9. Tolerances

Hidden cost factors

Tolerances – Injection mouldings cannot be produced to the same tolerances as machined parts. Although most people are aware of this, tolerances are continually being specified that cannot be attained and/or make cost-efficient production impossible.

Tolerances and their cost implications
A distinction is generally made between three quality classes: general-purpose injection moulding, technical injection-moulding and high-precision injection-moulding. In the DIN 16901 standard, these are specified in terms of general tolerances and dimensions with directly figured allowances (ranges 1 and 2):
– “general-purpose” injection-moulding requires a low level of quality control and is characterised by low reject rates and fast production cycles
– technical injection-moulding is considerably more costly, since it makes higher demands on the mould and the production process, requires frequent quality control checks and is therefore likely to have increased reject rates
– the third group, high-precision injection-moulding, requires precision moulds, optimum production conditions and 100 % production monitoring with continuous quality control. This affects cycle time and-through increased production and quality control costs-on the unit price.
Since designers play a key role in determining the costs of an injection-moulded part, they must also ensure commercially viable tolerancing. The selected tolerances should not be as tight as possible but as tight as necessary.

A commercially acceptable value for a production tolerance would be 0.25 to 0.3 % deviation from the nominal dimension, but this must be checked against application requirements (Fig. 1).

It should be remembered that thermoplastics, which typically have high elongation and elasticity, do not need to have the close tolerances that are specified for metals with their high rigidity, low elongation and low elasticity.

Factors influencing tolerances
To avoid excessively close tolerances for plastics components, the many different factors that influence the dimensional accuracy of an injection-moulded part (Fig. 2) must be kept in mind. Tolerances in tool-making have to be observed relatively closely. Designers should not forget, however, that demoulding tapers for easy, distortion-free ejection from the injection mould are vital (Fig. 3).

Adherence to tolerances is a problem when moulding parts from different materials or with different wall thicknesses. Mould shrinkage values are direction- and thickness-dependent. This behaviour can be seen most clearly with glass-fibre-reinforced materials. Here, the orientation of the glass fibres can produce significant differential shrinkage between the longitudinal and transverse directions, and this can lead to dimensional inaccuracies.

The geometry of the moulded part can also have an effect on shrinkage and hence on tolerances (Fig. 4).

If complex mouldings are to be produced to close tolerances, a prototype mould is essential to obtain accurate information on the actual shrinkage value and warpage behaviour.

Production and operating tolerances
It is important to decide whether only a production tolerance is required or whether an operating tolerance is also necessary, since thermoplastics are affected by their service environment. For example, thermal expansion – which can be ten times more than for metals (Fig. 5) – and the marked tendency of some polymers (e.g. nyons) to absorb moisture play a crucial role in the operational reliability of a part in service.
With semi-crystalline materials, post-shrinkage must also be taken into account. This phenomenon, which is influenced mainly by injection moulding conditions, can lead to dimensional changes in finished parts after demoulding. Quality control must not be carried out immediately after demoulding. The DIN 16901 standard specifies that quality control should be undertaken only after 16 hours’ storage under standard climatic conditions (23 °C, 50 % relative humidity) or after suitable pre-treatment.

Recommendations
The tolerances specified in DIN 16901 can be used as a starting point for cost-efficient production of moulded parts. However, the improved technology of modern injection moulding machines enables considerably closer tolerances to be attained than the values specified in this standard. For high-precision injection mouldings, individual industry sectors have developed separate tolerance tables because DIN 16901 is no longer adequate. In any case, however, when close tolerances are needed, it is important to consult with the injection moulder or material supplier to see if the required tolerances are technically feasible and commercially appropriate (Fig. 6).