7.5.4. Valve characteristic and rangeability

The control valve characteristic curve or inherent characteristic determines to a considerable degree the attainable control accuracy and control effectiveness. The ideal valve characteristic is smooth and without turning points and gives an unchangeable gain of the final control element. However, compromises are necessary in practice since the operating characteristic matches the inherent characteristic only in the rarest of cases. For this reason, no general preference exists and no general recommendation for a basic characteristic can be given.

The control valve **rangeability** specifies the ratio of the biggest to the lowest flow coefficient by which the deviations from the defaulted inherent flow characteristic are within authorized tolerances. Both the inherent characteristic and the rangeability depend alone on the travel position of the plug and the resulting free cross-sectional area of the flow path. Firstly the constructive presumptions shall be clarified in order to obtain a specific control pattern and rangeability. Application technical aspects for the selection of a suitable valve characteristic are discussed in chapter 11.

The **inherent valve characteristic** is defined as the relationship between the relative flow coefficient $\Phi = C_v/C_{v100}$ and the relative travel $h/h_{nom.}$. The corresponding standard IEC 60534-2-4 distinguishes generally between a linear and an equal-percentage characteristic, although other characteristics are conceivable and are useful too. The inherent characteristic is ideally determined with an unchanging differential pressure at the valve (test specimen). In practice, however, this is very seldom the case. This causes in most cases a degeneracy of the ideal inherent characteristics curve.

The relationships occurring in practice between travel and flow are determined by the so-called **operating characteristic**.

The relationships in case of inherently linear or inherently equal-percentage characteristics can be best represented mathematically.

Ideal inherent linear flow characteristic:

$$\phi = \phi_0 + m \cdot h \qquad (7\text{-}2)$$

In equation (7-2) Φ_0 is the relative flow coefficient at a travel of h = 0. This applies, however, not for the small remaining leakage at closed valve position but concerns a fictitious flow or flow coefficient which is determined by the theoretical rangeability of the valve under consideration. Most common, for industrial type control valves, is a rangeability of 50:1 or 30:1. The preceding example referred to a rangeability of 50:1. In this way, the initial value of Φ_0 = 1.0/50 = 0.02 is clearly determined.

The relative and absolute C_v-values (column 2 of Table 7.3.5.12.-2) were computed in accordance with equation (7-2). The inclination of the ideal characteristic is expressed by the factor m and is determined by the theoretical rangeability (in this example 50:1). The inclination is computed as follows:

$$m = \frac{1 - \phi_0}{1.0} \qquad (7\text{-}3)$$

This results in a theoretical rangeability of 50:1 with a gradient m = 0.98.

Ideal inherent equal-percentage flow characteristic:

In case of an equal-percentage flow characteristic, identical relative changes of travel show identical changes in percent of the flow coefficient. That means mathematically:

$$\phi = \phi_0 \cdot e^{n \cdot h} \tag{7-4}$$

The term Φ_0 corresponds to the initial value (here 0.02), is the basis of the natural logarithm and n expresses the slope of the characteristic, which in turn, depends on the theoretical rangeability (50:1). The equation for n reads:

$$n = \ln \frac{1}{\phi_0} \tag{7-5}$$

With Φ_0 at 0.02 the slope becomes n = 3.91. With this figure the relative C_v- value can be computed for every travel position h and specified in a tabular form for travels of 5, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100%.

For the rated flow coefficient or C_{v100} value, a tolerance of ± 10 % is permissible. But for all other relative flow coefficients specific values have to be adhered to. The permissible deviations in percent may be as larger as smaller the relative C_v-value is. The permissible limitation values follow from the international standard IEC 60534-2-4.