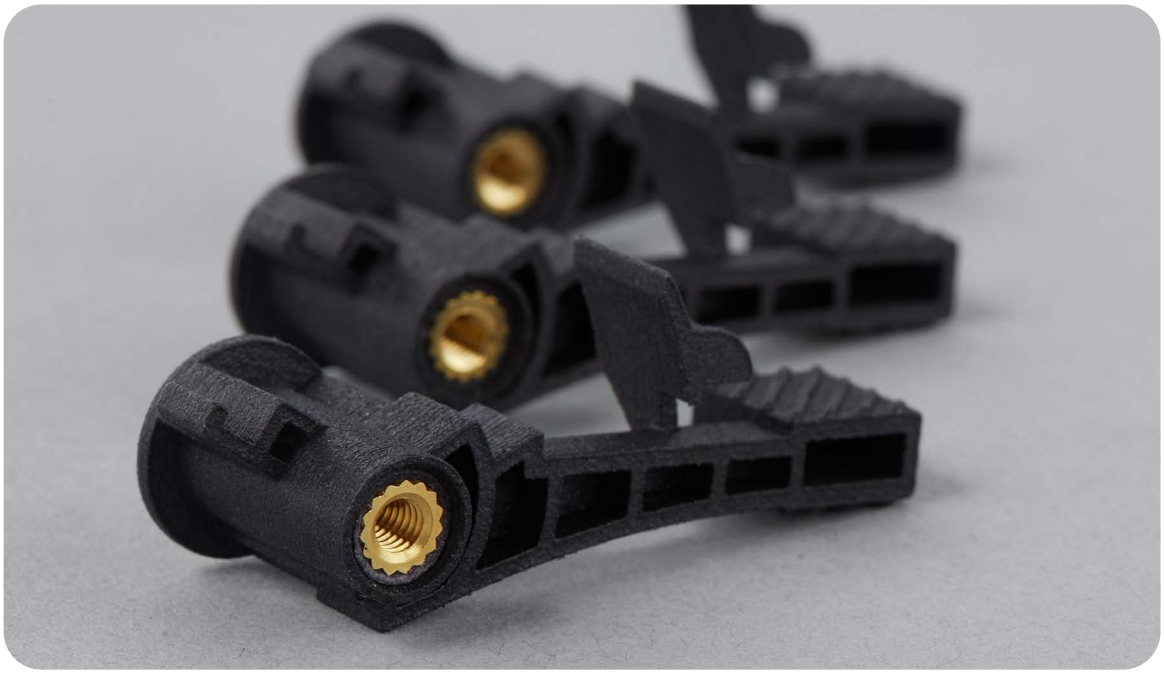
Threaded Inserts White Paper 2022

3D People

Version 1.0

Executive Summary



Performance of threaded inserts in 3D printed plastic materials

This report evaluates the mechanical performance of threaded inserts of different metric designations in the 3D printed plastic materials offered by 3D People. Three tests are undertaken to evaluate insert performance in terms of pull strength, torque strength and insert robustness after cyclic loading. The purpose of the report is to support the engineer in designing 3D printed products which incorporate metric threaded inserts.

The findings in this report show the average pull strength across the materials tested (PA12 Nylon, Onyx, PLA and PetG) and metric threads (M2 M2.5 M3 M4 and M5) is 1.759kN, equating to approximately 180kg loading capacity per insert. The variation in loading for each metric thread size is not significant over the extensive testing undertaken.

The average variance of pull strength after repeated high stress (80%) cyclic loading was a reduction of 1.37%, or around 25N.

The average insert torque strength was 4.76Nm.

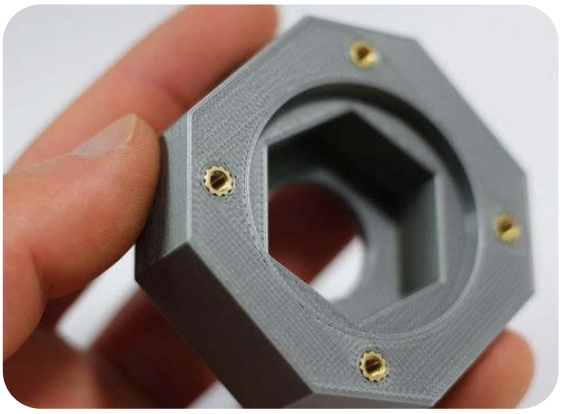
Contents

Introduction

Performance of threaded inserts in 3D printed plastic materials

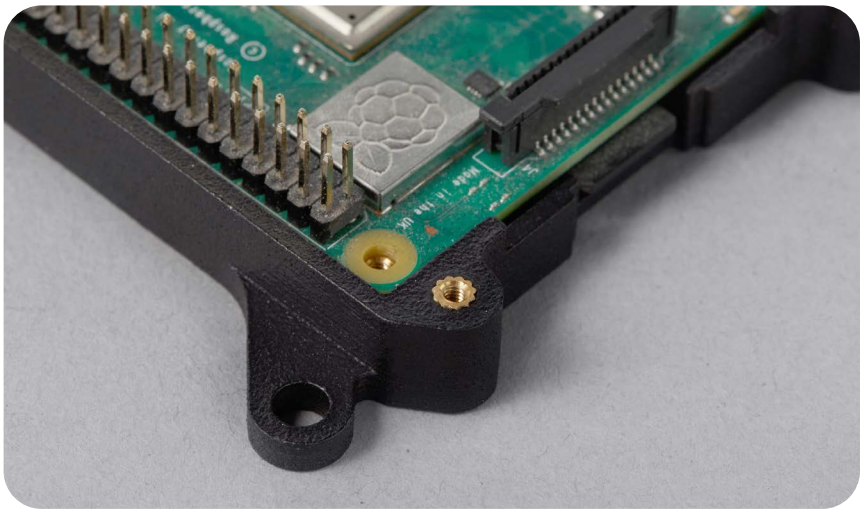
Threaded inserts are a fastening element which can be incorporated within 3D printed components and assemblies. They afford the engineer or designer with a consistent, repeatable, standardised and reliable method of part attachment and assembly. They are commonly produced in ISO Metric thread sizes, and are permanently installed using heat and force.

The benefits of threaded inserts can be wide ranging, from reducing the number of machining operations on individual parts, to facilitating repeatable and fast disassembly/reassembly for essential tasks like maintenance and repair. The use of threaded inserts bridges the gap between 3D printing and standardised off-the-shelf engineering components.



Threaded Inserts are ideal for projects which require:

- Regular and repeatable assembly and disassembly
- Standardisation of the attachment method across a variety of components or systems
- Robust attachment of parts
- Integration with off-the-shelf or standardised components and sub-assemblies



Scope of Testing

This report evaluates the mechanical performance of threaded inserts of different metric designations across four different 3D printed plastic materials. The table below outlines the five metric thread sizes tested in the different additive manufacturing technologies and materials offered by 3D People.

AVAILABLE METRIC THREAD SIZES

M2, M2.5, M3, M4, M5

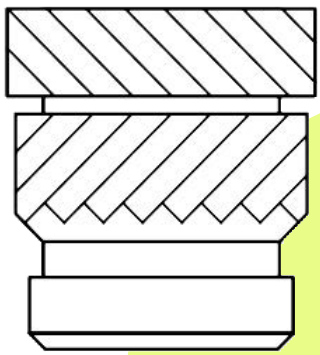
COMPATIBLE MATERIALS

PA12 Nylon, PLA, Onyx, PetG

The brass helix inserts (below) are considered best-in-class for fastening performance due to the increased surface contact provided by the conjunction of the left and right helix features. The inserts are heat set in position using digital controlled soldering equipment with specialist nipples and jigs for alignment. They also have a pilot hole for easy installation. The heat and force allow the plastic to flow into the notches and set in place to create the fastening bond. All of the tests in this report were produced on this setup.

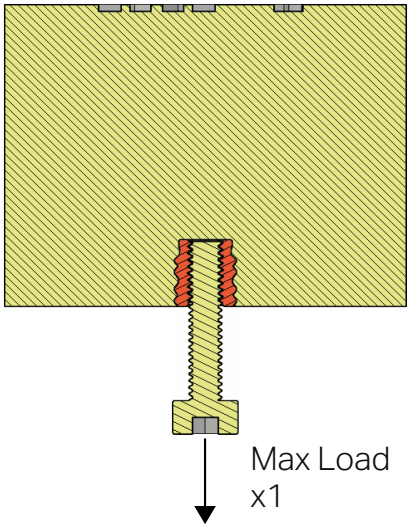
The following tests have been performed on the heat-installed ISO Metric threaded inserts:

1. Insert Pull Strength
2. Insert Robustness
3. Insert Torque Strength



Test 1: Insert Pull Strength

Test Methodology

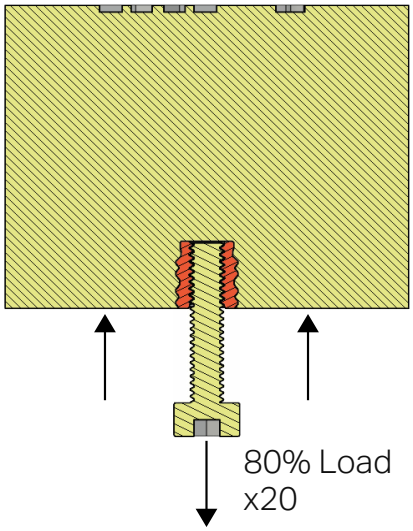


This test measures the axial force required to pull the insert out of the plastic material. A bolt is screwed into position and extracted using precision anchor testing equipment to record the tensile load. This force indicates the expected fastening strength for each material and inserts metric thread size. The equipment used for this test records the highest force measured at the failure to deliver a pull strength rating. Multiple readings are taken before averaging the result.

The output measurement is Newtons force at the point of failure, which we can also equate into a loading weight in Kilograms for ease of analysis.

Test 2: Insert Robustness

Test Methodology



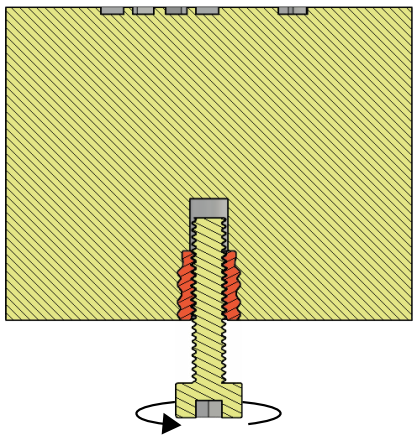
Test 2 measures the robustness of inserts after repeated heavy duty cyclic loading. The purpose of this test is to indicate the reliability of inserts which are expected to undergo repeated loading over time.

For this test, the installed insert is loaded and unloaded with a force set at 80% of the measured failure force from Test 1 for each specific metric thread size and material. After 20 loading cycles, the insert is tested to failure and results compared to data from Test 1.

The output measurement for this test will be failure force data for material and metric thread size, in addition to a % variation on Test 1 loading vs. pull strength after repeated cyclic loading.

Test 3: Insert Torque Strength

Test Methodology



Max Load
x1

This test measures the twisting force, or torque, required to break the insert out of its installed location. Analysing this data in conjunction with data from Test 1 can provide a more complete picture of insert loading capacity.

A hex head bolt is screwed into the installed insert, until the head bottoms out on the insert. A digital torque metre is used to increase the twisting force on the insert until it fails by starting to rotate with the bolt.

Multiple readings are taken before averaging the result.

Test Equipment

1 Insert Pull Strength

2 Insert Robustness

HydroJaws M2000 certified pull test equipment was used for Test 1 and Test 2. The equipment provides real-time digital readings of force as the equipment increases axial force on the threaded insert to failure. The equipment has been fully calibrated (with calibration certificate) ready for testing.

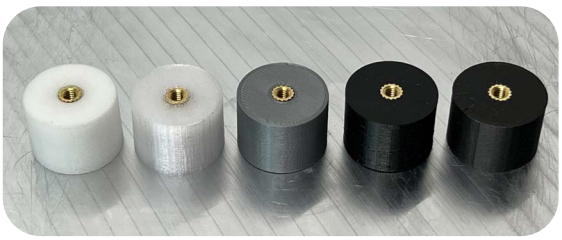
3 Insert Torque Strength

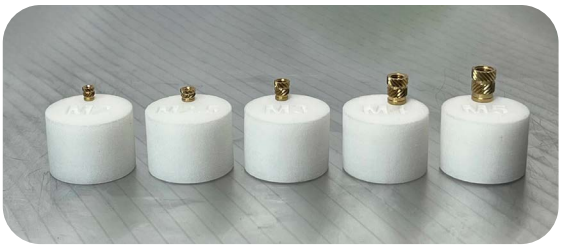
A calibrated torque wrench with a range of 1.5-20 Nm was used to measure the failure torque in Test 3.

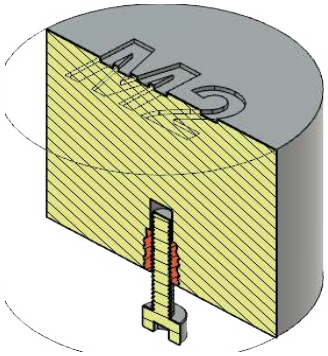
Test Specimens

The test specimens have been designed to fit into industrial pull test equipment to undertake the three tests in the scope of this report.

The inserts used for all testing are best-in-class left & right helical inserts. This design gives the highest figures for pull strength and torque resistance. All inserts used manufacturer-recommended hole diameter and depths to insert different metric designations.





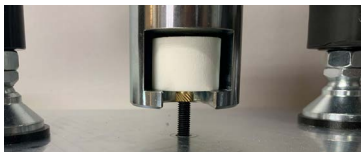
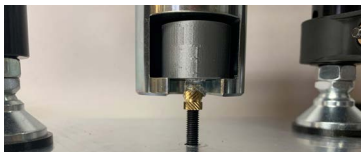
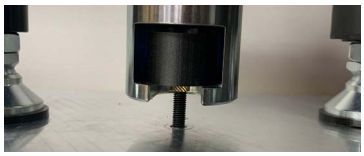
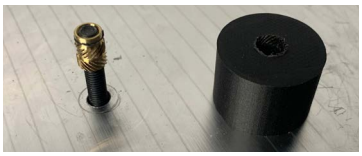


The above shows PA12 Nylon, PETg, PLA, TPU and Onyx test specimens.

Each material was tested with M2, M2.5, M3, M4 and M5 threaded inserts.

Test 1: Insert Pull Strength

Results & Analysis

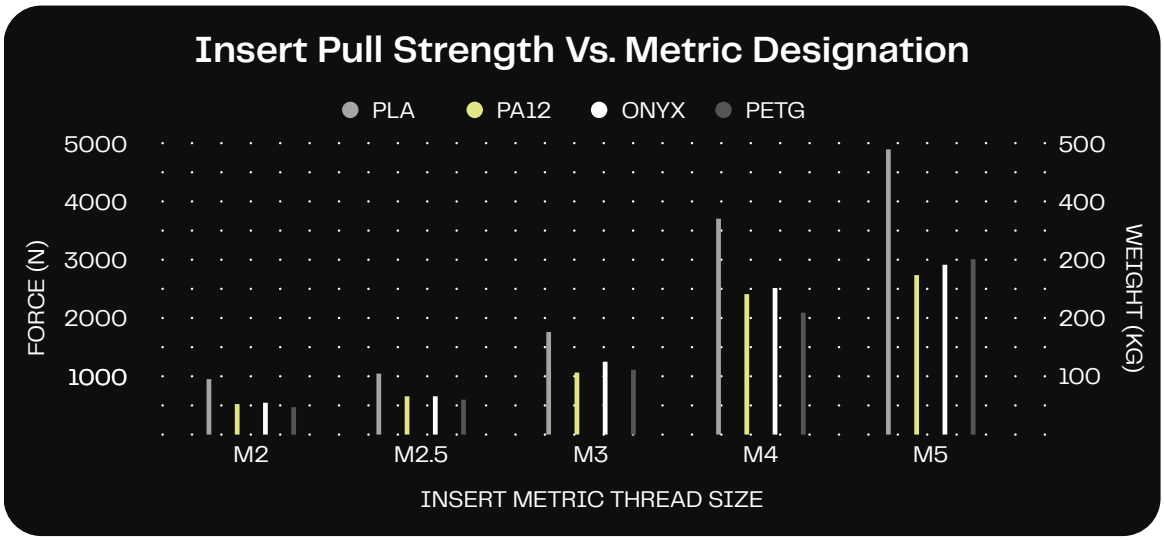
Material	Pull Observation	Failure Observation
PA12 (SLS)		
PLA (FDM)		
ONYX (FDM/CFF)		
PETG (FDM)		

The average pull strength for each insert was:

	Average Pull Strength (N)	Average Pull Weight (Kg)
M2	629.2	64.1
M2.5	737.5	75.2
M3	1304.1	132.9
M4	2704.2	275.7
M5	3420.8	348.7

Test 1: Insert Pull Strength

Results & Analysis



PLA had the highest pull strength of all materials

PLA had the highest pull strength data for all Metric Thread Sizes. PLA was the only material that showed visible shearing of material in the helical gear recesses after failure. The other materials showed a more ductile failure where the material does not shear in the notches and the insert has been pulled out without causing permanent fracture.

PLA has a higher Melt Flow Index than the other materials considered which indicates its suitability for melting and flowing into the helical gear recesses on the installed insert. The material (PLA) and the manufacturing technology (Fused Deposition Modelling) result in samples which are more brittle than the other materials testing in this report and therefore the failure mode of PLA differs (fracture) to the other materials (deformation).

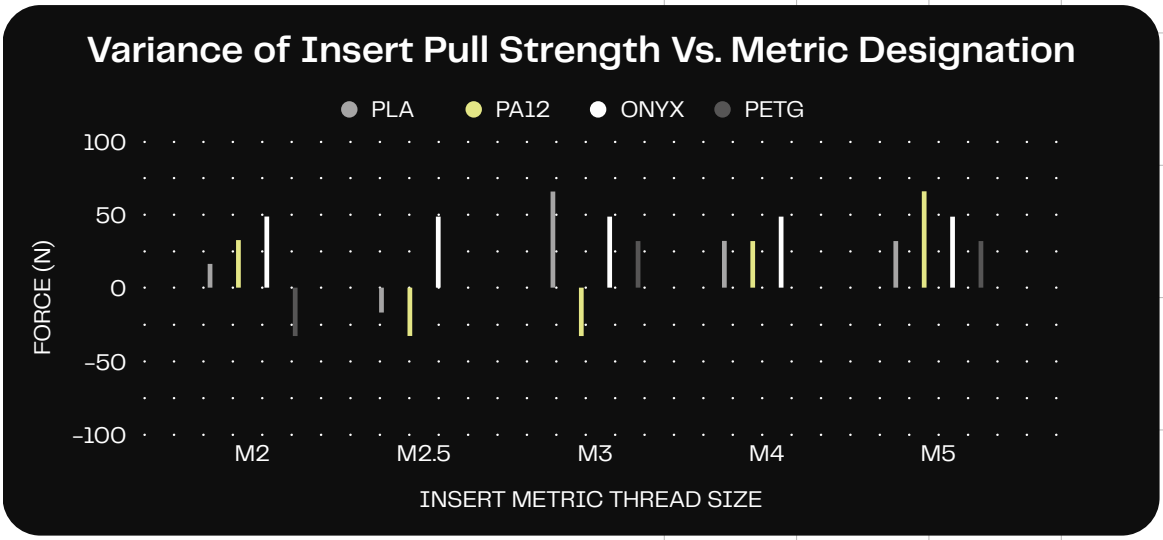
The consistency of readings across all materials and thread sizes was high

Tests have been undertaken and averaged across 5 results, with the variation in readings insignificant. The variation in results has been less than can be measured with the industrial test equipment used in this report.

Test 2: Insert Robustness

Results & Analysis

The variation in force after repeated loading was consistent across the different metric insert thread sizes.



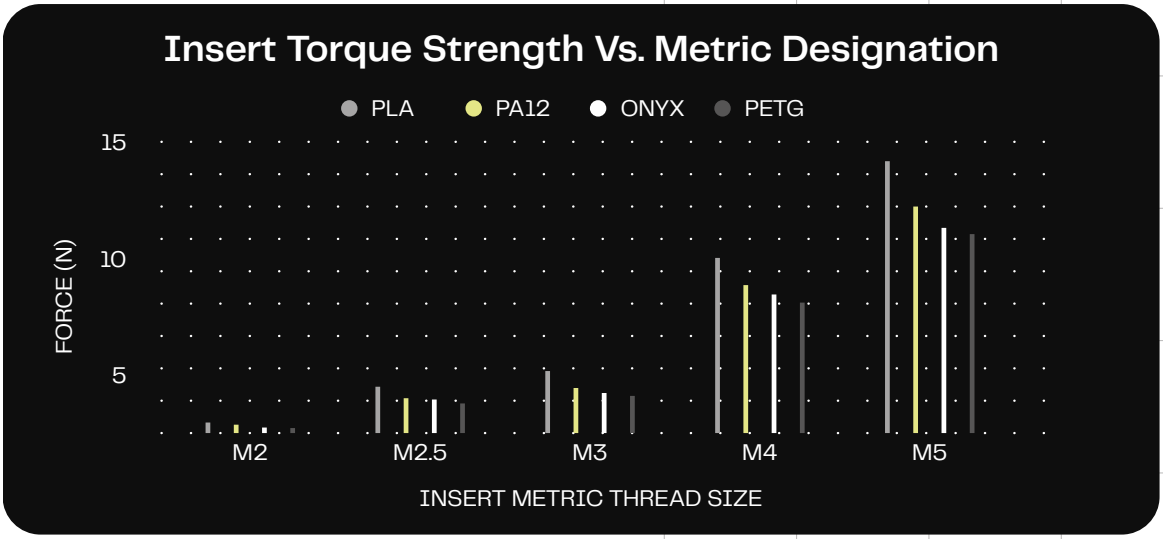
The variation in loading capacity after repeated loading was approximately -24N, or -1.37% pull strength across all materials and metric thread sizes.

Average Variation (±N)	24.15
Average Pull Force (N)	1759.2
Average % Variation (±N)	1.37

Test 3: Insert Torque Strength

Results & Analysis

The order of strength of materials was PLA, PA12, Onyx and finally PETg.



The variation in loading capacity after repeated loading was approximately -24N, or -1.37% pull strength across all materials and metric thread sizes.

Average Variation (±N)	24.15
Average Pull Force (N)	1759.2
Average % Variation (±N)	1.37

Conclusions

The results and analysis across the three performance tests have yielded some clear conclusions. Overall, it is evident that the high performing left and right helical inserts have proven commendable performance for pull testing, insert robustness and torque strength testing.

The following data outlines the average force and loading weight each insert can withstand - and, notably, a single M2 insert can withstand the weight of a small person.

	AVERAGE PULL STRENGTH (N)	AVERAGE PULL WEIGHT (Kg)
M2	629.2	64.1
M2.5	737.5	75.2
M3	1304.1	132.9
M4	2704.2	275.7
M5	3420.8	348.7

The use of inserts can add significant value to a project. We welcome enquiries on how you can unlock the benefits of metric inserts in your next project.