Rotary plug valves as an alternative for globe valves

Globe valves have traditionally been the number-one choice to handle challenging control tasks. These valves have proven their worth in various industrial processes, from complex chemical applications to the simple control of a heating circuit. However, a wide range of alternatives is available, such as ball-, butterfly-, rotary plug-, segmented ball-, gate- and plug valves.

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When taking a closer look, considerable differences between the various valve designs become evident. Fig. 1 provides an overview of the different valve types that are used to control process media in industrial processes. The illustration shows the average flow coefficients at maximum valve opening (K_{vs} coefficients) specified in manufacturer catalogs for valves in sizes up to NPS 10/DN 250.

At first glance, it becomes evident that the differences between the flow coefficients at maximum valve opening become more pronounced at larger valve sizes. At identical process conditions, flow rates and pressure drops, globe valves will always have to be used in a larger valve size than the other types considered. Obviously, this has a (considerable) influence on the purchasing price.

If only the above ratio was used for valve selection, the choice would always have to be made in favor of a segmented ball valve. Nevertheless, it is recommendable to look at further parameters before deciding on a specific valve style. In this article, we will take a closer look at the following aspects:

- Flow coefficient at maximum valve opening
- Rangeability
- Control accuracy
- Maximum permissible pressure drop
- Susceptibility to dirt and solid particles

Pressure reduction

Technical background information and information on possible fields of application for rotary plug valves can be found in [1], for example. On top, numerous additional parameters can have a considerable influence on valve selection. Such parameters include the space available at the site of installation, the maximum and minimum service temperatures and pressures, accessibility of the trim parts and the absence of dead cavities.

Giving a breakdown all influential factors in one overview is simply impossible. In summary, we can say that a wide range of different valve types has been available for decades to meet the different requirements that exist in the process industry.

Making a blanket judgement, the following could easily be concluded: the higher the flow coefficient, the smaller the valve size to be used in reality. When looking at the conditions that exist in a valve, it becomes evident that controlling a flow rate always involves reducing a pressure. As you will know, the K_v flow coefficient defines the relation between these two variables. The following applies to an identical pipe diameter and pipe size with water at room temperature as the process medium:

$$K_v = Q\sqrt{\frac{1\,\text{bar}}{\Delta p}}$$

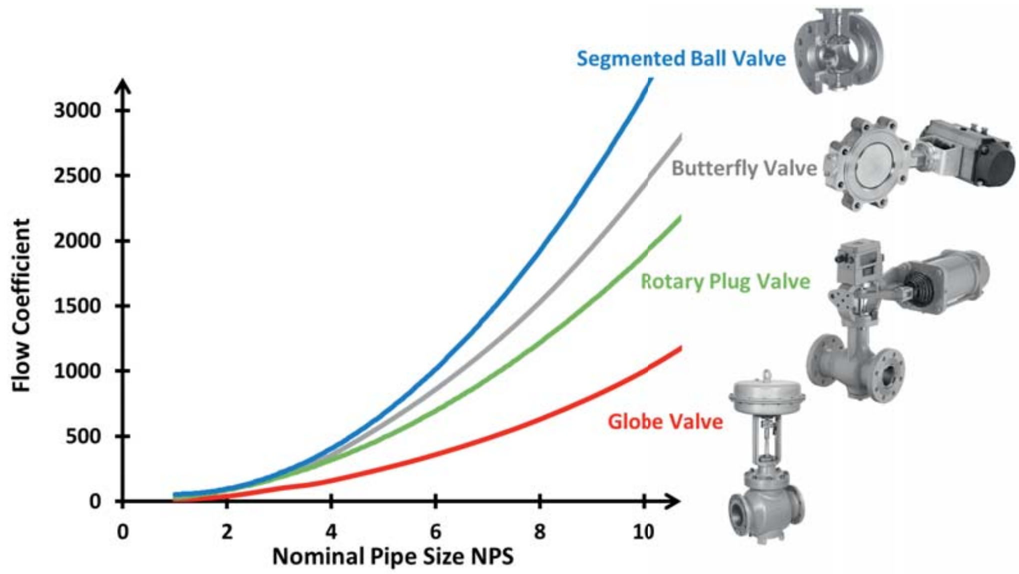

Fig. 1: Flow coefficients plotted against the valve size for different valve styles

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Assuming an average flow velocity in liquids of 2.5 m/s, which is realistic in real-life plant conditions, the maximum flow rate Q in DN 250 valves[1] is calculated as follows:

$$Q = c \cdot \frac{\pi \cdot d^2}{4} = 2.5\ \text{m/s} \cdot \frac{\pi \cdot (0.25\ \text{m})^2}{4} \approx 0.123\ \text{m}^3/\text{s}$$
$$\approx 442\ \text{m}^3/\text{h} \qquad \text{with}\ d \approx \text{DN} = 250\ \text{mm}$$

Based on the average K_v coefficients given in Fig. 1, the resulting pressure drops in a fully open valve are as shown in the table below:

Table 1: Pressure drops across different valve styles for Q = 440 m³/h at maximum valve opening in DN 250

	Globe valve	Rotary plug valve	Butterfly valve	Segmented ball valve
K_{vs} coefficient in m³/h	1000	2000	2500	3000
Pressure drop	0.2 bar	0.05 bar	0.03 bar	0.02 bar

Process parameters

The above values quickly show that the pressure drops across rotary plug valves, but particularly across butterfly and segmented ball valves, are nowhere near controllable flow rates. While butterfly valves and segmented ball valves normally have only one K_{VS} coefficient, rotary plug valves and globe valves can be fitted with different trims to adapt their K_{VS} coefficient to the operating conditions (refer to Table 2). As a result, butterfly valves and segmented ball valves are rather used in on/off applications.
Consequently, it is always important to take into account the process when looking at the maximum K_v coefficients: starting at a certain value, it becomes nearly impossible to generate any benefit from using an even higher flow coefficient. This is due to the valve authority, which relates the pressure drop across the fully opened valve to the pressure drop across the closed valve (for further information refer to [2], for example). Table 2 exemplifies the possible pressure drop increase for a reduced seat diameter. The right selection depends on several factors, such as the pressure ratio p_1/p_2, and will not be dealt with in this article.

Minimum controllable flow rate

In throttling service, the primary goal is to control different flow rates along the plant characteristic to achieve process stability and reliability. To have the widest possible range of application and the required safety margins for the running process and possible future adaptations, the ability to control maximum and minimum flow rates is beneficial – if not even necessary. As a result, we will look at the rangeability next. It establishes a relation between the maximum flow rate and the minimum controllable flow rate. The important thing to remember in this respect is that the rangeability is not about the minimum possible flow rate but the minimum controllable flow rate, i.e. the flow rate that can reliably be controlled by the opening and closing motion of the closure member.
Here is an example: various manufacturers specify a rangeability of up to 300:1 for a segmented ball valve with a high K_{VS}/DN^2 ratio (high flow coefficient relating to the valve size, refer to Fig. 1). As the valve has a single-eccentric design, considerable friction occurs in the closed position and while the valve opens. Stiction exists between the seat and segmented ball while the closure member is not moving. It is to be expected in the closed position because this is where the largest contact surface exists.

Realistic rangeability

If a rotary motion is initiated by the shaft, stiction and the initial breakaway torque are overcome and the segmented ball is moved from being stationary in the closed position. Depending on the change in set point, the valve must move to small opening angles, which are not reproducible due to different influence factors, such as pressure, temperature and medium properties. In technical terms, the smallest reproducible angle is considerably larger than the angle that is measurable in a few of many tests.
The challenge lies in the ability to reach this angle from both directions of operation, i.e. from the closed position in the opening direction and vice versa. If the segmented ball moves from the open position towards the seat, the dynamic forces create additional flow-related effects. They can also influence the smallest controllable angle. As a result, a realistic rangeability of a segmented ball valve is around 100:1.

Table 2: Pressure drop for Q = 440 m³/h in DN 250 valves with sample K_{vs} coefficient and reduced seat diameter

	Globe valve	Rotary plug valve	Butterfly valve	Segmented ball valve
K_{vs} coefficient in m³/h	250	500	No reduction possible	
Pressure drop	3.1 bar	0.78 bar		

[1] As we are dealing with a rough calculation only, we will make the simplified assumption that the inside pipe diameter corresponds to the valve size.

Table 3: Comparison of rangeabilities

	Globe valve	Rotary plug valve	Butterfly valve	Segmented ball valve
Rangeability	30:1 to 50:1	200:1	50:1	100:1

Table 3 gives an overview of technically realistic rangeabilities of standardized valve styles[2]. In this context, the rotary plug valves stand out as they cover the widest flow range by far. In addition to a relatively high throughput, rotary plug valves have by far the widest, reliably controllable range, which makes them perfect for throttling service.

Control accuracy

Key features of throttling valves are their control accuracy and their ability to handle the maximum permissible pressure drop. To achieve a high control accuracy, their characteristic must be as compliant as possible with the standard across the valve's full travel or rotational angle range. The maximum permissible pressure drop mainly depends on the turbulence created at the closure member and its mechanical bearing. Without dispute, globe valves have a distinct edge when it comes to meeting both requirements (high control accuracy and ability to handle high pressure drops). Nevertheless, rotary plug valves also produce good results in both categories. There are many investigations into this topic, which is why we only refer to the qualitative comparison presented in Table 4.

Dirt and solid particles

The last selection factor we will be looking at is the valves' susceptibility to dirt and solid particles. Particles can influence the control behavior and wear on the valve in different ways. Increased friction may occur while the valve moves, which can cause erosion damage on the facing as well as the entire closure member.
Rotary plug valves perform considerably better in this respect than other valve styles. Thanks to their double-eccentric design, which ensures that the plug and seat only touch in the closed position, there is no risk that particles deposit on the facing while the valves are closing and damage the facing. Particles are washed away by the high-flow velocities that exist immediately before the plug and seat touch. Contrary to segmented ball valves for example, particles between the seat and plug cannot cause increased friction while the valves are moving either. As the closure member is completely turned out of the medium flow and thanks to the split shaft, only minimal wear is caused by erosion and abrasion.

Cost benefit

The picture is rather inhomogeneous when looking at the qualitative comparison of criteria for selecting a suitable throttling valve presented in Table 5. Nevertheless, the multitalented rotary plug valves often emerge as a good alternative to globe valves in terms of control, resistance and cost.
The very high maximum flow coefficient in connection with the high rangeability often present the most competitive solution among the valve types considered. Rotary plug valves are all-rounders with their high control accuracy coupled with the ability to handle high maximum pressure drops and particularly their resistance to dirt and solid particles contained in the process medium. Other manufacturers run out of portfolio options where large valve sizes and high-pressure ratings are concerned, i.e. where the cost benefit is at its highest. This is exactly where VETEC, a 100 % subsidiary of SAMSON, located in Frankfurt, has its core competence. Rotary plug valves by VETEC can be used in virtually every field of application thanks to the wide variety of different materials they are available in: different steels and stainless steels, nickel-based alloys, bronze, zirconium as well as wear- and corrosion-resistant materials, including Stellite®, carbide metals and ceramics.

Table 5: Qualitative comparison of valve selection criteria considered (++ Excellent / + Good / o Satisfactory / – Below average)

	Globe valve	Rotary plug valve	Butterfly valve	Segmented ball valve
Max. throughput	–	+	++	++
Rangeability	–	++	–	+
Control accuracy	++	+	–	+
Max. pressure drop	++	+	o	–
Susceptibility to dirt	–	++	o	–

Table 4: Qualitative comparison of control accuracy and maximum permissible pressure drop (++ Excellent / + Good / o Satisfactory / – Below average)

	Globe valve	Rotary plug valve	Butterfly valve	Segmented ball valve
Control accuracy	++	+	–	+
Max. pressure drop	++	+	o	–

Bibliography

[1] Vogel, U. (2019). Das Drehkegelventil als Regelorgan. *cav chemie anlagen verfahren* 1/2019
Available in German at: https://prozesstechnik.industrie.de/

[2] Strohrmann, G. (2002). *Automatisierung verfahrenstechnischer Prozesse.* München: Oldenbourg Industrieverlag GmbH

[2] Considerable deviations may occur when using special versions with materials and tolerances tailored to specific operating conditions. As these versions are customized, their large-scale use is not economically viable.