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Designing with Plastics

Gunter Erhard

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Leseprobe 2

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8 Flexing Elements

Structural elements that are required to have high deformability should be designed so that they are capable of withstanding the flexural or torsional loads associated with the application (see also Section 6.1). Two examples of such designs common in parts made from polymeric materials are snap-fit or interlocking joint elements and elastic elements. Another common feature in parts designed for high deformability is their relatively thin wall thickness. For example, integral hinges are structural elements having extremely low wall thicknesses.

8.1 Snap-Fit Joints

Definition

Joint types are defined according to the mechanisms acting at the points of attachment holding the assembled parts together (see Figure 8.1) [8.1]. On this basis, a snap-fit joint is a frictional, form-fitting joint.

The structural features of a snap-fit joint are hooks, knobs, protrusions, or bulges on one of the parts to be joined, which after assembly engage in corresponding depressions (undercuts), detents, or openings in the other part to be joined.

Accordingly, the design of a snap-fit joint is highly dependent on the polymeric material(s). Snap-fit joints are also relatively easy to assemble and disassemble. A key feature of snap-fit joints is that the snap-fit elements are integral constituents of the parts to be joined.

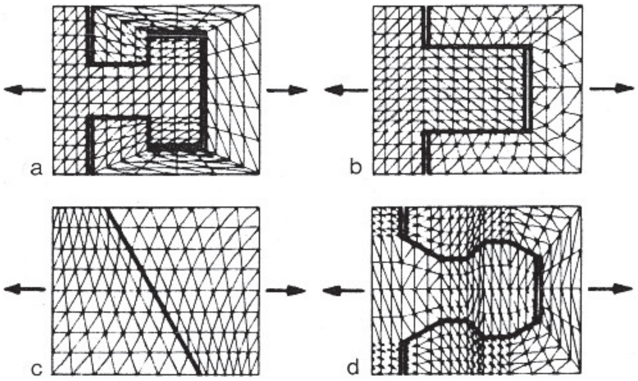
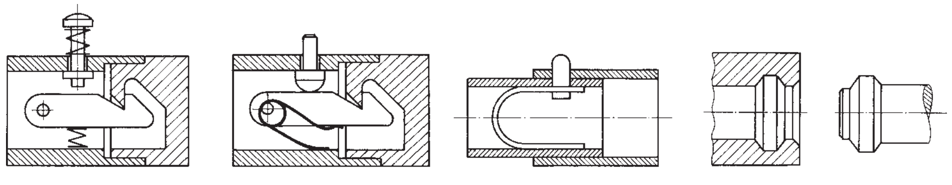


Figure 8.1 Types of joints (schematic) [8.1]
a) Form-fitting joint
b) Frictional joint
c) Adhesive joint
d) Frictional form-fitting joint
←→ Direction of action of forces

Differentiated and Integrated Construction

Design solutions using "differentiated" construction assign certain functions separately to the individual structural elements with the goal of fulfilling all of the functional requirements in an optimum manner. This inevitably means that there are a number of parts in a subassembly. "Integrated" construction, on the other hand, uses fewer parts and consequently results in lower assembly costs but may require the acceptance of restrictions or compromises in functionality. Figure 8.2 shows this trade-off with reference to the example of a bayonet coupling.



a 7 parts b 6 parts c 4 parts d 2 parts

Figure 8.2 Design variants for a coupling as described in [8.12] and [8.16]

The systematic reduction in the numbers of parts finally leads to variant d), a snap-fit joint made from polymeric material. Injection molding technology is so versatile, that it allows for the integration of functions directly into the parts to be joined.

Classification

Snap-fit joints are classified according to the most varied attributes [8.2, 8.3, 8.4, 8.13]. However, a classification based on geometrical considerations appears to be most appropriate here (see Figure 8.3).

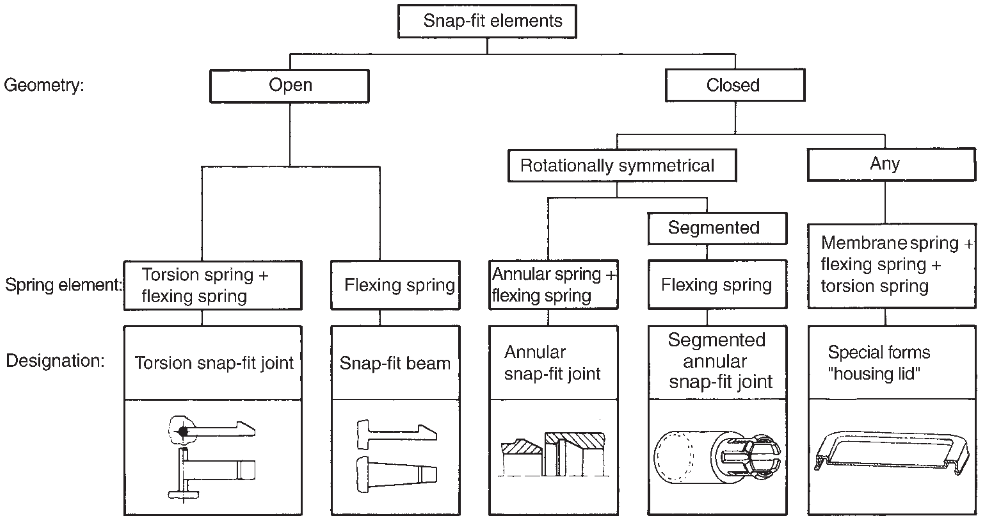


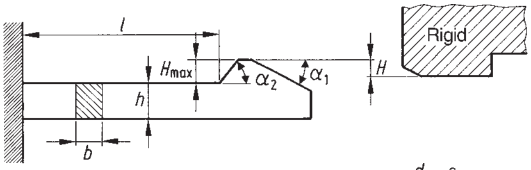
Figure 8.3 Classification scheme for snap-fit elements based on geometrical considerations

Dimensions and Forces

The dimensions and forces associated with assembly/disassembly are discussed in the following figures.

Figure 8.4 Dimensions and their designations for snap-fit hooks

α_1 = Joining angle
α_2 = Retaining angle
b = Breadth of cross section (hook breadth)
h = Height of cross section
l = Snap-fit length
H = Snap-fit height (undercut)



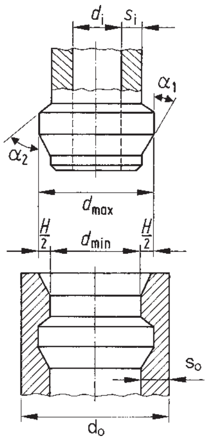


Figure 8.5 Dimensions and their designations in cylindrical annular snap-fit joints

d_{max} = Greatest diameter
d_{min} = Smallest diameter } of the snap-fit joint
d_o = Outer diameter
s_o = Wall thickness } of the outer part
d_i = Inner diameter
s_i = Wall thickness } of the inner part

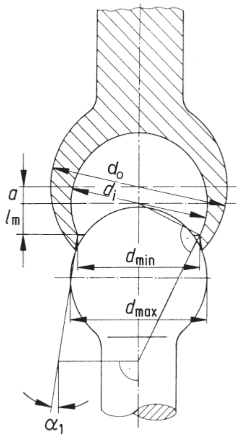


Figure 8.6 Dimensions and their designations in spherical annular snap-fit joints

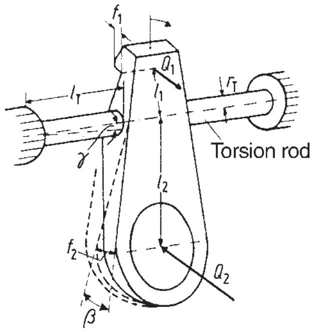


Figure 8.7 Dimensions and their designations in torsional snap-fit joints

l_T = Length
r_T = Radius } of torsion rod
β = Torsion angle
γ = Twisting angle
$l_{1,2}$ = Lever arm lengths
$f_{1,2}$ = Elastic excursions
$Q_{1,2}$ = Deflection forces

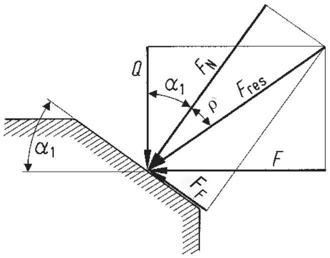


Figure 8.8 Angles and forces at the active surface
Q = Deflection force
F = Assembly force
F_N = Normal force
F_F = Friction force
F_{res} = Resultant force
α_1 = Joining angle (lead-in angle)
ρ = Friction angle

The forces and angles at the assembly contact surfaces of the joints (see Figure 8.8) apply in an analogous manner for all snap-fit joint design variations.

Assembly Operation

A review of the snap-fit assembly operation is helpful to gain a better understanding of the factors at work and of the calculations discussed below. The assembly force *F*, generally acting in the axial direction, is resolved at the mating surface in accordance with the mathematical relationships associated with a wedge (see Figure 8.8). The transverse force *Q* causes the deflection needed for assembling the joint. At the same time, friction and the joining angle determine the conversion factor η.

$$\eta = \tan(\alpha_1 + \rho) = \frac{f + \tan\alpha_1}{1 - f \cdot \tan\alpha_1} \qquad (8.1)$$

The relationship in Eq. 8.1 is plotted in Figure 8.9 against $\alpha_{1,2}$ for common values of η.

The retaining or release force of the joint can be altered using the retaining angle α_2. The use of a value of $\alpha_2 \geq 90°$ creates a self-locking geometric form-fitting joint. Figure 8.10 illustrates that a joint constructed in this way can be released again without forced failure of the joint when the moment of the force couple represented by the retaining and reaction forces is able to overcome the friction force in the active surface.

A design countermeasure to prevent release in this way is to attach a retaining guard or locking ring (see also Sections 8.1.1.3 and 8.1.3.3).

As snap-fit features are being assembled, the assembly force follows the characteristic pattern shown in Figure 8.11. This is also described in [8.11] and [8.23]. After a steep rise, the assembly force reaches a peak, falls to a lower level where it remains fairly constant as the lead angle causes the part to deform, and then falls back to zero, once the joint area of the part snaps into place.

Deformation during the assembly of snap-fit joints can be significant. As a result of these deformations during the assembly operation, the geometric relationships change (*e.g.*, the relative angular positions) [8.21, 8.10]. This, however, is not taken into account in the calculation of the assembly forces in the sections below. The local variation of the plane of action and its effect on transverse force during the assembly operation is likewise not taken into account (see Section 5.4).

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