ME-307L Manufacturing Processes Lab

Experiment Part manufacturing using 3D printing.

0.1 Learning Objectives

The students will learn about

1. Creation of G Code file for printing using commercially available slicing software.
2. Manufacturing of part using Fusion Deposition modelling 3D printer

0.2 Precautions

i. The temperature of extruder nozzle is very high, do not touch it.
ii. Do not touch or move or drag apparatus.
iii. Remove part carefully from glass bed using scrapper.

0.3 Theory

There are several 3D printing methods, also known as additive manufacturing processes, each with its own unique characteristics and applications. Some of these are discussed as.

0.3.1 Fused Deposition Modeling (FDM) / Fused Filament Fabrication (FFF)

FDM is a popular 3D printing method that uses thermoplastic filament. The filament is heated and extruded through a nozzle, layer by layer, to build up the object. It is Commonly used for rapid prototyping, functional parts, and hobbyist projects. It is a notable printing method for its affordability, ease of use, and accessibility.

0.3.2 Stereolithography (SLA)

SLA uses a liquid resin that's cured (solidified) by a light source, typically a UV laser or projector, layer by layer. It is advantageous for producing high-detail, smooth surface finishes for intricate designs and prototypes. It is used in jewelry making, dental applications, and industries requiring fine detail.

0.3.3 Selective Laser Sintering (SLS)

SLS uses a laser to fuse powdered materials (usually polymers or metals) layer by layer to create solid objects. It offers more design freedom and can produce functional parts with good mechanical properties. It is commonly used for producing end-use parts, rapid prototyping, and aerospace components.

0.3.4 Electron Beam Melting (EBM)

EBM uses an electron beam to melt and fuse metal powder, layer by layer. It is mainly used for producing metal parts with good mechanical properties in aerospace and medical applications.

0.3.5 Digital Light Processing (DLP)

DLP uses a light source (often a projector) to cure a liquid resin. It offers faster printing speeds than traditional SLA due to simultaneous curing of an entire layer. It is used in jewelry, dental, and small-scale manufacturing.

0.3.6 Working Principle of FDM

Fused Deposition Modeling (FDM) printer, also known as a Fused Filament Fabrication (FFF) printer, is a type of 3D printer that operates by melting and extruding thermoplastic filament to create three-dimensional objects layer by layer. It's one of the most common and popular 3D printing technologies used today.

Figure 1: FDM 3D Printer (Craftbot XL)

FDM printers use a thermoplastic filament, typically made of materials like PLA (polylactic acid), ABS (acrylonitrile butadiene styrene), PETG (polyethylene terephthalate glycol), and more. These materials become soft and malleable when heated but solidify when cooled. The filament is fed into a heated nozzle or extruder. The nozzle heats up the filament to its melting point, turning it into a semi-liquid state. The extruder moves along specific paths determined by the 3D model's design. It deposits melted filament in thin layers onto the build platform. As each layer is deposited and cooled, it fuses with the previous layers, gradually building up the object. Once the extruded filament is deposited onto the build platform, it quickly cools down and solidifies. This ensures that each layer retains its shape and supports the layers above it. The build platform can be heated, especially for materials like ABS, to prevent warping and promote adhesion. Some printers have removable build platforms or use adhesion aids like glue, tape, or special surfaces to improve print adhesion. For designs with overhangs or complex geometries, FDM printers often use temporary support structures made of the same material or a dissolvable material. These supports can be removed after printing is complete.

FDM printers are relatively affordable, widely available, and suitable for a range of applications, including prototyping, functional parts production, hobbyist projects, and educational purposes. However, the surface finish might not be as smooth as some other 3D printing methods, and layer lines might be visible. Nonetheless, FDM printing remains a versatile and accessible option for creating three-dimensional objects.

0.4 Procedure

This experiment is to be performed by students only under supervision of lab supervisor/engineer.

1. Import STL file of part to be manufacture in the commercially available slicing software.
2. Set the material, temperature of bed and extruder and other printing parameters in the software.
3. Create a G-code file and export it into USB.
4. Turn the 3D printer on.
5. Load the polymer filament into the printer.
6. Attach the USB containing G code file of the part to the printer.
7. Apply print command using machine user interface.
8. After completion of printing, remove the printed part carefully using scrapper.
9. Remove the supports if applied in slicing software.

0.5 Points of Discussion in the Lab Report

Make a report, detailing geometry of part, printing materials, Printing parameters and all the steps involved during manufacturing of part.

Appendix

Appendix A

Program Learning Outcomes (PLOs)

On the basis of the Knowledge Attributes defined in the Washington Accord, twelve (12) Program Learning Outcomes, also known as Graduate Attributes, are listed below:

(i) **Engineering Knowledge**: An ability to apply knowledge of mathematics, science and engineering fundamentals and an engineering specialization to the solution of complex engineering problems.

(ii) **Problem Analysis**: An ability to identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.

(iii) **Design / Development of Solutions**: An ability to design solutions for complex engineering problems and design systems, components, or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.

(iv) **Investigation**: An ability to investigate complex engineering problems in a methodical way including literature survey, design and conduct of experiments, analysis and interpretation of experimental data, and synthesis of information to derive valid conclusions.

(v) **Modern Tool Usage**: An ability to create, select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling, to complex engineering activities, with an understanding of the limitations.

(vi) **The Engineer and Society**: An ability to apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solution to complex engineering problems.

(vii) **Environment and Sustainability**: An ability to understand the impact of professional engineering solutions in societal and environmental contexts and demonstrate knowledge of and need for sustainable development.

(viii) **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.

(ix) **Individual and Team Work**: An ability to work effectively, as an individual or in a team, on multifaceted and/or multidisciplinary settings.

(x) **Communication**: An ability to communicate effectively, orally as well as in writing on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentations, make effective presentations, and give and receive clear instructions.

(xi) **Project Management**: An ability to demonstrate management skills and apply engineering principles to one's own work, as a member and/or leader in a team to manage projects in a multidisciplinary environment.

(xii) **Lifelong Learning**: An ability to recognize importance of, and pursue lifelong learning in the broader context of innovation and technological developments.

Course Learning Outcomes for Manufacturing Processes Lab

Sr. #	CLO Statement	Domain	Level	PLO
1	**DISPLAY** basic proficiency in operation of the apparatus and **PERFORM** the experiment to determine the solution of the engineering problems related to the subject.	Psychomotor	4	4
2	**Communicate** the learned concepts using different media i.e., verbal and written.	Affective	2	10
3	**Manifest** the professional responsibilities and norms of engineering practice.	Affective	3	8

Relation of CLOs of MP Lab with PLOs

PLO #	PLO Statement	CLO1	CLO2	CLO3
PLO-1	**Engineering Knowledge**			
PLO-2	**Problem Analysis**			
PLO-3	**Design/Development of Solution**			
PLO-4	**Investigation**	✓		
PLO-5	**Modern Tool Usage**			
PLO-6	**The Engineer and Society**			
PLO-7	**Environment and Stability**			
PLO-8	**Ethics**			✓
PLO-9	**Individual and Team Work**			
PLO-10	**Communication**		✓	
PLO-11	**Project Management**			
PLO-12	**Life Long Learning**			

Appendix B

Details of Domains

Cognitive		Affective		Psychomotor	
Level 1	Knowledge	Level 1	Receiving	Level 1	Perception
Level 2	Comprehension	Level 2	Responding	Level 2	Set
Level 3	Application	Level 3	Valuing	Level 3	Guided Response
Level 4	Analysis	Level 4	Organization	Level 4	Mechanism
Level 5	Synthesis	Level 5	Characterization by value or value complex	Level 5	Complex over response
Level 6	Evaluation			Level 6	Adaption
				Level 7	Organization

Appendix C

Lab Rubrics for ME-307L MP Lab

CLOs	Criteria	Poor (0 to 4)	Satisfactory (5-6)	Good (7-8)	Excellent (9-10)
CLO-1	**Apparatus Handling, Experiment Performance and Calculations**	No knowledge of apparatus, experiment not performed, nor any calculations done	Knows basic operation of the apparatus, performed the experiment with major errors in calculations	Can handle the apparatus well, experiment completely performed, and calculations have few mistakes	Fully understands the complete operation of the apparatus, experiment performed, and all calculations are correct
	Planning and Execution of an Experiment [OEL]	Experiment not planned for proper execution	Experiment planned but not executed properly	Experiment planned and executed but slight omissions	Experiment correctly planned and executed
CLO-2	**Communication [Report]**	Report neither covers technical details of experiment nor according to format	Correct report submitted according to format but not covering essential technical details	Report well written technically but format not completely followed / slight mistakes	Well-composed flawless report covering technical aspects of experiment
	Communication [Viva]	Either does not understand or cannot communicate concepts related to experiment	Understands the concepts related to experiment but does not communicate in technical terms	Understands and able to communicate the learned concepts but with slight mistakes	Fully understands all the concepts and can express them technically
CLO-3	**Punctuality, Teamwork and Safety**	Arrives too late for experiment with disregard to teamwork or safety	Arrives little late for experiment, somewhat adheres to teamwork and safety	Punctual but slightly lacking in teamwork and safety consciousness	Punctual, works as a team and adheres to safety instructions