Extrusion-Based AM Processes

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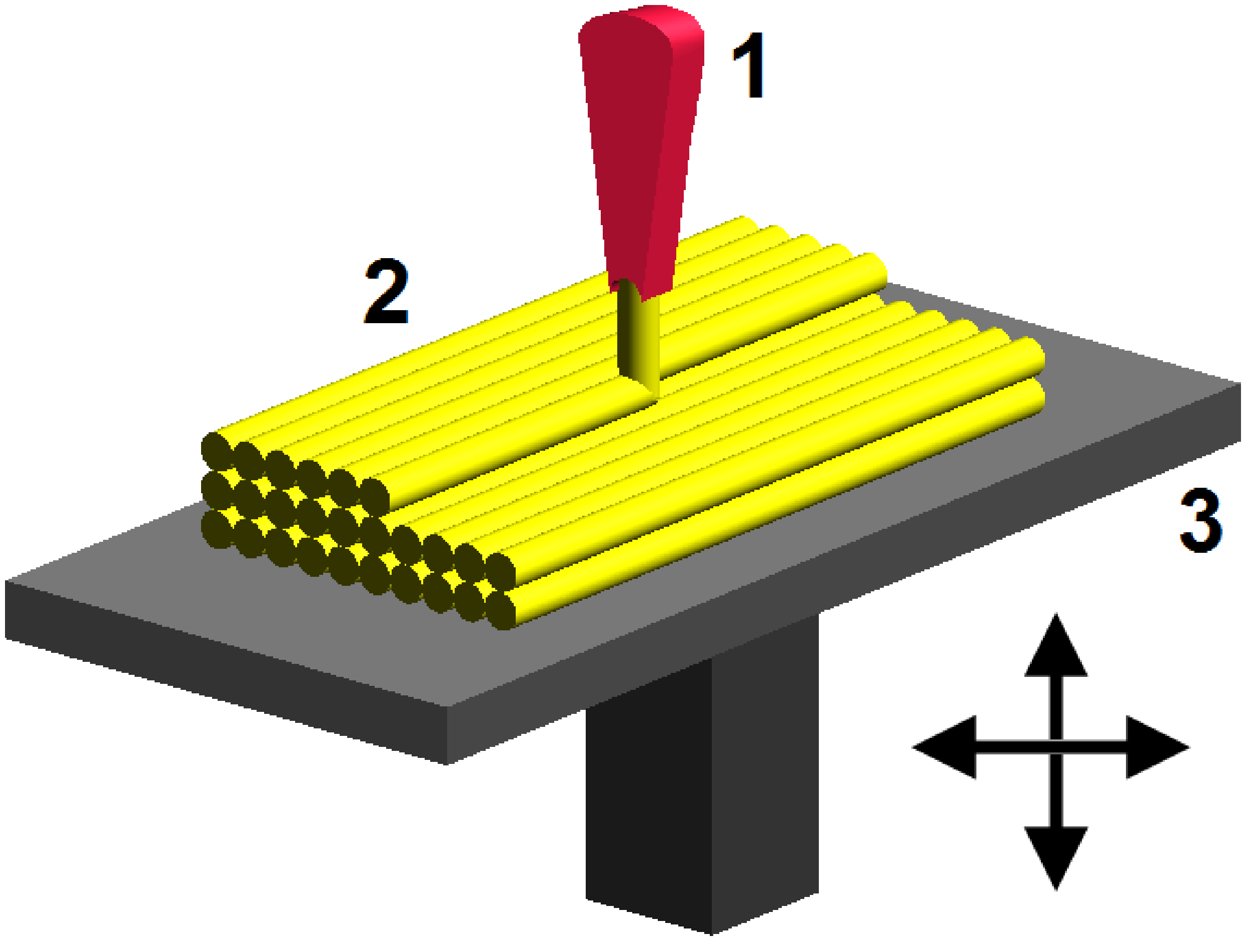
Lecture No 8

Extrusion-Based AM Processes

Introduction



Extrusion-Based AM Processes

- These technologies can be visualized as similar to cake icing, in that material contained in a reservoir is forced out through a nozzle when pressure is applied.
- If the pressure remains constant, then the resulting extruded material (commonly referred to as “roads”) will flow at a constant rate and will remain a constant cross-sectional diameter.
- The diameter will remain constant if the travel of the nozzle across a depositing surface is also kept at a constant speed that corresponds to the flow rate.
- The material that is being extruded must be in a semi-solid state when it comes out of the nozzle.
- The material must fully solidify while remaining in that shape.
- The material must bond to material that has already been extruded so that a solid structure can result.

Basic Principles

- Loading of Material
- Liquification of the Material
- Application of pressure to move the material through the nozzle
- Extrusion
- Plotting according to a predefined path and in a controlled manner
- Bonding of the material to itself or secondary build materials to form a coherent solid structure
- Inclusion of support structures to enable complex geometrical features

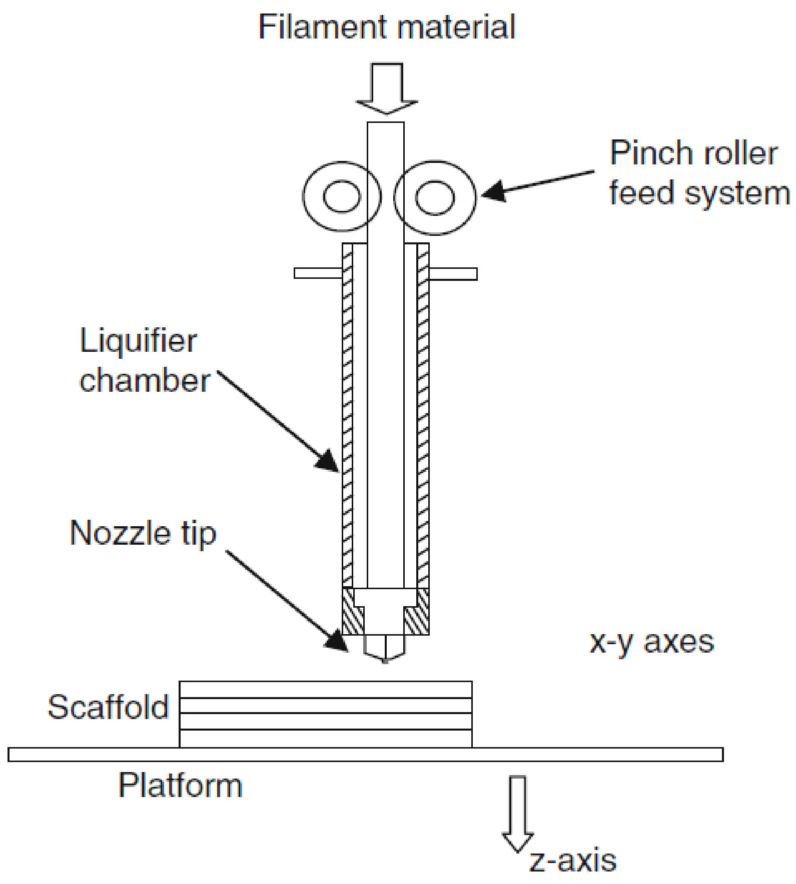
Basic Principles - Loading of Material

- Since extrusion is used, there must be a chamber from which the material is extruded. This could be preloaded with material, but it would be more useful if there was a continuous supply of material into this chamber.
- If the material is in a liquid form, then the ideal approach is to pump this material. Most bulk material is, however, supplied as a solid and the most suitable methods of supply are in pellet or powder form, or where the material is fed in as a continuous filament.

- The chamber itself is therefore the main location for the liquification process. Pellets, granules, or powders are fed through the chamber under gravity or with the aid of a screw. Materials that are fed through the system under gravity require a plunger or compressed gas to force it through the narrow nozzle.
- Screw feeding not only pushes the material through to the base of the reservoir but can be sufficient to generate the pressure needed to push it through the nozzle as well. A continuous filament can be pushed into the reservoir chamber, thus providing a mechanism for generating an input pressure for the nozzle.

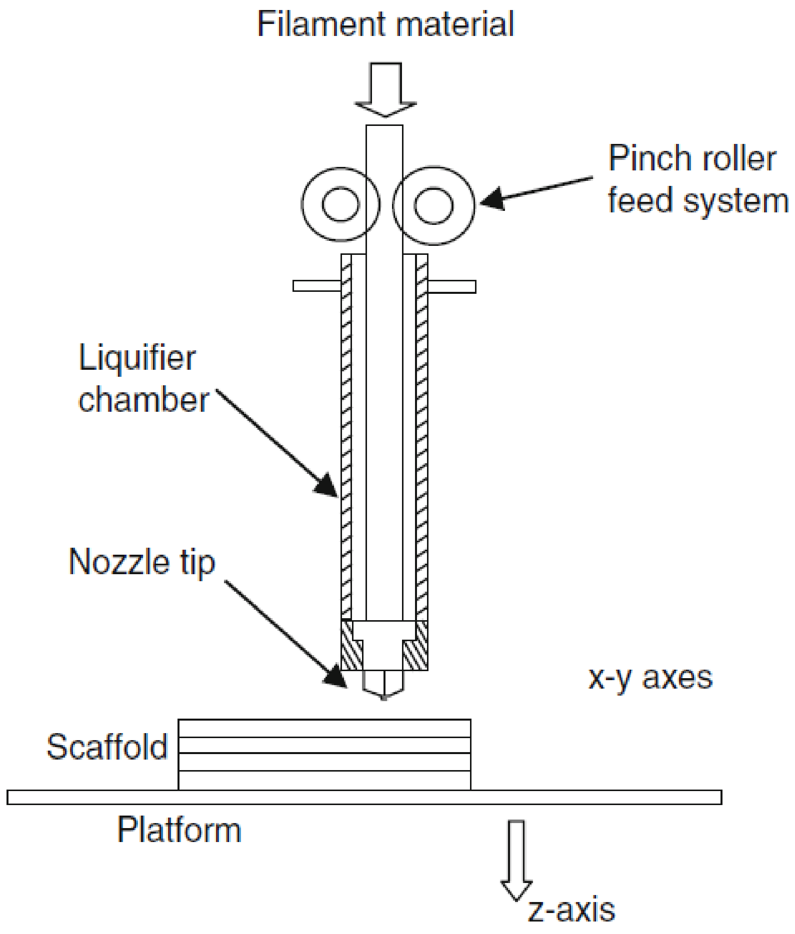
- Liquification

- The extrusion method works on the principle that what is held in the chamber will become a liquid that can eventually be pushed through the die or nozzle.
- The material could be in the form of a solution that will quickly solidify following the extrusion, but more likely this material will be liquid because of heat applied to the chamber.
- The heat would normally be applied by heater coils wrapped around the chamber and ideally this heat should be applied to maintain a constant temperature in the melt.



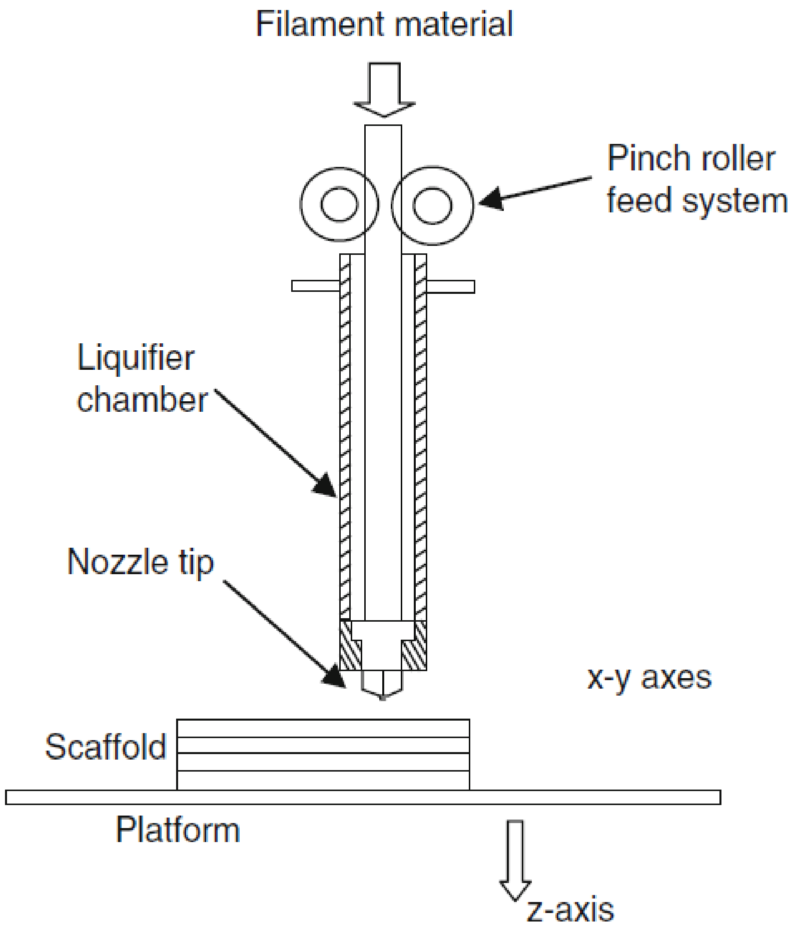
- Extrusion

- The extrusion nozzle determines the shape and size of the extruded filament.
- A larger nozzle diameter will enable material to flow more rapidly but would result in a part with lower precision compared with the original CAD drawing.
- The diameter of the nozzle also determines the minimum feature size that can be created.
- No feature can be smaller than this diameter and in practice features should normally be large relative to the nozzle diameter to faithfully reproduce them with satisfactory strength.
- Extrusion-based processes are more suitable for larger parts that have features and wall thicknesses that are at least twice the nominal diameter of the extrusion nozzle used.
- Material will flow through the nozzle is controlled by the pressure drop between the chamber and the surrounding atmosphere.



- Solidification

- Once the material is extruded, it should ideally remain the same shape and size.
- Gravity and surface tension, however, may cause the material to change shape, while size may vary according to cooling and drying effects.
- If the material is extruded in the form of a gel, the material may shrink upon drying, as well as possibly becoming porous.
- If the material is extruded in a molten state, it may also shrink when cooling.
- The cooling is also very likely to be nonlinear. If this nonlinear effect is significant, then it is possible the resulting part will distort upon cooling. This can be minimized by ensuring the temperature differential between the chamber and the surrounding atmosphere is kept to a minimum (i.e., use of a controlled environmental chamber when building the part) and also by ensuring the cooling process is controlled with a gradual and slow profile.

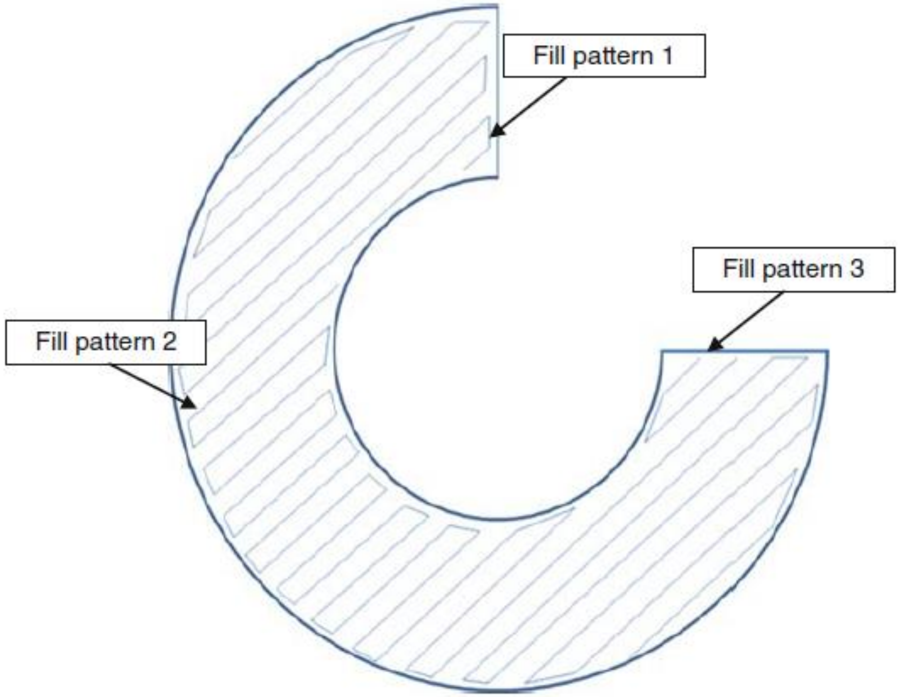


- Positional Control

- Like many AM technologies, extrusion-based systems use a platform that indexes in the vertical direction to allow formation of individual layers.
- The extrusion head is typically carried on a plotting system that allows movement in the horizontal plane. This plotting must be coordinated with the extrusion rate to ensure smooth and consistent deposition.
- The plotting head represents a mass and therefore contains an inertial element when moving in a specific direction, any change in direction must result in a deceleration followed by acceleration. The corresponding material flow rate must match this change in speed or else too much or too little material will be deposited in a particular region.
- Rapid changes in direction can make it difficult to control material flow, a common strategy would be to draw the outline of the part to be built using a slower plotting speed to ensure that material flow is maintained at a constant rate.

- Positional Control

- The internal fill pattern can be built more rapidly since the outline represents the external features of the part that corresponds to geometric precision.
- This outer shell also represents a constraining region that will prevent the filler material from affecting the overall precision.



- Bonding

- For heat-based systems there must be sufficient residual heat energy to activate the surfaces of the adjacent regions, causing bonding.
- Gel-based systems must contain residual solvent or wetting agent in the extruded filament to ensure the new material will bond to the adjacent regions that have already been deposited.
- In both cases, we visualize the process in terms of energy supplied to the material by the extrusion head. If there is insufficient energy, the regions may adhere, but there would be a distinct boundary between new and previously deposited material. This can represent a fracture surface where the materials can be easily separated. Too much energy may cause the previously deposited material to flow, which in turn may result in a poorly defined part.

Thanks