How strong are heat-set inserts in PLA? Pull-out figures

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Abstract. CNC Kitchen's measured pull-out loads for M3 heat-set inserts in PLA: 181 kg for Ruthex, 157 kg for eBay inserts, 39 kg for cheap ones, and how hole size changes it.

Keywords: heat-set-inserts, threads-and-fasteners, pla

Table 1. Measured pull-out loads

Fastening	Hole in CAD	Average pull-out	Torque to failure	Source
Ruthex M3 brass insert	4.0 mm	181 kg	3 to 4 Nm, bolt head sheared	Cheap vs Expensive
eBay M3 brass insert	4.1 mm	157 kg	3 to 4 Nm, bolt head sheared	Cheap vs Expensive
Cheap injection-molding insert	4.5 mm	39 kg	3 to 4 Nm, bolt head sheared	Cheap vs Expensive
M3 screw straight into PLA	2.7 mm	142 kg	About 1 Nm, threads stripped	Cheap vs Expensive
M3 insert	3.6 mm (smallest tested)	About 1400 N (almost 150 kg)	Not tested	Datasheets Wrong
M3 insert	4.2 mm	About 90 percent of the maximum	Not tested	Datasheets Wrong

1 How strong are heat-set inserts in PLA?

In CNC Kitchen's test, M3 inserts in Prusament PLA at 100 percent infill pulled out at 181 kg on average for Ruthex inserts, 157 kg for eBay inserts and 39 kg for cheap injection-molding inserts. A screw driven straight into the plastic held 142 kg. A later test in PolySonic PLA reached about 1400 N, near 150 kg.

1.1 Measured pull-out loads

Both tests are CNC Kitchen's, pulled on its own test machine. The first used Prusament PLA (polylactic acid) at 100 percent infill and 0.15 mm layers. The second used PolySonic PLA on a Prusa CORE One L and nearly 50 inserts.

The eBay and Ruthex inserts landed close together. The cheap inserts, which are designed for injection molding rather than for melting in, held a quarter as much. CNC Kitchen still noted that "39kg on an M3 bolt is still quite something" for a part that is not safety critical.

1.2 What decides the number

The plastic sets the limit. A screw straight into PLA reached 142 kg, close to the good inserts, because the same plastic carries the load either way. Inserts earn their place on torque and reuse. In the torque test the plain screw stripped at about 1 Nm while the insert joints held until the M3 bolt head sheared at 3 to 4 Nm. CNC Kitchen adds that 1 Nm on an M3 bolt already gives more than 1500 N of clamping force, which is plenty for most printed assemblies.

The hole size. The second test ran M3 inserts in holes from 3.6 to 4.6 mm in CAD. Strength stayed near the maximum until the hole reached 4.2 mm in CAD, then fell off steeply. In the drilled set the drop came between 4.1 and 4.2 mm. On that printer the holes came out about 0.25 mm smaller than drawn, so a 4.2 mm CAD hole was close to the 4.0 mm nominal on the M3 hole-size page. CNC Kitchen's advice is to keep the 4.0 mm datasheet figure and add 0.2 to 0.3 mm in CAD after measuring your own printer's shrink.

Infill and walls. Both tests used 100 percent infill. A boss with sparse infill behind the wall gives the knurl less plastic to grip, so expect lower numbers on a normal part. No source here gives a figure for a 20 percent infill boss.

Material. In CNC Kitchen's PETG test with four perimeters and 100 percent infill, the same class of M3 insert held 119 kg, and a screw straight into PETG held 118 kg. The inserts versus captive nuts page has that full set.

1.3 Ruthex and CNC Kitchen inserts

The two brands publish the same M3 geometry: 4.6 mm outer diameter, a 4.0 mm hole and a 1.6 mm minimum wall. CNC Kitchen's cheap-versus-expensive test used Ruthex inserts as its "expensive" sample, and its datasheet test is a check on its own packaging figures, which it decided not to change because "every printer and material shrinks holes differently".

1.4 How to get the published figure on your own part

1. Print the boss at 100 percent infill or with enough perimeters that the wall around the hole is solid to the 1.6 mm minimum.
2. Model the hole 0.2 to 0.3 mm over the datasheet size, then measure a test print. The target is a hole the insert's pilot tip sits in without force and no burr on the back after melting.
3. Install at 10 to 20 °C above the printing temperature, about 225 °C for PLA, per the temperature page.

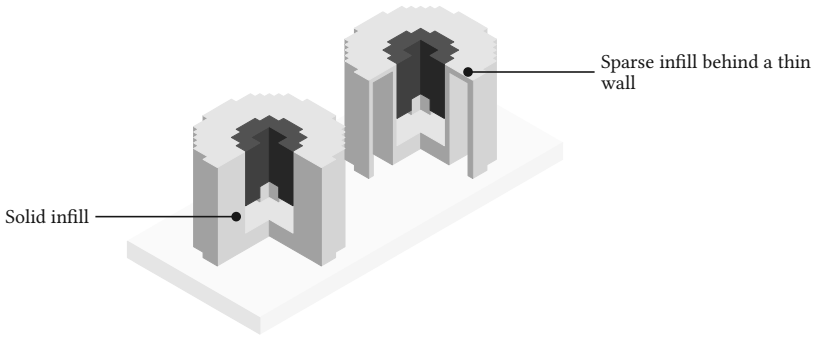


Figure 1. In the solid boss the knurl grips plastic all the way out, while in the sparse boss only a thin wall stands between the insert and empty infill.

4. Load a sample to failure by hand with a screw and a lever before trusting the joint. If the plastic whitens or the wall bulges, the boss is too thin, not the insert too weak.

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