Elegant route to the future

Clive Maier explains the principles of snap-fits, one of the most efficient methods of joining plastic parts

The PRW monthly Design Guides provide practical guidance for designers, toolmakers and moulders. Every month a different aspect of design technology will be tackled and together these guides will become an indispensable reference point for those designing successful products.

In the previous design guide we looked at bosses used with thread-forming screws as a means of joining or assembling plastics parts. There are many other ways of achieving the same object, for example by welding, adhesives, staking and snap-fits. But of all these methods, the snap-fit is perhaps the most elegant way of joining plastics parts together.

Snap-fits involve pushing a projection on one part past an obstruction on a mating part. They rely entirely for their effect on the elasticity of plastics. Generally, one part is more or less rigid, while the other part is flexible or resilient. Depending on the design, the joint can be permanent or releasable. Both parts can be plastics – either the same or different types – or one part can be a foreign material such as a metal shaft or a laminated circuit board.

There are three main types of snap-fit:

- the cantilever snap-fit, also known as a snap hook, catch spring, spur, or lug;
- the cylindrical or ring snap-fit; and
- the spherical snap-fit.

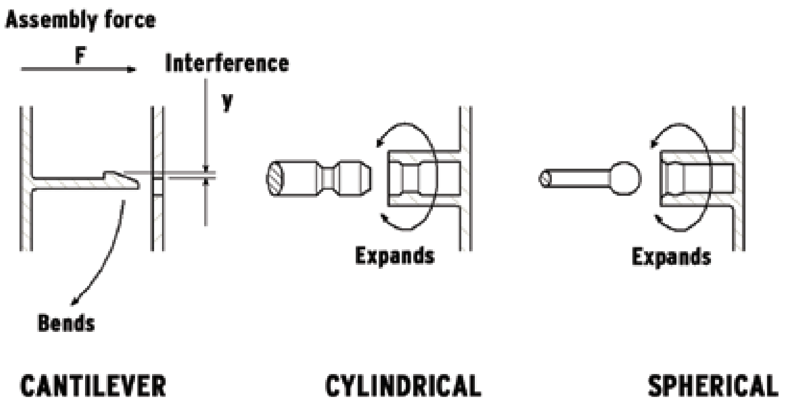
A further type, the torsional snap-fit, is not so common and may be regarded as an alternative to the snap hook; one in which the elastic action of the catch is supplied by placing a plastic member in torsion rather than flexure.

The cantilever, cylindrical, and spherical types share common basic principles. In each case, the joint is assembled by applying a force (F) to bring the parts together. When they meet, joining is opposed by an interference (y) between the parts. When the force is sufficient, an elastic deflection that is equal to the interference allows the parts to come together (see diagram).

The design of the snap-fit is such that the deflection is wholly or substantially released once the interference points have passed and the parts have come together.

For the cantilever type, the deflection is a simple bending or flexure of the lug. By contrast, both the cylindrical and spherical types require an elastic radial expansion. Mechanically, the cylinder and sphere are much stiffer structures than the cantilever, so the interference dimension is usually smaller.

Diagram 1: The principal snap-fit types



Designers' notes

- Snap-fits work by using the elasticity of plastics
- The three main types are cantilever, cylindrical and spherical
- Joints can be permanent or releasable
- Snap-fits are cheap, efficient and "green"

You may also see these types provided with a number of radial slots to make expansion easier. In effect, they have now become a set of snap hooks arranged in a circle.

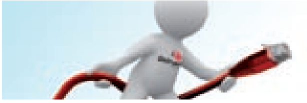
Earlier, we described snap-fits as elegant. By this we mean that they are efficient, virtually free of charge and "green".

The snap-fit features can be designed as an integral part of the moulding without any increase in cycle time and at the expense of only a small increase in mould cost and maintenance.

Assembly can be performed with little or no tooling, using almost no energy, and without the need to purchase and stock additional parts such as screws, clips, or adhesives. And when the time comes to recycle the part, there are no foreign materials needing to be removed before granulating.

For these reasons, snap-fits are likely to become an even more popular design feature in plastics assemblies of the future. Success or failure depends on the detail. We will set out the design principles in following design guides.

Clive Maier, Econology



Design **guide** Sponsored by Distrupol

May release force be with you

Clive Maier explains how to design the snap hook so that the release force is stronger than any other

The PRW monthly Design Guides provide practical guidance for designers, toolmakers and moulders. Every month a different aspect of design technology is tackled and together these guides are becoming an indispensable reference point for those designing successful products. Having started with relatively basic design guidance, more sophisticated and detailed issues are now being addressed as the series progresses.

In the previous design guide we looked at the general principles of snap-fits. Now let's examine the most popular type – the cantilever or hook – in more detail.

The cantilever type clicks or snaps into engagement when it is pushed past a catch on a mating part. The hook has a tapered face with a shallow engagement angle to help it past the obstruction.

A releasable snap hook has a second tapered face set at a release angle to allow it to be removed again. The release angle is greater than the engagement angle, to make release relatively difficult. If release is too easy, the snap-fit will not act as a reliable fastener. When the release angle approaches 90°, removal by pulling is virtually impossible and the snap-fit becomes a permanent joint.

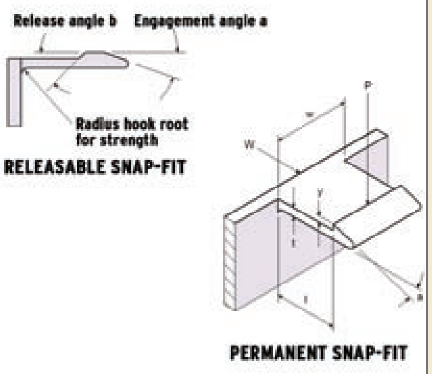
When the cantilever hook is pushed past the catch, it is forced to flex. The amount of deflection is equal to the interference between hook and catch, and this must be kept to a dimension that does not exceed the allowable strain for the cantilever material.

The table (below) shows approximate design data for a range of unfilled materials. The allowable strain figures are for a snap-fit that is used just a few times. If it is to be used only once, the strain figures can be doubled. The figures in the table should be taken as a guide only. For accurate design, you will need to get grade-specific figures from your materials supplier.

Typical data for snap-fits

Material	Allowable strain (%) e	Flexural modulus (Gpa) E	Coefficient of friction
PS	2	3.0	0.3
ABS	2	2.1	0.2
SAN	2	3.6	0.3
PMMA	2	2.9	0.4
LDPE	5	0.2	0.3
HDPE	4	1.2	0.3
PP	4	1.3	0.3
PA	3	1.2	0.1
POM	4	2.6	0.4
PC	2	2.8	0.4

Diagram 1 Snap-fit dimensions and forces



Designers' notes

- Keep within the allowable strain figure
- If the calculated allowable deflection is too small, try increasing the snap hook length
- Design so that the snap hook is no longer flexed after it has clicked into the catch
- Snap-fits are meant to be used either once or just a few times, so fatigue and wear can be neglected
- Radius the root of the snap hook to reduce stress concentration

For a snap hook with a constant cross-section, the maximum deflection Y can be worked out from this equation:

$$y = \frac{el^2}{1.5t}$$

The equation assumes that only the snap hook flexes. In many cases, the moulding face to which it is attached will also flex a little. This can be regarded as a safety factor. If the hook mounting is rigid, then you should reduce the calculated maximum deflection by a safety factor.

The normal force P needed to move the snap hook through deflection y comes from this equation:

$$P = \frac{wt^2Ee}{6l}$$

This result can be used to work out the force W needed to engage the snap fit with the catch.

$$W = P\frac{\mu + \tan\alpha}{1 - \mu\tan\alpha}$$

In the case of a releasable snap hook, the same formula can be used to work out the release force by substituting the release angle b for the engagement angle a.

If the release force approaches the tensile strength of the snap hook, it is likely to break as you try to release it. Similarly, the catch will shear off if its cross-section is too weak compared with either the engagement force or release force. Of course, if the snap hook is properly designed, the release force will always be the greater, even in a releasable design.

Clive Maier, Econology

Design **guide** Sponsored by Distrupol

More to a join than strength

Clive Maier explains why elasticity is the most important factor when using cylindrical snap-fits

The PRW monthly Design Guides provide practical guidance for designers, toolmakers and moulders. Every month a different aspect of design technology is tackled and together these guides are becoming an indispensable reference point for those designing successful products. Having started with relatively basic design guidance, more sophisticated and detailed issues are now being addressed as the series progresses.

The cylindrical or ring snap-fit has a continuous internal undercut that is engaged by a groove on a shaft. It is often used to retain a plastics part such as a knob on a metal shaft but it can also be used to secure two plastics parts together.

Like other snap-fits, the joint can be designed to be releasable or permanent depending on the slope of the release angle. When the joint is inserted or released, the hub is forced to expand elastically. This makes for a spring that is inherently stiffer and stronger than the cantilever hook type of snap-fit.

Strength is usually an advantage but there are some drawbacks too. The insertion force can be quite high and it is often necessary to make the undercut relatively small. The hub works best when it is moulded in a comparatively elastic material, not least because it must be ejected off an undercut core in the mould. This means that stiff glass-filled and other reinforced grades may not be suitable for the ring snap-fit.

Designers' notes

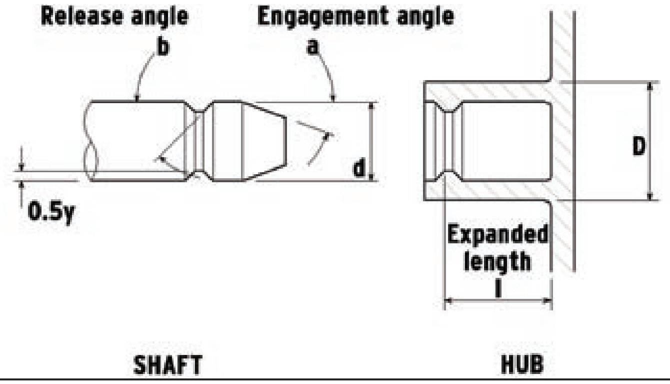
- ● Don't use cylindrical snap-fits with very stiff materials
- ● Use an engagement angle of 20°-30° and a release angle of 40°-50°
- ● Place the undercut near the open end of the hub
- ● Size the undercut so that the design stress figure is not exceeded

The stiffness of the hub spring depends not only on its thickness but also on its free length and crucially on how close the undercut is to the free end. Ring snap-fits should always be designed with the undercut reasonably near the hub free end, otherwise the stiffness of the spring will significantly greater and the joint may fail.

Assembly of the joint is made easier by providing a draft or engagement angle on the end of the shaft. An angle of 20°-30° works well. The release angle determines how easily the snap-fit can be disengaged. The greater the angle, the harder it is to release. An angle of 40°-50° is usual. Use a greater angle if you want the joint to be permanent.

The diagram (above right) shows the key features for a cylindrical snap-fit.

Diagram 1: Main features of cylindrical snap-fits



The maximum allowable undercut can be worked out from this equation:

$$y = \frac{Sd}{K}\left[\frac{K+v_{hub}}{E_{hub}} + \frac{1-v_{shaft}}{E_{shaft}}\right]$$

where S = design stress, v = Poisson's ratio, E = Modulus of elasticity and K = geometry factor.

The geometry factor K can be calculated from this equation:

$$K = \frac{1+\left[\frac{d}{D}\right]^2}{1-\left[\frac{d}{D}\right]^2}$$

The table (right) gives approximate values for Poisson's ratio for a range of unfilled materials. For accurate design, you will need to get grade figures from your materials supplier.

The expansion force exerted on the hub is given by the equation:

Material	**Poisson's ratio v**
PS	0.38
PMMA	0.40
LDPE	0.49
HDPE	0.47
PP	0.43
PA	0.45
PC	0.42
PVC	0.42
PPO	0.41
PPS	0.42
Steel	0.28

$$P = \frac{[\tan\alpha + \mu\ ]S_y dl\pi}{K}$$

where ◄ = coefficient of friction and Sy = stress due to interference.

Values for the coefficient of friction were listed in the previous Design Guide.

Clive Maier, Econology

Design **guide** Sponsored by Distrupol

Twist for an easy release

Clive Maier explains why torsion snap-fits are a good way of fastening a hinged lid on a box or container

The PRW monthly Design Guides provide practical guidance for designers, toolmakers and moulders. Every month a different aspect of design technology is tackled and together these guides are becoming an indispensable reference point for those designing successful products. Having started with relatively basic design guidance, more sophisticated and detailed issues are now being addressed as the series progresses.

As its name implies, the torsion snap-fit relies for its spring effect on twisting rather than flexing like the other types. It is less common than cantilever or ring snap-fits but it is particularly useful when you want to be able to release the catch easily and often. For example, a torsion snap-fit can be a good way of fastening a hinged lid on a box or container.

The torsion snap-fit catch is moulded with integral supporting shafts on which it twists when an opening force is applied. The design often includes a dimple or some other feature to indicate the right place to press.

The principle of levers applies, so depending on the dimensions of the catch it is possible to arrange for a small opening force to overcome quite a strong snap-fit.

The catch portion is relatively stiff compared to the integral shafts so that when the opening force is applied to the catch, the shafts are twisted in torsion. It is this that supplies the spring effect. The stiffness of the spring depends on the thickness and length of the shafts.

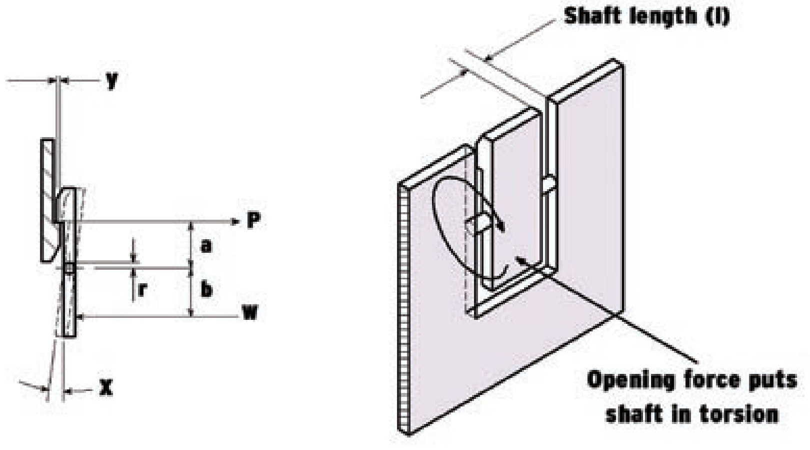
Designers' notes

- Use torsion snap-fits when you want to be able to release the catch easily
- Include a design feature to show where to press
- Design a stop feature to prevent excessive torsion
- Do not make the catch lever length too short, otherwise the twist angle and torsion becomes too great
- Reduce the opening force by making the length of the opening level longer than the catch lever

Ideally the shafts will be cylindrical, since this is the most efficient form for torsion but other shapes can be used. The torsion snap-fit can lead to some mouldmaking complications and in these circumstances it may be easier to use square or cruciform section shafts.

The degree of twist or torsion on the shafts should be kept to the minimum necessary to clear the snap-fit undercut. It is usually possible to arrange the design so that the catch meets an obstruction just after the undercut has been released. This prevents the catch being broken by an over-enthusiastic user. The minimum angle in radians that the catch must be moved through is:

Diagram 1: Main features of torsion snap-fits



$$x = \frac{\pi y}{180a}$$

where y = catch undercut and a = length of catch lever.

The general formula for torsion in cylindrical shafts is:

$$x = \frac{2Pal}{E\pi r^4}$$

where P = force to free undercut, l = shaft length, E = modulus of rigidity and r = shaft radius.

From these two equations we can deduce that:

$$P = \frac{\pi^2 r^4 Ey}{180a^2 l}$$

By applying the principle of levers, we can work out the opening force W thus:

$$W = \frac{Pa}{b}$$

where b = length of opening lever

So by making b relatively large compared to a, we can arrange for the opening force to be quite small. Be careful how you do this though. If a is made too small, the angle of twist x becomes too great.

Clive Maier, Econology