Additive Manufacturing Technologies for Small Institutions and Hospitals

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Additive Manufacturing and Single Use Items

Single-use plastic components, tools and pieces of equipment are extremely common in the science research and medical fields and are widely used as cost-effective alternatives to their metal counterparts. Some obstacles to both small and large institutions that use single-use items (predominantly injection molding manufactured items) include high operational costs and high amounts of waste. These issues make them less attractive for smaller facilities with tighter budgets, particularly with the advent of newer technologies: enter Additive Manufacturing (AM). AM, more commonly known as 3D printing, covers a wide range of processes that use as little raw material as possible to manufacture a given part. For the purposes of this article, Fused Deposition Modeling (FDM) will be covered for its ease of use, low costs, and ease of installation. This type of AM creates a component part by building up many thin layers (~0.1-0.2mm) over hundreds of passes of the machine’s toolhead.

FDM manufacturing of multi-use parts can be a cost-effective alternative to single-use plastics given that it is competitive in cost and for its ease of use when producing multi-use components made of readily available temperature-resistant plastics, such as select nylons, Polyethylene terephthalate (PET), Polyether ether ketone (PEEK), or Polypropylene (PP). FDM manufacturing allows the consumer to purchase only the quantity of raw material necessary to create the parts and equipment that the consumer requires. This process cuts out excess amounts of unneeded surplus.

Benefits to Institutions

Poorly funded or small hospitals and facilities could greatly benefit from producing custom or otherwise costly items in-house instead of relying solely on costly contract manufacturers. Industrial-grade AM machines are needed to produce these kinds of multi-use products, but are outside of these organizations’ budgets. Therefore, if institutions were to purchase consumer grade machines and upgrade them with the appropriate hardware, they could potentially save multiple thousands of dollars in starting equipment and continued operational costs by producing their own multi-use components in house. By utilizing these advanced technologies, medical facilities and institutions would be opening themselves up to better tackle adverse supply chain environments and participate in AM research at the same time. These consumer grade machines do not require institutions to hire a specialist to operate the machines, but, rather, an existing professional can learn how to run these machines as part of their existing duties. The initial knowledge to operate and modify FDM AM machines can be acquired from other institutions and universities, as well as the manufactures of the machines.

Why FDM AM.

Larger institutions and medical facilities can afford to purchase expensive, high-tech equipment that they can operate in-house. These types of machines require the operator to have a high level of skill in the field to run the machine, have expensive initial purchase and materials costs, and require a large amount of space to be stored and operated in (machines can range from two square meters and above). These machines are useful for producing engineering and medical grade components, but have the drawbacks listed above. One way smaller institutions who can’t accommodate these drawbacks could still produce in-house components of the desired quality would be to take a cheaper and more accessible technology, such as FDM, and modify these machines to fit the needs of the institution.

Modifications to FDM

Most FDM machines within the price range of smaller parties ($150 - $1,000 USD) need at least some modification to produce similar results to SLS and SLA technologies. These modifications fall under three main categories: material selection, temperature range expansion, and external enclosures.

Materials Selection Expansion.

FDM style printers will generally have access to spools of plastic materials that come in 1.75 mm and 2.85 mm strand widths. While 1.75 mm width material is more common for these types of machines, 2.85 mm filaments can generally be purchased for less than a comparable mass of 1.75 mm plastic of the same material due to the increased rarity of machines that can use this size of material and the frequency of bulk material sales in this width. FDM machines can use either size of material and produce similar results when producing small components or parts, but 2.85 mm filament, when coupled with a high flow Hot-End (H-E), can produce larger parts in much less time than the same machine running 1.75 mm filament. Depending on the needs of the institution, these advantages of 2.85 mm filament may be useful.

Temperature Range Expansions (H-E Modification).

FDM machines contain one or more toolheads that have a metal nozzle, a heating apparatus (heater block), and a form of cooling. In order for the machine to function effectively, the nozzle must be heated to the ideal temperature to melt the plastic being used, while the cooling unit (usually a fan) keeps the rest of the tool head from becoming too hot without affecting the nozzle's temperature. Many stock machines at the low end of the market prices can only maintain nozzle temperatures of around 240°C at most for standard use operations. Additionally, the tool head may include some form of part cooling, which can also affect nozzle temperature. Stock machines usually do not have sufficient part cooling or H-E cooling to reach higher printing temperatures that are required to use medical and engineering grade materials and, therefore, must have these parts upgraded first before other changes can be made.

Next, once there is sufficient cooling of the unit, the nozzle and other metal parts of the H-E unit that house the filament on its way to the nozzle can be replaced for higher grade materials along with an upgraded heater block. These improvements increase the maximum printing temperature, longevity of the H-E assembly (stock parts are generally brass or aluminum while upgrades can be steels or alloys), and overall print consistency by decreasing nozzle temperature fluctuations.

External Enclosures.

Many FDM printers have an option for an enclosure. Most printers with a preinstalled enclosure at this price range will have drawbacks for the institution, such as a small printing volume, modification issues, and harder maintenance operations. Many non-enclosed printers can have aftermarket or in-house produced enclosures fitted to them. Enclosures improve part consistency by reducing drafts that can negatively affect part cooling, reduce or eliminate the introduction of dust and foreign particles to the printer and parts, and reduce noise generated by the printer, which could be of interest if the printer is operated in an office or lab environment where other work is conducted.

Additional Modifications to FDM.

Some other modifications that can be made to FDM machines generally include quality-of-life upgrades that make the printing experience easier, more efficient, and more compatible with the institution's other equipment. For popular models of low-cost machines, premium, upgrade, and additional parts are often available on the general consumer market that improve user interface functionality, both physically and electronically. These improvements can save operators vast amounts of time depending on the improvements made to the machine. One example is an Automatic Bed Leveling (ABL) system: these systems automatically sense disturbances in the tram of the printer's alignment between the nozzle and the platform on which the component is being produced, i.e., the "bed." Before this improvement is made to the machine, an operator would have to complete this step manually in a much less precise manner that takes much longer to perform and requires advanced technical knowledge to perform the operation correctly.

Long Term Benefits to Institutions

The changes made to these low-cost machines will rarely exceed the original cost of the machine itself (~$300) and could overall be many times less expensive for the institution to purchase when compared to an industrial grade machine (~$10,000+). If small institutions take this route to include AM capabilities in their repertoire, they will be able to adapt to the changing needs of their researchers or staff, reduce operating costs by producing needed equipment in-house, and continue operations in adverse supply chain conditions.

Possible Growth.

The main benefits to these institutions include the ability to produce much needed parts in house for daily operations and advance and increase the scope of the work that can be conducted by adding these technologies. AM has become more accessible to the general market over the last 40 years. With this increased accessibility, smaller institutions could begin to see increased connection to bigger medical and academic facilities and share research that could be replicated through a broader research base. This increased connection could lead to the growth of smaller facilities and allow them to expand their horizons.

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