Universal 3D Printing Filament Spool Standard

Draft Specification

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1. Summary

This document is intended to summarise details and discussions with manufacturers and users on the topic of a universal filament spool standard for 3D Printing.

1.1 Project Overview

Background to the 'problem' / requirement for a universal filament spool standard can be found on the RichRap Blog here. - http://richrap.blogspot.co.uk/2014/03/universal-3d-printing-filament-spool.html

This is a small selection of the way many different 3D printing materials are sold and used. They all need to be fed into the 3D printer in the same way, but have no 'standard' for mechanical mounting onto a 3D printer.

Discussions, ideas and user comments to the universal filament spool standard idea can be found on the 3D Printing RepRap community forum thread here. http://forums.reprap.org/read.php?262,324209

1.2 Purpose and Scope of this Specification

The purpose of this document is to define a set of dimensions and capacities that seem to be broadly compatible with most types of filament, production processes and mechanical fit to existing and future machines (3D Printers).

The audience for this document and any standards around filament spool size, shape and operation, are both materials manufacturers and 3D printing machine designers.

3D Printing users, makers and many other interested parties may also find this information of use.

This is entirely an open standard, not enforced in any way. The desire for any community accepted standards must be beneficial for enough people to make this a worthwhile exercise.

While suggestions for suitable materials and indications of how the filament spool could be manufactured, stored and assembled has been provided, they do not constrain the standard or freedom of design or interpretation.

In scope

This document addresses requirements to the outline mechanical standard to ensure overall compatibility.

- Minimum and maximum overall mechanical dimensions
- An internal common mounting method – sizes and shape
- An external common mounting method – size and shape
- An example method for manufacture – material and design.

Out of Scope

The following items are outside the scope for this document:

- Weight of the filament is not limited; this can be defined by the manufacturer.
- Length of the filament is not limited; this can be defined by the manufacturer.
- Size and shape of the filament is not limited; this can be defined by the manufacturer.
- Construction method for the filament spool.
- Exact material used for the filament spool.
- Packaging, branding and company specific information.

2. Background Description – Spool Standard Guidelines

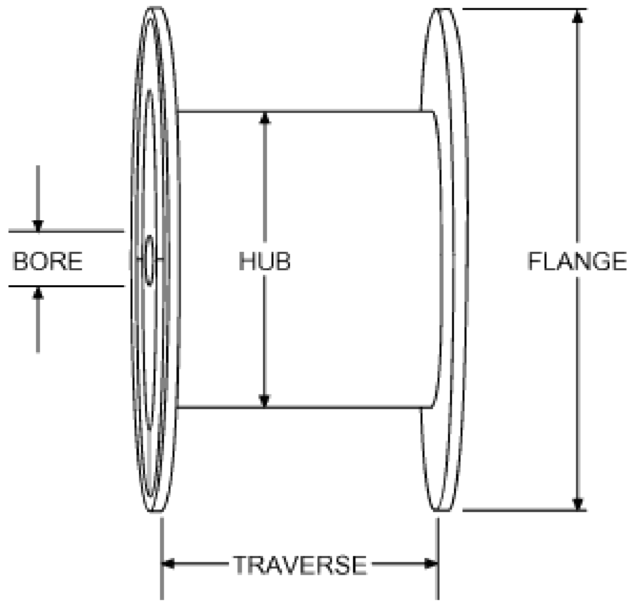
The concept of a universal standard for 3D printing materials is aimed at providing more choice for the user. The situation currently consists of many different spool sizes that will not fit on many of the available 3D Printers.

Many machine designers looking at 3D printing either do not accommodate mounting of materials or they opt for another proprietary standard, thus making even more non-standard spools or cartridges.

The closest thing we have to a 'standard' reel is based around the use of 3mm plastic welding rod/coils for automotive repair industry, these very large coils have been used with 3D printing for many years. They have some benefits, but also plenty of negative aspects. Mostly being heavy and big whilst also using more than 300+g of ABS/PP to make each one.

Consumers and users are forced to make spool racks or devise mounting methods for many different sized spools of 3D printing material. Loose coils of filament can be even more problematic to handle, store and use.

James Coleman (aka Makerstash) produced a drawing to help define how to describe the key aspects of a 3D printing filament spool. This standard terminology is used as the basis for further discussion in this document and with users or manufacturers.



2.1 Bore

A standard bore size is an important aspect for machine designers, in the case of a smaller bore size being required on a machine, a simple adapter can be used. Alternatively active or passive drive bearings and/or other types of friction could be added into the bore to control un-spooling of the filament in a 3D printer. The bore is also a good mechanical way to mount the spool in the 3D printer.

Some 3D printers or feeding mechanisms have used bearings or runners riding on the edge of the flange, this can function as long as the outer spool edge is not damaged.

2.2 Hub

The diameter of the hub is one aspect that can vary with regards to material type. Soft and flexible materials (like TPE and Nylon) can withstand a smaller hub diameter. Stiff materials like PLA can be damaged, bruised, crack or even break with a tight bend radius. This can also cause strain and extra loading on extruders that are trying to feed filament that still has a tight bend when unwound.

2.3 Traverse

This measurement has a large impact on the volume of filament that can fit onto a spool. Wide and heavy spools can be harder to mount and take up more space on a desktop 3D printer. This aspect was discussed in length with users and manufacturers. An ideal capacity is not unanimous or agreed by all, but an adequate range seems to be between 400g and 1Kg of printable material.

2.4 Flange

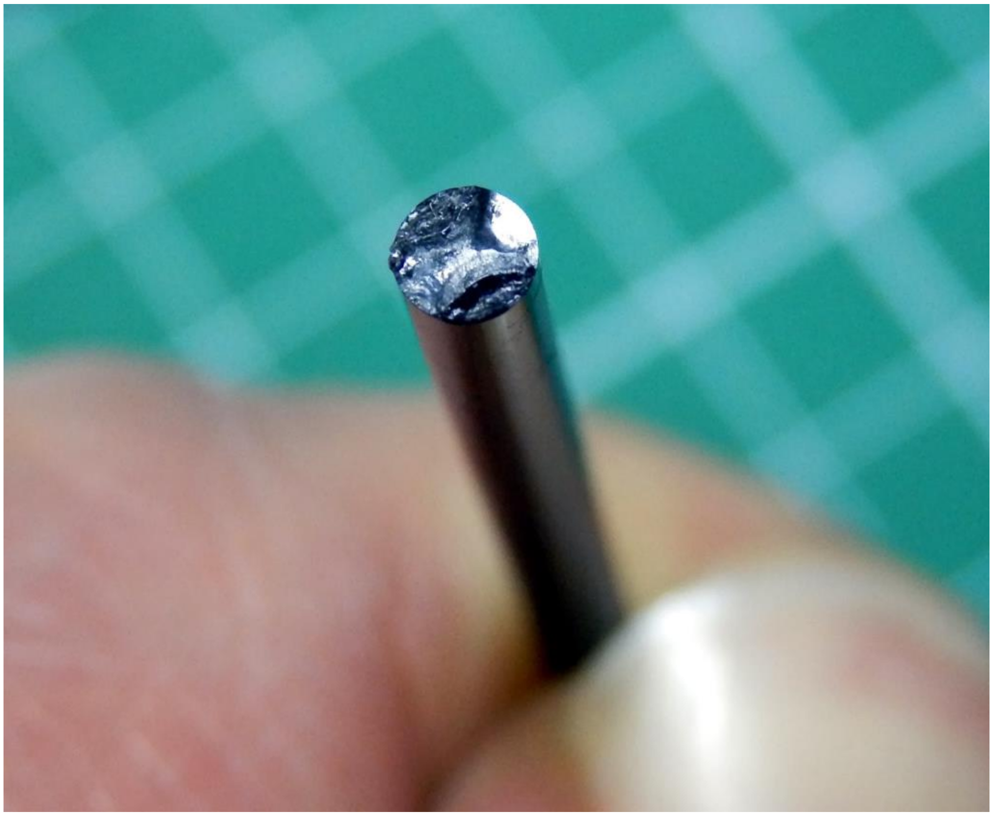
For the flange size it is again a measurement has a large impact on the volume of filament that can fit onto a spool. Wide and heavy spools can be harder to mount and take up more space on a desktop 3D printer. This aspect was discussed in length with users and manufacturers. An ideal capacity is not unanimous or agreed by all, but an adequate range seems to be between 400g and 1Kg of printable material.

2.5 Product Context

One of the most complex requirements is to define a spool size (along with volume and weight) of 3D Printing material that 'everyone' will be happy with. That's not really possible with all the various 3D Printers currently available or being designed now. What can be defined or considered is the next best range of optimum sizes for mechanical mounting, along with a typical material capacity for use. We will also consider the use of hard, soft and brittle 3D printing materials.

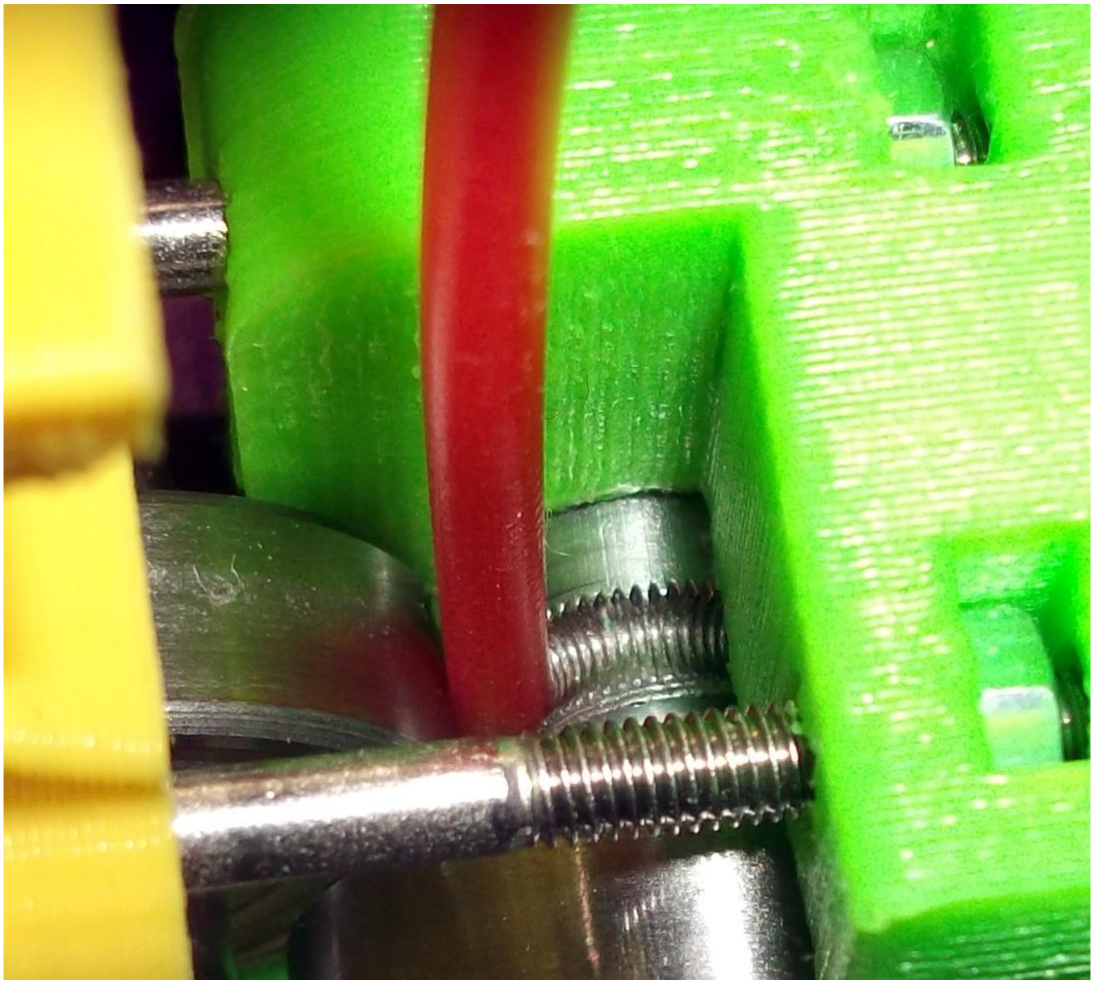
3D printing filament in use today already has a standard on size and shape to accommodate many different styles of machine and extruder drive mechanism.

These sizes are defined as 1.75mm round and 3mm round. The 1.75mm was designed for 3D printing and is actually that size. The 3mm is a legacy from the use of plastic welding rods for 3D printing, the 3mm standard now actually measures 2.85mm – this is to allow it to fit into a 'Bowden' (PTFE) feeding tube with an internal dimension of 3mm. Most material manufacturers have adopted the 2.85mm 'standard' for 3mm branded materials.



A filament spool should not bruise, restrict or deform the filament when being spooled or un-spooled.

Tolerance of materials varies, but is ideally quoted at +/- 0.1mm or better and a roundness of +/- 0.2mm or better.



3D Printing filament is inserted manually into most extruder mechanisms.

Most 3D Printing extruders require the round thermoplastic filament to be inserted manually, this is normally a simple task so should not have any significance on the filament spool standard. At this point onwards the only intelligence in the extruder, is the ability to control how much material is driven, how fast and the heater temperature control to around 1 Degree C.

Automatic loading and unloading of filament may be a consideration in future machines and standards.

2.6 Assumptions

The main assumption when embarking on this investigation was that it should be a good idea to have one universal standard for spool size, mounting and capacity. That is yet to be proven in the marketplace and when looking at consumables in other industries, this may not be desired by all manufacturers.

2.7 Constraints

Only minimal factors constrain the design options and implementation of a universal spool standard. Most manufacturers of 3D printing filament should be able to work with these constraints.

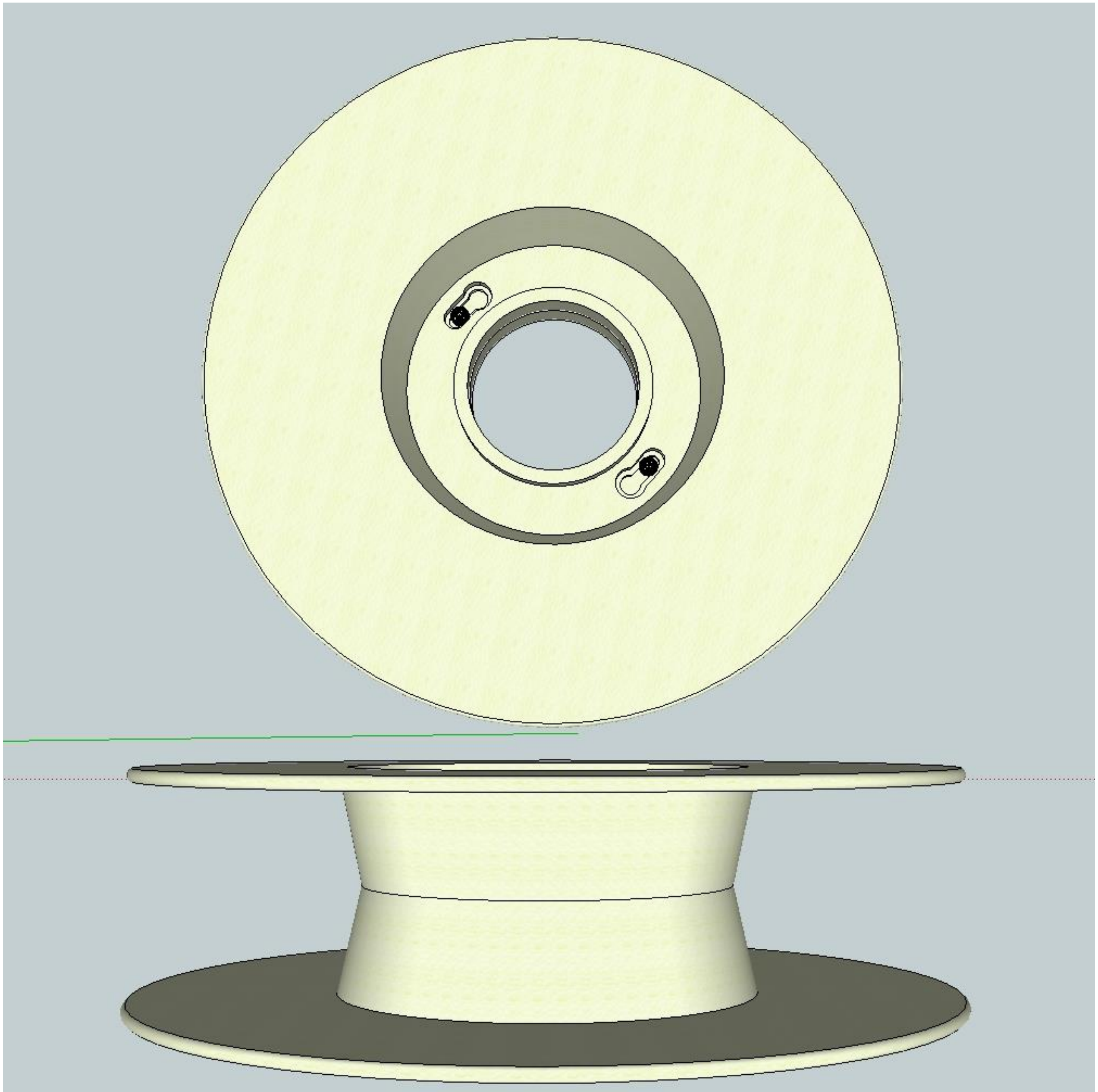
- Cost of spool tooling.
- The need to manufacture a spool rather than buying ready-made blank spools from a 3rd party.
- Parallel operation with an old standard – phase out of packaging and stock.
- Marketing, website and literature updates.
- Informing customers.

3. Specification Requirements

The standard is designed to have some level of flexibility, for filament material type and volumes of material being wound onto a spool. The key mechanical details of minimum bore and outer maximum flange size define the limits of the spool standard.

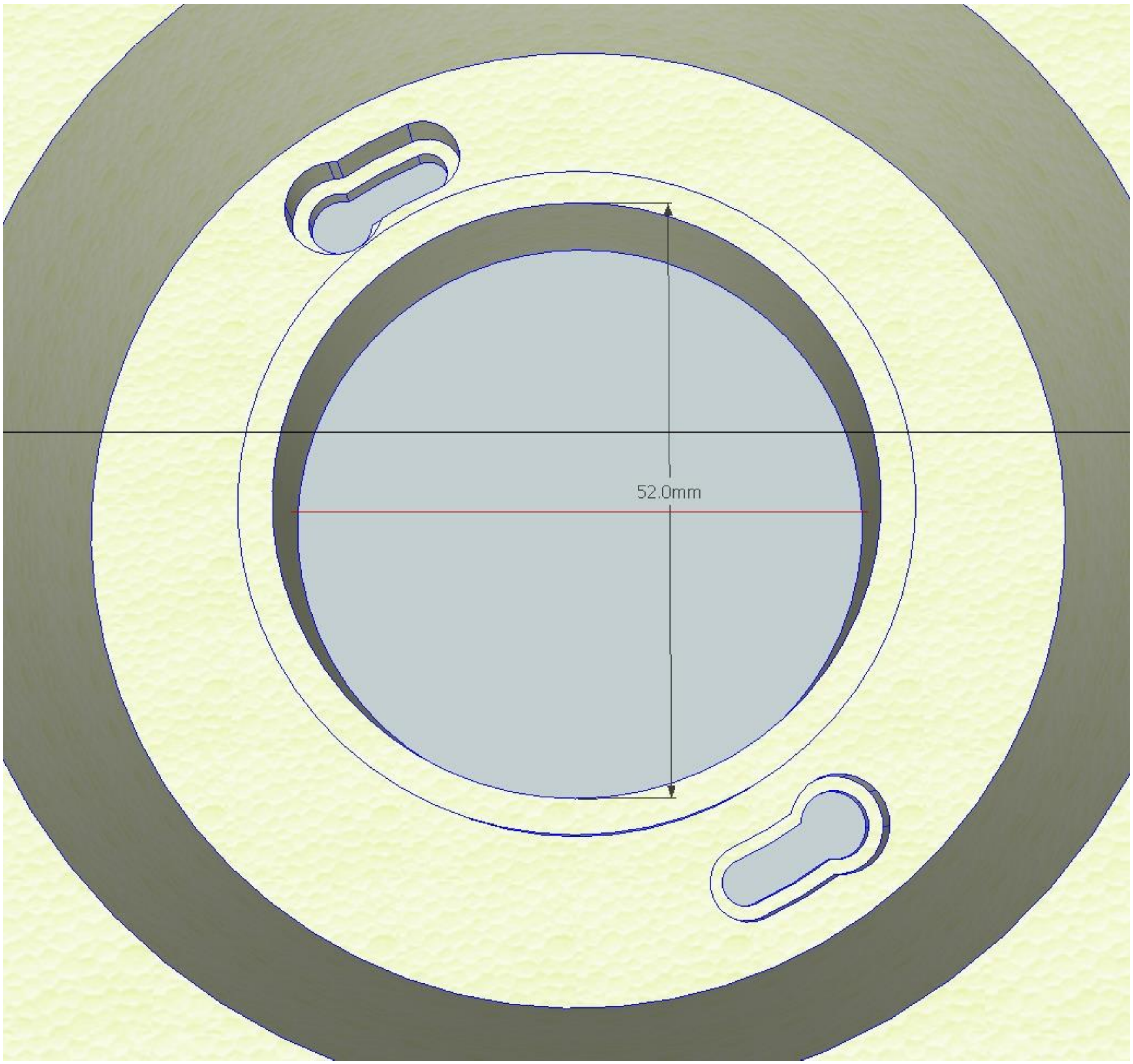
Spool design 'examples' are shown below to aid with understanding of the standard. Implementation of the spool and manufacturing process / materials are not part of the spool standard, they are for guidance only.

The below allows for ~750g to 1Kg of 1.75mm filament to be wound onto a spool of the following dimensions.



3.1 Bore: Standard is 52mm

Larger diameter bore would be compatible with the standard – may require an adapter for example.
Smaller diameter bore would be incompatible with the standard – no way to fit onto a ~50mm mount.

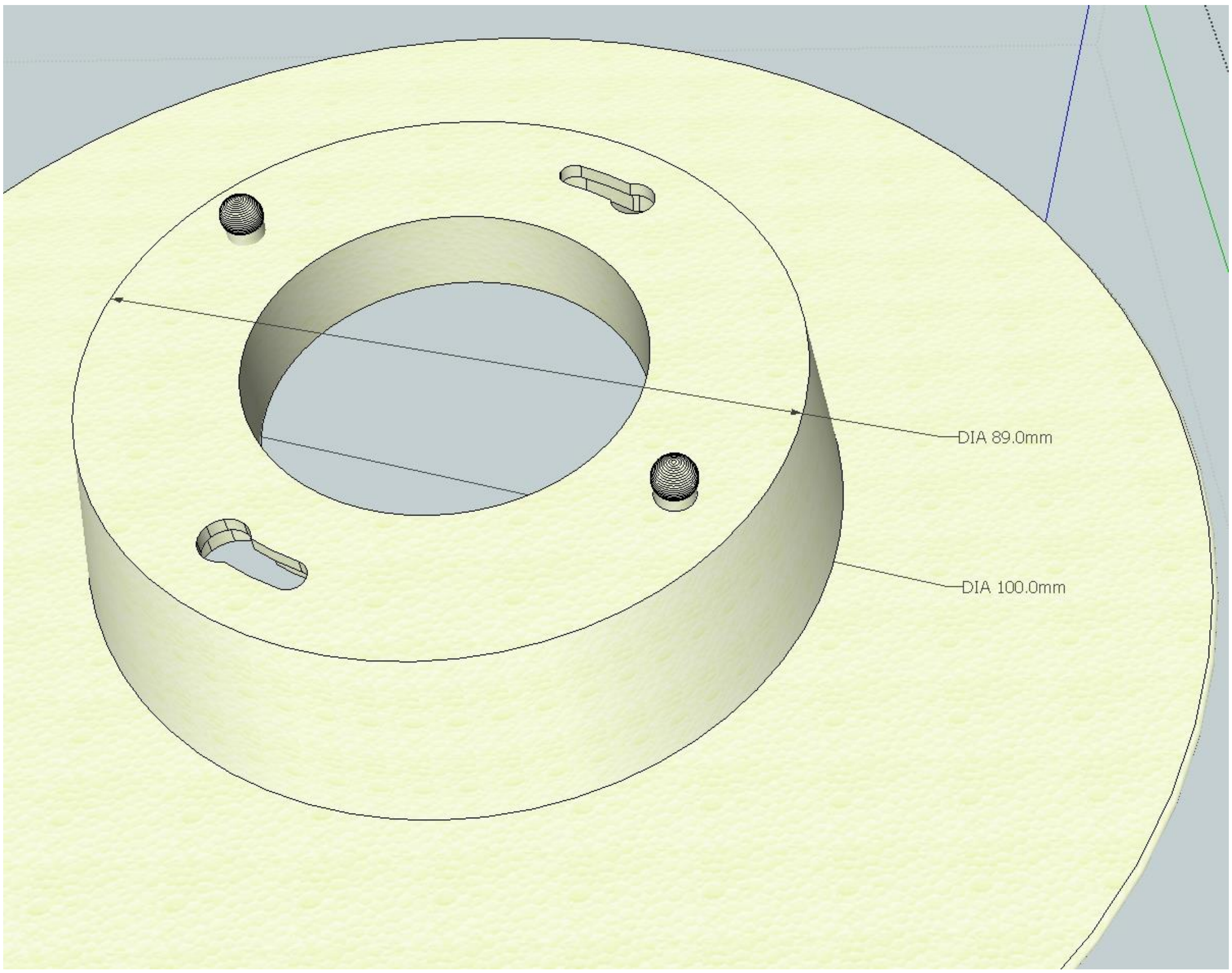


3.2 Hub: Standard is 100mm Outer edge diameter

Note a cone for molding is proposed, resulting in a minimum hub diameter of 89mm

Larger diameter hubs up to just below the flange size would be considered compatible with the standard.

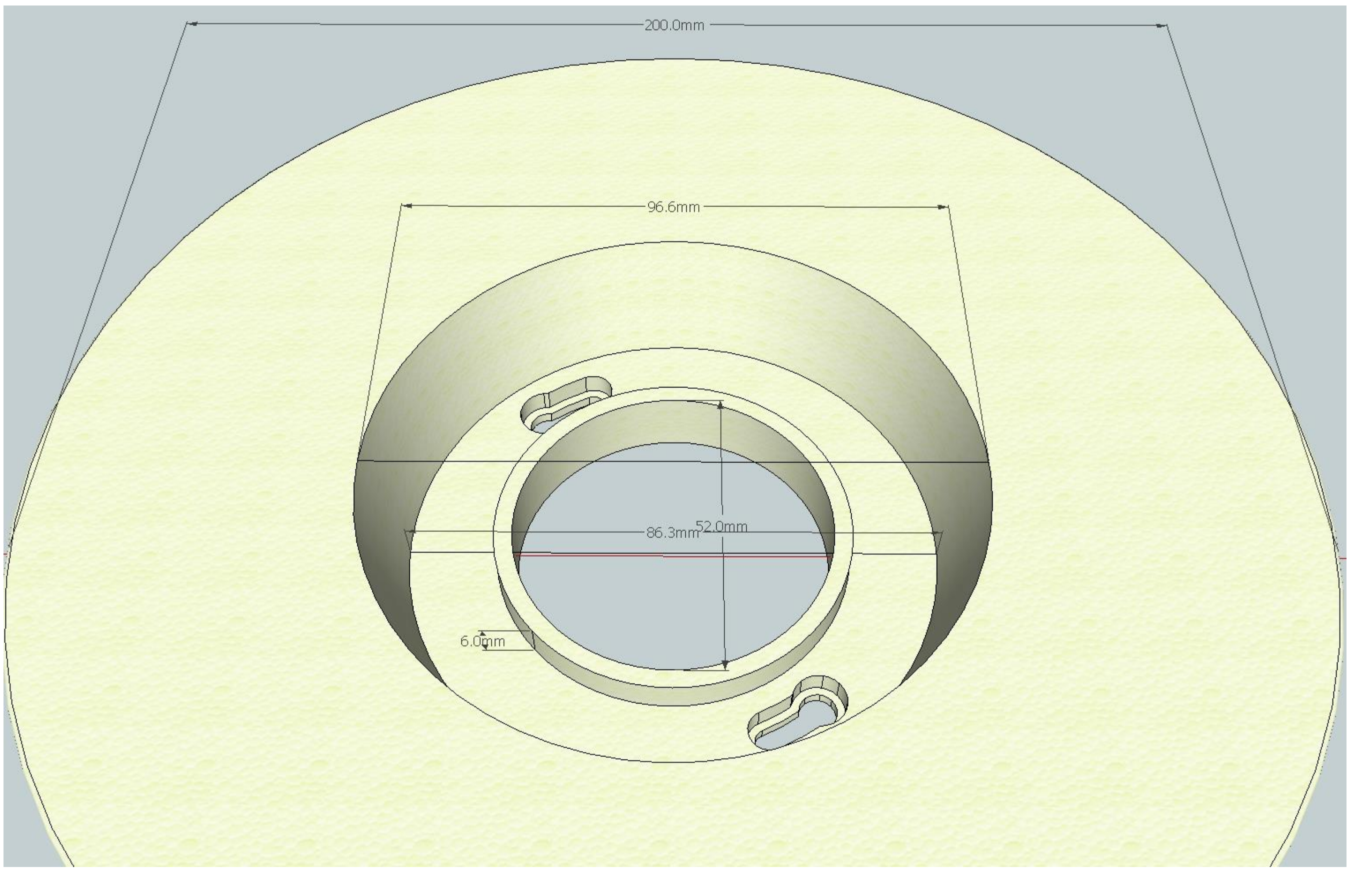
Smaller diameter hubs are not recommended with still materials like PLA or PET, but for materials like TPE (elastic/rubber), Nylon or PVA, then a smaller sized diameter hub would still be considered compatible with the standard.



3.3 Flange: Standard is 200mm Outer Diameter

Larger diameter flanges would be incompatible with the standard – may not fit into enclosure/s or mounting methods.

A smaller diameter flange could be considered compatible with the standard, for example this may be preferable for compact 3D printers or where a higher volume of material is not required. :- Note however this is only appropriate if machines use the bore for mounting and un-spooling. Any machine designs that used the edge or face of the flange may not be compatible with spools of a smaller flange size. Preference is to use the 200mm standard.



3.4 Traverse: Standard is 50mm Inner Diameter

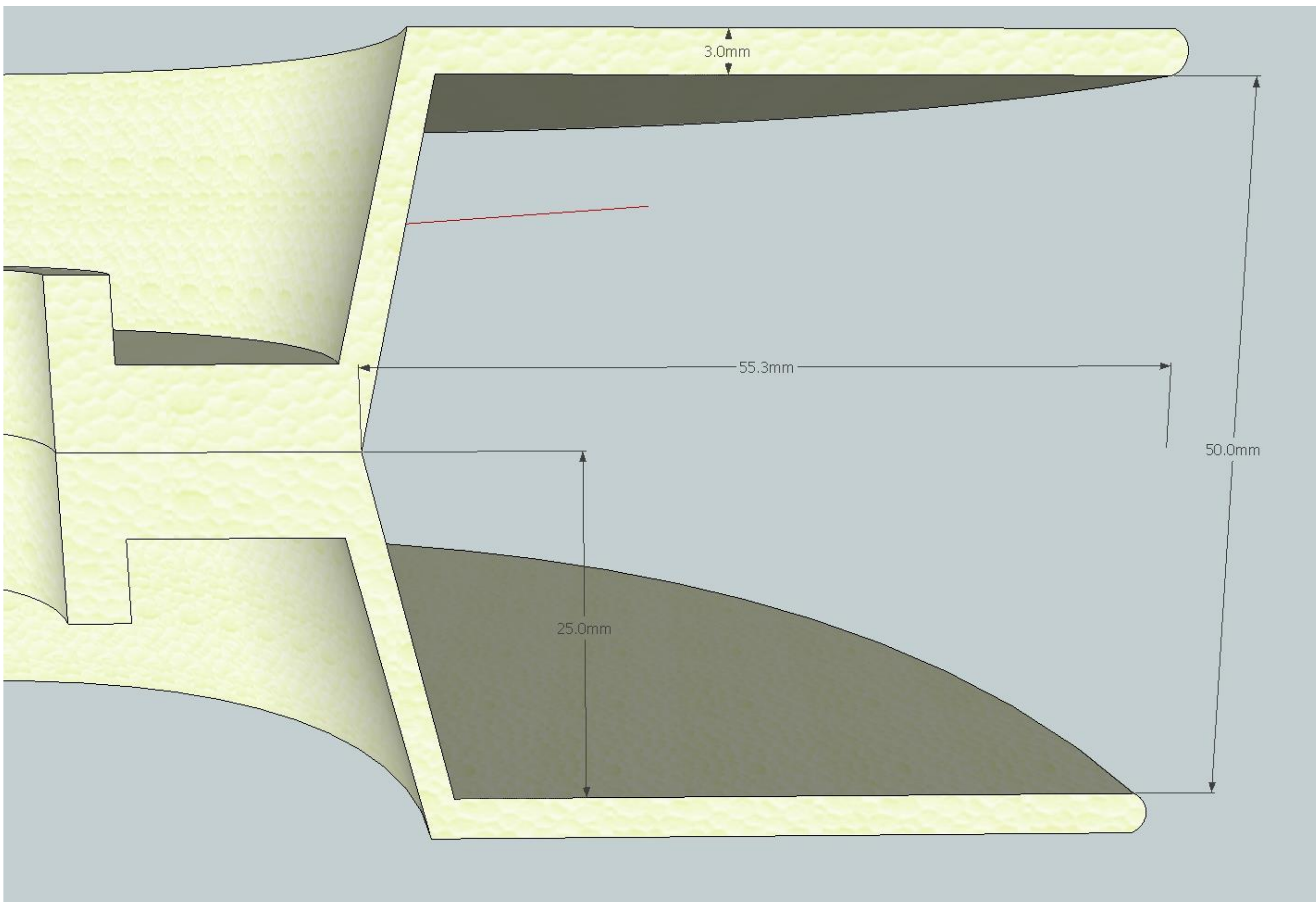
A nominal outer traverse width of 56mm is defined, with a maximum outer traverse of 60mm.

An outer traverse of over 60mm is not compatible with the standard.

An inner traverse of less than 50mm can be classified as compatible with the standard. The same note about Flange edge position is also valid for smaller width spools.

It is possible that two or three thin spools for example may occupy the space of the 60mm Maximum traverse width.

3D printers may also accommodate multiple spools traverse, for example a triple print-head machine may allow fitting of one, two or three standard sized (60mm max traverse width).

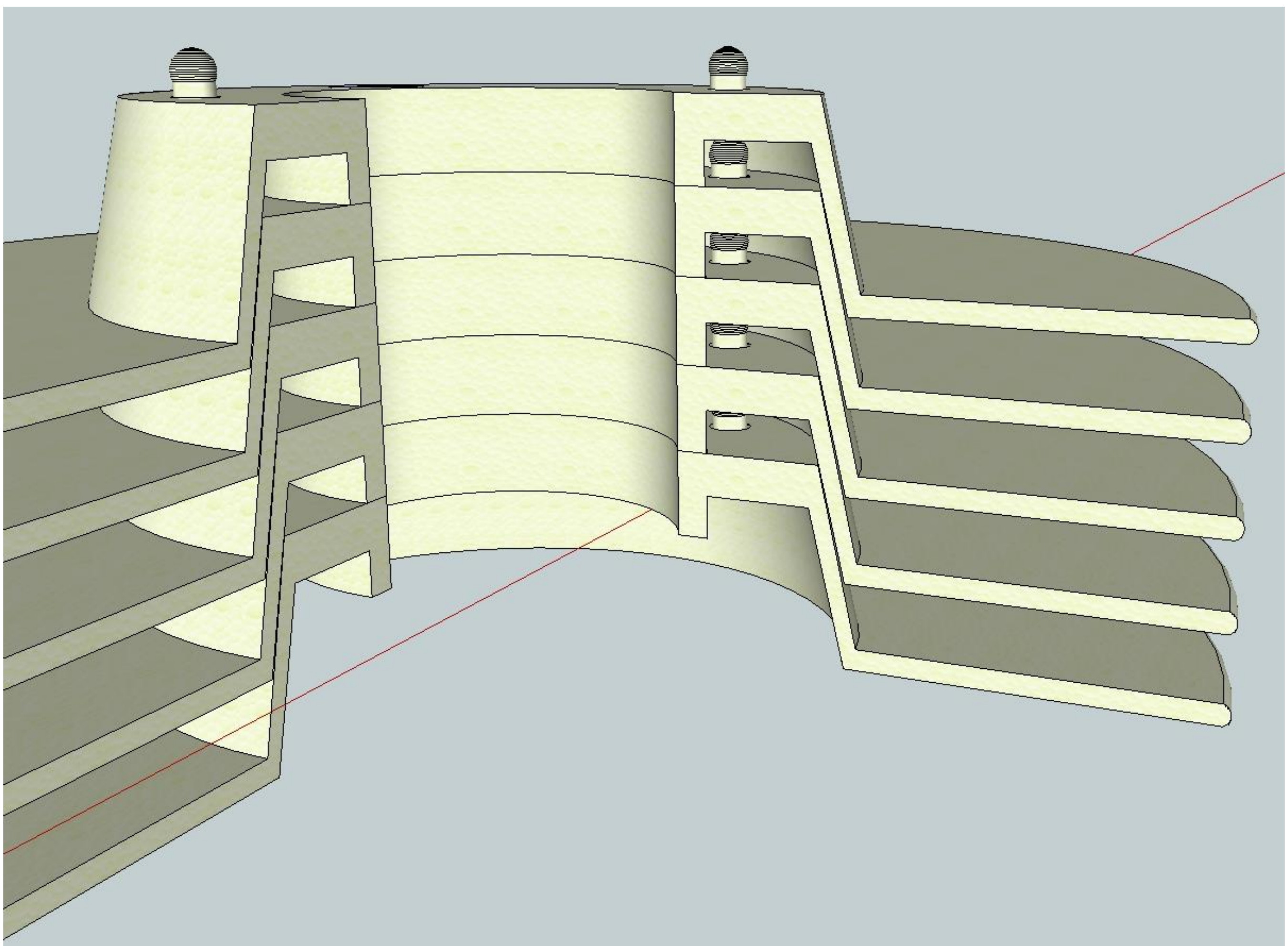


4. Example design – Stacking Spool made with Biofoam

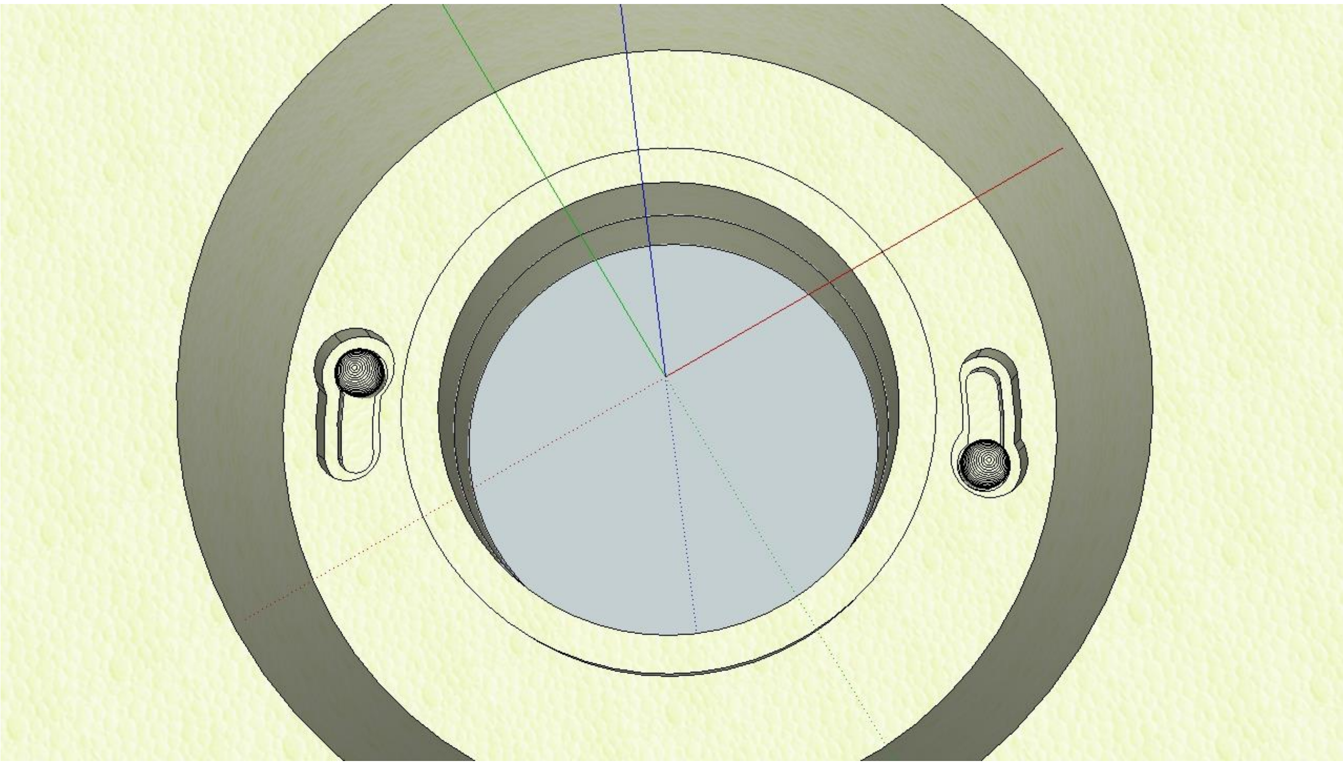
As an example of the spool standard implementation, the following design highlights further desirable aspects using BioFoam® and a single part mold that can be stacked to reduce storage space requirements.

BioFoam® is a PLA based expanding foam plastic. BioFoam® starts life as plastic beads, these are inserted into a mold and hot steam is injected, this expands the foam beads into the mold in seconds.

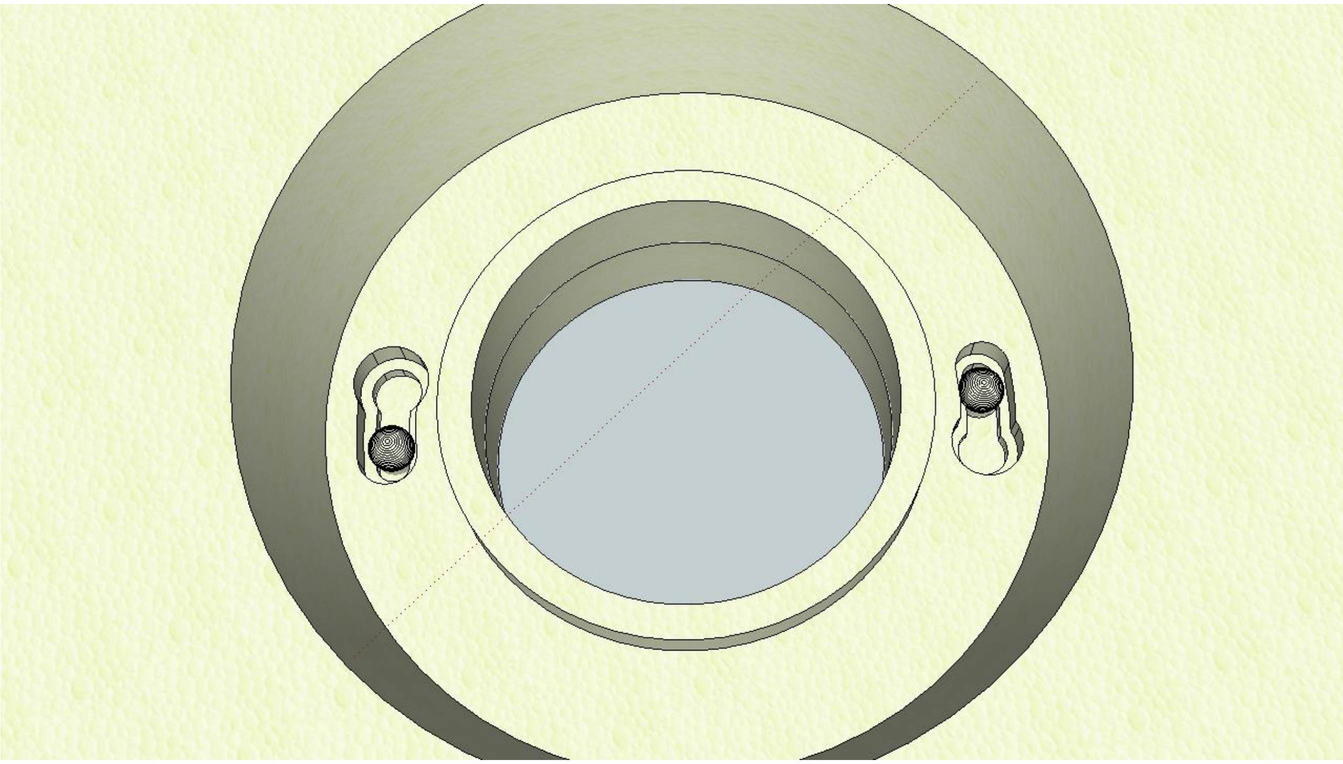
Being PLA based and with a strong but light honeycomb structure, BioFoam® would allow for a lightweight and easy to manufacture spool.

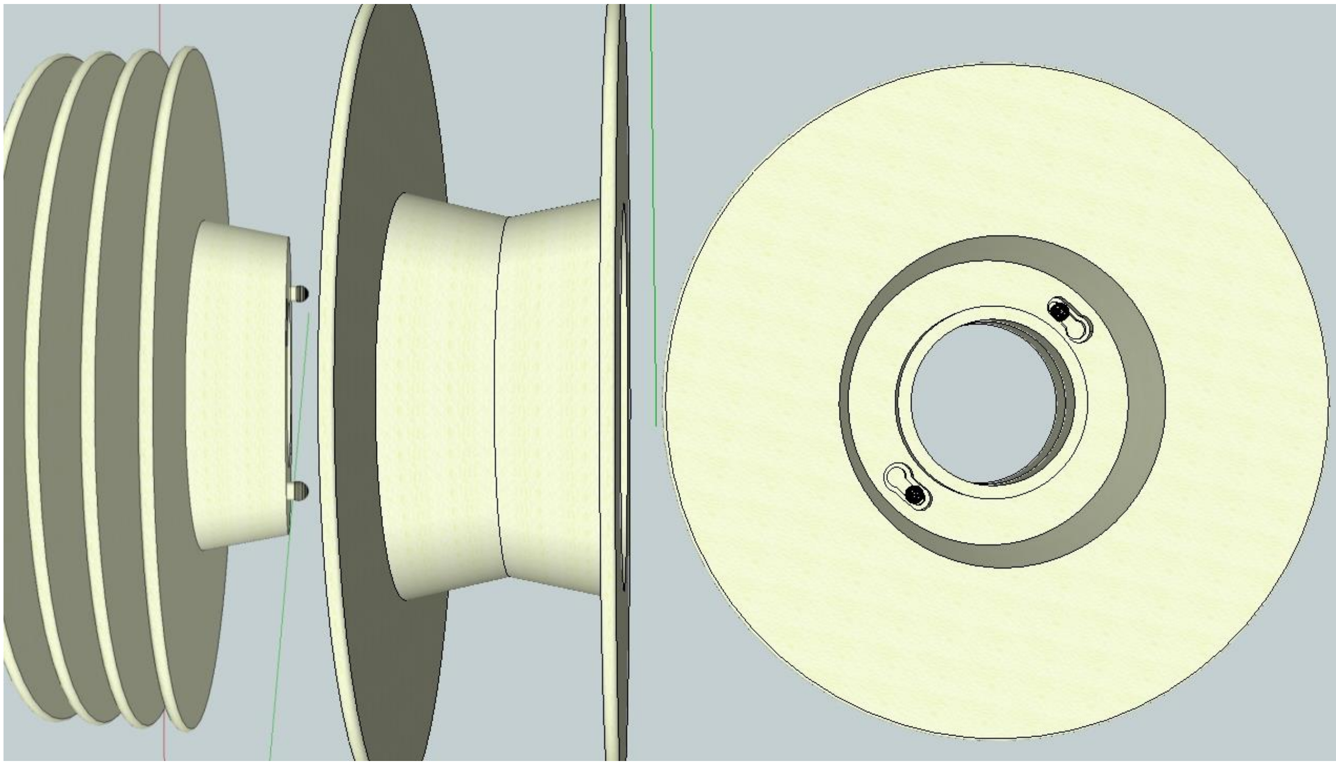


Identical halves of a BioFoam® molded spool can be stacked to reduce storage space and assembled as required.



Two halves are slotted together and locked with a rotation or slide – depending on type of tooling.





The finished spool is strong and in many ways similar to a 3D printed part with around 20% infill.

Further information about BioFoam® can be found here - http://www.biofoam.nl/index.php

Thank you to Colorfabb, who highlighted BioFoam® as a possible way to produce a light weight, strong and recyclable / degradable spool that could be manufactured anywhere on demand around the world. This would reduce shipping and storage costs and allow individual manufacturers to devise their own style of spool.

4.1 Labels and Electronic Tags

It is encouraged to label the spools with an identification of the material type and processing information. Other warnings or guidance should also be considered along with any part numbers or manufacturers logo's etc.

An electronic tag (RFID) or other type of near field memory device should be considered in the longer-term use of a standard. When mechanical aspects are defined in a spool standard, then a common electronic tag position could also be implemented. This would allow all/any data about the material to be directly read by the 3DPrinter for better processing and preparation of the object to be printed. See UFID in section 6 below.

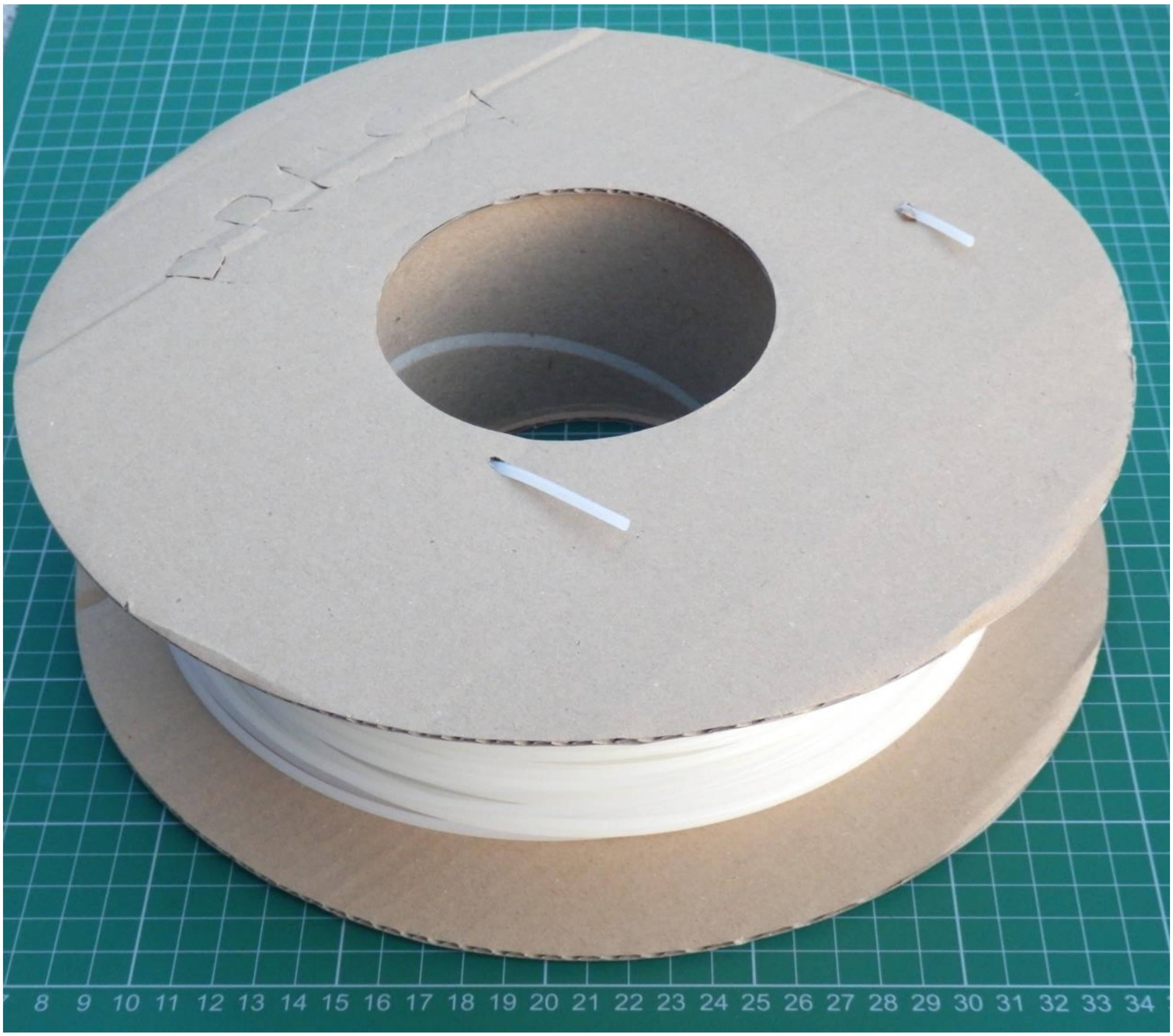
It may also be desirable to make parts of the spool open to allow the user to see the filament and how much remains on the spool.

5. Other Materials for Spool Manufacture – for information

The example above used BioFoam®. Many more materials are also available and have various benefits and weaknesses, some are discussed below.

5.1 Cardboard

Cardboard was originally considered to be a good and sustainable material for consumable 3D Printing filament reel spools. Whilst compressed and even corrugated cardboard can perform as a filament spool, some consideration must be given to the dust and fibers that cardboard can leave on the material.

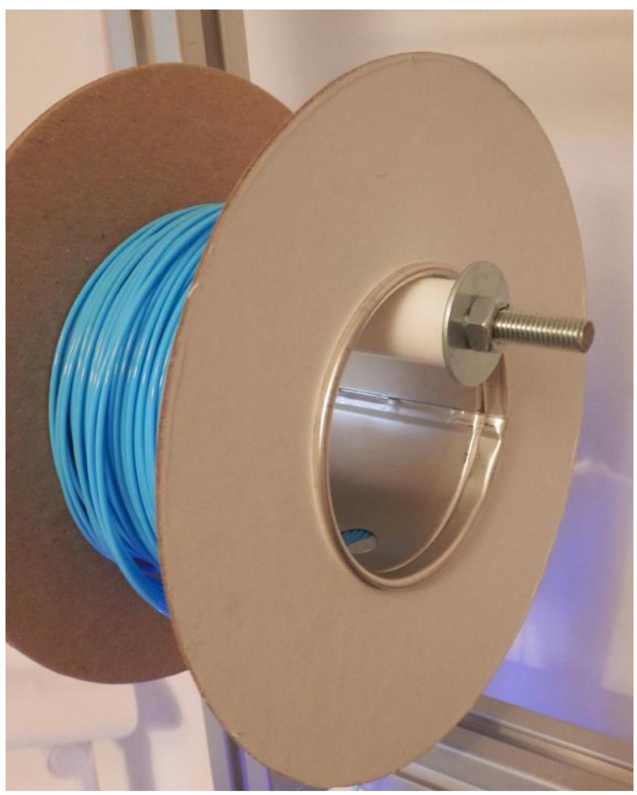


Corrugated cardboard is not self-supporting and can cause the filament to bind or jam on the spool, due to lack of constraint on the sides of the coils.

Fibers from a cardboard reel or even outer packaging can have a very bad impact on the print quality of a material; the very last thing you want is any non melting materials mixing inside the 3D printer hot-end.

Cardboard is also hydroscopic, meaning that it absorbs moisture from the environment. This can sometimes be a good thing, for example it will dissipate static charge, sometimes found when unwinding or re-spooling plastic filaments. But with 3D printing it is best to keep the filament as dry as possible at all times.

5.2 Metal / Cardboard & Metal



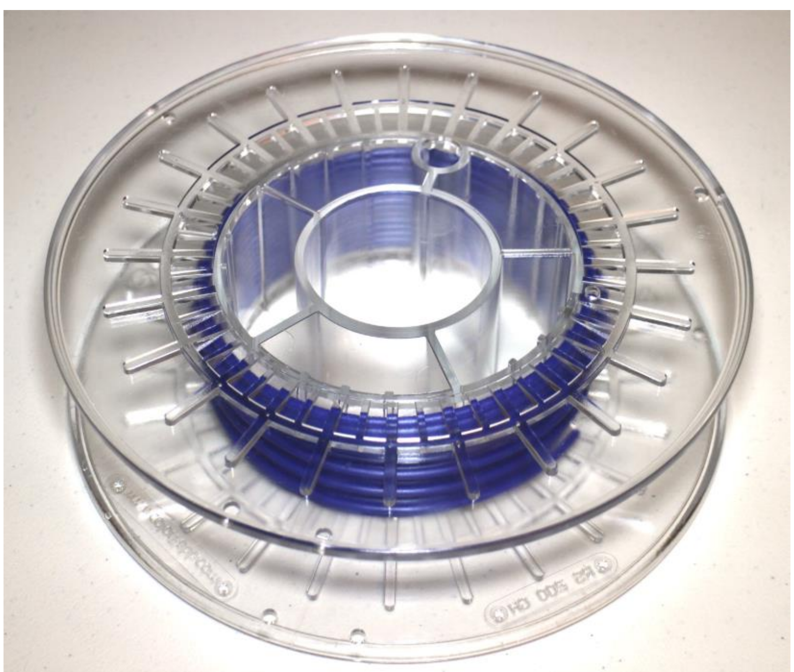
Suppliers have also tried to use standard spools used for the electrical cabling industry. These tend to have small diameter hubs and can deform, squash or bend the inner coils of filament. Some users stated that up to 1/3 of a reel can be wasted by the use of very tightly wound coils.

5.3 ABS/ Polypropylene (PP)

ABS Spool

Another of the most common materials for a plastic spool, often also used for copper cables and electrical wiring is ABS or Polypropylene, these materials are dense, somewhat impact resistant and hard wearing. Unfortunately they do not often tend to be recycled and end up in landfill.

5.4 Polycarbonate (PC)



PC Spool image

Polycarbonate is one of the strongest thermoplastic materials, impact resistant and optically clear. It's an expansive plastic and like ABS and PP is often not recycled enough.

5.5 Polyethylene terephthalate (PET/E)

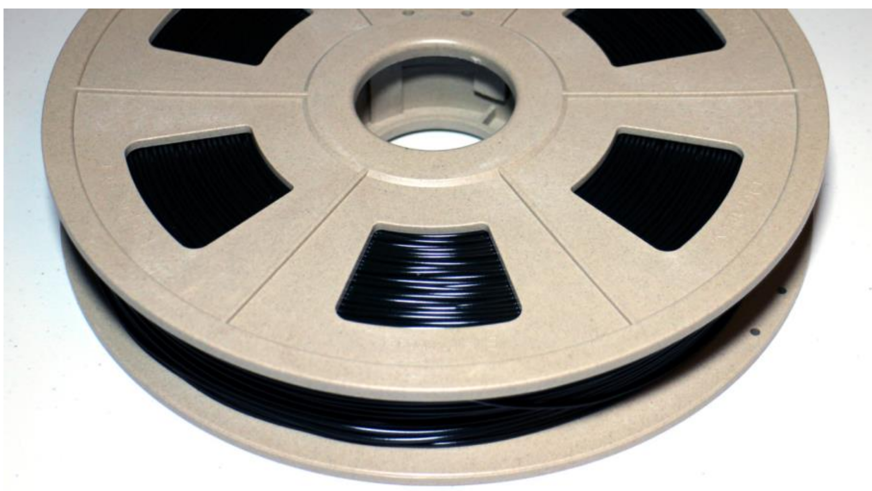
PET is used for drinks bottles and most food packaging, it’s well recycled in most parts of the world and is low cost.

5.6 Recycled plastic

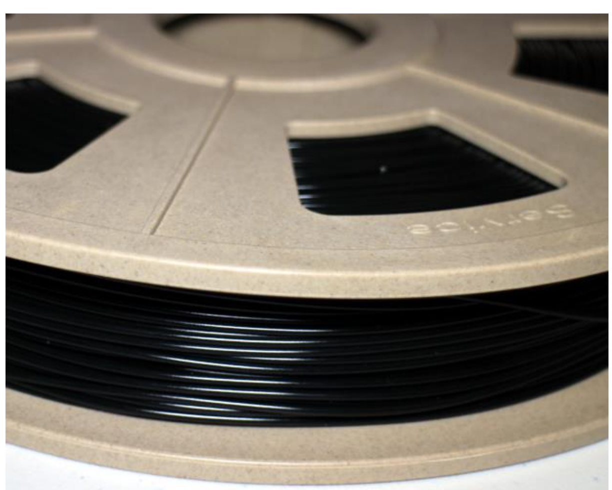
We have yet to see or find any examples of recycled plastic being used for spools in any industry. Why is not clear, but perceived ‘quality’ of the product may stop manufacturers from using recycled materials for this purpose.

5.7 Wood / mineral filled plastic

Some manufacturers are experimenting with the use of wood filled or other waste products being used as fillers for molding of various plastic products.



RepRapper Tech have already designed and manufactured a filled plastic spool, shown here.



Related Standards – for information

5.8 UFID (Universal Filament identification system)

The UFID 'standard' is an attempt to make the various materials and print properties of a 3D printing filament easy to read from the loading or scanning of a spool or outer packaging.

Development work and documentation into both labeling data (QR codes) and electronic tags (RFID) is being developed by the open source 3D printing community.

A Public UFID Google+ Community can be found here - https://plus.google.com/u/0/communities/107859862288161234107

The main UFID website is here - http://ufids.org/

Details from the UFID GitHub pages -

What is this project

As a community we have each experienced troubles when working with a new material for 3D printing. Because this problem is not exclusive to one manufacture or printer, a standard for distributing essential print settings could help to solve this problem.

Current Standard Version

As the 3D printing community grows we intend to grow along side. Currently we have a release candidate for public consumption. If you would like to review this please visit theRC1 Page for more information.

JavaScript Library

As part of making the UFID standard easy to implement, a library has been created, documentation on this library is available at the following location.https://github.com/camerin/UFIDS_pages/wiki/UFID-Library-Documentation

If you have any questions or comments please feel free to contact the 3D Printing Association.