PRAGATI ENGINEERING COLLEGE

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#1-378, ADB Road, Surampalem – 533 437, Near Peddapuram, E.G.Dist., A.P.
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DEPARTMENT OF MECHANICAL ENGINEERING

Academic year: 2023-24

Date: 30-09-2023

CIRCULAR

Additive Manufacturing Club of Mechanical Engineering Department in association with Career Guidance Cell is organizing a Seminar to the Mechanical Engineering students on 4th October 2023. The Theme of the Seminar is *"Introduction to Solid Based Rapid Prototyping Methods & Case studies"*.

Event	:	Seminar
Date and Time of Event	:	4th October 2023
Venue	:	CAD Lab.

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2. **Departmental file.**
3. **AM Club In-charge – ME.**
4. **Career Guidance Cell In-charge – ME.**

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INDUSTRY 4.0 CLUBS

ADDITIVE MANUFACTURING CLUB

ORGANISED BY DEPARTMENT OF MECHANICAL ENGINEERING IN ASSOCIATION WITH CARRER GUIDANCE CELL

"INTRODUCTION TO SOLID BASED RAPID PROTOTYPING METHODS & CASE STUDIES "

SPEAKERS :

Mr. P. Ram Prasad
Assistant Professor

DATE: 4th October 2023
TIME: 2:00 PM Onwards

FACULTY COORDINATOR

Mr. P. Ram Prasad
Assistant Professor
Mechanical Engineering Department

STUDENT COORDINATOR

Mr. D.Ashish Varma
III Year Mechanical Engineering Department
Contact No. : +91 7095338669

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Participants List

Name of the event: Introduction to Solid Based Rapid Prototyping Methods & Case studies

Venue : CAD Lab

Date : 04/10/2023

S.No	Roll No	Name	Signature
1	21A31A0354	Syed Mujahid Hussain	
2	21A31A0319	D. Ashish Varma	
3	21A31A0392	K. N. R. Narasimha	
4	21A31A0388	S. Abhiram	
5	21A31A0381	N. Satish	
6	21A31A0355	P. Dinesh	
7	21A31A0350	S. Vijay kumar	
8	21A31A0360	Y. D. V. Krishna	
9	21A31A0359	Y. chaitanya krishna chowdary	
10	21A31A0352	S. Jaswanth Charan	
11	22A35A0317	O. Bharath kalyan	
12	21A31A0391	Y. Sri venkat vasu	
13	21A31A0394	K. B. Manikanta	
14	21A31A0370	K. V. Subrahmanyam	
15	22A35A0396	Sk. habibul Rehman	

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S.No	Roll No	Name	Signature
1	21A31A0351	S. Vinay Kumar	S. Vinay
2	22A35A0319	P. Jagan Mohan	P. Jagan
3	21A31A0389	T. Anil	T. Anil
4	22A35A0325	K. Sai Varma	Sai Varma
5	21A31A0356	T. Durga mani Govind	T. D. M. Govind
6	21A31A0378	M. Kishore	Kishore
7	21A31A0332	M. Tharun	M. Th
8	21A31A0101	A. T. N. Sri Sai	A. T. N. Sri Sai
9	21A31A0147	U. Himani josh	U. Himani Josh
10	21A31A0107	G. Dayanidhi	G. Dayanidhi
11	21A31A0109	K. Harsha Sri	K. Harsha
12	21A31A0116	V. Sahithi	V. Sahithi
13	22A31A0392	T. Lokesh Pavan	T. Lokesh
14	22A35A0331	Raghavendra	Raghavendra
15	21A31A0380	Manohar	Manohar. K

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S.No	Roll No	Name	Signature
1	21A31A0333	M. Ramesh	M. Ramesh
2	21A31A0368	Dharnaraju	Dharnaraju
3	21A31A0371	Raj Kumar	Raj Kumar
4	21A31A0308	A-Hemanth Raja	Hemanth
5	21A31A0363	B. Abhiram	[illegible]
6	21A31A0362	B. Ikil	Ikil
7	21A31A0384	John Wesly	John
8	22A35A0324	SUBERNAWYAM	[illegible]
9	22A35A0328	Santosh	[illegible]
10	22A35A0323	Y. NAYAK	[illegible]
11			
12			
13			
14			
15			

TOTAL = 40

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REPORT

Title of the Event	: Introduction to Solid Based Rapid Prototyping Methods & Case studies.
Date of the Event	: 4th October 2023.
Time of the Event	: 2.00PM Onwards.
Venue	: CAD Lab
No. Students participated	: 40

Additive Manufacturing (AM) involves classes of manufacturing technologies which build 3D components by adding a material layer upon a layer. The material could be a polymer, concrete, metal or even a composite. For a manufacturing process to qualify to be classified as an AM technique, it must involve the following three significant aspects.

• The use of a computer and computer aided design (CAD) to create visual 3D models: There are several CAD tools that are used to generate 3D models some of which include AutoCAD, Inventor®, Solidworks®, CATIATM and so many others. Some of these software are available open source or closed source. The technologist or engineer involved in the field of additive manufacturing should understand how to use a few or many of the software for effective manufacturing through these technologies. Through these CAD tools, and based on the experience

of the user, any form of complex 3D models of the products can be generated. The amount of material to be extruded by the 3D printer and the time it will take to build the 3D model is determined and the information is created in a G-code file, which the printer can easily interpret.

• Slicing and generation of tool paths: The CAD 3D-generated models must be prepared in a format which can be interpreted by the additive manufacturing machine. The slicing software transforms the3Ddesign into layered model swhich the machine tool can easily trace. There are so many slicing software in the market and they are provided under different trademark names such as Cura, Prusa Slicer, Matter Control, Simplify3D,Repetier, idea Maker, Z-SUITE, Slic3r, IceSL, Slicer- Crafter, Astroprint, 3DPrinterOS, SelfCAD, KISSlicer, Tinkerine Suite, Netfabb Standard including others and each of the software operates differently to achieve the best slicing.

• Conversion of the 3Dmodel into real product: An additive manufacturing machine such as 3D printer and laser convert the 3D model into an actual product using engineering materials such as plastics, metal powders, composites, among others. The material(s) is melted and then allowed to flow according to the G-code (tool path) from the slicing software to create the 3D component.

Fused deposition modelling (FDM), also known as the material extrusion additive manufacturing technique, utilizes polymers as the raw material (filament). The filament is usually heated to a molten state and then extruded through the nozzle of the machine (3D printer). The nozzle head can move in three degrees of freedom (DoF) to deposit the extruded polymer on the build plate as per the G-code instructions.

The principle of the FDM process is illustrated in a schematic diagram in

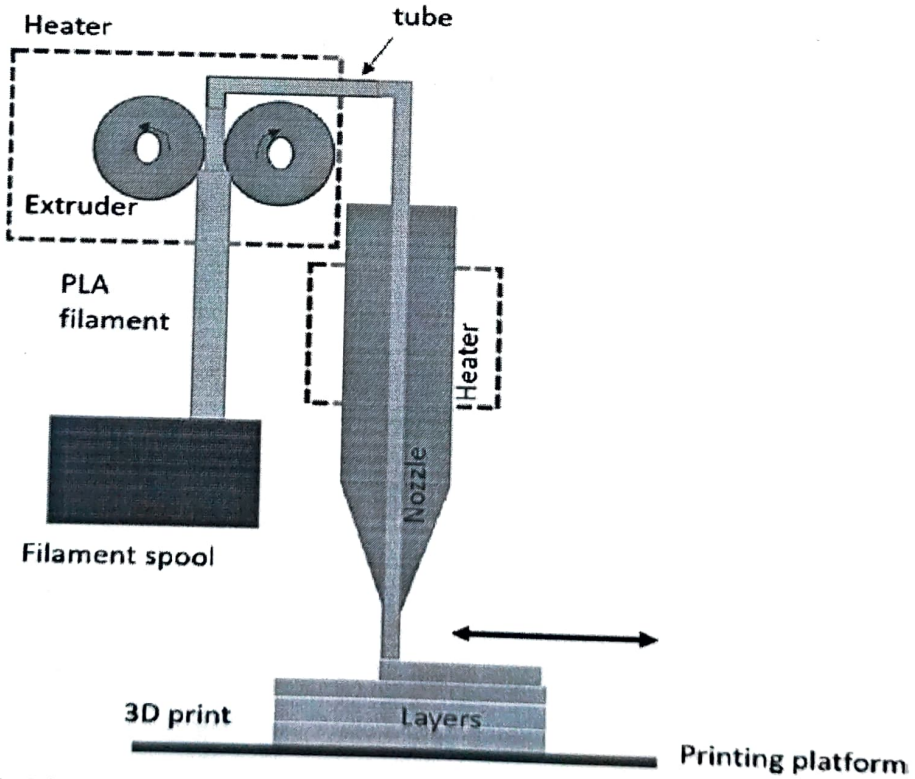


Fig. 1.1 Principle of fused deposition modelling

Fig. 1.1. As shown, the filament is continuously fed through the extruder and nozzle of the machine via the two rollers rotating in opposite directions. The material is deposited on the build

plate layer-by-layer until the required product shape and size are achieved. During the layering, the printer nozzle navigates back and forth as per the spatial coordinates of the original CADmodel in theG-code files until the desired size and shape of the component is produced. In some FDM systems (3D printers), multiple extrusion nozzles can be used to deposit the polymer constituents especially in cases where components of compositional gradients are required. Usually, the resolution and effectiveness of the extrusion largely depend on the properties of the thermoplastic filament and as such, different 3D printers are designed for specific filament materials. In fact, most of the low-cost FDM 3D printers can process only one type of thermoplastic and polylactic acid (PLA) is the most common material.

The components are usually layered onto the build plate (platform), which after printing can be removed by snapping off or soaking in a detergent depending on the type of the thermoplastic. Then, the printed components may be surface cleaned, sanded, painted or milled to enhance both their surface appearance and functionality.

There are various materials used in FDM and as stated earlier, PLA is the most adopted material by most 3D printer users at domestic and industrial levels due to the following reasons:

i. Polylactic acid (PLA) is a bioplastic and therefore eco-friendly and not harmful to human and animal health. PLA is a green material since it is fabricated from fully renewable sources such as corn, sugarcane, wheat or any other high carbohydrate containing resources . As such, it is recommended for use in making cooldrink cups, deli and food take aways, and packaging containers.

ii. PLA has a glass transition temperature ranging between 50 and 70°C and a melting point temperature ranging between 180 and 220°C . As such, most low-energy and cost-effective 3D printers can extrude it. It is harder than

Acrylonitrile butadiene styrene (ABS) although it (PLA) has higher friction when compared to ABS and therefore susceptible to extrusion blockage.

iii. PLA plastics are compostable and break down quickly upon disposal unlike the other plastics, which have posed serious disposal challenges. Being among the biopolymers, PLA degrades to natural and non-poisonous gases, water, biomass and inorganic salts when it is exposed to natural conditions, hydrolysis or even when incinerated.

iv. In its semi-crystalline form, PLA has shown to exhibit good flexural modulus, better tensility and flexural strengths.

v. PLA is preferred by most 3D printer users because it does not always need a heated bed for the adhesion to occur between the print and the platform. Graphene-doped PLA, however, presents a great challenge for non-heated bed

printers and it does not produce quality prints on non-heated build plates.

vi. PLA is commercially available in the market in a variety of colours and textures. This makes it attractive for users, especially domestic and decorative 3D printer handlers. The availability in various colours and texture has expanded the markets for CAD designers and toy enthusiasts. As such, the designers can develop interesting ideas and post in various databases (such as TurboSquid, CG Trader, Shapeways, Cults3D, 3DSquirrel and Thingsverse) where the toy enthusiasts can purchase, download and print with a variety of colours and texture designs of the PLA filaments.

Other materials used in FDM processing include polycaprolactone (PCL), polypropylene (PP), polyethylene (PE), polybutylene terephthalate (PBT),Acrylonitrile butadiene styrene (ABS), wood, nylon, metals, carbon fibre, graphene-doped PLA, etc.. These materials are available in different commercial brands and trademarks, as filament wires, and can be purchased through various online stores such as Alibaba, Amazon and so forth. However, it is advised that the buyers should be aware of the chemical composition of the filaments they would like to use based on their applications. From the experience of the authors of this book, most of the filament suppliers do not provide reliable information regarding the chemical constituents of the 3D printing filaments and it is therefore commended for the users, if necessary, to conduct their analyses to confirm the chemistry of these materials. These analyses can be conducted through phase identification on microscopy, X-ray diffraction (XRD) or more advanced chemical analysis facilities at their disposal.

The most common applications of FDM in modern society are listed below.

i. The technology has emerged as one of the most progressive methods for producing prototypes and rapid tooling of complex products in low and medium batches . The research currently is on the development of a larger pool of

materials for rapid prototyping applications and a lot of literature is available on this subject .

ii. There is an increasing adoption of theFDMtechnique in the toy and other related industries either as a direct manufacturing method or method for producing moulds for injection moulding for such industries .

iii. The potential of FDM on mass personalization of products cannot be overemphasized.

Due to flexibility and capability to produce intricate profiles, FDM finds application in producing customized products for various applications, for instance, personalized toys, automobile parts, interior design components,

implants, beauty products and so forth .

iv. TheFDMis also being applied in the medical field to produce moulds for casting of implants, medical devices and implants. The most exciting application is the 3D printing of moulds for investment casting of medical implants . In

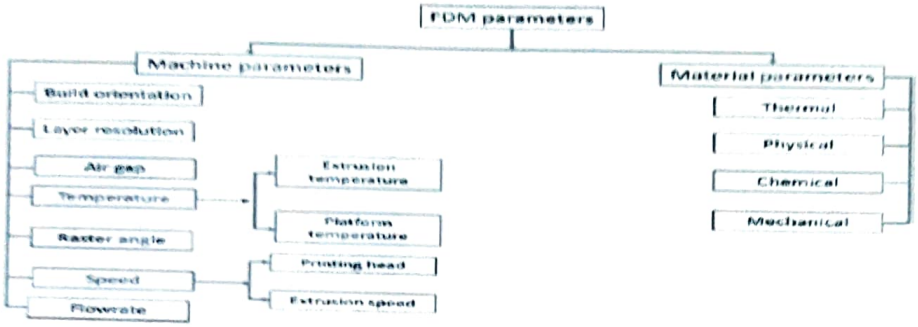
traditional investment casting, there is the use of metallic moulds and sacrificial patterns (e.g.wax) to create the complex shapes of any implant. Therefore, using 3D printed moulds eliminates the need of having to use the sacrificial material and hence reduces cost, time and material wastage. However, there are still challenges associated with the integration of FDM into the investment casting process, that is, poor surface quality; as such, as illustrated in the literature herein (for example, and others) a lot of research is currently underway in improving the surface properties of 3D printed parts and castings obtained from FDM moulds.

v. Other applications of FDM include direct printing of electrochemical cells for energy storage devices , micro-trusses for biomedical scaffolding drug delivery components in the pharmaceutical industry direct printing of conductors for electronic industry among others.

Process Parameters in FDM

Fused deposition modelling (FDM) is influenced by various parameters as summarized in the parameters have been classified into two broad categories, namely machine and material parameters. The machine parameters are those parameters the 3D printer user will specify on the slicing software during the generation of the G-code files whereas the material parameters are the properties of the filament material or materials being extruded through the nozzle. Some of the machine parameters, as shown, include the printing speed, raster angle, melt flow rate through the nozzle, air gap, layer thickness, infill density, build orientation and temperature. On the other

hand, the material properties such as thermal and mechanical influence both the extrusion and performance of the print.



The quality and performance of the printed parts depend on the choice of these parameters and there are various efforts in the literature on evaluating the effects of various parameters on the process and quality of the prints . The build orientation basically indicates the angle at which the longest length is inclined to the base of the build plate. The printed components may be inclined at 0°, 45°, 90°, etc. depending on the choice of the user. Layer resolution indicates the minimum thickness of every layer in one run of the print head and it may vary from a fewmicrometres to millimetres depending on the accuracy and application of the 3D printer. The extrusion temperature measures the temperature supplied from the external source to the printer heating elements to melt the filament material for easy extrusion whereas the platform temperature is the temperature applied on the build plate to enhance the adhesion of the prints onto the platform and avoid printing failure. It is noted that not all printers have a heated bed and except PLA, all the other materials require heating for them to stick onto the platform. At times, when using non-heated bed with some materials, it has become a common practice to use some sticking fluids such as office glue to enhance the sticking of the first layer of the print. However, from the experience of the authors on 3D printers, it usually affects the dimensional accuracy of the print and gradually blocks the nozzle orifice. Blockage of the nozzle passage may lead to a major failure of the 3D printer and replacement of some parts. During printing, the extrusion temperature should be set within the melting point of the filament material. The thermal properties of the material will influence the conditions of melting and flow through the nozzle of the 3D printer. The chemical properties of the filament material determine the glass transition region and hence the quality of the printed part. Mechanical properties such as strength and

friction in molten state determine the rigidity of the printed part and the flowability of the material and whether the material will jam the nozzle or not. The choice, optimization and interrelationships among the process parameters to the print quality are the main objectives of this book and will be detailed using literature case studies and some results obtained from research conducted by the authors in the subsequent chapters.

Quality Issues in FDM

As mentioned, FDM involves the layering of molten filament material to create the desired product. The adhesion and fusion between adjacent layers are very critical for quality prints. Additionally, the extrusion conditions of the filament material during the printing process affect the accuracy, quality and performance characteristics of the printed product. The surface roughness of the FDM products is one of the major drawbacks of the quality of this process. Due to the nature of the process, the surfaces of the product mostly exhibit the 'back-and-forth' tracks of the printing nozzle known as the stair stepping effect . These tracks create terraces on the surface, therefore, leading to relatively high average roughness values (Ra) in the range of micrometres. Such high levels of roughness ranges impede the application of the FDMmanufactured products in some fields such as dentistry, biomedical, sensing
and so many other areas of applications. The presence of terraces and deeps on the surface of the prints can lead to penetration of moisture and other environmental electrolytes into the inner layers of the product causing further degradation of its properties. For instance, such components (with high roughness) would be very detrimental for use as prosthesis or dental implants as they would react with body fluids,whichwould cause premature failure of the implants. At times, due to improper extrusion (over- or under-extrusion), there is a lack of enough adhesion between the adjacent layers of the filament material that enhances high roughness and other structural defects such as porosity and cracks.

The surface roughness of 3D printed parts is predicted using optical surface profilers and microscopes, and various post-processing methods have been adopted to lower the surface roughness. These processes are either mechanical or chemical methods. The most commonly used mechanical methods for enhancing surface quality ofFDMprints are machining, sanding, polishing, abrasion and barrel finishing whereas the chemical methods involve painting, coating,

choice of each of the methods depends on the materials and performance requirements of the FDM manufactured part. Additionally, at the design stage of the components, the stair stepping effects of the printer can be minimized by optimizing the slicing procedure and print resolution. Using very large slicing thickness reduces the printing time and produces very rough products due to the stair stepping effect. On the contrary, fine slicing reduces the stair stepping effect and reduces the surface roughness although it results in longer printing times, which may impact the other aspects of manufacturing, especially during mass production. The different strategies for slicing have also been shown to influence the quality of the print .

The lack of adhesion leading to structural defects considerably affects the dimensional accuracy and mechanical integrity of the FDM printed components. It is obvious that components consisting of a very high density of defects would experience dimensional errors and low properties such as hardness, flexural strength, tensility and compression, and impact strengths. If there is not enough adhesion between the layers, the filament material of the adjacent layers will be forced to flow and compensate between the resulting spaces. This may lead to shrinkage of the component causing dimensional errors between the CAD design and the actual print. Additionally, the presence of pores and cracks within the structure increases the stress raisers within the material such that the component cannot absorb the required energy during its performance without failure. These defects further enhance the propagation of the cracks and the components may not offer suitable and enough mechanical stability for various applications.

The flow rate of the filament material during the extrusion and deposition also plays an important role on the quality of the 3D printed parts. The choice of the extrusion and heated bed temperatures are based on the flow haracteristics of the filament material. Insufficient flow of the molten material between the layers causes spaces or incomplete adhesion; these weaken the component and failure can easily occur through delamination. The raster angle is also related to the material flow during the FDM process; for instance, Galeja et at have recently published an article in Materials (Basel) journal titled 'static and dynamic mechanical properties of 3D printed ABS, a function of raster angle.' The study demonstrated that for a range of raster angles 45°–90°, the raster angle of 55° provided the optimal flow of molten ABS during printing and at that angle, the printed ABS samples exhibited excellent static and dynamic responses to mechanical loads.

There is a continued effort by the scientific community to understand the influence of the specific parameters to the FDM process and the quality of the printed product. As illustrated in the previous section, the interactions among these parameters in an FDM process are complex and require multi-objective approaches to understand and enhance the quality of manufacturing. The general approach in every manufacturing process including FDM is to understand the influence of the individual parameters followed by evaluating the most significant of those factors and finally determining combined effects (multi-objective) of the parameters. There are several publications describing both of these approaches for enhancing quality in FDM processes For instance, Perez et al. investigated the effect of five FDM printing parameters (speed,wall thickness, layer height, temperature and printing path) on the surface roughness of PLA printed components using analysis of variance (ANOVA), graphical methods and non-parametric tests. It was reported that wall thickness and layer height were the most significant factors for surface roughness as compared to the other factors. It has been reported that the optimal choice of the wall thickness and enhancement of the geometry of the product (by defining clearly the G-code) eliminates the microstructural defects in FDM PLA products . In another study, Singh et al. optimized the quality of the FDMprintedABS samples for prosthetic investment casting using Taguchi L18 orthogonal array for the print orientation, fill density, vapour smoothing parameters and heat treatment time of the samples. The choice of the optimal conditions or settings for quality FDM printing during large-scale and mass customization production becomes more difficult. In such cases, the manufacturer is posed with the challenge of quality and time of manufacturing.

Usually, 3D printing is a very slow process and most of the Desktop 3D printers are slower compared to the other manufacturing processes. For instance, it is discussed in the literature that the stair-step effects of the FDM process can be eliminated by using very small layer height. Thin layers mean that a very small volume of the material is layered for every run as compared to relatively larger layer thicknesses. It means that longer time is required for enough melting and flow of the filament material within the layers to eliminate microstructural defects such as porosity and cracks. During FDM printing, the process should be closely monitored, especially during the initial stages and the following simple observations are recommended to ensure geometrically and dimensionally accurate prints:

• When the filament starts loading, remove the molten filament forming around the nozzle to avoid clogging and blockage. This filament is usually under-molten and cannot fuse strongly with the rest of the print material.

• The initial point of printing during the creation of the base support structures (e.g. brim and raster) should be cut off to avoid it being dragged by the nozzle and then destroying the entire support structure.

• Observe the adhesion of the support structure onto the build plate and if the structure appears to delaminate from the plate, stop the printer and repeat the printing process. Additionally, if the printer does not have a heated bed, and the PLA filament does not stick, office glue or other types of glues can be applied onto the printing table to enhance the adhesion and hence, the quality of the prints.

• Observe the critical points of the print (corners, holes, etc.) and check for any incomplete fusion, lack of proper filling and gaps between the layers. These deformities are caused by over-extrusion or under-extrusion of the filament and when this happens, the printer should be stopped, and the settings adjusted. The occurrence of stringing or formation of strings/hairs especially when the printer is moving between different sections of the print should also be checked.

• The layering consistency of the print should be checked; slight shifting or separation of the layers is an indication of poor-quality printing.

• The warping of large parts during the FDM processing causes poor sticking of the printed component onto the build plate such that the component shifts on the build plate causing form and dimensional errors.

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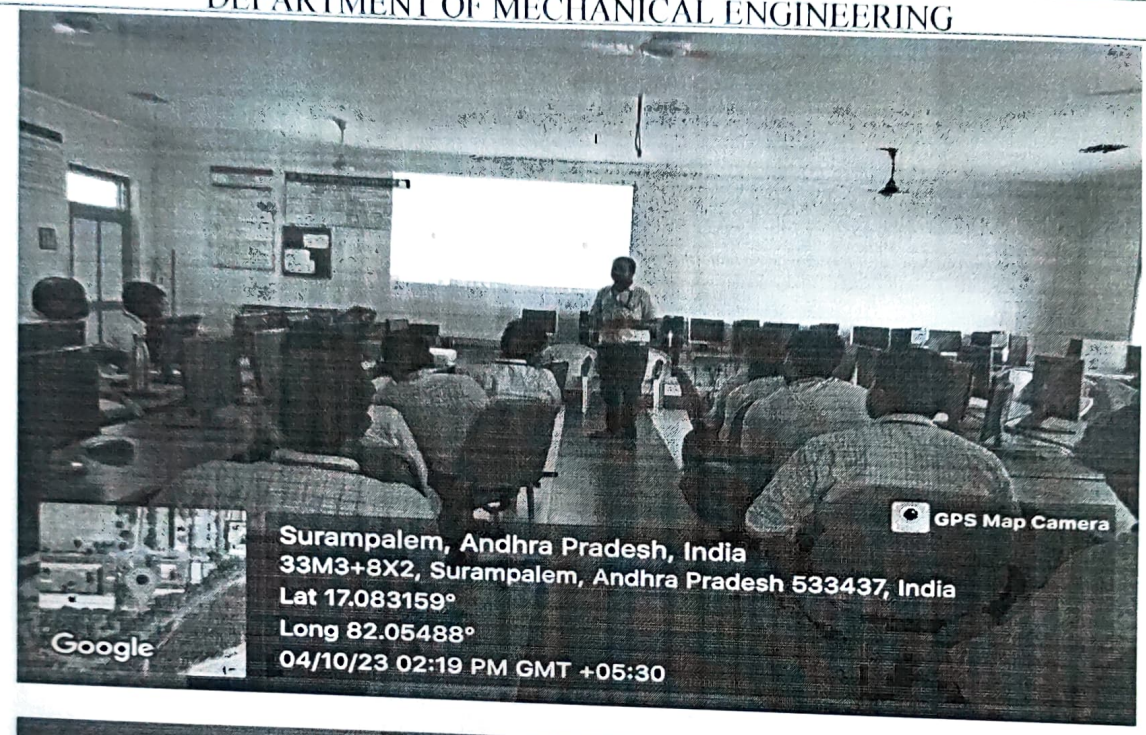

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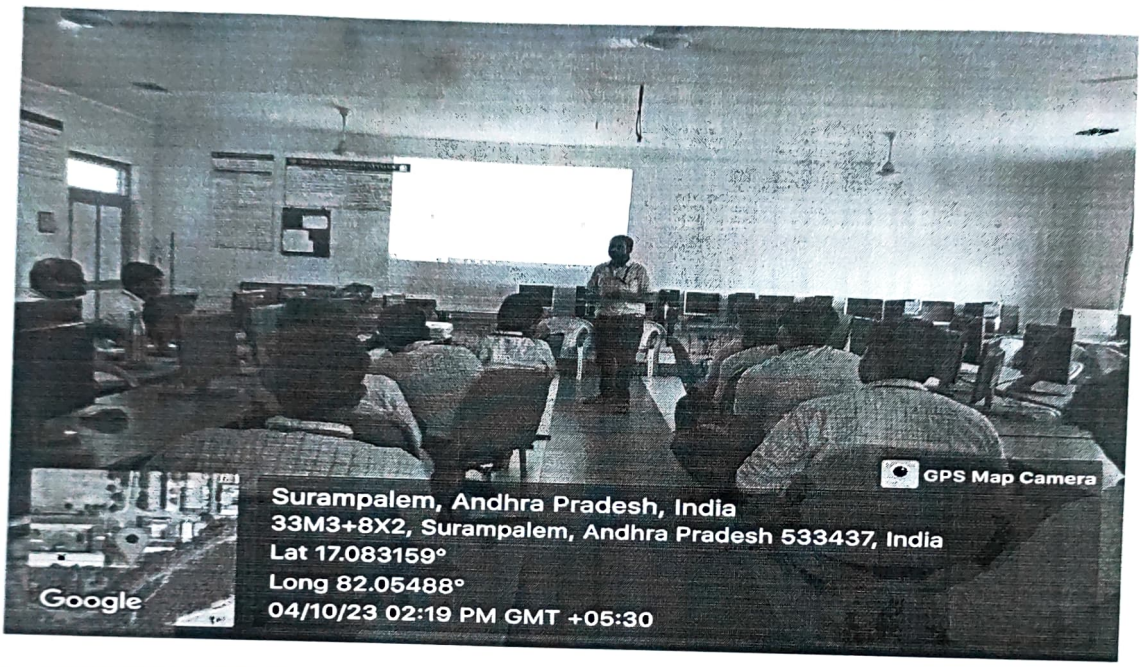

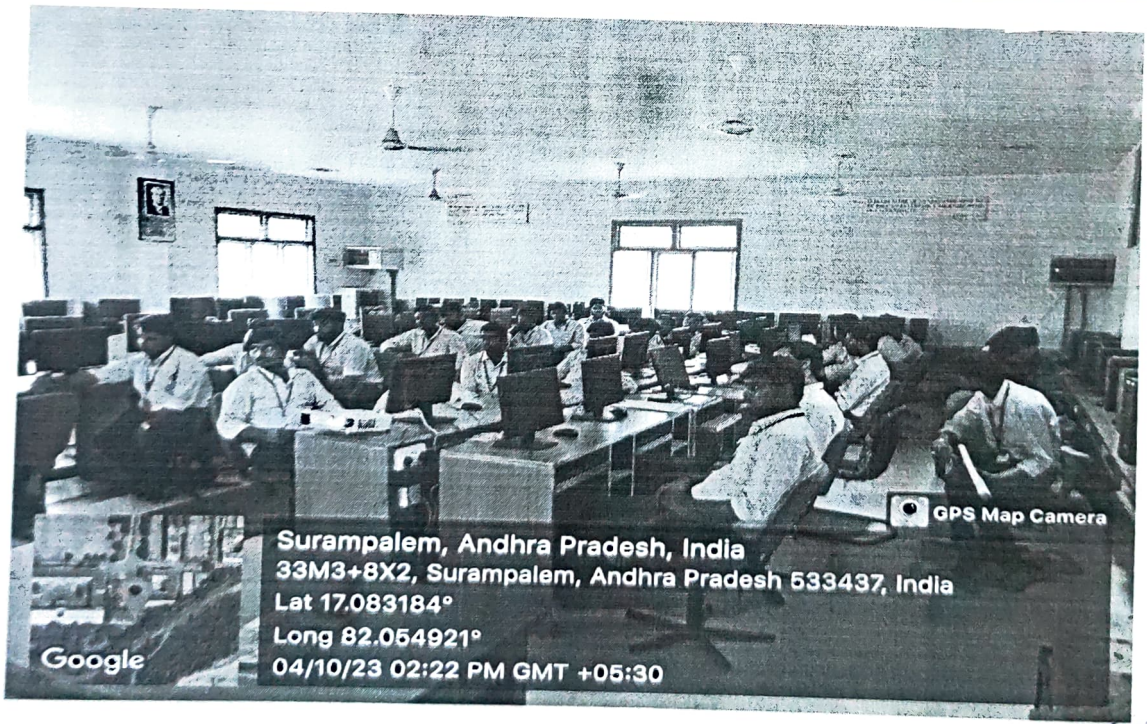

Coordinator

HOD-ME

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Additive Manufacturing Club

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STUDENT SESSION FEED BACK

Additive Manufacturing Club Organized By Department Of Mechanical Engineering In Association With Career Guidance Cell

Topic:	Introduction to Solid Based Rapid Prototyping Methods & Case studies	Date : 04/10/2023

INSTRUCTION: - Put ☑ mark in the box

Q1	Indicate the rating of the session as per your Opinion								
	1. Poor	☐	2. Average	☐	3. Good	☐	4. Very Good	☑	5. Excellent ☐
Q.2	Please provide us with ideas and suggestions if any								

THANK YOU for your feedback. Happy Learning!

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	1. Poor	☐	2. Average	☐	3. Good	☑	4. Very Good	☐	5. Excellent ☐
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Additive Manufacturing Club Organized By Department Of Mechanical Engineering In Association With Career Guidance Cell

Topic:	Introduction to Solid Based Rapid Prototyping Methods & Case studies	Date : 04/10/2023

INSTRUCTION: - Put ☑ mark in the box

Q1	Indicate the rating of the session as per your Opinion								
	1. Poor	☐	2. Average	☐	3. Good	☐	4. Very Good	☑	5. Excellent ☐
Q.2	Please provide us with ideas and suggestions if any								

THANK YOU for your feedback. Happy Learning!

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(Autonomous)

Certificate of Participation

This is to certify that

P.Jagan Mohan

*has participated in a Seminar on "**Introduction to Soild Based Rapid Prototyping Methods & Casestudies**"*

under Additive Manufacturing Club

*Organized by **Department of Mechanical Engineering***

in

association with Career Guidance Cell on 4th Oct 2023.

P. Ram Prasad

Mr. P. Ram Prasad
Convener

ADDITIVE MANUFACTURING CLUB
PRAGATI ENGINEERING COLLEGE

Dr. G. Avinash
HOD-ME

PRAGATI ENGINEERING COLLEGE

(Autonomous)

Certificate of Participation

This is to certify that

S.Vinay Kumar

*has participated in a Seminar on "**Introduction to Soild Based Rapid Prototyping Methods & Casestudies**"*

under Additive Manufacturing Club

*Organized by **Department of Mechanical Engineering***

in

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P. Ram Prasad

Mr. P. Ram Prasad
Convener

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