© 2023 IJNRD | Volume 8, Issue 5 May 2023 | ISSN: 2456-4184 | IJNRD.ORG

INTRODUCTION TO RAPID PROTOTYPING IN CAM

Ansh Verma[1]
[1]Student
Mechanical Engineering, Department of Mechanical Engineering, Delhi Technological University, Shahbad Daulatpur Village, Rohini, New Delhi, Delhi

ABSTRACT

Rapid prototyping in computer-aided manufacturing (CAM) is a process of creating physical prototypes of a product or part using computer-controlled machines. This technique involves the use of 3D modeling software, which allows designers to create a digital model of the desired object. The model is then converted into a set of instructions that are interpreted by the CAM machine, such as a 3D printer or CNC mill, to create a physical prototype. Rapid prototyping has revolutionized the product design and development process by significantly reducing the time and cost required to produce prototypes. It enables designers to quickly iterate and refine their designs based on feedback, resulting in a more efficient and effective design process. This paper provides an introduction to rapid prototyping in CAM, including its history, benefits, and applications. We also explore the various types of CAM machines used for rapid prototyping, as well as the materials commonly used in the process. Finally, we discuss some of the challenges and limitations of rapid prototyping and offer suggestions for overcoming them.

INTRODUCTION

Rapid prototyping is a crucial component of Computer-Aided Manufacturing (CAM). It is a process of quickly creating physical prototypes of a design using a variety of manufacturing technologies. Rapid prototyping has revolutionized the manufacturing industry by allowing designers and engineers to quickly test and refine their designs before they go into full-scale production. The rapid prototyping process typically begins with a computer-aided design (CAD) model of the product or component. The CAD model is then used to create a virtual prototype of the design. This virtual prototype can be reviewed, analyzed, and modified using software tools to optimize the design for manufacturing. Once the virtual prototype is finalized, the next step is to create a physical prototype. This is where rapid prototyping technologies come into play. There are several different methods for creating physical prototypes, including 3D printing, CNC machining, and injection molding. 3D printing is one of the most popular rapid prototyping technologies. It works by layering materials (such as plastics, metals, or composites) to create a three-dimensional object. This technology is ideal for creating complex shapes and geometries that would be difficult or impossible to create with traditional manufacturing methods. CNC machining is another common rapid prototyping technology. It involves using a computer-controlled machine tool to cut and shape materials into the desired shape. CNC machining is typically used for creating prototypes from metal or other hard materials. Injection molding is a rapid prototyping technology that is used for creating large numbers of identical parts. It involves injecting molten material (such as plastic or metal) into a mold to create a finished part. Overall, rapid prototyping is a critical component of the CAM process. It allows designers and engineers to quickly test and refine their designs, resulting in more efficient and effective manufacturing processes. With the increasing availability and affordability of rapid prototyping technologies, it is becoming easier than ever for companies of all sizes to take advantage of this powerful tool.

WHY RAPID PROTOTYPING?

1. **Speed** : Rapid prototyping allows for quick turnaround times from design to finished prototype. This can help accelerate the product development process and get products to market faster.
2. **Cost savings** : Since rapid prototyping allows for the creation of prototypes quickly, it can help reduce the overall cost of product development. This is because it enables designers to test and refine their designs before committing to expensive manufacturing processes.
3. **Improved accuracy** : Rapid prototyping can help designers create more accurate and precise prototypes, which can improve the overall quality of the final product.

Better communication : Rapid prototyping allows designers to share their ideas and designs with stakeholders more effectively. This can help ensure that everyone is on the same page and can help reduce the risk of miscommunication.

4. **Customization** : Rapid prototyping can enable designers to create custom products or parts that are tailored to the specific needs of their customers. This can help businesses stand out in a crowded market and improve customer satisfaction.
5. **Design flexibility** : Rapid prototyping allows designers to experiment with different designs and configurations without incurring significant costs. This can help encourage creativity and innovation.
6. **Risk reduction** : Rapid prototyping can help reduce the risk of product failure by allowing designers to test and refine their designs before committing to large-scale production.
7. **Improved time-to-market** : Rapid prototyping can help companies get their products to market faster, which can help them gain a competitive advantage over their competitors.
8. **Iterative design** : Rapid prototyping enables designers to iterate quickly and make changes to their designs in real-time. This can help speed up the design process and improve the overall quality of the final product.
9. **Enhancing customer feedback** : Rapid prototyping can help designers gather feedback from customers early in the design process. This can help ensure that the final product meets the needs and expectations of the target audience.

Stereolithography is a common rapid manufacturing and rapid prototyping technology for producing parts with high accuracy and good surface finish. Stereolithography (SLA) is a 3D printing technology that uses a UV laser to cure a liquid photopolymer resin layer by layer, creating a solid object. SLA was invented in the 1980s and is considered one of the oldest and most established 3D printing technologies. The SLA process begins with the creation of a 3D model using computer-aided design (CAD) software. The software slices the model into thin cross-sectional layers, which are then used to guide the laser as it selectively cures the resin. The laser scans each layer of the resin, causing it to solidify and adhere to the previous layer. Once a layer is complete, the build platform moves down, and a new layer of resin is spread over the previous one. The laser then scans the new layer, and the process repeats until the object is fully formed. After printing, the object is removed from the printer and washed in a solvent to remove any uncured resin. It is then typically post-cured in a UV oven to strengthen and finalize the curing process. SLA is a highly accurate and detailed 3D printing technology that can produce objects with intricate shapes and fine details. However, it is generally slower and more expensive than other 3D printing technologies such as fused deposition modeling (FDM). Stereolithography requires the use of support structures to attach the part to the elevator platform and to prevent certain geometry from not only deflecting due to gravity, but to also accurately hold the 2D cross sections in place such that they resist lateral pressure from the re-coater blade. Supports are generated automatically during the preparation of 3D CAD models for use on the stereolithography machine, although they may be manipulated manually. Supports must be removed from the finished product manually; this is not true for all rapid prototyping technologies.

Advantages

1. **High Precision** : SLA is known for its high level of accuracy and precision, producing objects with a resolution of up to 25 microns. This makes it an ideal choice for creating intricate and detailed objects.
2. **Smooth Surface Finish** : SLA produces smooth surface finishes, making it a popular choice for creating prototypes and parts that require a high level of detail and surface quality.
3. **Wide Range of Materials** : SLA can work with a variety of materials, including plastics, resins, and even some metals.
4. **Fast Production** : SLA can produce objects quickly, with some parts being produced in just a few hours.

Disadvantages

1. **Cost** : Compared to other 3D printing methods, SLA can be expensive, with the cost of the liquid resin being the primary contributor.
2. **Limited Size** : The size of the objects that can be produced with SLA is limited by the size of the build platform and the height of the resin tank.
3. **Material Limitations** : While SLA can work with a wide range of materials, it is not suitable for all types of materials, such as those that are highly conductive or heat-resistant.
4. **Post-Processing** : SLA parts require post-processing to remove excess resin and cure the object fully. This can be time-consuming and require additional equipment.

Applications

1. **Rapid Prototyping** : Stereolithography is often used for rapid prototyping because it can produce parts quickly and with a high level of accuracy. It allows designers and engineers to quickly create and test prototypes before moving on to mass production.
2. **Dental and Medical Applications** : SLA is also used in dental and medical applications to create custom dental and surgical implants, as well as other medical devices. SLA can produce highly detailed and accurate models, making it an ideal choice for these applications.
3. **Jewelry Making** : SLA is used in the jewelry industry to create highly detailed and intricate designs. The process allows jewelers to create custom pieces that are unique and one-of-a-kind.
4. **Aerospace and Automotive Applications** : SLA is used in the aerospace and automotive industries to create prototypes and parts with complex geometries. The high level of accuracy and detail that can be achieved with SLA makes it an ideal choice for these industries, where precision and performance are crucial.

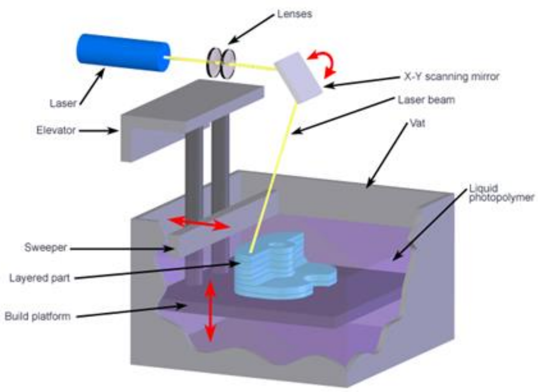

FIG 1 : Stereolithography

SELECTIVE LASER SINTERING

Selective Laser Sintering (SLS) is a 3D printing technology that utilizes a high-powered laser to selectively fuse powdered materials together to create three-dimensional objects. It was first introduced in the mid-1980s and has since become a widely used technique for rapid prototyping and small-batch manufacturing. The process begins by laying down a thin layer of the powdered material, typically nylon or other polymers, on a build platform. The laser then heats and fuses the particles in the designated areas, creating a solid layer. The build platform is lowered, and a new layer of powder is spread on top, repeating the process until the object is fully formed. SLS has several advantages over traditional manufacturing techniques, including the ability to produce complex geometries with no support structures required and the ability to create functional, end-use parts with high strength and durability. Additionally, SLS can use a variety of materials, including metals, ceramics, and composites, allowing for a wide range of applications. Overall, SLS is a powerful technology that offers a range of benefits for various industries, from aerospace to medical and beyond. As the technology continues to improve and evolve, it is likely to become an increasingly valuable tool for manufacturing and production.

Advantages

1. **Design Flexibility** : SLS can produce complex shapes and designs that would be difficult or impossible to make with traditional manufacturing methods.
2. **No Support Structures Required** : SLS does not require support structures, which reduces the amount of post-processing needed.
3. **Wide Range of Materials** : SLS can use a variety of materials, including plastics, metals, and ceramics.
4. **High Accuracy** : SLS can produce parts with high accuracy and precision.

Disadvantages

1. **Cost** : SLS can be more expensive than other 3D printing technologies, especially for small production runs.
2. **Surface Finish** : SLS parts can have a rough surface finish, which may require additional post-processing steps.
3. **Size Limitations** : SLS has size limitations, as the size of the parts that can be produced is limited by the size of the build chamber.
4. **Safety Concerns** : SLS involves the use of high-powered lasers, which can be dangerous if not operated properly.

Applications

1. **Prototyping** : SLS is commonly used for prototyping in various industries, such as aerospace, automotive, and medical.
2. **Manufacturing** : SLS can also be used for small-scale manufacturing of end-use parts, such as brackets, housings, and connectors.
3. **Tooling** : SLS can produce tooling inserts for injection molding and other manufacturing processes.
4. **Art and Architecture** : SLS has also been used in the creation of art and architecture pieces, such as sculptures and models.

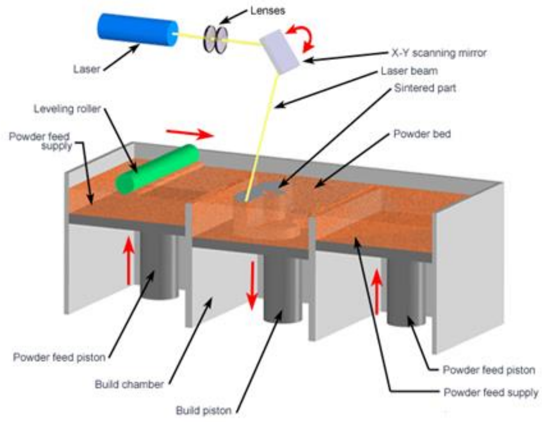

FIG 2 : Selective Laser Sinteringy

FUSED DEPOSITION MODELING

Fused Deposition Modeling (FDM) is a popular and widely-used 3D printing technology that is based on additive manufacturing. It works by melting a thermoplastic filament and then extruding it through a nozzle to create a three-dimensional object layer by layer. The process starts with creating a 3D model on a computer using CAD software or downloading one from an online repository. The model is then sliced into layers and converted into machine-readable code that instructs the 3D printer to create the object. During the printing process, the thermoplastic filament is fed through a heated nozzle and melted. The molten material is then extruded onto the print bed or previous layer, layer by layer, until the object is complete. The nozzle moves along the X, Y and Z axes, guided by the machine code. FDM 3D printers use a wide variety of thermoplastics such as ABS, PLA, Nylon, PET, etc. These materials have different characteristics, such as strength, flexibility, and temperature resistance, making them suitable for different applications. FDM 3D printing is widely used in prototyping, product design, and manufacturing. It has become increasingly popular in recent years due to its ease of use, low cost, and versatility. With the ability to produce complex geometries and functional parts with ease, FDM is an ideal technology for both hobbyists and professionals alike.

Advantages

1. **Versatile Materials** : FDM can use a wide range of thermoplastic materials, such as ABS, PLA, PETG, and Nylon, among others.
2. **Cost-effective** : FDM machines are relatively affordable and use inexpensive materials, which makes the technology accessible to individuals and small businesses.
3. **High Accuracy** : FDM can produce high-precision parts with excellent surface finish, especially when using a higher-end machine and/or post-processing techniques.
4. **Good for Prototyping** : FDM is an excellent technology for creating functional prototypes, as it allows for fast iteration and design testing.

Disadvantages

1. **Limited Resolution** : FDM produces parts with visible layer lines, which can limit the overall resolution of the final product.
2. **Poor Strength** : The parts produced by FDM can be relatively weak compared to those produced by other technologies such as injection molding, which can limit their use in high-stress applications.
3. **Limited Size** : The size of the parts produced by FDM is limited by the size of the build plate and the machine's overall dimensions.
4. **Requires Support Structures** : Some parts require support structures to be printed, which can add complexity and increase post-processing requirements.

Applications

1. **Prototyping** : FDM is widely used for creating functional prototypes in

various industries, including aerospace, automotive, and consumer products.

2. **Customized Parts** : FDM is an excellent technology for creating customized parts, such as prosthetics and orthotics, dental implants, and hearing aids.

3. **Education** : FDM is used in many educational settings, from K-12 schools to universities, to teach students about design, engineering, and manufacturing.

4. **Small-batch Production** : FDM is also used for small-batch production of parts, such as replacement parts for machines, jigs and fixtures, and specialized tools.

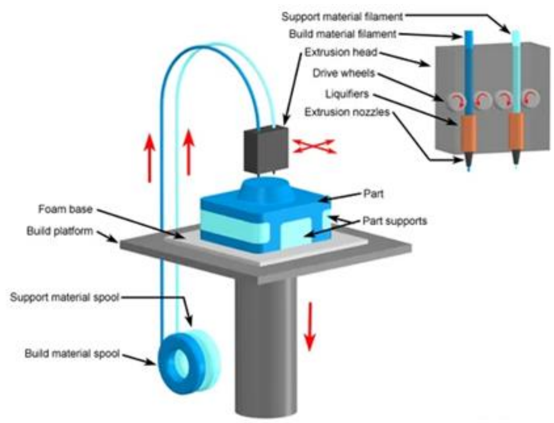

FIG 3 : Fused Deposition Modeling

Commercial System/Parameters	**SLA**	**SLS**	**FDM**
Model Material	Liquid photopolymer	Powder	ABS, wax, teflon filament
Processing Speed	Medium	Medium	Low
Max. part size (mm)	508 * 508 * 610	381 * 330 * 447	610 * 508 * 610
Accuracy (mm)	0.05 - 0.10	0.10 - 0.20	0.10 - 0.30
Fabrication technique	Laser curing of liquid photopolymer	Selective laser tracing of powder polymer	Fused deposition of molten polymer

TAB 1 : Different types of Prototyping Processes

LIMITATIONS & CHALLENGES

1. **Material Limitations** : The materials used in rapid prototyping are often limited to certain types of plastics, resins, or metals. This can restrict the complexity and functionality of the prototypes produced, particularly when compared to traditional manufacturing methods that allow for a wider range of materials to be used.

2. **Size Limitations** : Another limitation of rapid prototyping is the size of the prototypes that can be produced. Many CAM technologies have size limitations, which can make it difficult or impossible to produce large or complex prototypes.

3. **Accuracy and Precision** : While rapid prototyping can produce prototypes quickly, it may not always achieve the level of accuracy and precision required for certain applications. This is particularly true when producing complex parts or prototypes with fine details.

4. **Cost** : Rapid prototyping can be expensive, particularly when compared to traditional manufacturing methods. The cost of the equipment and materials needed for the process can be significant, making it less accessible to smaller businesses or individuals.

5. **Time Constraints** : While rapid prototyping can be faster than traditional manufacturing methods, it still takes time to produce a prototype. This can be a

challenge for businesses or individuals who need to produce prototypes quickly in order to meet deadlines or respond to changing market conditions.

6. **Design Limitations** : The design of the prototype may also be limited by the capabilities of the CAM technology being used. This can restrict the complexity and functionality of the final product, particularly when compared to traditional manufacturing methods that allow for greater design flexibility.

7. **Intellectual Property Concerns** : Rapid prototyping can also raise intellectual property concerns, particularly when it comes to protecting designs and patents. It is important to take appropriate measures to protect intellectual property rights when using rapid prototyping technologies.

CONCLUSION

RP technologies are definitely widely spread in different fields of medicine and show a great potential in medical applications. Various uses of RP within surgical planning, simulation, training, production of models of hard tissue, prosthesis and implants, biomechanics, tissue engineering and many other cases open up a new chapter in medicine. Due to RP technologies doctors and especially surgeons are privileged to do some things which previous generations could only have imagined. However this is just a little step ahead. There are many unsolved medical problems and many expectations from RP in this field. Development in speed, cost, accuracy, materials (especially biomaterials) and tight collaboration between surgeons and engineers is necessary and so are constant improvements from RP vendors. This will help RP technologies to give their maximum in such an important field like medicine. An artificial bone model was fabricated using ABS (Acrylonitrile Butadyine Styrene) by Rapid Prototyping Technology. This technique helps to analyze the actual bone structure and plate fixation can be done more accurately. Due to RP technologies doctors and especially surgeons are privileged to do some things which previous generations could only have imagined. However this is just a little step ahead. There are many unsolved medical problems and many expectations from RP in this field. Development in speed, cost, accuracy, materials (especially biomaterials) and tight collaboration between surgeons and engineers is necessary and so are constant improvements from RP vendors. This will help RP technologies to give their maximum in such an important field like medicine and new technologies can not only improve and replace conventional methods; they also offer the chance for new types of products and developing procedures.

REFERENCES

1. S.H. Ahn, M. Montero, D. Odell, S. Roundy, P.K. Wright, Anisotropic material properties of fused deposition modeling ABS, Rapid Prototyping J. 8 (4) (2002) 248–257. 2. 3. K. Thrimurthulu, P.M. Pandey, N.Venkata Reddy, Optimum part deposition orientation in fused deposition modeling, Int. J. Mach. Tools Manuf. 44 (2004) 585–594. F. Xu, H.T. Loh, Y.S. Wong, Considerations and selection of optimal orientation for different rapid prototyping systems, Rapid Prototyping J. 5 (2) (1999) 54–60. 4. 5. 6. 7. E. Fodran, M. Koch, U. Menon, Mechanical and dimensional characteristics of fused deposition modeling build styles, in: Proceedings of the 1996 Solid Freeform Fabrication Symposium, 1996, pp. 419–442. M. Bertoldi, M.A. Yardimci, C.M. Pistor, S.I. Guceri, G. Sala, Mechanical characterization of parts processed via fused deposition, in: Proceedings of the 1998 Solid Freeform Fabrication Symposium, 1998, pp. 557– 565. S.H. Ahn, C.S. Lee, W.B. Jung, Development translucent FDM parts by post-processing, Rapid Prototyping J. 10 (4) (2004) 218–224. E. Sachs, J. Haggerty, P. Williams, M. Cima, Three-dimensional printing techniques, US patent 5,204,055, 1993.