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Metal Rapid Prototyping – Overview of Technical Approach

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Abstract: ***Rapid prototyping is new product developing technology to replicate exact shape of crucial part. Prototype design and development has some traditional rapid prototyping process of three dimensional printing (3-DP), Direct metal deposition (DMD), Selective laser sintering (SLS), Electron Beam Melting (EBM) and Ultrasonic Consolidation processes. New hybrid approach developing for metal deposition technique which used apply for new tools, medical prosthesis and surgical bone implants, aerospace and military components. Especially human bones for transplantation, optical focusing instrument, micro devices. Implement of new hybrid fused deposition method with electrochemical action rapid prototyping known as Electrochemical fused deposition method. This based on type of CAD model for 3-D printing. Wide performance has studied with comparing different prototype technique based on evaluating aspect of application, work volume, accuracy, and post processing speed of deposition. The quality of deposition volume fraction and adhesion to the substrate has studied.***
Keywords: ***Metal Prototyping, Electrochemical Fused Deposition Method***

I. INTRODUCTION

Rapid prototyping has urge requirement to develop and manufacture metallic prototype of complicate design, expensive in typical manufacturing. Design and development of product is easier for rapid prototyping technology. It has number of ways to process prototype for various applications. Conventional prototype built up by various polymers but new hybrid development process toward combination of two type of technology such as Electrochemical and Fused deposition method [1]. Development of metal prototype help in better analysis of product design and testing of complex part. Currently research work has been working on development of metallic component and it available commercially in few of 3-DP, DMD, SLS, EBM and UC shown in Figure 1. Every method has its own capability in term of tolerance, surface finish and strength. The sustainable product development criteria has built by rapid prototyping technology due reduction in wastage and minimum material and process energy requirements.

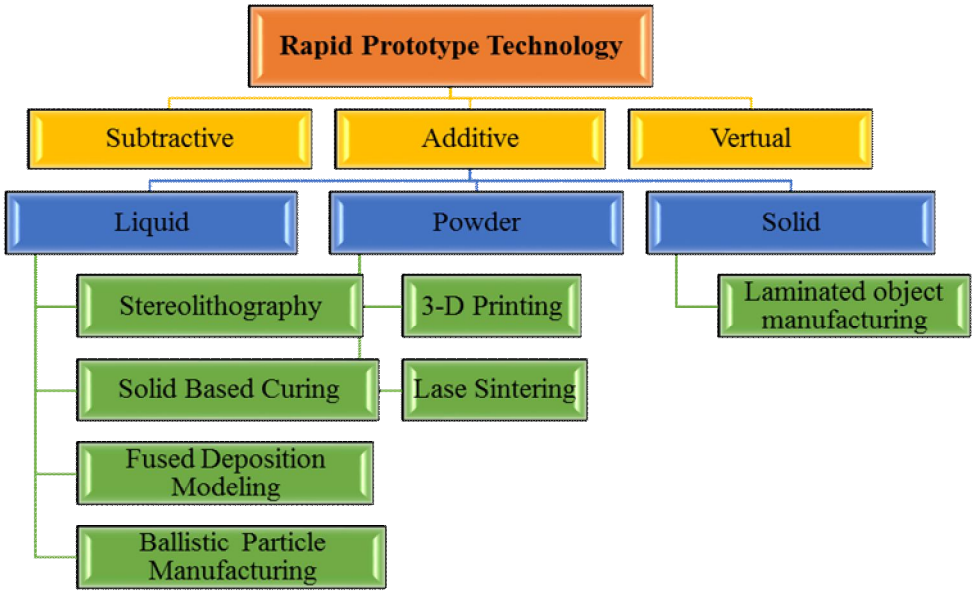

Figure 1. Classification of Rapid prototyping techniques [2].

The performance of rapid prototyping technique processes depend on following parameters of i. Raw material for prototype ii. Work area and volume iii. Deposition rate iv. Energy utilization v. Post processes requirement vi. Surface texture vii. Applications of product viii. Cost of prototype. Number of literatures are available for highlighting effectiveness of rapid prototypes for industrial used. There are three type of rapid manufacturing process of subtractive, additive and virtual. The physical model of part is generated from

CAD data files which can manufactured in significant hours. It allows evaluation of manufacturability and design effectiveness. Therefore it help to visualization and verification of preferred job. The selected manufacturing material used in subsequent manufacturing operation to obtain final parts -product manufacturing to design shape in slice of parallel layers. It seen like staircase in developing model part process [3].

A. The Various Type Of Prototyping Process Has Studied And Analysed Effective Parameters Highlighted Below

1) Maximum work- 3 DP, DMD and SLS processes produced all kind of size range component but EBM and UC critical for large size components. It mainly depend on capability, size of source of energy and raw materials used for particular rapid prototyping.
2) Accuracy- it is important factor of design and development of accurate product. It mainly depend on Z axis resolution, raw material and spot size of source.
3) Post processing- to develop good quality product post processing needed. It achieve desirable shape and surface finish. It develop deter surface texture on it due to temperature and pressure effect.
4) Deposition rate- layer thickness is increased due to decreasing process speed. The rate of deposition depend on heating and solidification time taken by different materials. Deposition rate may be several hour on based on material type.
5) Energy utilization- energy density play important role in heating material. It is high in case of laser, electron energy based rapid prototyping process because initial stage heating and warm up required for deposition. In UC process less heat required due to ultrasonic welding action.
6) Volume fraction- it is similar to deposition rate but it depend on deposition, melting and solidification of metal and resolution. It mainly 100% dense after completion of solidification.
7) Layer thickness- speed of deposition and size of source energy influences on surface finish and microstructure of deposition.
8) Process control- control uniform deposition of material sequentially on working envelops.
9) Surface texture- fine grain structure resulted in better mechanical properties and homogeneity in prototype.
10) Cost of product- for lower production units of component, rapid prototyping is more beneficial.

Present approach of overviews study utilised identified current work on existing metal and polymer of rapid prototyping processes and its capability for micro fabrication. Existing rapid prototyping methods requires very expensive equipment's and supportive post processing appliances to achieve target of new low cost metal/ polymer rapid prototyping method developed by Ghosh et al. FDED which has cross process innovation of two different processes of High Speed Selective Jet Electro deposition (HSSJE) and Electrochemical Discharge (ECD). The recent developed technology has not focused in-depth in view of its advantage, limitations and its user applications. The experimental process without feedback control system developed maximum deposition rate of 11 µg/s which obtained at a SOD of a 3mm and applied voltage of 230 V. A maximum volume fraction of 84% had obtained through voltage of 230 V. The higher current density in the impinging region leaded to heavy discharged on 260 V and it erodes deposited and reduced the deposition rate. Melting or semi-solid and fused deposit flush away from surface [1].

Commercial metal rapid prototyping process fabricated by deposition of layers on X-Y plane. The other perpendicular axis from single layer being stacked up on top surface on each other but not in continuous Z coordinate. The final part manufactured 3D either by raising or lowering the platform on substrate and cutting, curing or deposition of material using different source of energy. Most of rapid prototyping involved continues supply of feed material injected into melt pool form by different supply energy sources.

B. Advantages

1) Product design and development time as well as cost greatly reduced than manufacturing prototype by conventional methods/ machines
2) The product design cycle becomes shorter. Therefore availability of product in market is early sooner.
3) Better interaction and communication between marketing, engineering, manufacturing, and purchasing are enhanced due to availability of physical prototype.
4) It help to get critical design reviews of physical model and ease to accurate decision making.
5) It is possible to perform functional prototype testing before production decision.
6) Accurate physical prototype possible to generate precise production tooling
7) CAD file without need of tooling reduced lead time and cost of production

C. Limitations

1) The initial investment cost of equipment and accessories are relatively high.

2) Material choice for different processes limited due to their properties

D. Economic Consideration

1) Fast build up rate for completion large parts takes a day
2) Skilled worker required with automated process
3) Lead time nearly 1-2 weeks
4) Rate of material utilization is high but support has structural waste
5) Reworking is expensive
6) Photopolymer expensive and extra process required
7) Economical for low production runs 1-20 parts

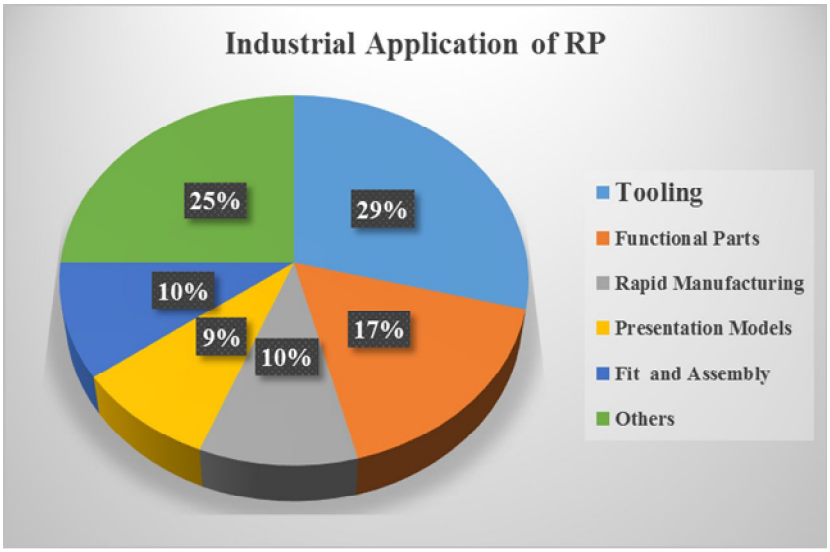

Figure 2. Industrial application of rapid prototyping [3]

E. Areas Applications

1) Check feasibility of new conceptual design and development
2) Ease in making functional models with limitation of material do any testing
3) Conducting market test/ evaluation
4) Creating tooling for metal casting, injection moulding, and some metal forming processes
5) Building sand prototype or metal mould and die-casting
6) Fabricating master patterns

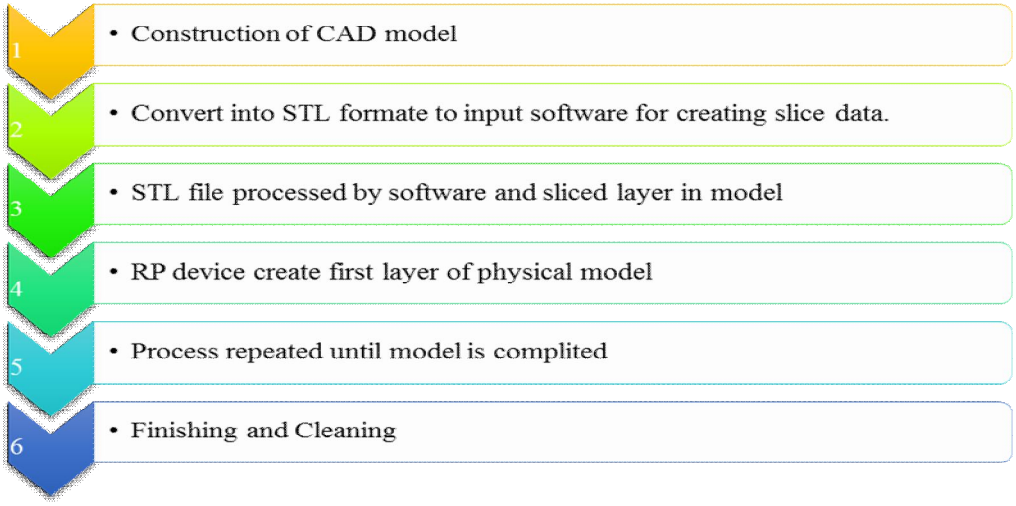

Figure 3. Steps of current rapid prototyping techniques [3]

II. FUSED DEPOSITION THROUGH ELECTROCHEMICAL DISCHARGE

Development of fused deposition through electrochemical discharge process uses an electrochemical discharge energy which does not affect costly focusing devices. Therefore FDED process has developed by using ECD as a source of energy which required low source of energy and it focused with help of electrolyte jet at required location [1].

III.DEVELOPMENT OF RAPID PROTOTYPING

Development of new metal rapid prototyping method in an electrochemical cell, when the voltage applied to the electrodes grossly different in size, exceeds a critical value, an electric discharge is produced at the tip of the smaller electrode, With a very low current of around 0.2 -0.4A and applied voltage of 40-60V. Hence the power required to produce ECD is of 8-24Wwhich is low. The temperature of discharge was found to be in the range of 8000-10000K in discharge zone. The discharge has to be directed towards substrate for deposition, HSSJE was a selective electrochemical deposition process which used Non Submerged Free Standing (NSFS) Jet of electrolyte impinging on a cathodically polarized substrate. The current density as high as 40000 A/m2can be achieved resulting extremely high rates of electrode position. In the view of this, a new process which is combination of ECD and HSSJE is developed which can produced metal parts on micro scale. It is developed with the intention to avoid the use of lasers and associated costly optical instruments. In this process, a fine metallic wire acting as anode is fed through the core of a controlled NSFS electrolyte impinging jet on a substrate acting as a cathode. A proper combination of electrolyte flow, electrical parameters and SOD between the electrodes results in tiny, discrete discharges at the surface of the substrate. The heat generated during the discharge fuses electrochemically deposited metal to the substrate or to the pre deposited layer. With proper movement of the substrate along X-Y axes, deposition could be done layer wise till required height to obtained 3-D solid. FDED may be proved to be a good alternative to laser assisted and high cost metal RP methods.

The reduction in effective SOD increases current in the cell and rate of dissolution of electrode wire. The wire dissolution depends upon applied voltage and flow rate. Throughout experiment flow rate is difficult to maintain constant which changes the effective SOD and it affects the current which ultimately leads to excessive electrochemical is solution of the wire tip which recedes from the nozzle tip. This leads to reduction in the deposition rate and the quality. It is difficult to maintain the constant SOD throughout without any feedback control system. Recently, FDED with a closed loop feedback control system to maintain the wire feed rate and SOD to enhance the deposition rate and volume fraction.is bell shape All paragraphs must be justified, i.e. both left-justified and right-justified.

IV.CONCLUSION

In this study principles of traditional rapid prototyping techniques are explained for design and development of polymer and metal material. The new technology of metal deposition is studied as new generation of product development using low melting temperature metal. Name as FDED- fused deposition electrochemical discharge in low cost compare to other micro fabrication technique. This method FDED only applicable for low range melting metal such as copper, tin. The other material tried but fumes during its chemical action its become complicate to achieve better mechanical properties.

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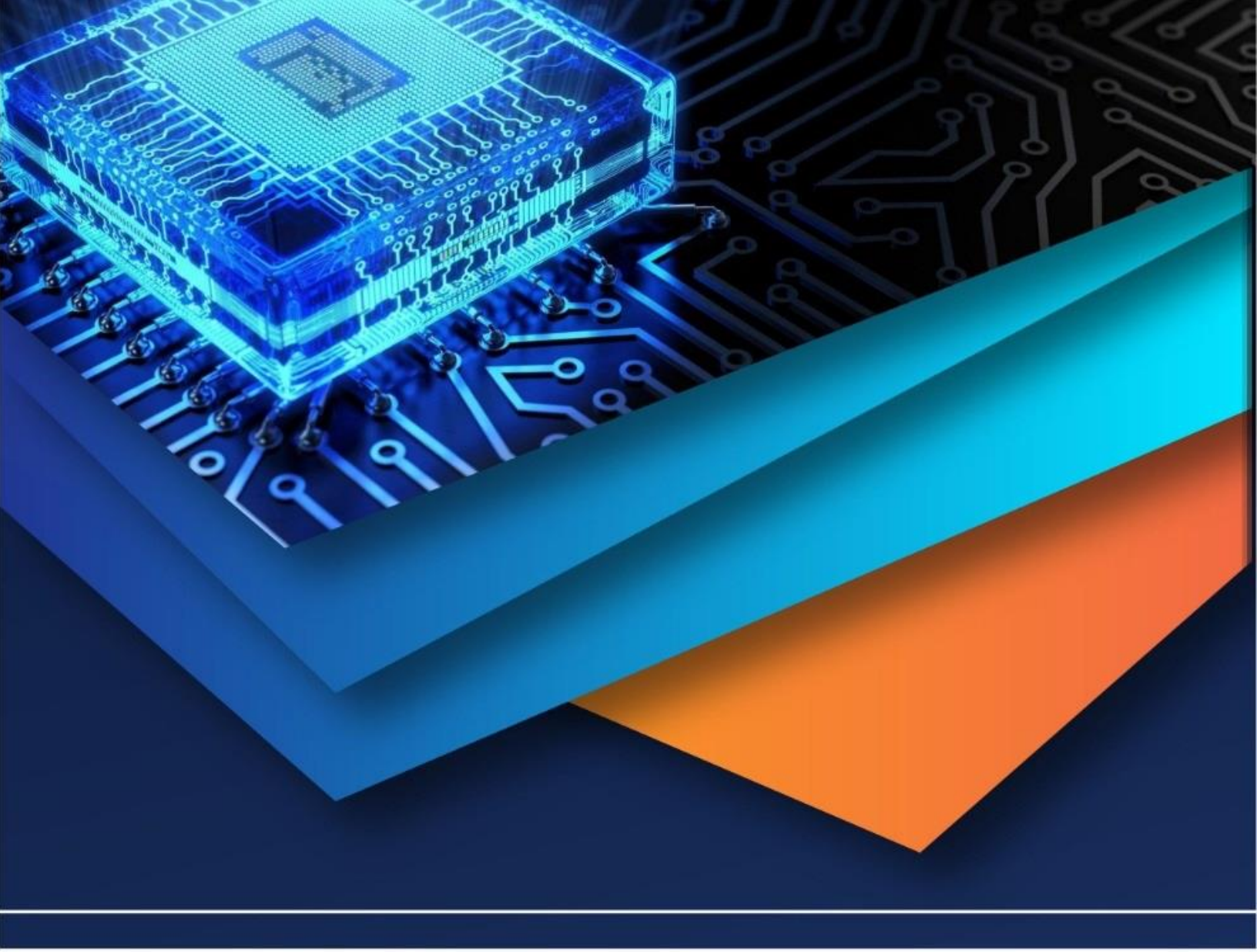

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