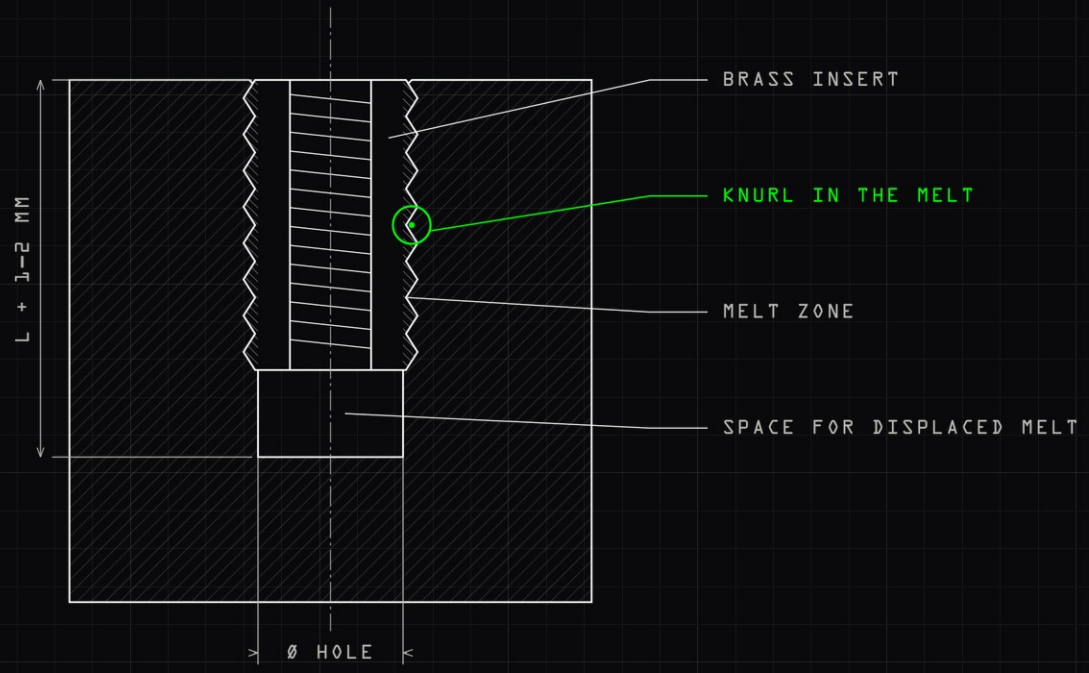
FIBERTHREE

SECTION A–A . THREADED INSERT



WHITE PAPER . WP005

HEAT-SETTING THREADED INSERTS

How are brass threaded inserts reliably heat-set into FFF parts, from the hole to the test?

DOCUMENT

WP005

FIBERTHREE WHITE PAPER

DATE

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00 . EXECUTIVE SUMMARY

Heat-set brass threaded inserts are the most reliable solution for detachable screw connections in FFF parts. According to Böllhoff, heat-setting achieves the highest retention values, ahead of ultrasonic insertion (80 %) and cold pressing (70 %). In polyamide a HITSERT insert holds pull-out forces from 1,700 N (M3) to 5,650 N (M8).

Tables on hole dimensions, materials and defects as well as a checklist make this paper a working document at the bench.

AT A GLANCE

- **Hole:** to the manufacturer's dimension, 1–2 mm deeper than the insert, with a chamfer. CNC Kitchen and ruthex share the hole dimensions, Böllhoff drills larger.
- **Material around the insert:** keep the minimum wall, 4–6 perimeters, hole axis in z
- **Temperature:** print temperature + 10–20 °C, heat-set only 90 %, press the rest flush cold
- **Sequence for polyamide:** anneal, heat-set, condition

Recommendation: Anneal first, then heat-set, condition last, and test load-bearing joints on your own part.

1,700 N	5,650 N	90 %
Pull-out force M3 in PA, manufacturer data	Pull-out force M8 in PA, manufacturer data	heat-set, press the rest flush cold

01 BACKGROUND

A screw driven directly into plastic lasts only a few assembly cycles. Each time it is tightened it deforms the thread a little further until it strips. Brass threaded inserts solve the problem: they are heat-set into the part, the plastic flows into their knurling and holds them positively. The screw then runs only metal on metal.

In FFF printing, heat-setting is the standard solution for detachable joints. It is inexpensive, needs no special machine and works with all Fiberthree thermoplastics. How well it holds, however, depends on details: on the hole, the wall thickness, the temperature and the order relative to annealing.

This paper complements our white paper series (overview in WP001): WP003 covers post-processing, WP004 design for manufacturing. WP005 describes heat-setting threaded inserts in detail. The dimensions refer to the inserts from CNC Kitchen, ruthex and Böllhoff that we work with.

The chapters follow the workflow at the bench: choice of insert and method, design of the hole, heat-setting, recommendations by material family, load capacity, defects and a checklist for release.

FIG. 1: SCHEMATIC

SECTION A–A . THREADED INSERT

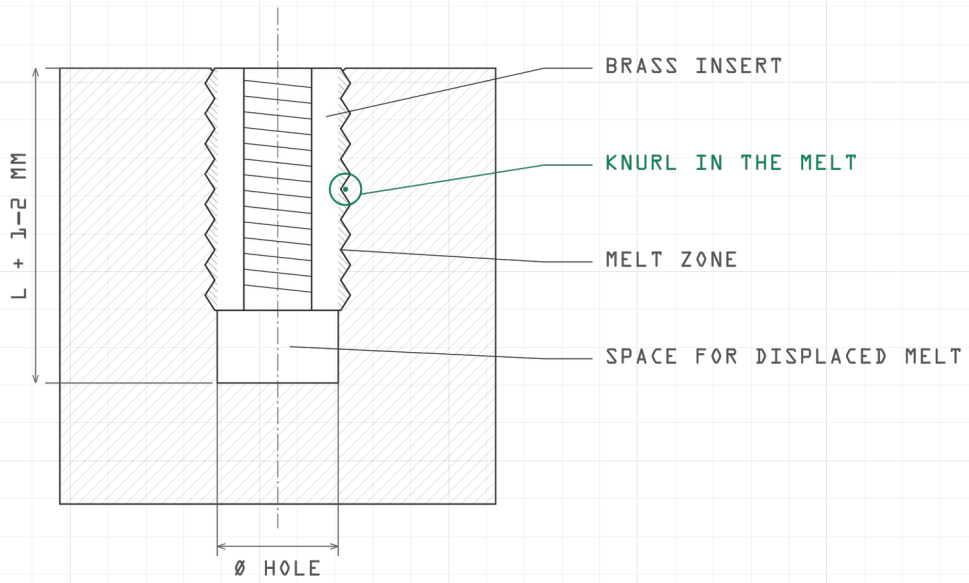


FIG. 1 Threaded insert in the hole with melt zone, schematic, not to scale.

02 INSERTS AND INSTALLATION METHODS

For FFF parts, heat-setting is the method of choice. It achieves the highest retention values and, on a small scale, needs nothing more than a soldering iron.

In its AMTEC catalogue, Böllhoff compares the methods by their retention values in the same thermoplastic:

METHOD	RETENTION	TOOL	NOTES
Heat-setting	100 %	soldering iron with insert tip, heat-set press, heat-staking machine	low stress, also for very small quantities
Ultrasonic	80 %	ultrasonic welding machine	loud, metal abrasion, Böllhoff recommends heat-setting
Cold pressing	70 %	toggle press	fast, but lower retention

TAB. 1 Inserts and installation methods.

THE INSERTS

All three manufacturers make their inserts from brass with knurling. CNC Kitchen and ruthex use opposing spiral knurls that resist pull-out and rotation equally. Both inserts have a centring tip that guides them in the hole.

MANUFACTURER	PRODUCT	SIZES	SPECIAL FEATURE
CNC Kitchen	Standard, Short, Voron	M2 to M10, UNC	lead- and cadmium-free, developed for 3D printing
ruthex	Standard, Short	M2 to M6, UNC	same hole dimensions as CNC Kitchen
Böllhoff	AMTEC HITSERT 2	M2 to M8	industrial insert for heat-setting, tapered (8°), self-centring

TAB. 2 The inserts.

WHEN AN ALTERNATIVE IS WORTHWHILE

- **Nut in a pocket:** highest pull-out force at low cost, if a print pause is possible (WP004).
- **Thread directly in the plastic:** only for joints that are rarely released.
- **Ultrasonic:** if an ultrasonic system for series parts is already available.

For single parts and prototypes, a soldering iron with a suitable insert tip is enough in most cases. Anyone who regularly heat-sets larger quantities gains above all uniformity with an insertion aid or press: the inserts sit straight and at the same depth, and the results are reproducible.

The choice of insert family also determines the hole dimensions. It is therefore worth committing to one manufacturer for a project and storing the holes in CAD accordingly.

03 DESIGNING THE HOLE

The hole decides the retention. If it is too large, the plastic does not fill the knurling. If it is too small, too much material is displaced, which piles up in front of the insert or bursts the wall.

HOLE DIMENSIONS OF THE THREE MANUFACTURERS

All dimensions in mm. CNC Kitchen and ruthex use the same holes for the standard lengths. Böllhoff drills larger because the HITSERT 2 has a larger outer diameter.

THREAD	CNC KITCHEN / RUTHEX: HOLE	LENGTH	WALL MIN.	BÖLLHOFF HITSERT 2: HOLE	LENGTH	HOLE DEPTH MIN.	WALL MIN.
M2	3.2	3.0 / 4.0	1.3	3.8	5.0	6.0	1.5
M3	4.0	5.7	1.6	4.4	5.0 / 5.5	6.0 / 6.5	1.8
M4	5.6	8.1	2.1	5.8	6.0 / 7.5	7.0 / 8.5	2.0
M5	6.4	9.5	2.6	6.9	7.0 / 9.0	8.0 / 10.0	2.0 / 2.5
M6	8.0	12.7	3.3	8.5	9.0	10.0	2.5

TAB. 3 Hole dimensions of the three manufacturers.

At CNC Kitchen, M2 has a length of 3.0 mm, at ruthex 4.0 mm. Short versions have the same holes, just shorter. Böllhoff calls its hole dimensions guide values with a tolerance of +0.1 mm, to be adjusted after installation trials.

HOLE, DEPTH, CHAMFER

- **Hole depth:** length of the insert plus 1 to 2 mm. The space below takes up the displaced plastic; otherwise it piles up and the insert protrudes.
- **Through hole:** with a through hole, the displaced plastic flows out at the bottom and must be removed.
- **Chamfer or countersink** of 0.3 to 0.5 mm at the entrance so that the insert starts straight.
- **Measure the hole:** printed holes often come out slightly smaller than in CAD. ruthex offers a drill set in exactly the hole diameters to re-drill them.

MATERIAL AROUND THE INSERT

- **Wall thickness** never below the manufacturer's minimum. For loaded joints, better allow twice that.
- **4 to 6 perimeters** around the hole so that the insert sits in solid material. Fill the area around the insert completely.
- **Below the insert** at least two to three full layers of floor so that it is not pushed through.

ORIENTATION

The hole axis is best placed in the build direction (z):

- The hole prints round and without supports.
- The perimeters enclose the insert like rings and carry the load along the bead, i.e. where the material is strongest (WP004).
- If the hole lies horizontally, it should have a teardrop shape and be re-drilled.

A joint in which the screw pulls the insert into the part carries the highest load. The insert then bears against the plastic instead of being pulled out.

04 HEAT-SETTING IN PRACTICE

The manufacturers' basic rule is simple: soldering iron temperature 10 to 20 °C above the print temperature of the material. The plastic should melt, not burn.

TOOLS

TOOL	SUITABLE FOR	NOTE
Soldering iron with insert tip	single parts, prototypes	Tip to match the thread size. ruthex and CNC Kitchen offer tip sets for common soldering irons (T18, 900M, Ersa).
Insertion aid, heat-set press	small series	Guides the soldering iron vertically. Crooked inserts are the most common mistake when heat-setting by hand.
Heat-staking machine	series	With controlled temperature, force and time. Böllhoff offers matching systems for AMTEC inserts.

TAB. 4 Tools.

An insert tip is better than a normal soldering tip. It sits in the thread of the insert, transfers heat evenly and does not slip.

PROCEDURE

01	**Prepare the part:** check the hole, place the part firmly and level. The part should be annealed and dry (Chapter 05).
02	**Heat up:** soldering iron to print temperature plus 10 to 20 °C.
03	**Position:** place the insert on the hole with the centring tip down and guide the tip into the insert.
04	**Heat-set:** press in vertically with light, even pressure. Do not press before the plastic is soft. Heat-set only about 90 % of the length.
05	**Set flush:** withdraw the soldering iron and press the last 10 % flush with a cold, flat tool. This makes the surface flat and the insert cools under pressure.
06	**Let it cool:** wait 2 to 3 minutes before driving in a screw.

SIGNS OF A GOOD INSERT

- It is flush with the surface, without a bead.
- It sits vertically, the screw runs without binding.
- It cannot be turned by the tightening torque of the screw.

Böllhoff recommends adjusting the hole dimensions through installation trials. The same applies to the soldering iron temperature: a test part with a few holes quickly shows which temperature suits the material and the insert.

05 RECOMMENDATIONS BY MATERIAL FAMILY

The soldering iron temperature is derived from the print temperature in the technical data sheet. For the polyamides there is also a fixed sequence with annealing and conditioning.

MATERIAL FAMILY	FIBERTHREE FILAMENTS	SOLDERING IRON	NOTES
PA6 filled	F3 PA-CF Pro, F3 PA-GF Pro, F3 PA-GF30 Pro	approx. 290–300 °C	For F3 PA-CF Pro the nozzle temperature is 270–285 °C. Fibres improve the seat, but use values for unfilled plastic for the design.
PA6 unfilled	F3 PA Pure Pro, F3 PA ESD	print temperature + 10–20 °C	Tough, good for frequently released joints
PA12	F3 PA-CF Lite, F3 PA Pure Lite	approx. 290–310 °C	F3 PA Pure Lite is printed at 270–300 °C. Lower moisture uptake, more stable dimensions
PC	F3 PC CF 150	print temperature + 10–20 °C	Sensitive to stress cracking: Böllhoff recommends nickel-plated inserts. Stress-relieve by annealing before heat-setting (WP003)
PP	F3 PP GF 25	approx. 240–250 °C	Printed at 230 °C. PP holds inserts less well than PA, choose a longer insert
PLA	F3 PLA GF	print temperature + 10–20 °C	Softens from about 60 °C. Inserts can loosen under heat and sustained load
TPU	F3 TPU 80A, F3 TPU 98A	–	Too soft for threaded inserts

TAB. 5 Recommendations by material family.

Print and nozzle temperatures according to the Fiberthree data sheets.

SEQUENCE FOR POLYAMIDE

01	**Anneal** (WP003). Polyamide shrinks depending on direction. If heat-setting is done afterwards, the insert sits in the final geometry and no stresses arise from later shrinkage.
02	**Check the hole** and re-drill to the hole dimension if necessary.
03	**Heat-set** in the dry part. Directly after annealing, polyamide is dry anyway.
04	**Condition** (WP003). After that the material is tougher and withstands load changes better.

FIBRE-REINFORCED FILAMENTS

- The fibres make the plastic stiffer, which improves the seat against rotation.
- Böllhoff recommends using the strength of the unreinforced material for the design, to be on the safe side.
- Use carbide drills when re-drilling (WP003).

Anyone processing different material families should determine and note the soldering iron temperature for each family on a test part. This keeps the temperature reproducible, even when several people heat-set inserts at the workstation.

06 PULL-OUT AND TORQUE STRENGTH

Böllhoff publishes guide values from laboratory tests for its heat-set HITSERT inserts. They show the order of magnitude of loads that heat-set inserts carry:

FIG. 2: PULL-OUT AND TORQUE STRENGTH

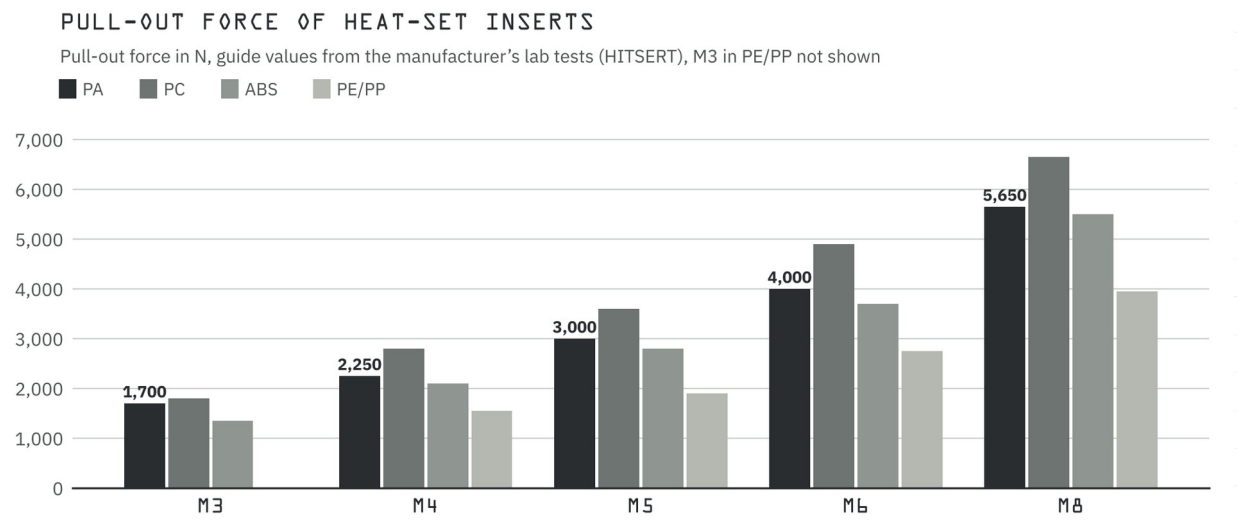


FIG. 2 Guide values from the manufacturer's laboratory tests for HITSERT inserts. M3 in PE/PP not shown, the catalogue value is implausible.

Polyamide lies in the middle of the plastics tested, PC holds the most, PE and PP the least. Böllhoff gives the torque until the insert turns in PA as 1.05 Nm for M3 to 12 Nm for M8. For M4 it is 2.4 Nm, for M5 3.75 Nm, for M6 5.5 Nm.

TRANSFERABILITY TO FFF PARTS

The values apply to solid plastic parts and industrial installation conditions. In a printed part, retention additionally depends on:

- **Wall thickness and perimeters:** often it is not the seat of the insert that fails but the wall around it.
- **Orientation:** if the hole lies in z, the perimeters carry the load like rings. If it lies horizontally, the insert can break out between two layers.
- **Installation conditions:** hole size, temperature and straightness change the values considerably.
- **Load direction:** if the screw pulls the insert into the part, the joint can carry considerably more load than when it is pulled out.

For load-bearing joints, the values should therefore be verified on your own part.

Outlook: Our own pull-out and torque tests on Fiberthree materials are still pending. Meaningful tests would cover F3 PA-CF Pro, F3 PA Pure Pro and F3 PA-GF30 Pro, each with M3 and M5, inserts from different manufacturers, hole axis in z and in x-y, and annealed and unannealed.

The manufacturer’s values give the order of magnitude and show that a cleanly heat-set insert does not usually limit the screw connection. In a printed part, the surroundings of the insert are usually the weak point: the wall, the perimeters and the position of the layer boundaries.

Designing these points according to Chapter 03 exploits the potential of the insert. For safety-relevant joints, however, this does not replace testing on your own part.

07 DEFECTS AND REMEDIES

DEFECT	CAUSE	REMEDY
Insert protrudes, bead at the edge	hole too small or too shallow, displaced plastic has no space	re-drill, hole 1–2 mm deeper than the insert
Insert sits crooked	inserted by hand without guidance, pressed too early	use an insertion aid or press, wait until the plastic is soft
Insert turns when tightening	hole too large, wall too thin, too few perimeters	check hole dimension, keep the minimum wall, 4–6 perimeters
Insert pulls out	too little material around the insert, hole horizontal between layers	reinforce the wall, place the hole axis in z, route the load so that the screw pulls the insert in
Crack in the wall	hole too small, wall too thin, plastic too cold	check hole dimension and temperature
Discoloured or bubbly zone around the insert	temperature too high, soldering iron applied too long, moist polyamide	lower the temperature, insert quickly, heat-set the part dry
Plastic in the thread	heat-set too deep, melt pushed into the thread from below	heat-set only 90 %, press the rest flush cold, deeper hole
Cracks or warping at the insert after annealing	heat-set first, then annealed: the part shrinks around the rigid insert (WP003)	keep the sequence: anneal first, then heat-set

TAB. 6 Defects and remedies.

A wrongly placed insert can be reheated with the soldering iron and pulled out. CNC Kitchen offers a removal tool for this. The hole is usually widened afterwards, and a new insert holds less well there.

08 CHECKLIST

Design

01	Hole to the manufacturer’s hole dimension, with a small chamfer
02	Hole 1–2 mm deeper than the insert
03	Wall thickness at least the manufacturer’s value, better double
04	Hole axis in the build direction (z)
05	4–6 perimeters around the hole, area fully filled
06	Load routed so that the screw pulls the insert in

Preparation

01	Polyamide annealed (WP003)
02	Hole measured, re-drilled if necessary
03	Soldering iron at print temperature + 10–20 °C, matching insert tip

Heat-setting

01	Positioned vertically, with insertion aid or press
02	90 % heat-set, the rest pressed flush cold
03	Allowed to cool for 2–3 minutes

Afterwards

01	Seat checked: flush, vertical, torque-proof
02	Polyamide conditioned (WP003)
03	For load-bearing joints: pull-out tested on a test part

The checklist is structured so that it can be ticked off step by step at the workstation. It is also suitable as the basis for a work instruction when several people heat-set inserts.

09 CONCLUSION

Heat-set threaded inserts are the most reliable solution for detachable screw connections in FFF parts. How well they hold depends on details: a hole to the manufacturer’s dimensions, enough material and perimeters around the insert, temperature, and the right order with annealing. Tables and checklist make this paper a working document at the bench.

Keeping the order with annealing and designing the hole carefully gives joints that survive many assembly cycles. For load-bearing joints, testing on your own part remains the most reliable proof.

ABOUT FIBERTHREE

Fiberthree develops and produces technical filaments for FFF printing in Darmstadt, with polyamide at the heart of the portfolio. Building on our background as an engineering office, we also offer engineering, training and contract manufacturing on more than 30 printers, from first sample to small series.

WHITE PAPER SERIES

All white papers are available at www.fiberthree.com. We update the series regularly; the latest version applies.

NO.	TOPIC	HELPS WITH
WP001	Plastics for the FFF Process: Material Overview and Process Comparison	Choosing material and process
WP002	Effect of Moisture on Polymers in the FFF Process	Drying filament and keeping it dry
WP003	Annealing and Post-Processing of FFF Parts	Annealing, conditioning, finishing
WP004	Design for Manufacturing in the FFF Process	Designing parts for FFF
WP005	**Heat-Setting Threaded Inserts in FFF Parts (this paper)**	**Detachable screw connections**
WP006	Nozzle Selection for Filled Filaments	Nozzle material and diameter
WP007	Print Bed and Adhesion	First-layer adhesion
WP008	Electrostatic Dissipative (ESD) Parts in FFF Printing	Printing and testing ESD parts
WP009	Interlayer Adhesion in the Build Direction: Nozzle Temperature, Print Speed and Hotend	Strength in the z direction

TAB. 7 Overview of the Fiberthree white papers.

FIBERTHREE

START WITH THE RIGHT MATERIAL

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