EML2322L – Design & Manufacturing Laboratory

3D Printing Guidelines

The purpose of this document is to explain why this course focuses exclusively on traditional manufacturing processes, as opposed to newly developing processes like additive manufacturing, and the guidelines regarding the allowable use of the latter.

Why Focus on Traditional Manufacturing Methods?

Traditional manufacturing processes are currently responsible for over 90% of industrial production. Consequently, it is imperative for mechanical and aerospace engineers to understand how to design parts which can be manufactured using traditional manufacturing methods. Students who do not understand traditional manufacturing processes will be at a distinct disadvantage when transitioning into industry, as their designs will have the tendency to be inefficient or even impossible to make using the traditional methods commonplace in industry today.

The second reason this course focuses on traditional manufacturing processes is because they require a hands-on, experimental component to learn, compared to additive manufacturing, which only requires a basic understanding of the 3D printed material properties. Due to the shift in consumer goods from primarily repairable mechanical products to disposable electrical products over the past few decades, fewer and fewer students have the opportunity to obtain experience with traditional manufacturing processes growing up. We therefore intentionally focus on traditional manufacturing processes, because they are much more difficult for you to learn than additive processes.

What about Times When Additive Manufacturing Offers Better Solutions?

Traditional processes do have their limitations, specifically when it comes to making certain types of features. Since uncommon or hollow 3D shapes, for example, are quite difficult or even impossible to make with traditional processes, this is where 3D printing can shine.

Considerations before 3D Printing

When deciding if a part should be 3D printed for use in EML2322L, please read the following points and their respective sections to determine if additive manufacturing may be the appropriate solution.

1. 3D printing is an option ONLY when a part cannot be redesigned to be manufactured using traditional processes, or the time to do so is deemed excessively high by a course instructor. A course TA is always available to assess the design and provide feedback regarding whether it may be redesigned to use the traditional manufacturing resources provided in the lab.
2. 3D printed materials ALWAYS have lower strength than the identical unprinted solid material due to porosity and anisotropy; although the values vary for different materials, 50% reduction in raw material strength is a realistic value.
3. 3D printing is NOT free with regards to your course project budget. Material cost is $\$7/in^3$, which includes support material.

Material Properties

The most important consideration before making a decision to manufacture a part using 3D printing is the material strength of the printed part. Three main factors drive material strength in reference to 3D printing: (1) the type of material, (2) how it is layered, and (3) how densely it is printed.

The two principal materials available to students at UF are ABS and polycarbonate. Basic, raw (non-printed, normal solid) and printed material strengths for these two plastics are listed in table 1.

Table 1: Tensile Strength (psi) of Common 3D Printed Materials

Material	Tensile Strength of Unprinted Material (psi / MPa)	Tensile Strength of Printed Material (psi / MPa)
ABS	6,000 / 40	3,000 / 20
Polycarbonate	10,000 / 70	5,000 / 35

As seen in figure 1, when a 3D part is printed, gaps are created between each printed element of material, resulting in a composite that is *mostly* (about 80%) but not *completely* the printed material ***This porosity produces the first major reduction in material strength.***

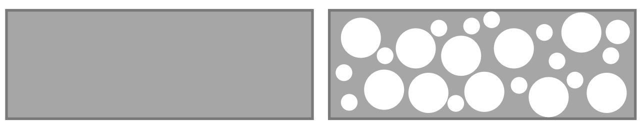

Figure 1. The image on the left is a solid piece of material. The figure on the right has bubbles of a second material in conjunction with the first, consequently affecting its material properties.

The material strength of 3D printed parts is further reduced due to the ***anisotropic*** nature of the printed material, which means the material properties are not the same in all directions. A common example of anisotropic material is wood, which possesses a grain structure that provides good stiffness in one direction, but easily splits in another. Imagine a log that is chopped with an axe. Chopping perpendicular to the grain (through the width of the log) will take a much more force than splitting the wood parallel to the grain (through the ends). In a similar manner, 3D printing creates a grain structure as it deposits one layer at a time parallel to the printer bed. ***This anisotropic layering process further reduces the material's strength or ability to withstand stresses caused by forces parallel to the grain (figure 2).***

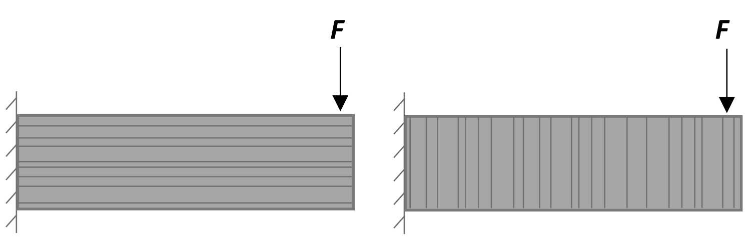

Figure 2. Force applied perpendicular to the grain (image on the left) and parallel to the grain (image on the right). The material on the right will fail much sooner than the material on the left.

The third factor that directly affects the material strength of 3D printed parts is ***print density.*** Objects are generally printed in lower density to reduce print time and material use; however this results in more voids within the printed piece. There is an outer shell of solid plastic, but within the shell is a honeycomb-like fill that dramatically reduces material strength versus a comparable solid piece of the printed material. Imagine the material with bubbles from figure 2, but with significantly larger voids in addition to the gaps between layered materials as previously discussed. Figure 3 shows examples of the infill gradient which are a measure of the print density. Keep in mind that most parts printed for students have approximately a 50% infill.

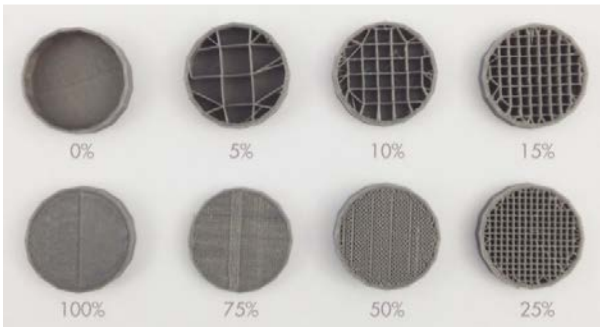

Figure 3. Examples of different densities of infill in 3D printed material. Many parts are printed with lower infill percentages to save time and material. This reduces the overall strength of the part.

Fastener Threads

Because of the lower material strength inherent in 3D printed plastic parts, conventional threads typically fail due to the relatively high shear stresses. One alternative is to redesign the part to use a threaded insert intended for weaker plastics.

In conclusion, because of the layered, anisotropic nature of common 3D printing methods, as well as average print densities found on budget-friendly printers, the true strength of 3D printed materials readily available from the print lab is at most 50% of that of the solid material. Therefore, before making a decision to 3D print a part, the required strength and stiffness must be analyzed and found within the parameters of the printing material.