Summarization of 3D-Printing Technology in Processing & Development of Medical Implants

*1Ganzi Suresh, 2M. Harinatha Reddy, 3Gurram Narendra Santosh Kumar, 4S. Balasubramanyam

1, 3Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Guntur, India – 522 502

2, 4Department of Mechanical Engineering, Guru Nanak institutions Technical campus, Ibrahimpatnam, Hyderabad – 501 510

Corresponding Author: Ganzi Suresh
Email: ganzi.suresh@kluniversity.in

https://doi.org/10.26782/jmcms.2019.02.00012

Abstract

3D-printing technology is otherwise called added substance assembling or fast prototyping, is an advanced manufacturing technique which builds 3D parts directly in layer by layer from the computer aided plan model in raster way with minimal wastage of material. Rather than in conventional manufacturing process where material is removed by the hard tool to bring the 3D component in desired model, 3D printing is completely contrast to it where material is added in sequence parts are built in layer by layer, it doesn’t require any post processing as in conventional process. 3D printed parts are more performing under different loading conditions and easy to build and repair parts any stage of design cycle. Due its flexibility of manufacturing, it shows its applications in auto ancillaries, aerospace and medical filed. 3D printing technology showing it influencing in making medical implants. Manufacturing of medical implants in conventional process is very expensive. As these implants vary patient to patient, and it is difficult to make tailor made implants in conventional manufacturing processes. Hence 3D printing technology can overcome this issue with minimal cost for making tailor made implants for individual patients

Keywords: Additive manufacturing; bio- materials; medical implants.

I. Introduction

Three-dimensional printing (3D-P) technology is also known as ‘additive manufacturing’ (AM); ‘rapid prototyping’ (RP); ‘rapid manufacturing’ (RM); ‘solid free form fabrication’ (SFF), is an advanced manufacturing technique / technology to build 3D parts / components directly form the Computer Aided Design (CAD) data
directly by adding the build material in sequence of layer by layer. 3D-printing innovation happened due to advancements in a wide range of innovation parts. These days, we have turned out to be very acclimated with having great PCs and other complex robotized machines around us and now and then it might be troublesome for us to envision how the pioneers attempted to build up the first AM machines [I-II]. Quick assembling/prototyping (RM/P) may follow back to the mid-1980s with the approach of stereolithography. Basic empowering improvements incorporated the appearance of personal computers and the monetary advancement and accessibility of mechanical lasers [III]. In the late 1980s and early 1990s a plenty of RP forms showed up including however not restricted to specific laser sintering, overlaid protest producing, intertwined statement demonstrating. Over the resulting twenty years, the exploration network has connected these procedures and process varieties in novel approaches to assault a wide assortment of research issues in a differing number of specialized zones including car, aviation, biomedical, vitality, and shopper products. The effect of RP keeps on developing, as far as the aggregate number of parts created, the quantity of machines sold, and the measure of academic movement as productions and licenses [IV]. This procedure, amassing the part layer-by-layer beginning from the most punctual stage, is Fig.1 [V]

**Fig.1. Build steps in Additive Manufacturing**

Added substance fabricating (AM) structures can convey models from 3D CAD data, CT and MRI checks, and 3D digitizing system. Using an additional substance approach, quick prototyping structures join liquid, powder or sheet materials to shape physical dissents on a layer by layer commence. Fast prototyping machines process plastic, paper, aesthetic, metal and composite materials from feeble, level cross territories of PC helped models. This report gives an extensive graph of quick prototyping systems assembled into three standard social occasions in light of the sort of material used to produce a 3D display (Table 1) [VI]. This report gives a sweeping
chart of fast prototyping procedures assembled into three rule get-togethers in light of the sort of material used to fabricate a 3D demonstrate (Table 1) [VI].

**Table 1. Classifications of Additive Manufacturing processes**

| Additive Manufacturing Processes based type of build materials | Liquid Based | Solid Based | Powder Based |
|---------------------------------------------------------------|--------------|-------------|--------------|
| Stereolithography (SLA)                                       | fused Deposition | Modeling | Selective laser sintering |
| Jetting System                                                | (FDM)        | Object     | Melting (SLS/M) |
|                                                               | Laminated    | Manufacturing (LOM) | Laser Engineered |
|                                                               | Object       | Shaping (LENS)     | Net            |

Altogether, notwithstanding, the expense of model demonstrating is extraordinarily diminished from more routine model shop manufactures. Albeit fast prototyping has gotten to be imbued into the item advancement transform far and wide, it appears that development is more probable than coming to full development. The business discourses itself deluged in new methods, materials, and frameworks that will inevitably prompt open new markets, described by new clients and novel applications.

**Liquid Based Process**

**Stereolithography (SLA).**

Stereolithography is at present the most broadly utilized process in the fast prototyping and assembling (RP&M) field [VII-VIII]. "It deciphers PC helped outlines (CAD) into strong protests through a mix of laser, photochemistry and programming. A schematic representation shown in Fig.1. A basic printing process goes like this “A 3-D model of an object is created in a CAD program. This process repeats layer by layer, with successive layers bonding to each other, until the part is “Traditional prototype production is a long, inefficient, expensive and fraught-within accuracy process that adds to the ultimate cost of a product, wastes manpower and materials, and slows the production cycle”. SL technology provides a solution to these problems inherent in the traditional approach. “It is a technological breakthrough that allows solid physical parts to be made directly from computer data in a short time using an automated [XVIII].

Although SLA is a remarkable improvement over the conventional prototyping production in many aspects, it still needs further improvement in speed and resolution to meet the demands of industry. Resolution is particularly important as it indicates the minimum feature sizes and surface finish achievable. One important factor that affects SL resolution is inherent the laser. For example, for the case of a Gaussian laser and a resin obeying the Beer-Lambert law, the resin will cure in a shape of a parabolic cylinder upon a single laser scan vector. Using a smaller layer thickness can reduce this boundary effect, but it also increases the build time. Resolution can be improved by shrinking the laser beam size, but it also causes an increase in the building time. Increasing the laser intensity can improve SL speed
since both the rate and degree of cure increase with the intensity. However, since the cure reaction is exothermic and SL resins have low thermal conductivities, the heat of reaction associated with the local photopolymerization cannot be easily dispersed. When the laser intensity is increased to increase the part building speed, it also unfortunately leads to faster heat generation. Consequently, some thermally initiated polymerization might occur near the exposed region, which would reduce the resolution of the prototype being constructed. Furthermore, the temperature gradients built within the resin might cause considerable thermal stresses and correspondingly thermal strains, which could deteriorate the mechanical/chemical properties of the part, or even manifest themselves as part distortion. Can these two features in the SL process, resolution and speed, be improved simultaneously or do they have to be compromised with each other? If there is an optimized solution, what are the limits for such optimization given a photosensitive material system? What are the most sensitive parameters that affect the resolution or speed? To answer these questions, having the capacity to recreate and anticipate part shape, manufacture time, and potential troubles would be extremely advantageous.

Fig. 2. Schematic representation of Stereolithography (SLA) process (Image courtesy of 3D Systems)

**Jetting System.**

One delegate blend based totally liquid system is Poly-Jet, a 0.5 sort of texture gushing or printing. As coordinator’s scene unit unpalatably mindful of the work area forming, the strategy by thing Geometries utilizes printing progression to store support and accumulate material coagulated with picture or splendid possible materials. Not at between times the most modest sum like around 3D printing machines, it's set up for transference comes about like those from stereolithography traces. As appeared in Figure 3, in this strategy, the spilling head slides forward and in invert on the X-focus reason, stinting one super thin layer of photopolymer onto the construct plat. Speedily among the wake of building each layer, light-weight bright enlightenment radiation open the gushing augmentation release attractive
power wave light in a split second set and movement each layer. This progression swears off the prerequisite for any post indicating set, as required by totally shocking movements. The inner flying plate moves down with radiating exactitude and subsequently the plane head starts building up the following layer. This system is repeated until the point that the model is finished. The strategy programming manages the methodology that uses eight spilling heads. When strategy plant made, each layer is then restored and intense by prologue to property shaft lighting. The running with layer is then kept up prime of that at that point forward. At the reason once the fabricate is finished, a water-fly suitably purges the gel like help material.

![Schematic representation of Jetting process](Image courtesy of Objet)

**Fig.3. Schematic representation of Jetting process (Image courtesy of Objet)**

**Solid Based Process**

**Fused Deposition Modelling (FDM).**

Fused Deposition Modeling (FDM) is an additional substance manufacturing development regularly used for illustrating, prototyping, and creation applications. It is one of the strategies used for 3D printing. Intertwined testimony displaying tackles an "included substance" manage by setting down material in layers a plastic fiber or metal wire is free up from a turn and supplies material to make a section. Intertwined Deposition Modeling begins with an item procedure which shapes a stereolithography record (. STL record design) tentatively cutting and masterminding the model for the produce process [IX-X]. In case obliged, brace structures might be made. The machine may apportion materials to achieve indisputable goals; for occasion, one may use one material to add to the model and use another as a dissolvable reinforce structure or one could use distinctive shades of a similar kind of thermoplastic on a similar model.
Fig. 4. Schematic representation of Jetting process
(Image courtesy of Stratasys)

The gush takes after a device path controlled by a PC upheld collecting (CAM) programming group, and the part is created from the base one layer on the double [XI-XII]. Stepper motors or servo motors are routinely used to move the ejection head. But as a printing development combined statement demonstrating is to a great degree versatile, and it is fit for overseeing little shades by the sponsorship from bring down layers intertwined affidavit displaying by and large has two or three confinements on the slant of the shade and can't make unsupported stalactites [XIII].

**Laminated Object Manufacturing (LOM).**

LOM is additive manufacturing process in which 3D solid physical model made by stacking layers of sheet stock, each an outline of the cross-sectional shape of a CAD model that is sliced into layers as shown in Fig. 4. Starting sheet stock includes paper, plastic, cellulose, metals, or fibre-reinforced materials. The sheet is usually supplied with adhesive backing as rolls that are spooled between two reels. After cutting, excess material in the layer remains in place to support the part during building [XIV]. Most sand casting designs are produced using wood, albeit some are made of urethanes and metals. Example making is viewed as a profoundly gifted assignment and most examples today are made by claim to fame design shops that serve the foundries, albeit a few foundries keep up design making offices. Utilizing a CNC switch or processing machine gives the essential geometric and material abilities for the example business; yet a computerized or Rapid innovation is yet not accessible. Fast Prototyping and Manufacturing (RP&M) strategies developed just a couple of decades prior. Early adopters of a few advances were design improving shops that required a strategy for testing part and additionally design outlines. This permitted distinctive therapist, draft and gating frameworks to be tried by making a couple of sand forms and pouring metal.
Powder Based process

Selective Laser Sintering / Melting (SLS/M)

Selective Laser Sintering or Melting (SLS/M) is an added substance producing method that uses a laser as the power source to sinter powdered material (normally metal), pointing the laser naturally at focuses in space characterized by a 3D demonstrate, restricting the material together to make a strong structure [XV-XVI]. Laser sintering (SLS) was created and protected by Dr. Carl Deckard and scholastic counsel, Dr. Joe Beaman at the University of Texas at Austin in the mid-1980s.

Not at all like some other added substance fabricating forms, for example, stereolithography (SLA) and intertwined testimony displaying (FDM), SLS does not need help structures because of the way that the part being developed is encompassed by un-sintered powder consistently, this considers the development of already unthinkable geometries.
Laser Engineered Net Shaping (LENSTM)

Laser built net forming (LENS) [XVI-XVII] is currently filling in as one of the key advancements in the immediate assembling or repairing of metal parts. Beginning from a Computer Aided Design (CAD) strong document, the LENS procedure produces parts layer by layer from base up with the warmth contribution of a powerful laser. Fig.6 demonstrates the procedure design of LENSTM. Contrasted with conventional surface treatment forms, LENS has a higher repair effectiveness, less post handling, higher cooling rate, and littler warmth influenced zone in this way accomplishing better mechanical practices after testimony forms. unique tooling for infusion shape. As of late, LENS has been effectively connected in coordinate creation of complex auxiliary parts, practically reviewed coatings, high-esteem included segments repair, and unique events, for example, aviation, protection, biomedical, and so forth. With the expanding consciousness of vitality sparing and ecological security, natural issues have stirred more worries amid item producing forms.

Fig.7. Process layout of Laser Engineered Net Shaping (LENSTM) (Image courtesy of Optomec Inc.)

The two governments and enterprises are being pushed to consider the ecological weights of the item. Since created by Sandia National Laboratories in 1997, LENS has shown an awesome potential to upset the path for metal parts manufacture and pulled in an ever-increasing number of worries in both scholarly world and enterprises. In the most recent decades, broad research has been led on the enhancement of mechanical properties and microstructures of parts created by LENS, and warm displaying and control over the whole powder statement.

II. Medical Implants

A medicinal implant is an artificial structure made from metals, polymers and ceramics are inserted to the human body through surgical methods, will restore those shape, structure of the muscle/bone Furthermore give backing to the body weights without any uneasiness of the patients. Bio-Medical implants can be inserted to
As it is outstanding, the expression "rapid prototyping" alludes to a wide range of yet related advances that can be utilized for building extremely complex physical models and model parts specifically from 3D CAD demonstrate. Among these innovations are stereolithography (SLA), specific laser sintering (SLS), melded statement displaying (FDM), covered question fabricating (LOM). RP advancements can utilize extensive variety of materials (from paper, plastic to metal and these days biomaterials) which gives probability for their application in various fields. RP (counting Rapid Tooling) has essential been created for assembling industry in or-der to accelerate the improvement of new items. This paper covers conceivable outcomes of utilizing RP advances as a multi-train region in the field of medication. Utilizing RP in prescription is a very unpredictable errand which infers a multidisciplinary approach and great information of designing and additionally pharmaceutical; it likewise requests numerous HR and tight coordinated effort amongst specialists and architects.

To appropriately evaluate the best in class in tissue substitution and enlargement, it is first important to precisely audit the physiology, life structures, organic chemistry and biomechanics of ordinary tissues and in addition the pathophysiological changes that expect intercession to reestablish typical capacity. Moreover, since most therapeutic inserts require careful mediation for establishment, it is important to be acquainted with the repair and recovery reactions that outcome before it is conceivable to characterize the biocompatibility of an embed material. The bio-compatibility and engineering use of devices are intimately associated with the chemical and mechanical properties of the materials used in device construction. Therefore, we will briefly review the relationship between chemical and physical structures and mechanical properties of implant materials prior to establishing the utility of each type of material in medical applications. After reviewing this material, it will be easier to understand the types of preclinical biocompatibility tests that are required before clinical tests can begin.

Medicinal gadget fabricating is a directed industry in which strength metals are utilized to deliver superior parts. With its expenses and time favorable circumstances, Rapid prototyping/Manufacturing (RP/M) is a perfect answer for applications including the improvement, prototyping and generation of forte careful instruments and orthopedic inserts, for example, hip, knee and spinal gadgets. Fast prototyping is the programmed development of physical items utilizing strong freestyle creation. It takes virtual outlines from Computer Aided Design (CAD) or activity. Huge numbers of the therapeutic segments have received the 3D printed components as a feature of the mechanical upheaval that the 3D innovation is
bringing. A portion of the primary favorable circumstances of fast prototyping procedures are, it doesn’t require multi-steps generation activities or any extra tooling and that it limits the requirement for having a stock.

![Fig. 8: Possible Medical Implants in Human Body](image)

**III. Bio-Compatible Materials**

In the field of biomaterials there are a few difficulties that must be tended to for fruitful outline of a medicinal embed. Biocompatibility is a mind-boggling issue in that both the creation and size of the biomaterial can manage the cell reaction in vivo. Numerous inserts can be defenceless to untimely disappointments because of natural assault, and this confines the selection of materials that can be securely utilized as a part of the body. Bio-materials are fake or normal materials utilized as a part of natural frameworks. Investigates in the extent of biomaterials are multidisciplinary and incorporate different parts of materials science, science, science and prescription. Table.2 Shows the arrangement of bio-materials. The material can be regular or manufactured and incorporates metals, earthenware production and polymers. They primarily are utilized as a part of the restorative field for tissue repair, heart valves and inserts. Table 1. Shows the sorts of bio-materials.
**Table 2: Classification of Bio-Compatible materials**

| Polymers       | Ceramics             | Metals               |
|----------------|----------------------|----------------------|
| Silicones      | Aluminum oxide       | Stainless steel      |
| Poly ethylene  | Zirconia             | Titanium alloys      |
| Poly vinyl chloride | Calcium phosphates | Tantalum alloys      |
| Polyurethanes  |                      | Cobalt alloys        |
| Polylactides   |                      | Gold / Platinum      |

**Ceramics.**

Advances in the utilization of earthenware production for counterfeit joints have gotten a lot of consideration. Clay on-fired hip joints got FDA endorsement in 2003. Customary metal-polyethylene hip framework wear creates polyethylene particulate flotsam and jetsam, actuating osteolysis, debilitating of encompassing bone, and brings about extricating of the embed, an essential driver of expensive modification tasks. Artistic materials create fundamentally less polyethylene flotsam and jetsam when utilized as a part of conjunction with polyethylene acetabular segments in bearing couples. Wear execution broadens the life of counterfeit joints, giving clay on-earthenware joints an anticipated existence of well more than 20 years. Serving the necessities of the expanding quantities of more youthful patients for whom such medical procedure is currently a suitable task, these fired on-fired joints enable them to keep driving dynamic ways of life.

**Polymers.**

Polymers offer the advantage of being characteristically impervious to ecological assault; in any case, polymeric biomaterials confront interesting requests when used in stack bearing restorative gadgets in that the mechanical worries in which they work regularly put them at coordinate hazard for yield, weariness, wear, crawl, and crack. Therapeutic gadgets made out of polymers, as other biomaterial frameworks, are not invulnerable to mechanically instigated organic disappointments. Medicinal polymers are utilized as a part of an expansive scope of uses including tissue repair and substitution, medicate conveyance, and wound healing. Polymers show time-subordinate mechanical conduct and are known to be viscoelastic. For instance, the versatile modulus and yield quality of a polymer for the most part increments with expanding strain rate while the strain to disappointment ordinarily diminishes with expanded stacking rates. Also, managed burdens can bring about time-subordinate strain or sneak in polymers.
Metals

Metals and metal alloys are commonly used for medical implant applications as they are strong enough to bear weight of the body so they are used for load bearing implants applications. Metal implants must exhibit high strength, minimal wear and corrosion. Finally, bio-compatible to the human body without any allergic reaction to the patients and smooth functioning of the implants for a long run. A very few existing metals and metal alloys such as stainless steel, gold, titanium alloys, tantalum alloys, zirconium alloys and cobalt alloys are suitable for medical implants. Still there is a huge space for the researchers to develop new metals and metal alloys exhibit sufficient picture to satisfy the above properties [XX-XXII].

IV. Classifications of Medical Implants

Load Bearing Implants.

The planned utilization of bone frameworks is for implantation in basic size bone deformities, which by and large need to manage mechanical stacking. Effective platform configuration ought to animate new bone development coming about, toward the end state, in local bone tissue with no hint of the framework. The craving to achieve this assignment and the present condition of the field are a long way from meeting. Current outlines have neglected to create a framework that can stay practical all through the length from implantation to the finish of the recuperating stage under load-bearing conditions, in this way missing the objective of an improved and reordered bone design that is as utilitarian and steady as the local bone. Just with the joining of both biomechanical contemplations and organic prerequisites to deliver an internationally advanced structure from the general shape to the compound synthesis of the restorative gadget can there be promise for the accomplishment of both the embed and the resulting in growth of bone. The initial phase in the mending of a bone deformity starts with the implantation of the designed framework. Following implantation, the framework takes the whole heap of the blemished locale and the encompassing territory is subjected to the typical condition of pressure.

Bone Fixation.

In certain types of fractures, on the other hand, experience has shown that open reduction and some means of internal fixation is the only procedure which offers the patient a reasonable expectation of satisfactory function. The wholesale adoption, by the inexperienced, of the first steel plates used for the internal fixation of fractures was followed by such a deluge of disastrous results that the method, in general, fell into disrepute. This unfortunate situation, however, has led to certain developments in bone surgery which now permit a more aggressive attitude toward those fractures in which serious impairment of function appears inevitable by treatment with conservative measures. The introduction by Doctor Venable of vitallium, an alloy which is practically inert in the tissues, as a means of internal fixation, has been one of the outstanding contributions to our advance in bone surgery. Vitallium is a nonferrous alloy, being composed of cobalt, chromium and molybdenum. Its physical and chemical properties, and its reaction when placed in living tissue, have been described in articles by Doctors Venable, Stuck and Beach.
Experimental and clinical evidence indicate that vitallium is the most "silent" of all the metals or alloys employed for internal fixation of fractures. The most serious objection to other material utilized for this purpose was their electrolytic action upon the host tissue, as manifested by a local area of tissue necrosis, with absorption of the bone about the screws and plate. The consequent loosening of the screws impaired the stability of the internal fixation, and the devitalized tissue favoured bacterial growth.

Sherman and others have employed metallic plates in the treatment of compound fractures for many years and have reported excellent results. Following the use of ferrous alloy plates, most surgeons have found the incidence of infection with loosening of the screws and loss of position resulting from instability of the plate relatively high. For this reason, foreign materials for internal fixation in compound fractures have been utilized with some hesitancy. The immediate accurate reduction and secure fixation of the bony fragments in compound fractures, however, has several advantages. Third, with internal fixation there is need for less external immobilization, thus permitting observation and treatment of the damaged soft parts without constant movement at the fracture site—a disadvantage of skeletal traction having no unfavourable influence upon the incidence of infection, and the fact that there is no absorption about the screws even in the presence of infection.

Prosthetic Joints.

Prosthetic remedy for patients with bring down appendage removal is fundamentally in light of observational information. Numerous alternatives are accessible for various prosthetic segments; be that as it may, solution criteria are construct for the most part with respect to subjective encounters of doctors, specialists, and prosthetists. Then again, outsider payers every now and again require legitimization for buying expensive prostheses. The initial step is to separate however much experimentally based learning from the writing as could be expected. In this regard, two kinds of studies can be recognized: (1) clinical investigations concentrating on engine execution or day by day working with a lower-appendage prosthesis and (2) specialized examinations concentrating on the mechanical qualities of prosthetic parts without particularly human working. In perspective of prosthetic rule improvement, just examinations tending to engine execution and human working with a lower-appendage prosthesis are viewed as important.

Dentistry.

The Pharmaceutical Society of Ireland (PSI) featured the advantages of mixed getting the hang of utilizing a blend of on the web and up close and personal exercises and an online portfolio to permit an adaptable approach that spotlights on results pertinent to an individual professional's training (PSI 2010). It has been recommended that hours gathered from exercises including dynamic and focused on investment, which have been appeared to be more compelling than aloof learning, ought to pull in more credits (Bloom 2005). Be that as it may, both Schostak (2010) and Grant (2011) have portrayed the shortcoming of utilizing inputs, for example, long periods of CPD finished to gauge CPD. Freidman and Woodhead (2008) have recommended that a yield approach that endeavors "to gauge what CPD is expected
to accomplish straightforwardly” and empowers singular experts to screen their own particular advance might be better. The writing distinguished a scope of potential administrative advantages of cooperation in CPD. These incorporate guaranteeing movement levels and competency, fulfilling open desires, staying up to date with propels in persistent care and as an enlistment instrument.

**Tissue Engineering.**

Tissue designing related bioreactors have for some time been thought of as secret elements, inside which, cells are refined primarily by experimentation. Wendt et al suitably expressed that “The optimal operating conditions of a bioreactor should not be determined through a trial and error approach but should instead be defined by integrating experimental data and computational models”. It is recognized that remain solitary exploratory information may not uncover the better subtle elements of procedures and reactions that might happen inside such frameworks, and all things considered, we might be just be breaking down information that does not present us with the general picture. By coupling test and computational methodologies, a cooperative energy is accomplished which should yield information that will expand our understanding and in addition increment the cohesiveness of information got from future bioreactor thinks about.

**V. Conclusions**

Additive manufacturing or rapid prototyping process where 3D components can be manufactured layer by layer within less time and minimal material wastage. This process can also be referred as 3D printing as it is capable of manufacture 3D components directly from the computer aided design models. This technology shows it applications in manufacturing of medical implants with less cost comparatively to conventional manufacturing processes. 3D printing technologies are classified in to three categories based on type of material used for building 3D components. There are different materials available for implants manufacturing such as ceramics, polymers and metal alloys. Based on the type of application different process is selected to build the implants.

**References**

I. C. Nastase-Dan, P. Doru Dumitru, G. Gheorghe Ion, and P. Sanda, “Innovative technology through selective laser sintering in mechatronics, biomedical engineering and industry,” Incas Bull., vol. 3, no. 1, pp. 31–37, 2011.

II. D. T. R. S. G. Pham, “A Comparsion of RP Technologies.pdf.

III. D. V Mahindru, P. Mahendru, V. Mahindru, and P. Mahendru, “Review of Rapid Prototyping- Technology for the Future,” Glob. J. Comput. Sci. Technol. Graph. {&} Vis., vol. 13, no. 4, pp. 27–38, 2013.
IV. F. P. W. Melchels, J. Feijen, and D. W. Grijpma, “A review on stereolithography and its applications in biomedical engineering,” Biomaterials, vol. 31, no. 24, pp. 6121–6130, 2010.

V. G. Suresh and K. L. Narayana, “3D Printing: Breakthroughs in Research and Practice,” in 3D Printing, IGI Global, 2016, pp. 1–21.

VI. G. Suresh and K. L. Narayana, “A Review on Fabricating Procedures in Rapid Prototyping,” Int. J. Manuf. Mater. Mech. Eng., vol. 6, no. 2, 2016.

VII. G. Suresh, K. L. Narayana, and M. K. Mallik, “A Review on Development of Medical Implants by Rapid Prototyping Technology,” Int. J. Pure Appl. Math., vol. 117, no. 21, pp. 257–276, 2017.

VIII. Ganz Suresh, K L Narayana and M. Kedar Mallik., “Bio-Compatible Processing of LENSTM Deposited Co-Cr-W alloy for Medical Applications”. International Journal of Engineering and Technology (UAE). 7 (2.20) (2018) 362-366. DOI:10.14419/ijet.v7i2.20.16734.

IX. Ganz Suresh, K L Narayana, M. Kedar Mallik, V. Srinivas and G. Jagan Reddy., “Processing & Characterization of LENSTM Deposited Co-Cr-W Alloy for Bio-Medical Applications”. International Journal of Pharmaceutical Research (IJPR) Volume 10, Issue-1, 2018, 276-285.

X. Ganz Suresh, K L Narayana, M. Kedar Mallik, V. Srinivas, G. Jagan Reddy and I.Gurappa., “Electro Chemical Corrosion Behavior of LENSTM Deposited Co-Cr-W Alloy for Bio-Medical Applications”. International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) Special Issue, Jun 2018, 41-5

XI. Hangobo Lan, “Web-based rapid prototyping and manufacturing systems: A review,” vol. 60, pp. 643–656, 2009.

XII. I. Palčič, M. Balazic, M. Milfelner, and B. Buchmeister, “Potential of laser engineered net shaping (LENS) technology,” Mater. Manuf. Process., vol. 24, no. 7–8, pp. 750–753, 2009.

XIII. Kumar, G. N. S. and A. Srinath. 2018. "An Ergonomical conditions of Pedestrians on Accelerating Moving Walkway: A People Mover System." International Journal of Mechanical and Production Engineering Research and Development 8 (Special Issue 7): 1376-1381. www.scopus.com.

XIV. Kumar, Gurram Narendra Santosh, and A. Srinath. "Exploration of Accelerating Moving Walkway for Futuristic Transport System in Congested and Traffical Areas." (2018): 616-624.

XV. L. Villalpando, H. Eiliat, and R. J. Urbanic, “An optimization approach for components built by fused deposition modeling with parametric internal structures,” Procedia CIRP, vol. 17, pp. 800–805, 2014.

XVI. M. Domingo-espin, I. Engineering, and U. Ramon, “A methodology to choose the best building direction for Fused Deposition Modeling end-use parts.
XVII. M. E. W. M. Johnson, M. Rowell, B. Deason, “BENCHMARKING EVALUATION OF AN OPEN SOURCE FUSED DEPOSITION,” pp. 197–211, 1997.

XVIII. M. L. Griffith et al., “Free Form Fabrication of Metallic Components Using Laser Engineered Net Shaping (LENS),” Proc. 7th Solid Free. Fabr. Symp., pp. 125–132, 1996.

XIX. M. Montero, S. Roundy, and D. Odell, “Material characterization of fused deposition modeling (FDM) ABS by designed experiments,” Proc. Rapid Prototyp. Manuf. Conf., pp. 1–21, 2001.

XX. P. B. Klosterman D, Chartoff R, Graves G, Osborne N, “Interfacial characteristics of composites fabricated by laminated object manufacturing,” Compos Part A, vol. 29A, p. 1165–74., 1998.

XXI. P. Chennakesava and Y. S. Narayan, “Fused Deposition Modeling - Insights,” Int. Conf. Adv. Des. Manuf., pp. 1345–1350, 2014.

XXII. P. Rochus, J. Plesseria, M. Van Elsen, J. Kruth, R. Carrus, and T. Dormal, “New applications of rapid prototyping and rapid manufacturing (RP / RM) technologies for space instrumentation,” vol. 61, pp. 352–359, 2007.

XXIII. Q. Wei et al., “Selective laser melting of stainless-steel/nano-hydroxyapatite composites for medical applications: Microstructure, element distribution, crack and mechanical properties,” J. Mater. Process. Technol., vol. 222, pp. 444–453, 2015.

XXIV. Rama Chandra Manohar, K et al. Modeling and Analysis of Kaplan Turbine Blade Using CFD. International Journal of Engineering & Technology, [S.l.], v. 7, n. 3.12, p. 1086-1089, july 2018. ISSN 2227-524X. Available at: https://www.sciencepubco.com/index.php/ijet/article/view/17766>. Date accessed: 05 jan. 2019. doi:http://dx.doi.org/10.14419/ijet.v7i3.12.17766.

XXV. Sk.Hasane Ahammad,V.Rajesh, “Image Processing based segmentation for spinal cord in MRI”,Indian Journal of Public Health Research and Development 9(6), pp.317-323