# The insertion of connecting elements using ultrasound

Covestro Engineering Thermoplastics
Processing and design characteristics

In contrast to the joints produced by ultrasonic welding and riveting, which cannot be undone again, disconnectable joints between plastics moldings are achieved by introducing metal inserts equipped with internal or external threads into the parts. Readily disconnectable joints with a high torsional and pull-out strength can be achieved in this way, as a function of the shape of the plastic, the injection molding parameters and the design features of the threaded bushes and stud bolts used.

There are several different ways of introducing connecting elements with internal or external threads into thermoplastic parts in order to create joints that can be undone again at any time. The different processes are set out below:

– direct encapsulation during the injection molding of the plastic component
– subsequent insertion with the aid of heat and pressure
– mechanical screwing-in of the inserts
– the press-in process, with inserts that expand when the screw is inserted at a later date
– insertion using ultrasound

Ultrasonic waves, which take the form of mechanical, alternating oscillations at approximately 20 kHz, are used to start the threaded metal component resonating via a sonotrode. The interfacial friction that develops between the metal and the plastic, under a defined contact pressure, causes the polymer to heat up and melt at the contact surface, thus permitting the metal component to sink into the plastic part as the pressure continues to act. The molten compound flows around the undercuts on the threaded insert and anchors the insert in place during the subsequent solidification process. The pressure required to insert components by the ultrasonic method must be set in advance as a function of the dimensions of the threaded component (its diameter and length) and the melting point or melting range of the thermoplastic. For metal components with a diameter of 5 mm or so it is best to work with no more than a medium sinking rate.

This method has the following advantages compared with encapsulation by injection molding:

– rapid, clean, low-stress and cost-effective insertion
– the injection molding process can be run with short cycle times, since the time-consuming insertion of threaded bushes is dispensed with
– the metal components do not need to be preheated as is necessary with certain thermoplastics in order to permit encapsulation by injection molding
– the injection molds are not damaged due to incorrectly positioned threaded inserts or stud bolts

The ultrasonic method can also be used to introduce more than one insert at a time, as with encapsulation by injection molding. Threaded inserts can be introduced into all types of thermoplastics, including those with poor ultrasonic weldability.

As extensive investigations have shown, insertion by the ultrasonic method takes place in stages, with downtimes of a few hundredths of a second in between. The metal component is thus truly hammered into the plastic, particularly during the initial phase. As already stated above, the metal component generates frictional heat as it vibrates at the contact surface between the metal and the plastic. This frictional heat causes a relatively thin layer of the plastic to melt, enabling it to flow into the undercuts on the metal component. The frictional heat is above the softening or melting range of the plastic, which means that virtually no additional stresses develop in the plastic, providing that certain conditions are respected. What, then, are the points that need to be borne in mind for insertion by the ultrasonic method?

**The production of the plastics parts**

In the majority of cases, metal components are inserted into "injection moldings". Inherent stresses develop in thermoplastic injection moldings on account of the molding process and the subsequent cooling phase. Plastics with a high relaxation capacity eliminate these internal stresses in the course of time without undergoing any essential change in shape, whilst plastics with a lesser capacity to relax cannot do this so well on account of their low tendency to creep under stress. These include a range of "engineering plastics". These materials largely retain their internal stresses and, under some circumstances, have the functional stresses acting via the metal component superimposed upon them.

Where injection moldings possess excessively high inherent stresses, it is thus possible for crazing to occur either immediately after insertion or at a subsequent stage, particularly if the metal components are subject to high tensile, compressive or torsional stresses. To ensure that low-stress parts are obtained, it is essential that the following processing parameters recommended for the plastic in question be observed:

– melt temperature
– injection speed
– injection pressure
– holding pressure
– mold temperature

In many applications, such as in housings, the side opposite the insert will be visible on the finished part. The hole to take the insert must then not leave any marks on the surface. In such a case, it is necessary to establish a compromise between the minimum wall thickness of the boss which is necessary to achieve the requisite pull-out or torsional strength and the maximum wall thickness of the part which will just permit marks to be avoided. Table 1 contains approximate values for the wall thickness ratios of the part and the boss for a number of plastics.

Since many of the standard commercial metal bushes are conical in shape, conical holes are frequently required. The thickness of the boss is thus greatest at the transition to the housing wall. This leads to an increase in the cross-section, which can cause sink marks to form on the reverse side in this region on account of the slow cooling of the material during injection molding. Even selecting a somewhat higher melt temperature and a higher injection and holding pressure will not, as a rule, solve this problem. The sink marks will be more visible on smooth or high-gloss surfaces than on profiled surfaces and more visible with dark colors. In addition, the flow path, i.e. the distance from the gate, and the melt viscosity play a role here. It should also be borne in mind that the transition from the boss to the housing wall should be rounded off with a small radius of ≥ 0.2 mm. This is illustrated in Fig. 1.

There are a number of different ways in which bosses can be connected to the rear of visible surfaces in order to ensure that they are correctly tailored to the application in question.

| Abmessungen der Aufnahmebohrung | | | |
|---|---|---|---|
| Plastics from the Covestro range | | Rib / wall thickness ratio | |
| | | Wall thickness of boss | Wall thickness of boss |
| Bayblend®<br>Makrolon® | PC + ABS<br>PC | 1<br>1 | 2.0 – 2.5<br>2.0 – 2.5 |
| Visible sink marks can be avoided by:<br>– a higher holding pressure<br>– not locating bosses in flat sections, where possible<br>– surface roughness or a grain finish<br>– light colors<br>– a radius of ≥ 0.2 mm at the transition from the boss to the wall | | | |

**Table 1: Approximate values for rib / boss / wall thickness ratios to prevent sink marks in different plastics**

The diameter of the hole to take the insert should be smaller than the insert itself and be dimensioned in such a way that the volume of molten compound that is displaced corresponds approximately to the volume of the undercuts or knurling on the metal component, or is no more than 10 to 15 % greater than this. Table 2 gives details of the bush diameters and holes required for inserts from two manufacturers of threaded inserts. These dimensions will be subject to variation if different metal parts are used, depending on the volume of the undercuts or knurling etc. In general, it can be assumed that for metal components with an outside diameter of up to 5 mm, the hole to take the element should be approximately 0.4 mm smaller and for components of more than 5 mm, approximately 0.6 mm smaller. If conical metal components are to be inserted into cylindrical holes, then the diameter of the hole should correspond approximately to the mean diameter of the metal component:

$$\frac{D1 + D2}{2}$$

Slightly different dimensions may be required, depending on the shape of the insert. This will guarantee a firm connection inside the plastic part. With blind holes, care must be taken to ensure that the hole to take the insert is at least 1.5 to 3 mm deeper than the metal part, depending on the diameter in question. If semi-crystalline plastics are being used and large holes are required, meaning that the boss to take the insert has a relatively large wall thickness, it is important to make allowance for the overall shrinkage of the plastic as well. If this is not done, dimensional changes could result, leading to insertion difficulties (excessively small hole) or to an insufficient level of strength (excessively large hole). With conical metal inserts, the diameter will generally be some 0.3 to 1.1 mm smaller than the diameter at the top of the hole. This will make it possible for the insert to be introduced without it becoming tilted. With cylindrical inserts, a guide hole can be provided to permit tilt-free insertion. This is also illustrated in Fig. 1.

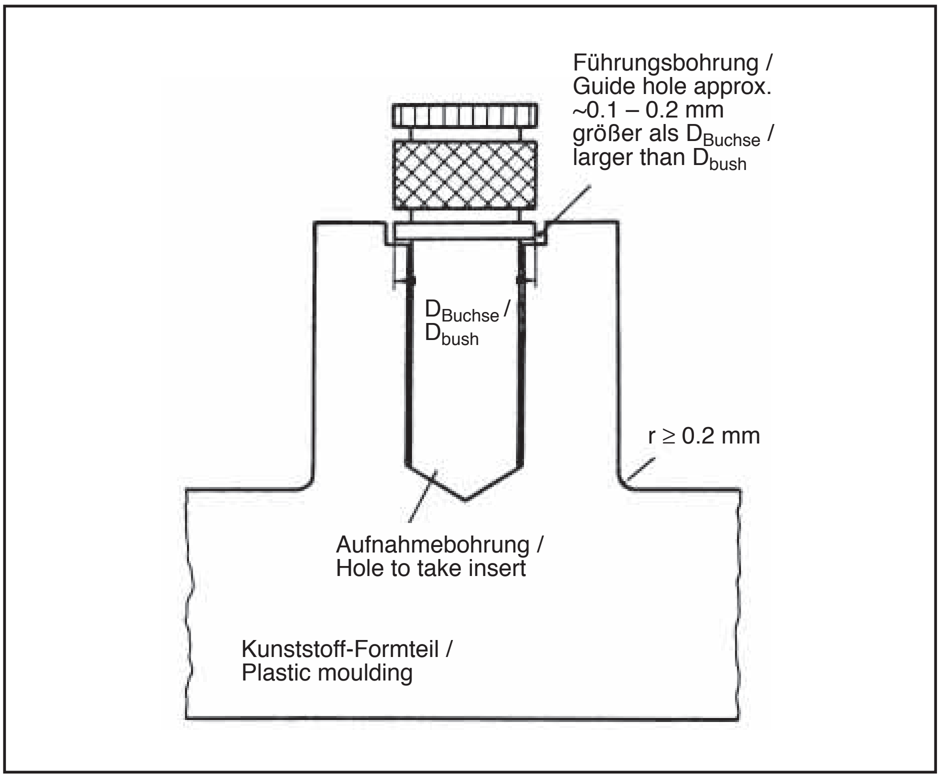



**Fig. 1: Schematic diagram of the hole to take the insert**

**Insertion**

The diameter of the sonotrode, the tool that is used to introduce the insert, should be at least equivalent to that of the metal part and preferably somewhat larger. The plastic component must be fixed in place in order to stop it from slipping under the influence of the ultrasound. The sonotrode must also make good contact with the metal insert, otherwise disturbing noises may develop at audible high frequencies. has been fully inserted. If the sound is applied for longer than this, it will loosen the structure of the plastic. In transparent plastics, this is indicated by the previously transparent melt going cloudy (Fig. 2).

The amplitude should be somewhere between 25 and 40 µm. The higher the amplitude, the greater the danger of stresses or crazing developing, or even of the boss being destroyed in the case of bosses with thin walls. Care should also be

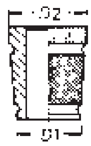
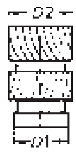
| Metric thread | Length of bush in mm | Diameter of bush in mm | | Diameter of hole in mm (approx. values) | ®Hit-Sert threaded bush |
|---|---|---|---|---|---|
| | | D1 | D2 | | |
| M3<br>M4<br>M5<br>M6<br>M8 | 5.5<br>7.5<br>9.0<br>10.0<br>12.0 | 4.0<br>5.2<br>6.4<br>7.7<br>9.7 | 4.70<br>6.15<br>7.35<br>8.75<br>11.30 | 4.30<br>5.65<br>6.85<br>8.25<br>10.80 |  |
| **Metric thread** | **Length of bush in mm** | **Diameter of bush in mm** | | **Diameter of hole in mm (approx. values)** | **®Sonic-Loc threaded bush** |
| | | **D1** | **D2** | | |
| M3<br>M4<br>M5<br>M6<br>M8 | 5.8<br>8.2<br>9.5<br>12.7<br>12.7 | 3.9<br>5.5<br>6.3<br>7.9<br>9.5 | 4.7<br>6.3<br>7.1<br>8.7<br>10.2 | 4.0<br>5.6<br>6.4<br>8.0<br>9.6 |  |

**Table 2: Dimensions of ®Hit-Sert 2 and ®Sonic-Loc threaded bushes with approximate values for the hole to take the insert**

It is best to work with a sonotrode that is already emitting sound when it comes into contact with the metal part. The insert should be introduced at the lowest possible sinking rate in order to ensure that the plastic has sufficient time to melt and that stresses are avoided. An excessively high sinking rate can lead to crazing or can cause the boss to burst apart. The pressure should also be set at the lowest possible level. To ensure that optimum strength is achieved, the sound should only continue to act until the metal part taken to ensure that, when the threaded bushes have been inserted, the surface of the bush is either flush with the surface of the plastic or protrudes several tenths of a millimetre above it. This will ensure that, when the connection is made at a later stage, the force of the nut acts on the surface of the bush and not on the surface of the plastic part. If this is not so, permanent tensile stresses will develop between the bush and the plastic, and this can lead to a loosening of the structure or to crazing in a whole series of plastics.

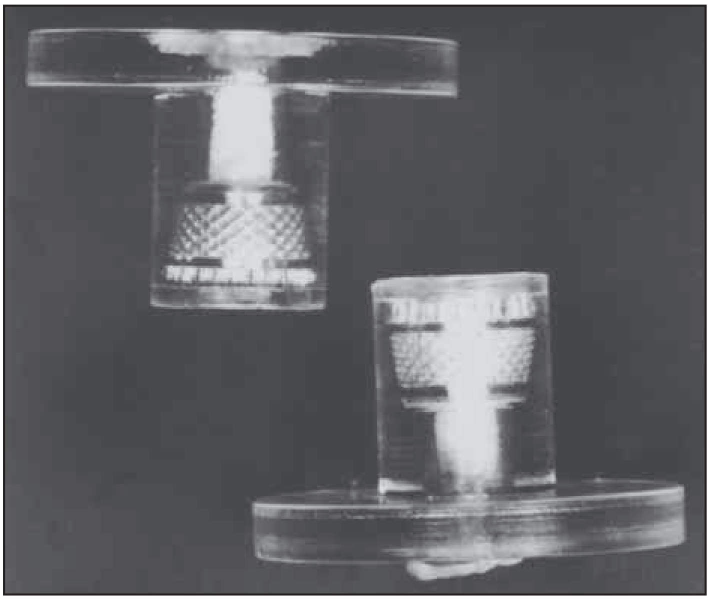


**Fig. 2: "Hit-Sert 2" threaded bush inserted in transparent PC. Left: ts = 0.5 s = good; right: ts = 1.0 s = cloudy. The structure has become looser again; the ultrasonic action time was excessively long.**

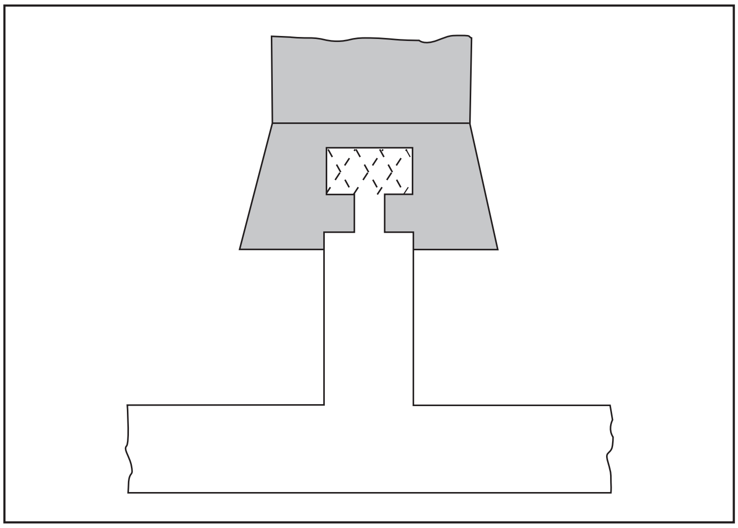


**Fig. 3: Diagram showing the insertion of a long metal part in plastic**

It is only possible to insert more than one metal component at once using a sonotrode if the inserts are all more or less of the same height. If the inserts are of different heights, then a graded sonotrode will be required. In such cases, however, it is difficult to achieve an optimum match between the sonotrode and the entire face of the part.

In many cases, difficulties are encountered in inserting long metal parts into plastics by the ultrasonic method, if, indeed, insertion proves feasible at all. Where the shape of the part will permit, the opposite approach should be adopted, i.e. the sonotrode should be placed on the plastic part and the latter inserted into the metal, as is shown by the diagram in Fig. 3.

**Results**

Providing that the parameters described above are observed in the manufacture of the finished parts and during the insertion process, very good pull-out and torsional forces will be attained, which correspond more or less to those of parts which have been encapsulated by injection molding. These forces will, however, be conditioned to a large extent by the shape of the metal part (length, diameter), the nature, depth and number of undercuts to receive the molten plastic, the wall thickness of the bosses and the type of plastic used. A further important point is whether the forces that will subsequently be acting on the part are dynamic or static.



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