die mittels Räumrad erweiterte Zellenradschleuse ist für Drücke bis 1,5 bar(ü) und Temperaturen bis 200 °C im Einsatz. Das klebrige Schüttgut, welches nicht selbständig im Auslauf aus dem Rotor des Zellenrads fällt, wird von einem Räumrad aus der Zellenradkammer ausgetragen. Die mehr als ein Dutzend in Deutschland in Betrieb befindlichen Schleusen haben sich bisher im Betrieb als sehr zuverlässig erwiesen. Anhand von drei Beispielen werden im Folgenden die Einsatzmöglichkeiten aufgezeigt. Gegenwärtig haben vielleicht nur etwa 1 % der weltweit ca. 4 500 Zementwerke mit besonders hohen Chlor- und Schwefelkonzentrationen im Bypass-Staub zu kämpfen. Aber schon in den kommenden Jahren wird durch die zunehmende Verfeuerung von Sekundärbrennstoffen nahezu jedes Zementwerk mit einem Bypass-System ausgestattet werden müssen. Um den schleißenden und klebrigen Bypass-Staub zuverlässig und effizient pneumatisch transportieren zu können, steht mit der Räum-Zellenradschleuse von Kreisel ein ideales Einschleus- und Dosiersystem zur Verfügung. .

PROCESSING

The self-cleaning rotary valve from Kreisel: an essential infeed and metering system for the pneumatic transport of bypass dusts of a cement rotary kiln fired with secondary fuels

Die Räum-Zellenradschleuse von Kreisel: Ein unverzichtbares Einschleus- und Dosiersystem für den pneumatischen Transport von Bypass-Stäuben eines mit Sekundärbrennstoffen befeuerten Zementdrehofens

1 Introduction

Around 7 % of the annual worldwide CO_2 emissions are caused by the cement industry. Alternative fuels, also known as secondary fuels, represent a more climate-friendly alternative to reduce the process-related high CO_2 emissions and fuel costs in cement production [1]. In Europe, the use of these alternative fuels rose steadily from less than 10 % to more than 60 % between 1990 and 2019. ❱ Fig. 1 shows this increase in relation to the specific energy input in kJ/kg cement. This development trend shown here for Germany can be expected worldwide in the coming years.

A current analysis of the fuels used in Germany is shown in ❱ Fig. 2. According to this, the use of alternative fuels in the German cement industry increased from 61 % to almost 69 % between the years 2010 and 2019.

Due to the increasing substitution of fossil fuels by alternative fuels in the coming years, the proportion of sulphur and chlorine concentrations will also increase significantly. The chlorine and sulphur compounds are released when the fuels are burnt and react with alkalis to form vaporous alkali chlorides. Between 700 and 900 °C, these compounds finally condense on the fuel or on the kiln gas dust and thus enter the rotary kiln again. This cycle between the rotary kiln and the preheater usually leads to the formation of deposits. In order to reduce these deposits, a controlled gas discharge takes place at the kiln inlet, whereby the alkalis and sulphates condense on the dust particles by means of gas cooling. After the gas has been dedusted, it is then fed back into the rotary kiln to reduce energy losses. In the separated bypass dust, there is a high concentration of alkalis and a lower concentration of sulphates. Dust separated in this way is usually processed during cement grinding. The dust is transported from the kiln to the cement grinding plant, often over distances of more than 100 m, usually via a pneumatic conveying system.

2 Problem definition

The increasing use of alternative fuels not only increases the total amount of bypass dust, but also the concentrations of alkalis and sulphates. ❱ Fig. 3 shows the predicted use of alternative fuels in the cement industry over the next decades. This development poses a particular challenge for pneumatic conveying in the coming years. When a limiting concentration is exceeded, adhesion, cohesion and liquid bridges can cause the material to stick together both in the conveying lines and especially in the feeding elements (❱ Fig. 4).

A large number of established cement manufacturers have already decided to equip their kiln plants with a bypass system in order to be able to burn ever higher proportions of alternative fuels. In the course of this development, Kreisel GmbH & Co. KG supplied customised system solutions to Opterra Karsdorf GmbH, Schwenk Zement KG, HeidelbergCement AG, Spenner GmbH & Co. KG and Dyckerhoff GmbH, among others. Further pneumatic conveying systems are currently being planned, for example for Sinoma TCDRI from China.

3 Injection systems

Bulk materials in dust form, such as the bypass dust or cements just described, are usually conveyed pneumatically

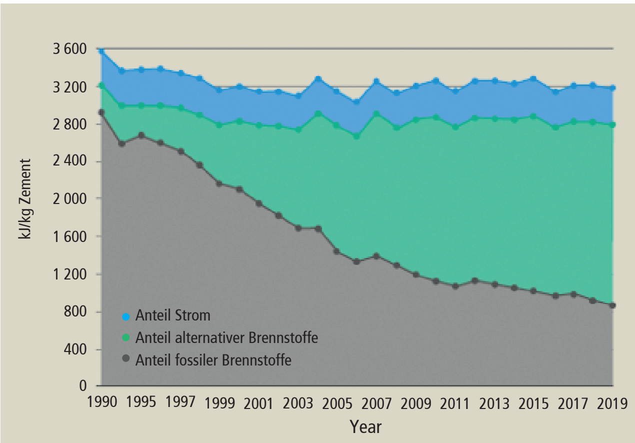

Figure 1: Development of specific energy use in Germany [2]

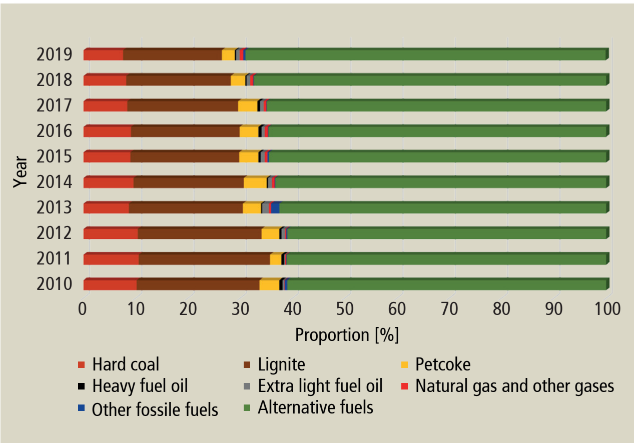

Figure 2: Fuel energy use by energy source from 2010 to 2019 [3] in %

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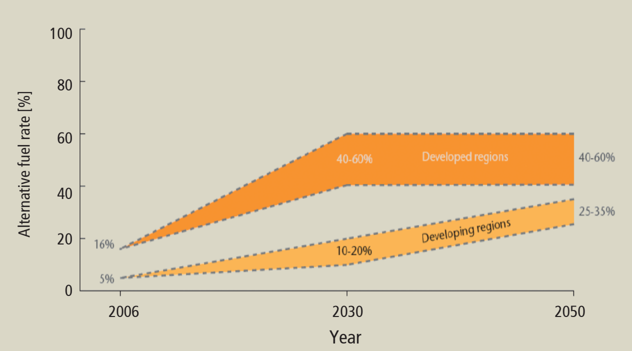

Figure 3: Worldwide alternative fuel rates in the next decades in the cement industry [4]

Figure 4: Bonded delivery pipe [5]

through a pipeline system by means of a conveying gas due to the often complicated conveying paths. Each system is individually designed and specifically adapted to the local conditions, insofar as the friction occurring between the pipe wall and the bulk material, as well as the stroke of the bulk material, are relevant variables when calculating the required system pressure. Since in a pneumatic conveying system the bulk material must always be fed into a conveying pipe under positive pressure, various feed systems such as pressure vessel systems, screw pumps or rotary valves are used. These three common infeed systems are explained in more detail below.

3.1 Pressure vessel system

In this infeed system, a compressed air station provides an air flow that is divided into a portion fed to the pressure vessel and a partial flow fed directly into the conveying line. Depending on the requirements of the material being conveyed, the gas flow to the vessel can be further divided into a portion to the vessel cone, which supports trouble-free discharge from the vessel, and a portion to the vessel head. Conveying with a pressure vessel system is discontinuous due to the cycle that takes place in the following four steps: filling – pressurising – conveying – depressurising. Material is only transported through the conveying line during conveying. The time used for conveying is therefore less than the cycle time. Thus, during the actual conveying phase, a higher solids throughput must be realised compared to the required nominal throughput. By interconnecting several pressure vessels, as shown in ❱ Fig. 5, an almost continuous but nevertheless pulsating delivery can be realised. The wide range of applicable conveying pressures, the universal applicability and the relatively good energy efficiency speak in favour of a pressure vessel system. However, high investment costs, regular inspections of the pressure vessels and the large amount of space required make the use of this injection system not always practical. When used to inject bypass dust, it has been shown that the dust is compressed in the outlet of the pressure vessel and the fluidising elements stick together. Due to such system problems, Spenner GmbH & Co. KG replaced its pressure vessel system in 2019 with a Kreisel rotary valve with forced clearing.

3.2 Screw pump

Up to now, screw pumps have often been used for the infeed of abrasive and/or adhesive materials. ❱ Fig. 6 shows the core components of such a screw pump, also known as a Fuller pump. In this infeed device, the bulk material first falls through the inlet (1) into the pump top box (2), which is needed to discharge the seal gas and the air displaced from the bulk material. The conveying or compression screw (3) usually rotates at speeds of about 1 000 rpm, captures the material and then transports it to the outlet. In the process, the material is strongly compressed in order to create a seal against the conveying line pressure. The outlet housing with the non-return cap (4) supports this process. The compressed material then falls into the outlet area (6) of the screw pump, is caught by the delivery gas and enters the delivery line (8).

The screw pump is convincing due to its continuous material feed, its moderate investment costs and its relatively small space requirement compared to the pressure vessel system. However, higher operating costs, caused by the enormous specific energy consumption, and possible disruptions in operation due to changes in bulk material properties, the presence of foreign bodies or feed fluctuations must be taken

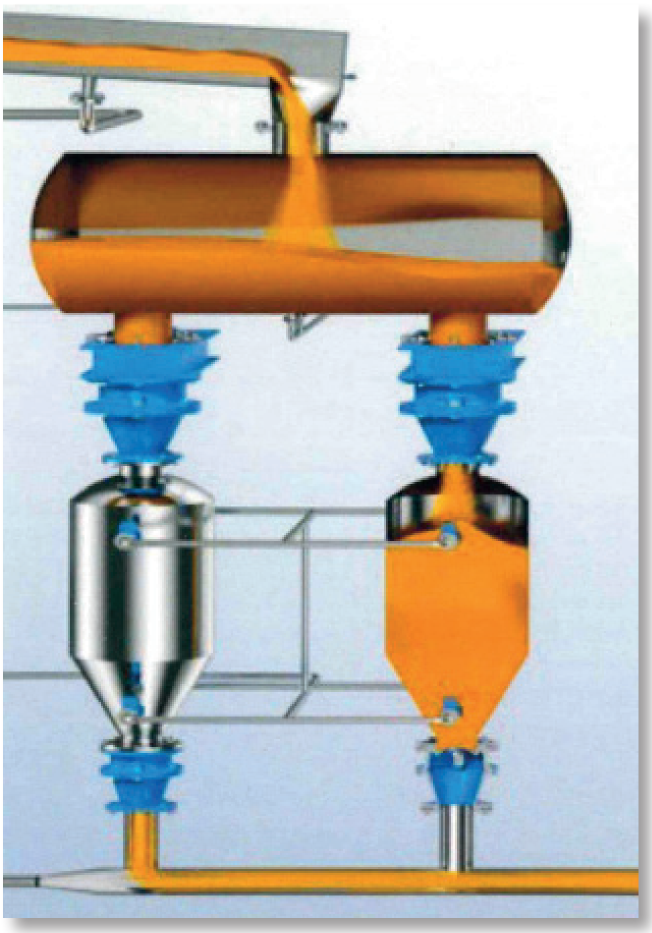

Figure 5: Interconnected pressure vessel system

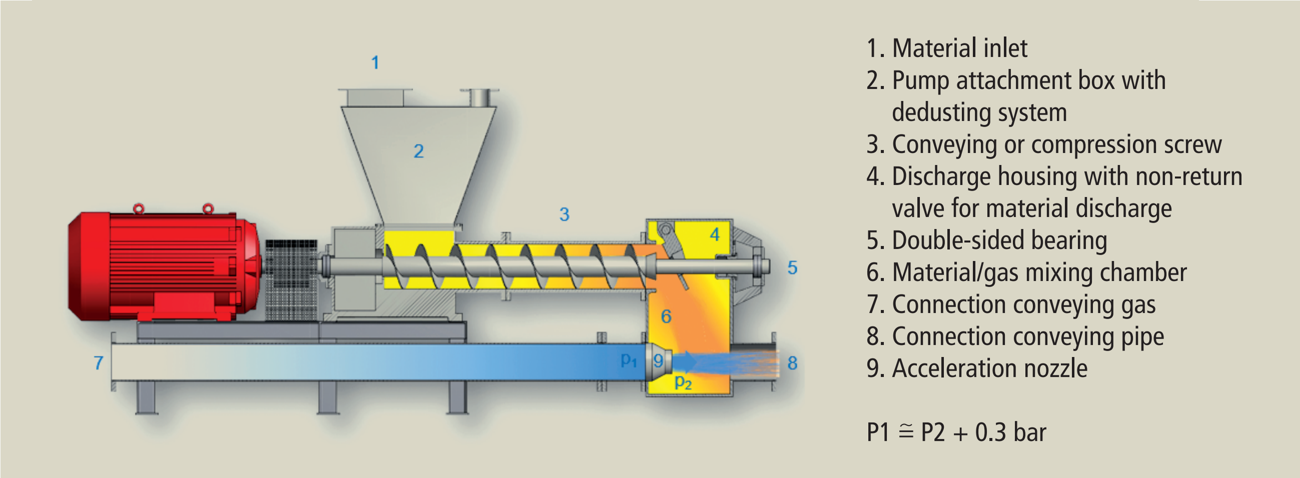

Figure 6: Core components of a screw pump

into account when deciding in favour of this system. When using screw pumps for pneumatic conveying of bypass dust, however, there are further disadvantages that prohibit their use. The compression of the dust in the discharge area of the compression screw causes the bypass dust to heat up. Sulphur, which assumes a liquid phase in the temperature window of 120 to 140 °C, can stick to the outlet area of the screw pump. In general, the finer the bulk material, the worse the sealing behaviour of the screw pump. For these reasons, the use of a screw pump for the introduction of bypass dust into a pneumatic conveying system is not recommended.

3.3 Rotary valve

For bulk materials that do not wear or do not stick strongly, the rotary feeder has been in widespread use for years. With the further development of industrial ceramics, this infeed system has also been further improved and can now be used effortlessly in conveyor systems for transporting abrasive bulk materials. By lining the housing with highly wear-resistant industrial ceramics, the rotary valve becomes insensitive to impact stress. Depending on the application, highly wear-resistant rotary valves can be used for the high-pressure range up to 200 °C.

The functional principle of a rotary valve is very simple: Bulk material falls from above onto the rotary valve, which rotates at speeds of up to 30 rpm. On the underside, the material falls into the pressurised conveying pipe. ❱ Fig. 7 shows the functional principle of a rotary valve. Very small gaps of < 0.2 mm between the rotor and the housing ensure that the air is sealed off between the inlet and outlet of the new self-cleaning rotary valve. The compressed air supply for pneumatic conveying is provided by conventional compressors or blowers.

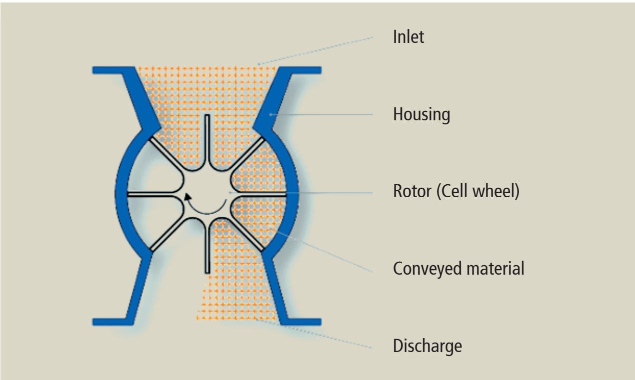

Figure 7: Functional principle of a rotary valve

Low investment costs, a very high level of reliability, a small space requirement and the simplicity of integration make the rotary valve (❱ Fig. 8) an indispensable infeed and metering device in bulk material conveying. In contrast to the screw pump or the pressure vessel, the material to be conveyed is not heated or compressed, which has an effect on the subsequent conveying process.

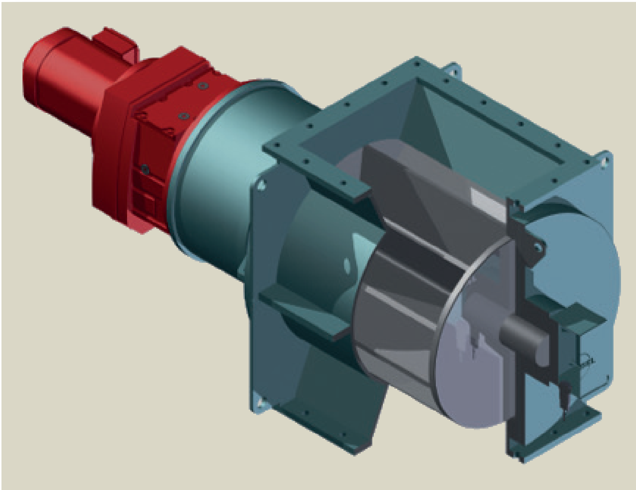

Figure 8: The Kreisel rotary valve in spatial representation

4 Overall comparison of the injection systems

The advantages and disadvantages of the different infeed systems for pneumatic conveying of bypass dust can be found in ❱ Table 1. An exemplary calculation for conveying cement raw meal of 100 t/h over a distance of approx. 160 m clearly shows the difference between screw pump and rotary valve in terms of energy requirements. ❱ Table 2 shows the energy requirements of four conveying systems operating in parallel. The very different space requirements must also be taken into account when comparing the infeed systems. A size comparison with the same conveying capacity can be found in ❱ Fig. 9. According to ❱ Fig. 10, the rotary valve is also superior to the other systems in terms of its space requirement. However, even a modern rotary valve can reach physical limits with adhesive bulk solids.

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Table 1: Evaluation of the infeed systems for pneumatic transport of bypass dust

Injection unit	Reliability	Energy efficiency	Investment costs	Simplicity of integration	Total score
Conveying with pressure vessel	2.5	1.0	3.0	3.0	2.4
Conveying with screw pump	2.5	2.5	2.0	1.5	2.1
Conveying with rotary valve	1.0	1.5	1.5	1.0	1.3

1: good/positive/well suited, 2: adequate/average, 3: negative/low suitability

Table 2: Comparative energy calculation of screw pump and rotary valve

Data	Screw pump size 300	Rotary feeder 630 x 630
Operation time [h/a]	7 500	7 500
Energy cost [€/kWh	0.07	0.07
Motor power at coupling of feeder [kW]	4 x 140	4 x 2
Motor power at coupling of pressure generator [kW]	–	–
Sum energy consumption [kW]	560	8
Sum energy per year [kWh/a]	4 200 000	60 000
Energy cost [€/a]	294 000	4 200
Profit using rotary feeder [€/a]	290 000	

5 The self-cleaning rotary valve

In order to be able to use the numerous advantages of a rotary valve also for the handling of adhesive, poorly flowing, moist or pasty bulk materials, Kreisel GmbH & Co. KG has developed the self-cleaning rotary valve with the type designation ZSR for this special application in recent years. The self-cleaning rotary valve combines the advantages of the classic rotary valve with the possibility of conveying particularly difficult bulk materials. This new type of rotary valve also uses a so-called clearing wheel, which is driven synchronously to the speed of the valve by means of a gear wheel. With the help of this scraper wheel, the individual cells of the rotary valve, in which the bulk material would normally stick, are cleared out. ❱ Fig. 10a shows a sectional view of the self-cleaning rotary valve, while ❱ Fig. 10b shows the scraper wheel in its dismantled state.

The housing of the self-cleaning rotary valve can also be lined with highly wear-resistant ceramic. The self-cleaning rotary valve type ZSR can be used for discharging with a constant volume throughput or for volumetric metering of poorly flowing, moist, pasty and sticky bulk materials such as bypass dust, kiln dust or hydrated lime. Sizes up to 700 mm rotor diameter, which can convey a volume flow of up to 120 m³/h, can be realised. Special designs can be offered for special applications and individual wear protection concepts can be integrated depending on the material to be conveyed. Furthermore, explosion-proof designs up to a pressure surge of 10 bar are possible. Designed to be safe against ignition penetration, the airlocks can also be used with the ATEX certificate. Currently, self-cleaning rotary valves with the following technical parameters are available:

- Maximum delivery pressure at the outlet: 1.5 bar (gauge pressure)
- Maximum material temperature: 200 °C
- Maximum volume flow: 120 m^3/h

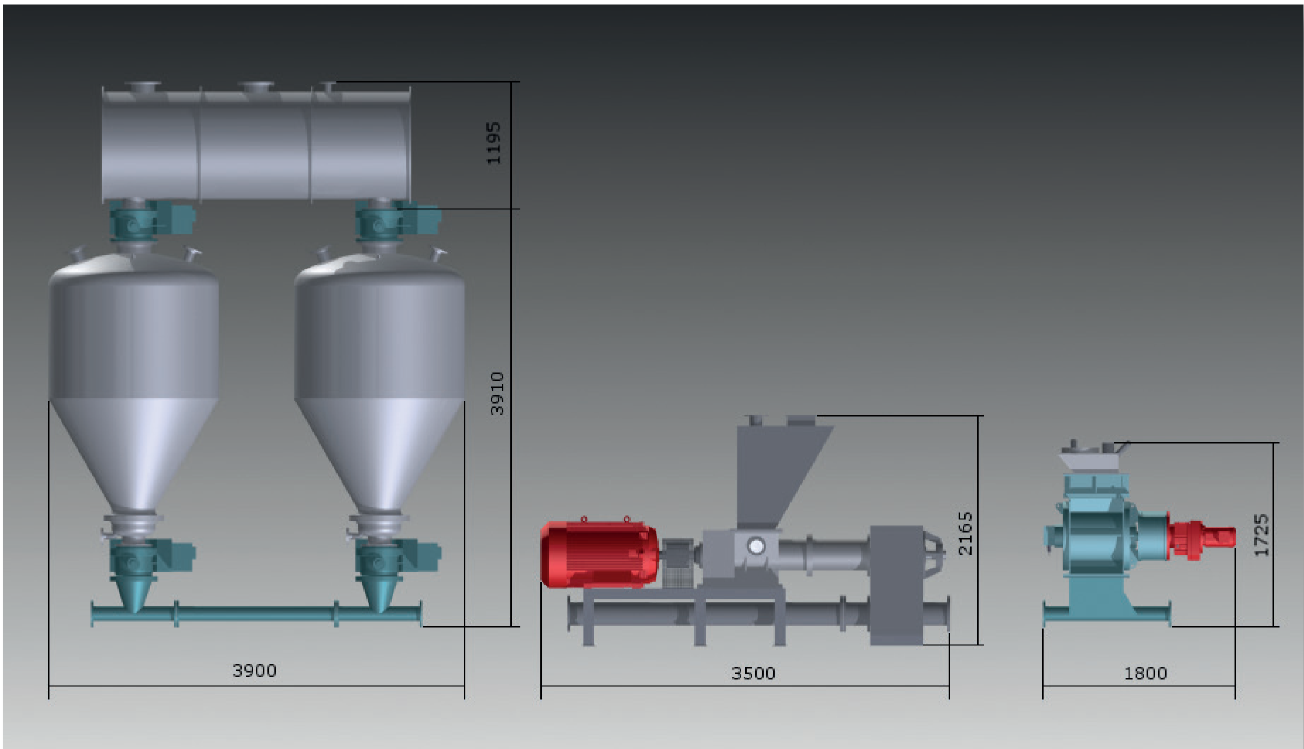

Figure 9: Size comparison of the three injection systems

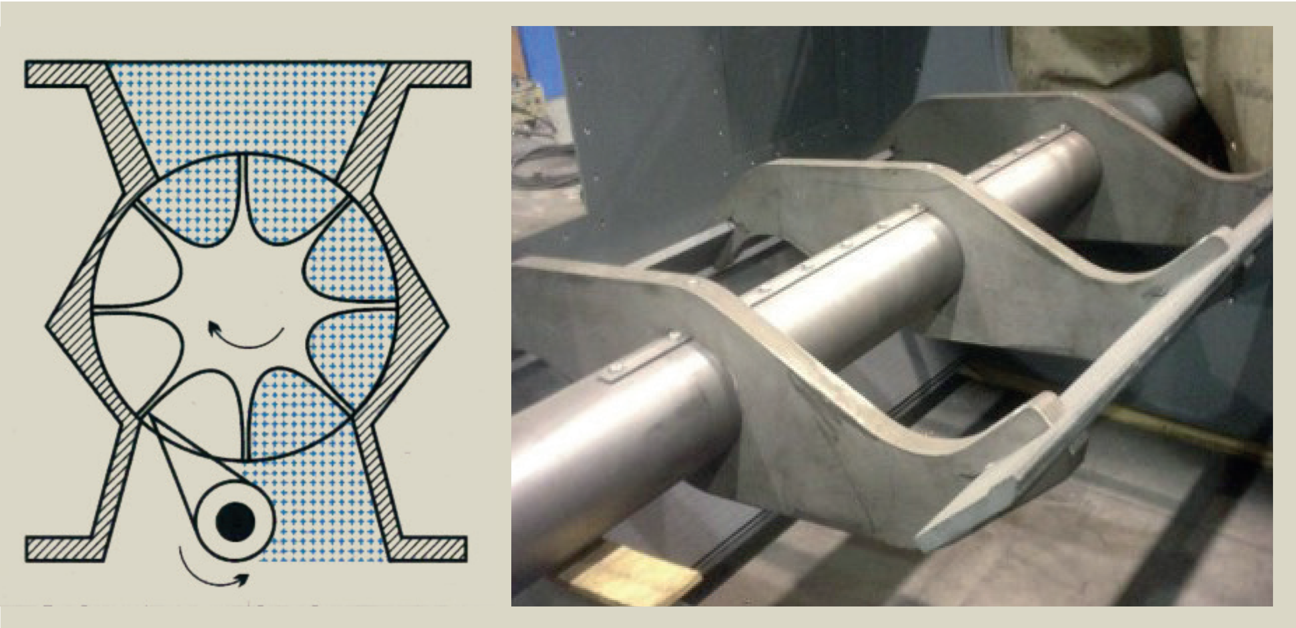

Figure 10: a) Functional principle of a self-cleaning rotary valve, b) Scraper wheel in dismantled condition

Kreisel GmbH & Co. KG has already successfully commissioned several of these rotary valves in the past: As early as 2015, three self-cleaning rotary valves with the type designation ZSR-H 250 x 250 were commissioned at the cement manufacturer Opterra Karsdorf GmbH in Germany. At a pressure difference of 0.5 bar (gauge pressure), bypass dust is conveyed with a throughput of 1.5 t/h per airlock. In addition to a more stable operating behaviour, the energy efficiency of the pneumatic conveying could also be improved by replacing the screw pumps used so far. ❱ Fig. 11 shows one of the self-cleaning rotary valves installed in the Karsdorf cement plant.

Since 2018, Spenner GmbH & Co. KG in the Erwitte cement plant in Germany has been pneumatically conveying bypass dust with a differential pressure of 0.4 bar (gauge pressure) by means of a self-cleaning rotary valve of the type designation ZSR-H 400 x 400. At Lafarge Holcim West Zement GmbH in Germany, a decision was made in 2019 to use a self-cleaning rotary valve with the type designation ZSR-H 400 x 400 for the pneumatic transport of bypass dust with a throughput of 10 t/h at a pressure difference of 0.8 bar (gauge pressure).

6 Outlook

Currently, only about 1 % of the 4500 cement plants worldwide have the problem of pneumatically conveying bypass dusts with high and build-up-forming chlorine and sulphur concentrations. In the course of the increasing substitution of fossil fuels with alternative fuels, however, almost all cement plants will have to be equipped with bypass systems in the next few years. For reliable and efficient pneumatic conveying of these dusts, the self-cleaning rotary valve from Kreisel is an indispensable infeed and metering system.

Figure 11: Self-cleaning rotary valve for pneumatic conveying of bypass dust at the cement works Karsdorf of Opterra

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