A Comprehensive Literature Survey of the Application of Modeling and Optimization Techniques in Additive Manufacturing Processes

A Final Year Project

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by

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Abstract

Day after day Additive Manufacturing (AM) process is gaining increasing importance as the process allows manufacturing with literally no waste while most complex shapes could be between the users' hands at home. Industries have recognized the significant role this technology could play in the fourth industrial revolution.

Emphasizing this fact, the present Final Year Project is about summarizing the researches that target modeling and optimization of the AM process. Over 50 contemporary studies on Modeling of Additive Manufacturing were collected and chronologically presented. The researches accentuate modeling in AM punctuating from 2003 to 2018. On the other hand, in addressing optimization, 49 studies were also collected and presented chronologically published from 1999 till 2018. Our results have shown that most of the researches on modeling and optimization were published in years 2016 and 2017. This indeed showed the increasing importance of AM (including 3D-Printing technologies). Our survey should help professionals get more information in a shorter period of time as most of the results are listed in this project.

Acknowledgment

Firstly, we would like to thank our family for being with us in any situations, and our thanks extend to all staff of the Department of Manufacturing Engineering who are encouraged us to complete this research. We are enormously indebted to our supervisor Dr.-Ing. Rastee D. Ali for his notes, suggestions and encouragements through the preparation of this work, in addition to his guidance and special advice to enrich and complete the research.

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Chapter 1

INTRODUCTION TO THE 3D-PRINTING TEGHNOLOGIES

What is 3D-Printing?

3D-Printing or additive manufacturing is a process of making three dimensional solid objects from a digital file; 3D-Printing has evolved dramatically in the last few years. 3D-Printers have become plentiful and affordable enough that anyone can own one. Indeed, the cost of 3D-Printers [as little as $200 USD] makes them an attractive choice for small businesses, researchers, educators, and hobbyists alike. You can use a 3D-Printer in your business to create prototypes for manufacturing, develop architectural or engineering models or anything plausible[Tyag05].

Classification of the AM Systems

Additive manufacturing [AM] systems can be classified into two main sub-groups according to the temperature as follow:

1. *Processes based on material melting*: Fused deposition modeling [FDM], precision extrusion deposition [PED], 3D fiber deposition, precise extrusion manufacturing [PEM] and multiphase jet solidification [MJS] [Ying17].

- FDM :- is the most commonly additive manufacturing technology available currently [RoKa17] .In this process, a plastic or wax material(filament) is extruded or feeds through a nozzle that signs the part's cross sectional geometry layer by layer, and heated above the melting temperature of the material(Fig.1) [Yang16].

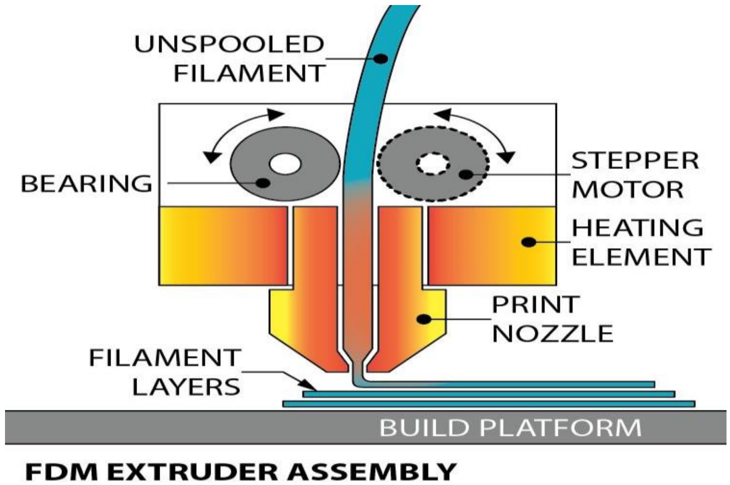

Fig .1: Assembly of fused deposition modeling (FDM).[Jona17]

-MJS:- is another extrusion based – technique which was originally used for the manufacturing of a rapid density metallic and ceramic parts using a low melting point alloys or a powder-binder mixture [RoKa17].

2. *Processes without material melting*: Pressure-assisted micro syringe [PAM], low-temperature deposition manufacturing [LDM], 3D bio printing , robocasting, direct-write assembly and solvent-based extrusion free forming [SEF] [Ying17].

-Robocasting:- has been developed for operating high solid suspension, for printing heavy ceramics and composite materials [RoKa17].

-LDM: low-temperature deposition manufacturing process developed to produce scaffolds in a low temperature environment, and it can protect biological activity by fabricating custom pore-sized three-dimensional (3D) scaffolds[Hash14].

In the following sections, a special focus is directed to the most familiar types of the 3D-Printing.

Resin-Based 3D-Printing

Resin is known as one of the most widely technology which has a capability of real translating from a solid model to a physical model in an easy fast process[GiRS15]. It is often referred to as "The mother of all 3D-Printing technologies".

Fig. 2:show process it is called top for a modest reason [00b]

About this figure the process takes place at top of the resin tank, as opposite to the bottom, the most other resin-based 3D-Printing solidifies layers during the process. Finally, all of these about where and how to polish accurate ultraviolet light onto liquid resin reason solidification.

The resin printers used Sterolithography (SLA) or digital light processing (DLP) as the way that can create the layers [Josh15].

Advantage of stereolithography including:

- High precision
- Quality of the part
- Smooth finish.

Limitation of stereolithography including

- Fragility
- Expensive machines
- Unit production

Optical Approach to Resin Formulation for 3D-Printed Microfluidics:

Microfluidics imposes various demands on 3D-printing compared to many applications because the critical features for microfluidics comprise of inner micro voids. Resins for general 3D-printing applications, yet, are not necessarily formulated to meet the demands of microfluidics and minimize the size of fabricated voids. They used an optical approach to guide custom formula of resins to minimize the cross-sectional size of fabricated flow channels models of such voids. So they focused on sterelithography (SL) 3D-Printing and Digital Light Processing (DLP) because they based on a micro mirror array and using a commercially available 3D-Printer. They develop a mathematical model for the optical potion recognize through the thickness of a 3D printed section, including the impact of voids. Found that there is a basis trade-off between the homogeneity of the optical dose within individual layers and how far the critical potion penetrates to a flow channel through fabrication [GBPW15].

Powder-Based 3D-Printing

Powder bending –which is more commonly known as 3D-Printing, in this process many layers of powder will be laying and then liquid binder will be used to stick them all together in the required way, the powder in almost every systems is made up of gypsum plaster and starch, then water based binder will be used to activate the plaster, Finally, in the last step of build process the user is left with a cubic container full of loose powder [GoMC16] & [Epma13].

It has some usefulness of powder building:

- low build coast
- Rapid build time
- Full color capability.

It has some disadvantages of powder building:-

- Poor mechanical properties
- Rough surface finish when compared to SLA or Selective Laser Sintering (SLS) [GoMC16].

Powder bed in pharmaceutical 3D-Printing

In this type of printing a liquid binder solution is atomizer with an device print head over a thin layer of powder- where the binder solution contact the powder bed, the powder particles are adhered together, Once the first-initial layer is printed the new layer of powder will be atomized over the initial bed and then excess loose powder brushed off there`s an obvious rule of this type of printing is that it cannot print hollow objects [Mish16] & [BiEP15].

Powder bed fusion (DMLS, SLS, SLM, and EBM)

The full melt in operation such as electron beam melting (EBM) and selective laser melting (SLM) creates chances to alter the grain and crystallinity of materials .but needs more energy to be changed to the build material. Sintering processes include selective laser sintering (SLS) and direct metal laser sintering (DMLS) can result in lower energy, coasts shorter time, a powder bed step by step fills up with the build material as the desired area of powder is solidified through melting or shaping by the energy beam, which is usually directed by mirrors across the desired cross section of material. And finally the parts have to be removed from third powder. Unlike powder binding, many part failure, and these will have to be removed from the part post process[GoMC16]. (Fig.3) shows layers of the powder.

Fig. 3: Layers of powder

Extrusion-Based 3D-Printing

Extrusion is an additive technology commonly used for modeling, prototyping, and production applications [Mart16]._and is a concept used for a process to manufacture materials of fixed cross-sectional profile[Nikh16], The extruder of a 3D-Printing is the part of the printer that does the actual printing[Josh15] so In context to 3D-Printing, the term "Extrusion" has more accurate meaning and refers to involvement of a "Hot End" and a "Cold End" in the process[Nikh16] or can say direct extrusion is typically made of two main part; the extruder body and the hot end[Josh15]. It creates an object by laying down material in layers; a plastic filament or metal wire is unwound from a coil and supplies material to produce a part[Mart16], the extruder body can act very different depend on the printer, most of the shelf printers use a direct drive system where the extruder stepper motor directly drives the plastic filament into the hot end[Josh15]and a reservoir is pushed out through a nozzle when pressure is applied ,if the pressure remain Constant, then the resulting extruded substance will flow at a invariant rate.[GiRS10]the business end of a 3D-Printer is the hot end that gets hot, as the name suggests, to melt the plastic filament which consist of three main components; the nozzle, full size dictates part quality and print speed; the heater cartridge, which produce the heat needed; and the heating barrel, which the plastic filament is fed through to be heated.[Josh15]another type of extruder exists called the Bowden extruder, which the filament is drawn to the nozzle. However the extruder body (thrust motor) is separated from the hot end by the model, but Complexity cause more difficult to assemble and maintain in operation[Alex17].

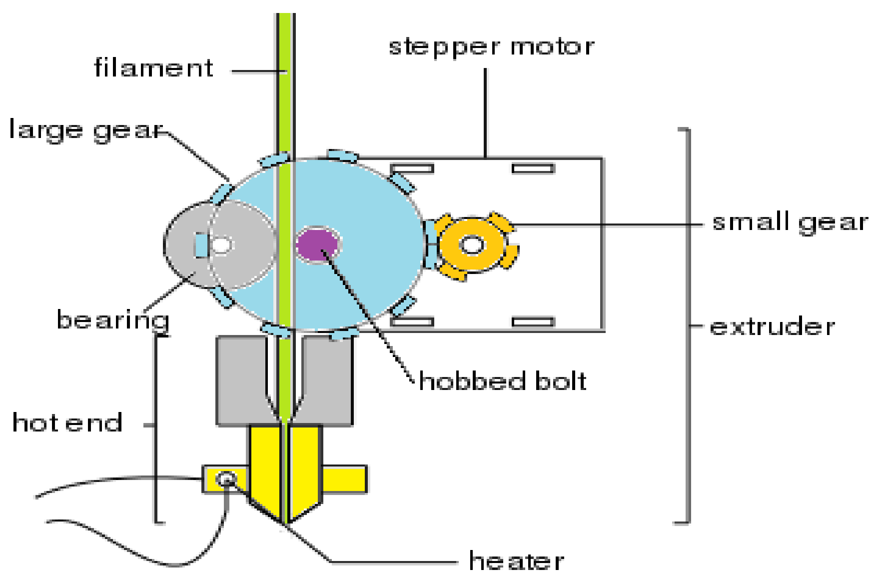

Fig.4: Extrusion parts in general shape [Brem16]

There are a number of key features that are common to any extrusion-based system:

- Loading of material,
- Liquefaction of the material,
- Application of pressure to move the material through the nozzle,
- Extrusion
- Plotting according to a predefined path and in a controlled manner,
- Bonding of the material to itself or secondary build materials to form a coherent solid structure, and
- Inclusion of support structure to enable complex geometrical features [GiRS10].

Chapter 2

Literature Survey on Modeling of Additive Manufacturing

What is modeling?

Modeling of additive manufacturing technologies is improving the performance of device, machine, and mechanism parts. These technologies include stereolithography, electrolytic deposition, thermal and laserbased 3D-Printing, 3D-IC fabrication technologies, etc. They are booming nowadays, because they can provide rapid low-cost high-accuracy production of 3D items of arbitrarily complex shape [MaLy14].

Literature Survey of Modeling Techniques in Different AM Industries

- Davies et al. (2006), Provided an overview about determined whether practitioners stilled embraced conceptual modeling seriously. In addition, What were the most popular techniques and tools used for conceptual modeling? What were the major purposes for which conceptual modeling were used? The study found that the top six most frequently used modeling techniques and methods were ER diagramming, data flow diagramming, systems flowcharting, workflow modeling, UML, and structured charts. Modeling technique was found to decrease significantly from smaller to medium-sized organizations, but then to increase significantly in larger organizations (proxying for large, complex projects) [DGRI06].

- Daneshmand et al. (2012), casting, machining and additive manufacturing technologies were used in order to produce wind tunnel testing models. The models could also be analyzed by computational fluid dynamics methods. Both have their advantages and disadvantages. Since several wind tunnel models were required to accomplish aerodynamic experiments, nowadays, one of the best methods for models and airfoils manufacturing were additive manufacturing technologies. Those methods were increasingly used in aerospace industry. Wing and tail of a wind tunnel test model which has complicated sections, were produced by fused deposition modeling technology. In order to improve mechanical properties and surface roughness an electroplating were used on the surface of a RP model. Metal models along with fused deposition modeling models and electroplating models were tested in wind tunnels with different angels of attack [DaAg12].

- Michaleris et al. (2014), reviewed both quiet and inactive element activation in detail and techniques for minimizing errors associated with element activation errors were proposed. 1D and 3D numerical examples were used to demonstrate that both methods could give equivalent results if implemented properly. Additive Manufacturing (AM) processes for metallic parts used both laser and electron beam heat sources are becoming increasingly popular due to their potential of producing near net shape structural components. The thermal history generated by additive manufacturing was essential in determining the resulting microstructure, material properties, residual stress, and distortion. Finite element techniques for modeling metal deposition heat transfer analyses of additive manufacturing were investigated in detail, in particular [Mich14].

- Seufzer et al. (2014), Additive manufacturing are coming into industrial used and had several desirable attributes. Control of the deposition remains a complex challenge, and so that literature review was initiated to capture current modeling efforts in the field of additive manufacturing. Contain summarizes about 10 years of modeling and simulation related to both welding and additive manufacturing. The goals were to learn who was doing what in modeling and simulation, to summarize various approaches taken to create models, and to identify research gaps. Later sections in the report summarize implications for closed-loop-control of the process, implications for local research efforts, and implications for local modeling efforts [Seuf14].

- Denlinger et al. (2014), a finite element modeling strategy is developed to allow for the prediction of distortion accumulation in additive manufacturing (AM) large parts (on the order of meters). A 3D thermo elastoplastic analysis was performed using a hybrid quiet inactive element activation strategy combined with adaptive coarsening. At the beginning for the simulation, before material deposition commences, elements corresponding to deposition material were removed from the analysis, then elements were introduced in the model layer by layer in a quiet state with material properties rendering them irrelevant. As the moving energy source was applied on the part, elements were switched to active by restoring the actual material properties when the energy source was applied on them. A layer by layer coarsening strategy merging elements in lower layers of the build was also implemented such that while elements were added on the top of build, elements were merged below maintaining a low number of degrees of freedom in the model for the entire simulation [DeIM14].

- Turner et al. (2014), provided an overview about systematically and critically review the literature related to process design and modeling of fused deposition modeling (FDM) and similar extrusion-based additive manufacturing (AM) or rapid prototyping processes. Design/methodology/approach – A systematic review of the literature focusing on process design and mathematical process modeling was carried out. Findings – FDM and similar processes were among the most widely used rapid prototyping processes with growing application in finished part manufacturing. Key elements of the typical processes, including the material feed mechanism, liquefier and print nozzle; the build surface and environment; and approaches to part finishing were described. Approaches to estimating the motor torque and power required to achieve a desired filament feed rate were presented. Models of required heat flux, sheared on the melt and pressure drop in the liquefier are reviewed. On leaving the print nozzle, die swelling and bead cooling were considered. Approached to modeling the spread of a deposited road of material and the bonding of polymer roads to one another were also reviewed [NtSA14].

- Liu et al. (2014), showed how modeling technology is always the bottleneck problem of the product development process, as it involved most time of the product development. Contain illustrate how to improve the efficiency of modeling for additive manufacturing. As the application conditions of Additive Manufacturing continued to be mature, rapid modeling technologies would be discussed , including hierarchical modeling, standardized modeling and parametric modeling technology, which would lay the foundation for rapid modeling of product development [LiZh14].

- Manzhirov et al. (2014), showed mathematical modeling of additive manufacturing technologies is aimed at improving the performance of device, machine, and mechanism parts. Those technologies include stereolithography, electrolytic deposition, thermal and laser based 3D-Printing, 3D-IC fabrication technologies, etc. They were booming nowadays, because they could provide rapid low-cost high-accuracy production of 3D items of arbitrarily complex shape [MaLy14].

- Ganeriwala et al. (2014), the modeling and simulation of selective laser sintering of particulate materials was discussed. Such processes involve harnessing optical energy to heat and fuse powdered materials together in an additive process. Selective laser sintering allows for the rapid manufacturing or prototyping of parts with complex geometries. In order to simulate such a process in a rapid manner, the approach pursued by the authors was to develop a computational tool by assembling relatively simple, physically meaningful, models at the small scale, for many interacting particles. There allows for much more refined estimates of the resulting overall system temperature and, ultimately, it was changed of phase from a solid, to a liquid, and possibly even to a gas. Large-scale three-dimensional examples were provided [GaZo14].

- Bibb et al. (2015), showed a medical modeling and the principles of medical imaging, Computer Aided Design (CAD) and Rapid Prototyping (also known as Additive Manufacturing and 3D-Printing) were important techniques relating to various disciplines - from biomaterials engineering to surgery. The first edition, Medical Modeling: The application of Advanced Design and Rapid Prototyping techniques in medicine provided readers with a revised edition of the original text, along with key information on innovative imaging techniques, Rapid Prototyping technologies and case studies. Second edition there was an extensive section of peer-reviewed case studies, describing the practical applications of advanced design technologies in surgical, prosthetic, orthotic, dental and research applications. Covers the steps towards rapid prototyping, from conception (modeling) to manufacture [BiEP15].

- **Schröder et al. (2015)** showed how to develop a business model which evaluates process costs of additive manufacturing technologies. The relevant technologies were Stereolithography, Selective Laser Melting, Fused Deposition Modeling, Selective Laser Melting, Electron Beam Melting and Laser Cladding. Product costs could be calculated easily and the outcome of the evaluation would serve as a valuable decision base for industrial decision makers on how to invest in a special technology. The contain was structured in four steps. Firstly, based on a detailed description of the state of the art research, an analysis of the most important process steps in additive manufacturing was presented (see Fig.1). A new business model for additive manufacturing technologies was introduced afterwards including the implementation of their business model in a software tool. In the last step, a sensitivity analysis was done to find the most important parameters (cost drivers) for those case studies [ScFS15].

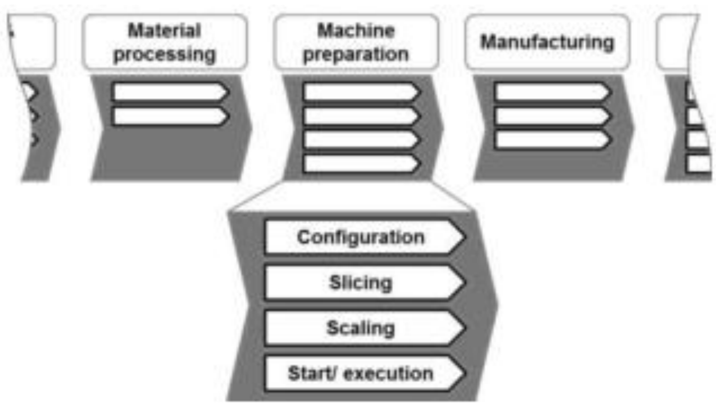

Fig.1 business model process[ScFS15]

- **Romano et al. (2015),** showed that modeling and simulation could be used as a facilitating tool to predict the behavior of materials and processes and alleviate the need for extensive random experiments. Finite element simulation of thermal modeling thermal modeling of laser melting process to determine the melt pool geometry and temperature distribution in powder bed. There model was used to compare their characteristics between commonly used powder materials to include Ti6Al4V, Stainless Steel 316L, and 7075 Aluminum powders [RoLS15].

- **Denlinger et al. (2016),** showed how a method for modeling the effect of stress relaxation at high temperatures during laser direct energy deposition processes was experimentally validated for Ti-6Al-4V samples subjected to different inter-layer dwell times. The predicted mechanical responses were compared to those of Inconel® 625 samples, which experience no allotropic phase transformation, deposited under identical process conditions. The thermal response of workpieces in additive manufacturing was known to be strongly dependent on dwell time. Contain the dwell times used vary from 0 to 40 s. Based on past research on ferretic steels and the additive manufacturing of titanium alloys it was assumed that the effect of transformation strain in Ti-6Al-4V acted to oppose all other strain components, effectively eliminating all residual stress at temperatures above 690 °C. The model predicted that Inconel® 625 exhibits increasing distortion with decreasing dwell times but that Ti-6Al-4V displays the opposite behavior, with distortion dramatically decreasing with lowering dwell time [DeMi16].

- **Jin et al. (2016),** provided an overview for ankle-foot -orthosis (AFO) is a common assistive device or those to provide the support of the foot for users who have the drop foot syndrome. Custom AFOs offer better fit, comfort and functional performance than pre-fabricated ones. The 3D-printing technique was ideal for fabrication of personalized AFOs. Fused deposition modeling (FDM) was a 3D-printing method with the desired strength and material deposition rate for custom AFO applications. The process planning was critical for the cycle time and quality for FDM of AFOs. Four steps in the process planning are: 1) orientation determination, 2) support generation, 3) slicing and 4) tool path generation. In the orientation determination, several factors were taken into accounts to improve the printability and mechanical performance of the fabricated AFO. To reduce the support structure, structural optimizations were applied on the AFO part without compromising of the strength. Adaptive slicing strategy was used to slice the AFO with full consideration of it was geometric characteristics. In the tool-path generation, wavy tool-path was developed to improve the manufacturing process and enhance the structural strength by parameters optimization[JiHS16].

- **Schönemann, Malte Schmidt et al. (2016)**, showed how a hybrid lightweight parts aimed at improving the economic and ecological performance of automobiles by reducing weight and, consequently, CO2 emissions. The environmental advantageousness required careful attention during the car's design phase to prevent problem shifting from used phase into production. Due to the degree of novelty of hybrid components, reliable data about energy and resource demands in production was not available. A multi-level simulation framework for coupling models from different disciplines in order to derive LCA-relevant data (see Fig.2). Exemplarily, a discrete-event process chain simulation was connected with a physical process model for a forming process [SSHT16].

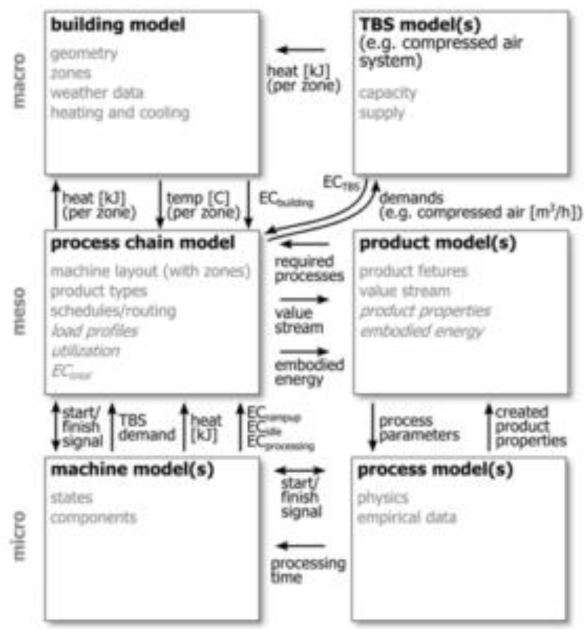

Fig.2. Framework for multi-level modeling and simulation[SSHT16]

- **Montevecchi et al. (2016),** provided an overview about wire-Arc-Additive-Manufacturing (WAAM) is an Additive-Manufacturing (AM) process, allowing to produce metal components layer by layer by means of Gas-Metal-Arc-Welding (GMAW) technology. The advantages of their technology were the capability to create large parts with a higher deposition rate with respected to other AM technologies. Despite these great benefits, WAAM components were affected by severe distortions and residual stresses issues. Finite element process simulation provided an efficient way to study mitigation strategies for such issues. A WAAM modeling strategy was proposed based on a novel heat source model that took into account the actual power distribution between filler and base materials. In order to prove the effectiveness of proposed modeling, an experimental validation was provided by comparing the measured distortions of a WAAM tests-case with the simulated ones, highlighting the accuracy of proposed model [MVSC16].

- **Thompson et al. (2016),** showed how a new two-dimensional approached to modeling manufacturing process chains. Their approach was used to consider the role of additive manufacturing technologies in process chains for a part with micro scale features and no internal geometry. It was shown that additive manufacturing could compete with traditional process chains for small production runs. Combining both types of technology added cost but no benefit in their case. The new process chain model could be used to explain the results and supported process selection, but process chain prototyping was stilled important for rapidly evolving fields like additive manufacturing [ThSM16].

- **Steuben et al. (2016),** showed how a critical element for the design, characterization, and certification of materials and products produced by additive manufacturing processes was the ability to accurately and efficiently model the associated materials and processes. That was necessary for tailoring these processes to endow the associated products with proper geometrical and functional features. In an effort to address these needs in a computationally elegant and at the same time physically realistic manner, concludes with a discussion on how their approach might be generalized to broader classes of additive manufacturing systems, and details are given regarding future work necessary to further developed the present methodology [StIM16].

- **Yang (2016),** provided an overview about three-dimensional thermo-elastic-plastic model is proposed to predict the thermo mechanical behavior in the laser engineered net shaping (LENS) process of Ti-6Al-4V using Finite Element Method (FEM). It was shown that the computed thermal history and mechanical deformations were in good agreement with the experimental measurements. The main contributions of their study are: (I) in the past, a point-wise comparison between simulation results and experimental measurements is more favored to validate the employed model, where the general picture was lost; (II) Rather few works have been done to show the effectiveness of widely employed quasi-static mechanical analysis in the transient LENS process[YZCM16].

- **Vastola** et al. **(2016)**, Beam-based additive manufacturing (AM) is an innovative technique in which parts were built layer wise, starting from the material in powder form. As a developing manufacturing technique, achievement of excellent mechanical properties in the final part was of paramount importance for the mainstream adoption of their technique in industrial manufacturing lines. At the same time, AM offers an unprecedented opportunity to precisely control the manufacturing conditions locally within the part during build, enabling local influence on the formation of the texture and microstructure. In order to achieve the control of microstructure by tailoring the AM machine parameters, a full understanding and modeling of the heat transfer and microstructure evolution processes was needed [VZPZ16a].

- **Vastola et al. (2016**), provided an overview about minimizing the residual stress build-up in metal-based additive manufacturing played a pivotal role in selecting a particular material and technique for making an industrial part. In beam-based additive manufacturing, although a great deal of effort had been made to minimize the residual stresses, it was stilled elusive how to do so by simply optimizing the manufacturing parameters, such as beam size, beam power, and scan speed. With referenced to the Ti6Al4V alloy and manufacturing by electron beam melting, they perform systematic finite element modeling of one-pass scanning to study the effects of beam size, beam power density, beam scan speed, and chamber bed temperature on the magnitude and distribution of residual stresses. their study elucidates both qualitative and quantitative features of the residual stress fields originated by these manufacturing parameters [VZPZ16b].

- **Bikas et al. (2016)** Additive manufacturing is a technology rapidly expanding on a number of industrial sectors. It provided design freedom and environmental/ecological advantages. It transformed essentially design files to fully functional products. However, it was stilled hampered by low productivity, poor quality and uncertainty of final part mechanical properties. The root cause of undesired effects lied in the control aspects of the process. Optimization was difficult due to limited modeling approaches. Physical phenomena associated with additive manufacturing processes were complex, including melting/ solidification and vaporization, heat and mass transfer etc. The objective of the current study was to map available additive manufacturing methods based on their process mechanisms, review modeling approached based on modeling methods and identified research gap[BiSC16].

- **Lee et al. (2016),** showed how a computational models of the direct energy deposition and powder bed fusion processes developed for process control applications. Both models were built upon a regression metamodel of heat transfer beneath the laser beam, to which an auxiliary thermal model was added to account for residual heat in track-to-track interactions. Both models were coupled by taking temperatures predicted with the auxiliary model and incorporating them as initial conditions for metamodel predictions of future laser scans [LePr16].

- **Andersson et al. (2016),** Framework for modeling metal AM processes and enabling streamlined model generation has been presented. The toolset provides means to derive complex models with ease as well as modify them e.g. to run DoE on the model The approach enables the definition of a machine realistic model of the metal AM build process. The model outcome could be exploited in evaluation of engineering material properties as well as e.g. analyzing in more detailed part performance with respected to fatigue. Mesh refining/coarsening was to be further developed to decrease computing times and increase model sizes. Improve links with other tools to improve physical descriptiveness, e.g. solidification and powder bed models to enhance and mitigate limitations of thermo mechanical finite elements (see Fig. 3) [AnLP16].

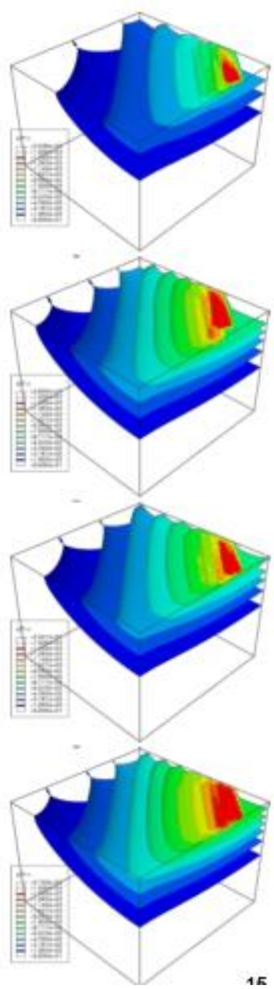

Fig.3.[AnLP16]

- **Lieneke et al. (2016),** Additive manufacturing offers several benefits compared to established manufacturing processes. However, the industrial distribution for end-use part production purposes was still limited. Reasons became apparent in process-specific challenges. There applied particularly to the limitation of geometrical deviations. The method development started with the definition of materials, machines, and process parameters for FDM, LS, and LM. Furthermore, factors influencing the geometrical accuracy of additively manufactured parts were identified. For The experimental tests, the key influencing factors were selected. The nominal dimension and alignment showed a strong impact on the dimensional deviations (See Fig.4) [LDAZ16].

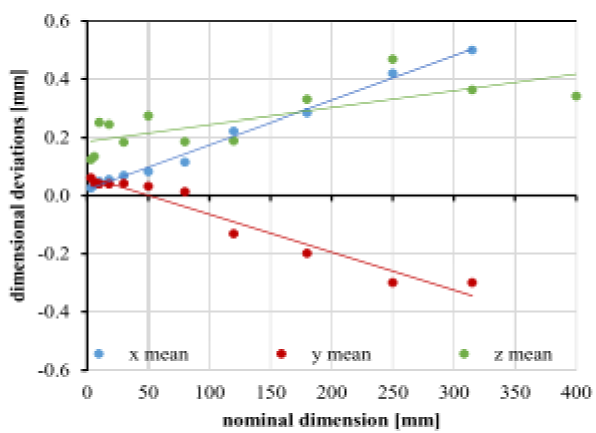

Fig.4 : Means of dimensional deviations and their trend lines for x, y, and, z alignment depending on nominal dimension for FDM[LDAZ16]

- **Q.Yang et al (2016),** Showed how aspired to apply elastic material to print LOC (Lab-on-the-chip) immunoassay with manufacturing addictive techniques. The device was designed for the detection of infectious diseases in the field of developing countries. Applying elastic material could shorten the fabrication time of the device. The first manufacturing technique they chose was Fused Deposition Modeling (FDM). The reason they chose FDM was because of it was low cost and popularity. The elastic material TPU has been chosen to print our LOC immunoassay device. In order to accomplish the final design, different states of prototypes were developed to find the proper settings, geometry, functionality, and to solve emerging difficulties resulted from the characteristics of the elastic material. From their tests, they found leakage in their prototypes; they thought there problem was resulted from the resolution limit and characteristics of the FDM technique. After they applied the plastic dips method on the prototypes, the leakage problem improved and the LOC immunoassay functioned properly. They then employed the SLA technique, which could provide higher resolution and density. They used Formlabs SLA printer with their flexible resin to print their prototypes. The problem of leakage did improve, but there were two main issues. First, the elasticity of SLA prototypes was not as good as the FDM prototypes. Second, the clog problem caused by the flexible resin increased the difficulty of miniaturization [Yang16].

- M. Francois et al. (2017), Provided an overview about current modeling and simulation tools used to simulate materials processing were been extended to model additive manufacturing. Models were needed at multiple length scales to account for the structural details of their new class of materials and to understand the basic physical processes that were active in the performance response of these materials. Models at multiple length scales would enabled the development of the dominant physics basis within macro-scale models for used in component performance simulations. There included an elastoplastic representation to allow prediction of the propensity for damage in these components – a long term endeavor [FSKH17].

- **M.Yuan et al. (2017),** as a new advanced service-oriented networked manufacturing mode, cloud manufacturing (CMfg) is currently one of the main directions of development in the manufacturing industry. A resource modeling method oriented to (CMfg) was proposed to solve manufacturing resource data consistency problems, which were often caused by heterogeneity, diversity, and complexity of manufacturing resource. Motivated by the manufacturing resource modeling literature, they constructed a classification model of manufacturing resource used a line indexing method and a manufacturing resource information model for CMfg from the perspective of resource information [YuDC17].

- **F.Ning et al. (2017),** fused deposition modeling, as one of the additive manufacturing techniques, has been reported for fabricating carbon fiber-reinforced plastic composites. The process parameters used in fused deposition modeling of carbon fiber-reinforced plastic composites follow those in fused deposition modeling of pure plastic materials. After adding fiber reinforcements, it was crucial to investigate proper fused deposition modeling process parameters to ensure the quality of the carbon fiber-reinforced plastic parts fabricated by fused deposition modeling. In the experimental investigations, carbon fiber-reinforced plastic composite parts were fabricated used a fused deposition modeling machine. Tensile tests were conducted to obtain the tensile properties. The effects of fused deposition modeling process parameters on the tensile properties of fused deposition modeling-fabricated carbon fiber-reinforced plastic composite parts were investigated. The fracture interfaces of the parts after tensile testing were observed by a scanning electron microscope to explain material failure modes and reasons [NCHW17].

- E.Brusa et al. (2017), showed the numerical modeling of a geometrically complex structural bracket for aerospace application, which was re-designed through a topological optimization and produced in Ti-6Al-4V by means of the AM. The design activity herein described required to resort to a suitable model of constitutive properties of material by facing the problem of a large number of porosity/low density areas, as detected by a tomographic analysis of the mechanical component. According to some references an equivalent isotropic and homogeneous model of material was applied. The Finite Element model based upon the assumptions of homogeneous and isotropic material might be effective in predicting the material and component strength, at least in static design
(see Fig.5)[BrSO17]

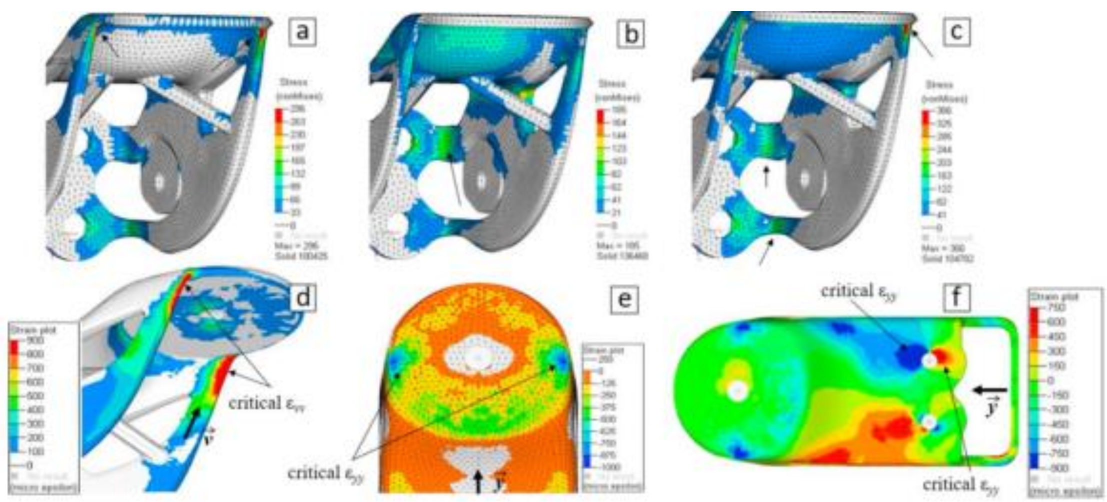

Fig.5: FEM results: equivalent Von Misses stress distribution for load case 1 (a), 2 (b) and 3 (c); strain[BrSO17]

-D.Pollard et al. (2017), Fused Deposition Modeling (FDM), a form of Additive Manufacture, could produce 3D components directly from CAD data. Investigated fluctuations in filament temperature during step changed in feed rate and start/stop motions, monitoring temperature used a thermal camera and thermistors embedded in both the block and nozzle. Temperature overshoots 12°C and 18.5°C were observed during a step increase in feed rate and a priming motion respectively. Evaluating these changed with a sintering model predicted a 20% increase in bond formation, although no significant differences of bond sizes were observed using optical measurement.[PWHE17]

- **Wendt et al. (2017),** Provided an overview about dumbbell specimens are shown to be inadequate for the tensile testing of Additive Manufacturing monolayers. Finite Element Method (FEM) has been used in this contribution for comparing tensile-stress distributions in both conventional and rectangular samples. Different extrusion paths for the manufacturing via Fused Layer Modeling (FLM) were taken into account. The calculations showed stress concentrations in the dumbbell type specimens in the zone of variable width away from the gauge length. The results were used for explaining the differences between mechanical behavior of dumbbell and rectangular specimens made with FLM from Poly-Lactic Acid (PLA) [WVDB17].

Fotinopoulos et al. (2017), a two-dimensional Finite Difference (FD) model of the thermal history of parts manufactured in powder bed fusion Additive Manufacturing (AM) processes is presented. The temperature of the part was calculated in each time-step taking into account the moving laser heat source, the melting phase change and functions of both temperature and porosity was used for the material thermal properties. Also, an algorithm for node birth and distance adaptation over time is utilized, minimizing computational time and memory. A validation of the results of the model was included[FoPS17].

-S. Leng et al. (2017), showed how to provide a framework for the development of a quality assurance (QA) program for using in medical 3D-Printing applications. An interdisciplinary QA team was built with expertise from all aspects of 3D-Printing. A systematic QA approach was established to assess the accuracy and precision of each step during the 3D-Printing process, including: image data acquisition, segmentation and processing, and 3D-Printing and cleaning. Validation of printed models was performed by qualitative inspection and quantitative measurement. The latter was achieved by scanning the printed model with a high resolution CT scanner to obtain images of the printed model, which were registered to the original patient images and the distance between them was calculated on a point-by-point basis. A phantom-based QA process, with two QA phantoms, was also develop [LMMA17].

-K. Gnanasekaran et al. (2017), Fused deposition modeling (FDM) is limited by the availability of application specific functional materials. They illustrated printing of non-conventional polymer Nano composites (CNT- and grapheme-based polybutylene terephthalate (PBT)) on a commercially available desktop 3D-Printer leading toward printing of electrically conductive structures. The printability, electrical conductivity and mechanical stability of the polymer Nano composites before and after 3D-Printing was evaluated. The results showed that 3D printed PBT/CNT objects had better conductive and mechanical properties and a better performance than 3D printed PBT/grapheme structures[GHBW17].

- Z. Zhu et al. (2017), Provided an overview about methods and approaches that have been developed to model and predict shape deviations in AM and to improve geometric quality of AM processes. A number of concluding remarks were made and the Skin Model Shapes Paradigm was introduced to be a promising framework for integration of shape deviations in product development, and the digital thread in AM[ZKAM17].

-S. Kale et al. (2017), a feature-based bio-CAD modeling of three-dimensional tissue scaffolds by considered spatial distribution of biologically active materials was presented for bio manufacturing and tissue engineering applications. Proposed model was based on uniform distribution of bio-active particles in different regions of scaffold, which was constrained by geometrical and biological features. The proposed method was integrated with a recently developed method of multi-material additive manufacturing of hydrogel structures, for bio-additive manufacturing of the heterogeneous scaffolds. 3D bio printed heterogeneous scaffolds were provided as an example for physical implementation of developed algorithm to validate the model[KKNK17].

- Simunovic et al. (2017) , showed metal Big Area Additive Manufacturing (MBAAM) was a new additive manufacturing (AM) technology for printing large-scale 3D objects. MBAAM was based on the gas metal arc welding process and used a continuous feed of welding wire to manufacture an object. An electric arc forms between the wire and the substrate, which melts the wire and deposits a bead of molten metal along the predetermined path [SNNC17].

-Z. Zhu et al. (2017), provided an overview about manufacture parts with complex shape, architected materials and multiple structure. The dimensional and geometrical accuracy of the resulting product remain a bottleneck for AM regarding quality assurance and control. Design for Additive Manufacturing (DfAM) used different methodologies to help designer took into account the technological or geometrical specificities of AM, to maximize product performance during the design stage Additive Manufacturing (AM) technologies had gained extensive applications due to their capable[ZhAM17]

-W. Yan et al. (2017), Electron beam selective melting (EBSM) is a promising additive manufacturing (AM) technology. The EBSM process consists of three major procedures: ① spreading a powder layer, ② preheating to slightly sinter the powder, and ③ selectively melting the powder bed. The highly transient multi-physics phenomena involved in these procedures posed a significant challenge for in situate experimental observation and measurement. To advance the understanding of the physical mechanisms in each procedure, they leverage high-fidelity modeling and post-process experiments. The models resembled the actual fabrication procedures, including ① a powder-spreading model used the discrete element method (DEM), ② a phase field (PF) model of powder sintering (solid-state sintering), and ③ a powder-melting (liquid-state sintering) model used the finite volume method (FVM)[YQMZ17].

- Asadollahi et al. (2017), Additive Manufacturing could produce three dimensional complex products based on the virtual CAD model. There new manufacturing method brought new possibilities in design and manufacturing cycle by it was new parameters and Design for manufacturing approach could be used to consider these issues. An integrated methodology of Design for manufacturing approach was proposed for additive manufacturing. There methodology investigated the characteristics related to Additive Manufacturing in design stage. Skin-Skeleton approach was used to model the procedure from the first step to final one. This skin-skeleton model consisted of usage and manufacturing model which were used to present the customer requirement, product specification and design trend by usage model as well as manufacturing procedure and it was constrained by manufacturing model [AsGL17].

- Chaudhari et al. (2018), showed how the need of manufacturing of prototype of any newly designed components had significant, importance for obtaining realistic model since evolution of engineering. The ability to select the optimal orientation of build-up was one of the critical factors since it affects the part quality, build time, and part cost. It was found from the experimental results that the FDM process given lowest surface roughness across the length was obtained for specimens built with orientation along YZ0, 100% infill and at 0.30 mm layer thickness (see. Fig.6) [ChJP18].

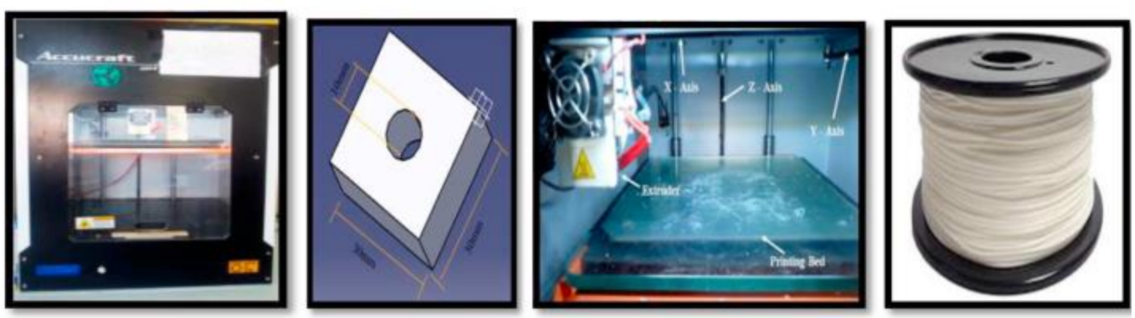

Fig.6. (a) Photographic view of Accurate i250+ RP machine, (b) 3D model using CATIA, (c) Internal View of FDM Machine, and (d) Raw material ABS.[ChJP18]

-C. Seidel et al. (2018), showed a control volume-based multi-scale approached for heat input modeling in laser-based powder bed fusion of metals was described. Rosenthal equation was used to analyses beam-powder interaction for a single laser track. Based on both the Rosenthal results for melt pool dimensions and experimentally determined melt pool depth, a single layer model was developed. Results for the temperature field, gathered by applying the single layer model, serve as data for validating the control volume-based approach on the build-up scale [SeZa18].

- P.Terriault et al. (2018), the emergence of additive manufacturing had enabled the design and manufacture of lightweight parts such as lattice structures with a complex geometry. Many different types of cells could be used in lattice structures, such as tetrakaidecahedral [3–5], cubic [6, 7] and diamond [8, 9]. Predictions of the mechanical behavior of such lattice structures could rely on analytical methods or on numerical ones such as finite elements. In an analytical model, Bernoulli-Euler or Timoshenko beam theories could be used to predict the behavior of a single cell; indeed, several types of unit cells (cubic, tetrakaidecahedral, octahedral and diamond) were studied using these theories [TeBr18].

Chapter 3

Literature Survey on Optimization of Additive Manufacturing

What is optimization?

Optimization is a fundamental part of Additive Manufacturing. Material parameters, processing parameters, scanning parameters, support structures and the printed parts and must be optimized to ensure products with smallest environmental impact and highest efficiency and life time, the mini-symposium covers all aspects of optimization methods for AM. Special interest is devoted to topology optimization for AM which can be said to constitute an ideal marriage. The topology optimization parameterization represents the ultimate design freedom realizable with AM[ImDa17].

Application of Optimization Techniques in Different AM Industries

In this chapter we summarize the application of the mathematical optimization techniques in 49 researches by organizing it according to years of publishing.

-Fragniere and Jacek (1999), the access to advanced optimization software needs more and more sophisticated modeling tools. Tools that facilitate the decision making process based on the optimization paradigm. Among the variety of modeling tools, the algebraic modeling languages seem to be the leaders. The optimization modeling tools evolve together with the progress in optimization techniques. Links with solvers were crucial, especially, in nonlinear optimization. New classes of problems such as complementarity, stochastic programming, combinatorial optimization or global optimization problems could be modeled with these tools. In a wider context, interesting developments of modeling tools also emerged from other ends such as chemical engineering or computer science. Indeed, approaches based on object-oriented modeling or constraint programming influences the evolution of optimization modeling languages too. Optimization modeling tools evolved toward fully integrated modeling management systems opening the access to databases, spreadsheets and graphical user interfaces[FrGo99].

-Jayal et. al (2010) ,Achieving sustainability in manufacturing requires a holistic view spanning not just the product, and the manufacturing processes involved in its fabrication, but also the entire supply chain, including the manufacturing systems across multiple product life-cycles. This requires improved models, metrics for sustainability evaluation, and optimization techniques at the product, process, and system levels. This paper presents an overview of recent trends and new concepts in the development of sustainable products, processes and systems. In particular, recent trends in developing improved sustainability scoring methods for products and processes, and predictive models and optimization techniques for sustainable manufacturing processes, focusing on dry, near-dry and cryogenic machining as examples, are presented[JBDJ10].

-Chen et. al (2011), novel 7-axis robot for mechanical huge 3D-Printing applications was displayed in their paper, which was created by Established of Mechanical autonomy and Programmed Data Framework, Nankai College. Base on the model, the component on three-dimensional printing was profoundly dismembered. By examining the reason of color mutilations in 3D-Printing, a novel multi-step recompense calculation based on demonstrate optimization and picture emolument is created. At long last, the test comes about appear the execution of the 3D-Printing robot stage and the proposed calculations [CLLS11].

-Brackett et. al (2011),topology optimization could give the plans required to completely advantage from AM flexibility, AM creates completely printable optimization plans: this disposes of the require and costs of portion overhaul, bolsters, post handling and counting and counting AM confinements could keep up tall plan execution[BrAH11].

-Ashcroft et. al (2011),showed how most topology (TO) calculations include the penalization of complex basic highlights to dispense with fabricating troubles. Since added substance fabricating was less subordinate on fabricating imperatives, it gets to be fundamental to adjust these calculations for AM. We propose a half breed calculation comprising of an versatile coinciding technique (AMS) and a adjusted shape of the bidirectional developmental basic optimization (BESO) strategy. By tackling a standard cantilever issue, we appear that the cross breed strategy offers moved forward execution over the standard BESO strategy. It is proposed that the modern strategy is more reasonable for optimizing structures for AM in a computational effective way[AAWH11].

-Nedelcu and Anisor (2011), Two distinctive 3D-Printing advances are displayed, inkjet printing and polymer flying. To begin with innovation utilize a powder that's sticking by a cover and the moment innovation combine polymer inkjet with photo-polymerization prepare. The inquiries about have begun and have developed by the most creator, inside Mechanical Imaginative Advances research facility from Progressed Fabricating Innovations and Frameworks office, Transylvania College of Brasov, Romania. The proposed optimization approach is centered on three added substance fabricating applications. To begin with, the introduction of one portion on a construct plate taking into agreement least constructs time model, least back structure and best quality surface. Moment application is centered on fitted testing of parts gotten by 3D-Printing. Taking into agreement the rules for the primary two applications. It is imperative to say that within the polyjet prepare able to select between two parameters that influence the surface quality: mate or reflexive. The normal esteem for the mate surface are Ra_m=1.04 microns, Rz_m=5.6 microns and for the shiny surface are Ra_m=0.84 mi-crons, Rz_m=3.8 microns. The surface surface was analyzed utilizing an ETALON TCM 50 measuring magnifying lens. The quality of portion surface gotten by polyjet innovation is exceptionally great and isn't essential a post preparing of the RP portion. The part delivered on the Z Printer appears to have the least exactness and it is the foremost delicate (needs post-processing), but it was created much faster [DrNe11].

-Krol et. al (2012), Metal-based additive manufacturing processes require a supporting of overhanging portion regions amid the powder solidification e. g. for making strides the warm scattering to the substrate. Technology users these days endeavor to decrease support areas due to conservative angles, whereas at the same time improving the method stability by maximizing the support stiffness. For the simplification and acceleration of this support design procedure, the displayed work de-scribes a strategy for optimizing back structures by implies of finite element models. Subsequently, the most approaches are covering a fractal adjustment of the back format and an optimization of piece bolsters depending on the calculation comes about. The displayed strategies were connected by utilizing exploratory component[KZSM12].

-Verma and Rahul (2013), showed how Material wastage and energy consumption were two major concerns of the process that requires immediate attention. In their research, a multi-step optimization enabling additive manufacturing process towards energy efficiency was developed. Process objectives were minimized both in part and layer domain. Numerous examples were presented to demonstrate the applicability of the developed approach. The models formulated here for selective laser sintering (SLS) process could be easily extended to other additive manufacturing technologies. The energy consumed by the selective laser sintering (SLS) machine during whole part build could be categorized into: (1) processing energy, and (2) non-processing energy (see fig. 1). Non-processing energy consists of energy consumed by machine during recoated arm movement, build piston movement (upward/downward), and initial heating. On the other hand, processing energy consumption is largely determined by the amount of material which is required to be fused together to build the whole part. . In the present research, both processing and non-processing energy consumption is minimized by (1) reducing the number of recoated arm movement, build piston movement, and (3) optimizing the laser scan movement to sinter the part for each layer(sls)[VeRa13].

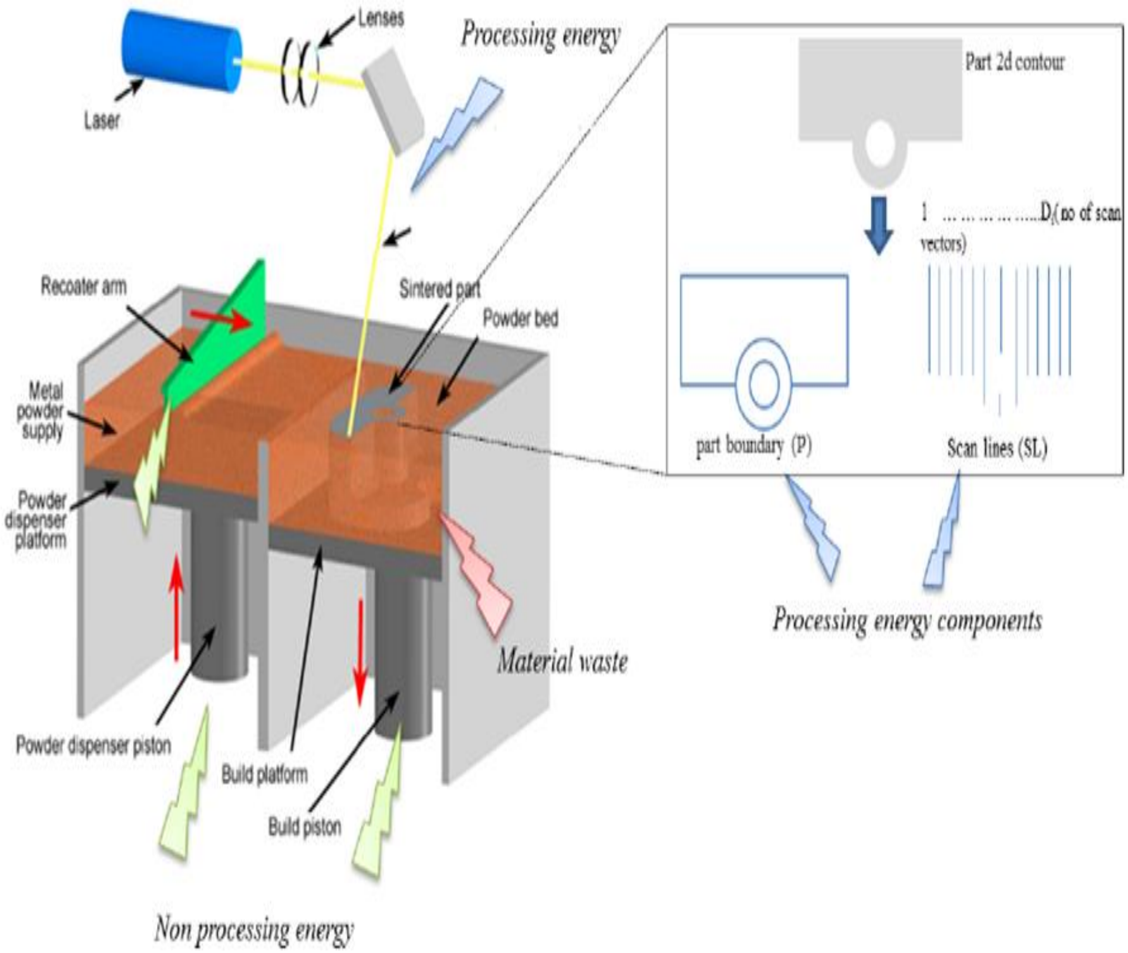

Fig1:Schematic of selective laser sintering (SLS) with highlighted energy components[VeRa13].

-Rezaie et. al. (2013), Hybrid additive-subtractive manufacturing gained popularity by making full use of geometry complexity produced by additive manufacturing and dimensional accuracy derived from subtractive machining. Part design for the hybrid manufacturing approach has been done by trial-and-error, and no dedicated design methodology exists for this manufacturing approach. To address this issue, this work presents a topology optimization method for hybrid additive and subtractive manufacturing. To be specific, the boundary segments of the input design domain were categorized into two types: (i) Freeform boundary segments freely evolve through the casting SIMP method, and (ii) shape preserved boundary segments suppress the freeform evolvement which composed of machining features through a feature fitting algorithm[RBGM13].

-D. Panesar et. al (2013), there work investigated design analysis and optimization methods for the integration of active internal systems into a component for manufacture using multi-material 3D-Printing processes. This enables efficient design of optimal multifunctional components that exploit the design freedoms of additive manufacturing (AM). The main contributions of two area contain: 1) the automated placement and routing of electrical systems within the component volume and, 2) the accommodation of the effect of this system integration on the structural response of the part through structural topology optimization (TO). A novel voxel modeling approach was used to facilitate design flexibility and to allow direct mapping to the 3D-Printer jetting nozzles[BPAW13].

-Tobergte et. al (2013), showed how Additive manufacturing could make complex shapes very effortlessly since it works by layer-by-layer. This is often an on- going field of investigate and not numerous optimization algorithms make utilize of the advantages of additive manufacturing. Various researches are done in the field of optimization which are coordinated towards Homogenization and Solid Isotropic material with Penalization (SIMP). But most of the strategies drive the convergence to either completely thick or void material. Since additive manufacturing could fabricate halfway densities fundamental strategy of SIMP with no penalization proposed. The coming about fabric dissemination is fabricated through Fused Deposition Modeling [ToCu13].

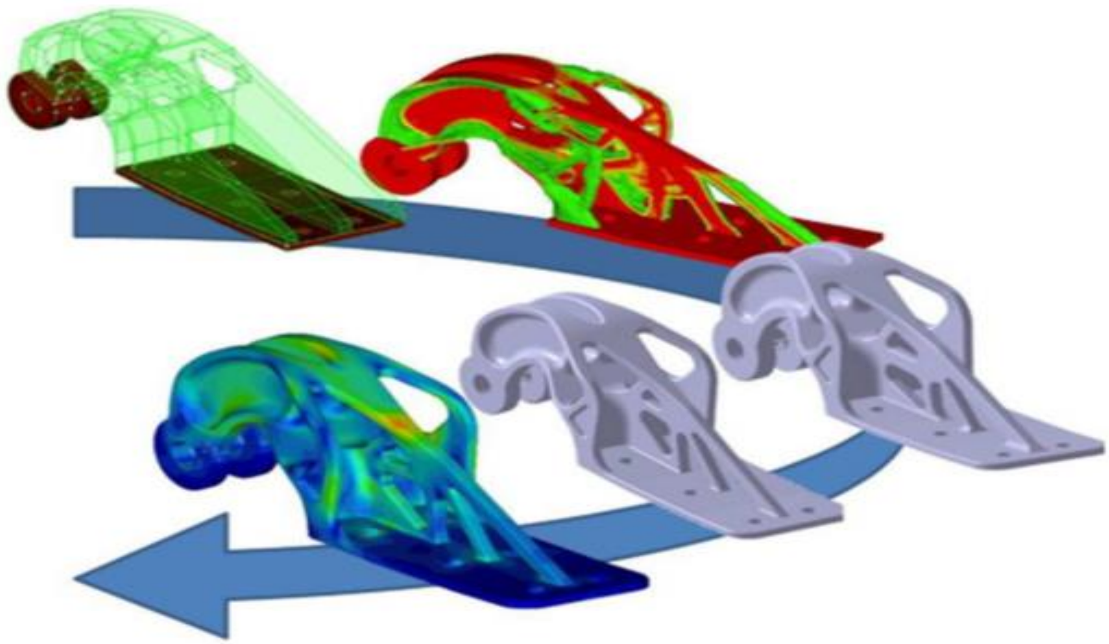

Fig 2:-Optimization loops two of aerospace part.

-Paul, Ratnadeep(2013), focused on the Metal powder based Additive Manufacturing (AM) processes which was creakingly being accepted across several industries such as aero-space, automobile, medical, consumer products and electronics systems. However, the most pressing issues faced by AM technology concerned to achieving part accuracy and excessive material and energy utilization. Therefore, a comprehensive part-level approach analyzing the relation between the different physical phenomena occurring during the manufacturing of a metal AM part is required. The virtual manufacturing model simulated the geometry of the AM part using computational geometry techniques. Points are sampled from the surface of the simulated parts simulated and used for calculating the Geometric Dimensioning and Tolerance (GD&T) errors and also for correlating these errors to the input parameters[Paul13].

-T.CROL(2013),showed how several tendencies like market globalization induce an increased usage of additive manufacturing technologies in different branches (e.

g. mold and tool making, medical devices, aerospace and automotive industry). A resource efficient application of these processes requires a high process stability and reproducibility. These target figures were reached by numerous test rigs at the manufacturing system which cause high resource consumption and an uneconomic application of these processes. A virtual process design prior to the building phase used opportunity to enhance the process efficiency of metal-based, additive processes. Previously developed technology specific simulation models enable users to examine and optimize different process parameter compositions. Though, whilst planning the design of experiments study for the simulation based optimization, it should be considered, that with every single additional process parameter which is thereby taken into account the calculation time increases significantly. Regarding this fact, the presented research works in this publication which include procedure models for an efficient and target figure dependent analysis of a high amount of different process parameter constellations by means of the developed simulation models. Methods and procedures for the identification, categorization and prioritization of influencing parameters and their interdependencies amongst each other are shown for the target figure “dimensional accuracy” and with utilizing the alloy AlSi12. The results of these investigations are summarized in a process-specific prioritization and correlation matrix [KrSZ13].

-Rogers and Ierapetritou (2014), provided an overview of the challenges associated with modeling and optimizing particulate processes and discussed the opportunities for improving pharmaceutical process development through the use of concepts from process systems engineering.

Process systems engineering (PSE) tools could play a role in developing robust and economically efficient manufacturing processes. However pharmaceutical companies had lagged behind other specialty chemical manufacturers in the adoption of these tools. This was in part due to the challenges associated with modeling and optimization of solids-based processes. However recent advances in the modeling of particulate processes and the optimization of complex process models have created opportunities to apply PSE methods to pharmaceutical manufacturing processes [RoLe14].

-A.roger et. al(2014),investigated about The pharmaceutical industry which currently faced economic and regulatory challenges associated with process development. This was in part due to the challenges associated with modeling and optimization of solids-based processes. However recent advanced in the optimization of complex process models have created opportunities to apply PSE methods to pharmaceutical manufacturing processes. This work will provide an overview of the challenges associated with modeling and optimizing particulate processes and discuss opportunities for improving pharmaceutical process development through the use of concepts from process systems engineering[RoIe14].

-E.vilalpando et. al (2014), explained how Fused deposition modeling (FDM) in an additive fabrication process that build a part from extruded filaments of a melted thermoplastic. Several studies have focused on the depositing parameters; however, none of them have characterized internal support structures in different geometrical arrangements. The incorporation of reconfigurable parametric internal matrix structures based on primitive elements will balance the mechanical properties, the material usage and the build time. Parametric internal structures were designed, and compressive test components built and tested both experimentally and used simulation tools to depict the compressive characteristics. Extensive physical tested as the components built by the FDM process have anisotropic properties. The material usage, build time, and loading characteristics were captured for a variety of parametric structures (solid, shell, orthogonal, hexagonal, pyramid) built orientations, and internal densities (loose, compact). From this data, a model was developed that serves as a predictive tool to: (i) estimate the mechanical properties and (ii) calculate the build time and materials utilized based on various internal structural configurations for the component's application. A model that generates an optimal solution (minimum material, minimum build time, etc.) needs to be developed.(see figure 3.) Using the collected data as a foundation, an optimization model that considered the built time, material usage, surface finish, interior geometry, strength characteristics, and related parameters is presented and could be used to assist designers making informed decision with respect to strength, material usage and time, etc[ViEU14]**.**

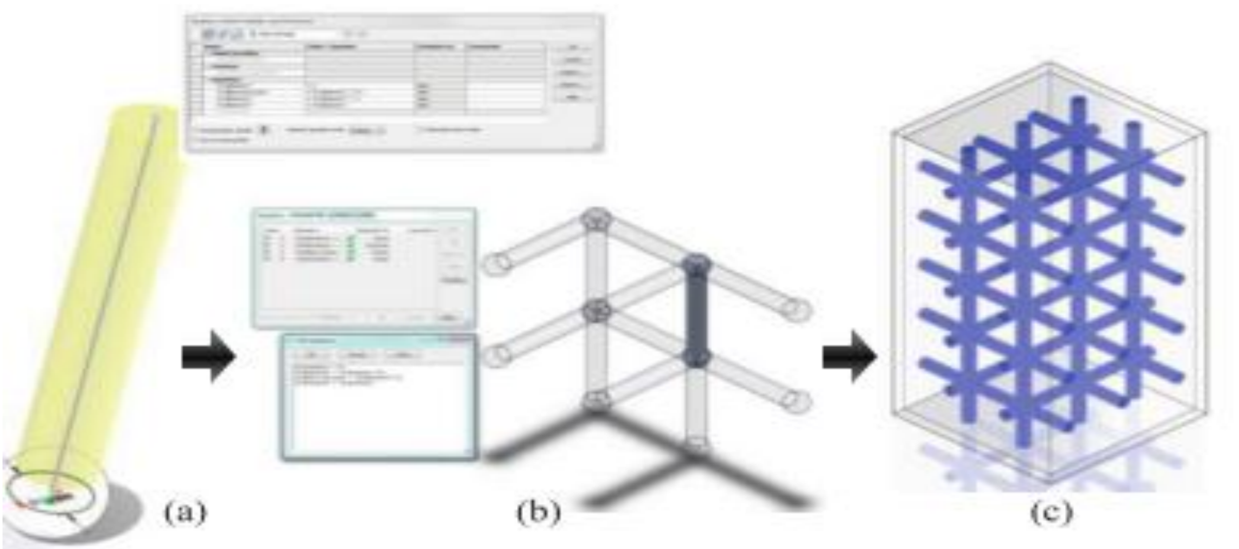

Fig.3 :-Parametric modeling of the modifiable element structure (a), the, parametric web-like structure, and (c) the internally modified shelled part [2][ViEU14]**.**

-Y,jin et .al (2014), proposed a tool-path generation approach for material extrusion-based additive manufacturing (AM) that considered the machining efficiency and fabrication precision, which inherent drawback of general AM techniques compared with conventional manufacturing methods. The proposed approach aims to tackle the generation of direction-parallel tool-paths for the interior filling of simple connected areas, which comprises three main steps: (1) determining the inclination of reference lines; (2) generating and grouping tool-path segments into individual sub-paths; and (3) linking sub-paths based on specific requirements. These three modules interacted to affect the efficiency and precision of AM significantly. In order to found an optimal inclination, at first the impacts on the fabrication efficiency and manufacturing accuracy analyzed with different inclinations. A comparatively accreted building time model subsequently developed to obtain the optimal tool-path inclination, but without compromising the machining precision, based on the analysis of a geometrical accuracy model. The proposed approach employed different inclinations in distinct layers according to specific manufacturing scenarios and technological requirements. After determining the reference lines, the tool-path segments were selected and grouped based on some characteristics (e.g., the number of intersections between reference lines and boundaries) to make up individual sub-paths, which connected to a zigzag-shaped path with short line segment connections. In the module for sub-path linked, some strategies were introduced to decrease the number of useless tool-paths, i.e., uncut paths, which could jeopardize the manufacturing quality by frequently turning the print head on and off. In addition, parametric curves are used to link the final sub-paths to avoid deceleration/acceleration processes in the end/starting parts of the sub-paths. The proposed approach has been used in practice to generate tool-paths for a wide range of models and the results verify its effectiveness and obvious advantages[JHFG14].

-F.riss et .al(2014),Due to their feasible geometric complexity, additive layer manufacturing (ALM) processes showed a high potential for the production of lightweight components. Therefore, ALM processes enable the realization of bionic-designed components like honeycombs, depending upon load and outer boundary conditions optimization was used, based on a closed-loop, three-step methodology: At first, each honeycomb was conformed to the surface of the part. Secondly, the structure was optimized for lightweight design. It was possible to achieve a homogeneous stress distribution in the part by varying the wall thickness, honeycomb diameter and the amount of honeycombs, depending on the subjected stresses and strains. At last, the functional components like threads or bearing carriers are integrated directly into the honeycomb core. Using all these steps as an iterative process, it is possible to reduce the mass of sandwich components about 50 percent compared to conventional approaches[ChLe14].

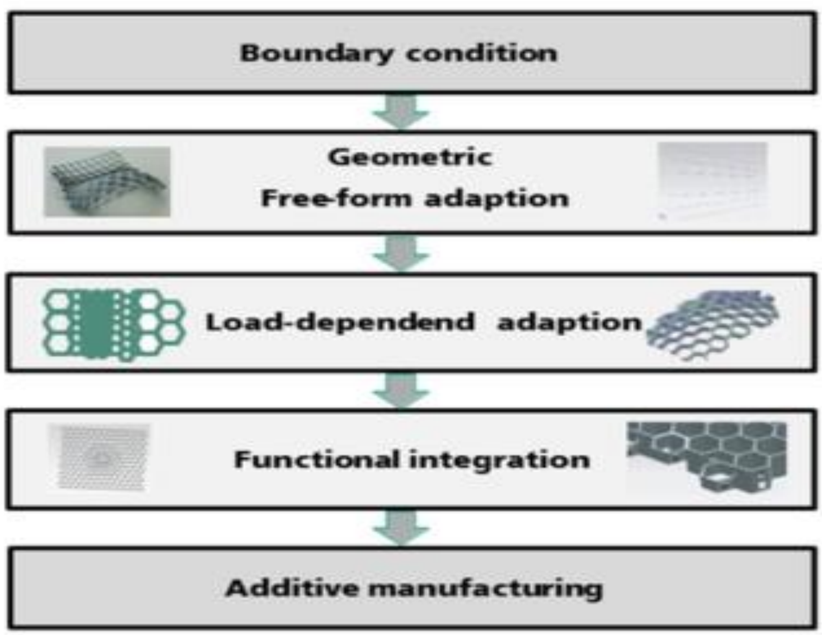

Fig 4.:-. Procedure for the design of three dimensional, load-dependent sandwich components. Free-form surface adaption[RiSR14]

-N.gardan et. al (2015), showed how Rapid prototyping (RP) and more generally Additive Manufacturing (AM) enable the manufacture of complex geometries, which was very difficult to build with classical production. Different kind of material used numerous technologies. For each of these, two materials exist: the production material and the support one. Support material, cleaned and becomes a manufacturing residue in most cases, the material volume and the global mass of the product Improved, and an essential aim surrounding the integration of simulation in additive manufacturing process. Moreover the layer-by-layer technology of additive manufacturing allowed the design of innovative objects and the use of topological optimization in this context could create a very interesting combination. The purpose of these paper is to present a methodology and a tool, which allow the use of topological optimization for the preparation of model for RP and AM[GaSc15].

-Jahan and Suchana A (2015), a framework for optimizing additive manufacturing of plastic injection molds presented in this work. The proposed system consists of three modules, namely process and material modeling, multi-scale topology optimization, and experimental testing, calibration and validation. Advanced numerical simulation is implemented for a typical die with conformal cooling channels to predict cycle time, part quality and tooling life. A multi-scale thermo-mechanical topology optimization algorithm was developed to minimize the die weight and enhance its thermal performance. The technique was implemented for simple shapes for validation before it is applied to dies with conformal cooling in future work. Finally, material modeling using simulation such as design of experiments is underway for obtaining the material properties and their variations[WJKT15].

-A.gainor et. al (2015), showed how Topology optimization was a powerful free-form design tool that couples finite element analysis with mathematical programming to systematically design for any number of engineering problems. Additive manufacturing (AM), specifically by 3D-Printing, which is a manufacturing process where material was added through deposition or melting in a layer-by-layer fashion. Additively manufactured parts were 'built' from the bottom up, allowing production of intricate designs without extra effort on the part of the engineer or technician – complexity was often said to be 'free'. This dissertation seeks to leverage the full potential of this burgeoning manufacturing technology by developing several new design algorithms based on topology optimization. These include multi-material projection methods appropriate for multiphase 3D-Printers, an overhang-prevention projection method capable of designing components that do not need sacrificial anchors in metal AM processes, and models for simultaneously optimizing topology and objects embedded in process. These algorithms were demonstrated on several design examples and shown to produce solutions with capabilities that exceed existing designs and/or that require less post-processing in fabrication[Gayn15].

-Lching et. al (2015) indicated that Cellular structures are promising candidates for additive manufacturing to design lightweight and complex parts to reduce material cost and enhance sustainability. Focus on the integration of the topology optimization with the additive manufactured cellular structures. To take advantage of these two technologies for light-weight manufacturing, a totally new design and CAD method was developed to build up the bridge between the optimal density distribution and the cellular structure. First, a systematic theoretical and experimental framework was provided to obtain the mechanical properties of cellular structures with variable density profile. Second, a revised topology optimization algorithm was introduced to optimize arbitrary 3D models with given boundary conditions. In this process, the minimum compliance problem and allowable stress problem were considered to get the relative density distribution. Third, CAD methods were developed to obtain the function between the local relative density and the variable density of cellular structure. With the aid of the function, one can convert the density distribution to the cellular vertex radius distribution and build variable density cellular structures in the given parts. Finally, a real part named pillow bracket is designed by this process to illustrate the efficiency and reliability of the new method[CZBB15].

-N.chin et. al (2015), indicated that Binder Jetting (BJ) process is an Additive Manufacturing (AM) process in which powder materials were selectively joined by binder materials. Products could be manufactured layer by layer directly from 3D model data. It was not always easy for manufacturing engineers to choose proper BJ process parameters to meet the end-product quality and fabrication time requirements. Due to the quality properties of the products fabricated by the BJ process were significantly affected by the process parameters. The relationships between process parameters and quality properties were also very complicated. The BJ AM process involved many different disciplines and physics theories, such as 3D computer graphics, Computer Numerical Control (CNC), metallurgy theory, materials science and chemistry, etc. a process model was developed by the Backward Propagation (BP) Neural Network (NN) algorithm based on 16 groups of orthogonal experiments designed by the Taguchi Method to express the relationships between 4 key process parameters and 2 key quality properties. The result also converted to Signal-to-Noise (S/N) ratios and analyzed by the Analysis of Variance (ANOVA). An intelligent parameters recommendation system was developed to predict end-product quality properties and printing time with a given design. It could recommend process parameters based on the quality requirements. Some physical interpretations was introduced to explain the experiment results. The research outcome could be used as a guideline for selecting the proper printing parameters to achieve the desired properties and help to improve the quality control of components fabricated by the BJ AM process[Chen15].

-k.salonitis et. al (2015), showed how Improvements in additive manufacturing technologies have the potential to greatly provide value to designers that could also contribute towards improving the sustainability levels of products as well as the production of lightweight products. With these improvements, it was possible to eliminate the design restrictions previously faced by manufacturers. The principles of additive manufacturing examined, design guidelines, capabilities of the manufacturing processes and structural optimization using topology optimization. Furthermore, a redesign methodology was proposed and illustrated through a redesign case study of an existing bracket. The optimal design was selected using multi-criteria decision analysis method. The challenges for using additive manufacturing technologies are discussed. The proposed methodology addressing this challenge was characterized by several advances in how the redesigned and optimized models were approached. These advances were briefly:

• A new way of thinking by starting straight from the characteristics of the chosen ALM technology and the functional specifications of the component to design, Designers could found the geometry that optimizes the use of the chosen ALM technology characteristics while meeting the functional specifications of the part.

• The use of topology optimization to realize and optimized geometry of the model by removing all unstressed material from the part. Designers could compare the existing and the optimized design to found alternatives than could be manufactured by the chosen ALM process.

• MCDA analysis helps designers to choose one final design from the optimized designs. This analysis depends on predefined criteria than could be collected from the client[SaZa15].

-M.chcu et. al(2016),indicated that Medical implants were usually mass produced in fixed sizes, shapes and material properties. However, this process was not sustainable due to high levels of material wastage resulting from unused products because of the low demand of particular sizes. Furthermore, these modular implants were not optimized to specific patient's anatomy in terms of geometry, material composition and properties. This often leaded to risk of injury, implant displacement, impairment of intended functions or even rejection by the host body, thus contributing to further healthcare costs, implants wastage and discomfort to patient. Patient-specific design methods have been investigated to tailor implant design and material composition to the patient's anatomy. With patient-specific implant modeled and simulated, rule-based methods, Genetic Algorithm (GA) and material knowledge bases are used to perform multi-objective optimization of the material composition for additive manufacturing. This method is investigated with reference to the design and fabrication of a patient-specific ENT implant[ChCh16].

-R.rao et. al(2016),showed how The success of any RP process in terms of these performance measures entails selection of the optimum combination of the influential process parameters. Thus, in this work the single-objective and multi-objective optimization problems of a widely used RP process, namely, fused deposition modeling (FDM), are formulated, and the same are solved using the teaching-learning-based optimization (TLBO) algorithm and non-dominated

Sorting TLBO (NSTLBO) algorithm, respectively. The results of the TLBO algorithm are compared with those obtained using genetic algorithm (GA), and quantum behaved particle swarm optimization (QPSO) algorithm. The TLBO algorithm showed better performance as compared to GA and QPSO algorithms. The NSTLBO algorithm proposed to solve the multi-objective optimization problems of the FDM process in this work is a posteriori version of the TLBO algorithm. The NSTLBO algorithm was incorporated with non-dominated sorting concept and crowding distance assignment mechanism to obtain a dense set of Pareto optimal solutions in a single simulation run. The results of the NSTLBO algorithm are compared with those obtained using non-dominated sorting genetic algorithm (NSGA-II) and the desirability function approach. The Pareto-optimal set of solutions for each problem was obtained and reported. These Pareto optimal set of solutions will help the decision maker in volatile scenarios and are useful for the FDM process[RaRa16]**.**

-Clausen et. al (2016) al showed how the so-called coating approach to topology optimization provides a means for designing infill-based components that possess a strongly improved buckling load and, as a result, improved structural stability. The suggest approach thereby addressed an important inadequacy of the standard minimum compliance topology optimization approach, in which buckling is rarely accounted for; rather, a satisfactory buckling load is usually assured through a post-processing step that may lead to sub-optimal components. Their work compared the standard and coating approaches to topology optimization for the MBB beam benchmark case. The optimized structures were additively manufactured using a filamentary technique. This experimental study validated the numerical model used in the coating approach (see Fig. 5). Depending on the properties of the infill material, the buckling load might_be more than four times higher than that of solid structures optimized under the same conditions [ClAS16].

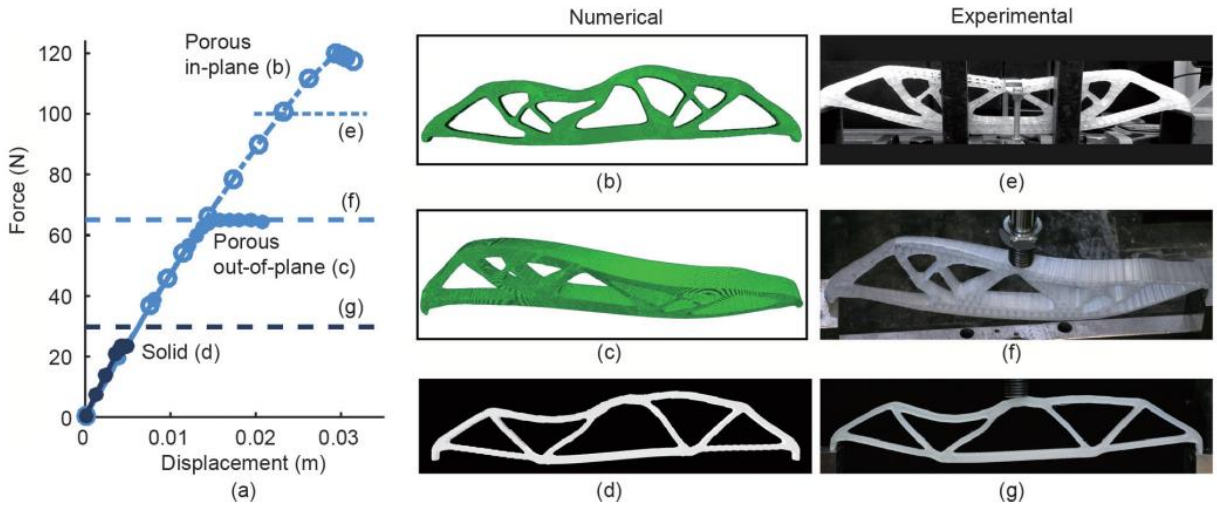

Fig 5. Buckling analysis. (a) Comparison of the geometrically nonlinear numerical response (curves with arc-length steps indicated) with experimentally observed buckling loads (two lower horizontal dashed lines); (b)–(d) numerically determined mode shapes corresponding to curves in (a); (e) experimental response of the porous structure to a load of 100 N, indicated by the upper dashed line in (a); (f) and (g) experimental mode shapes corresponding to numerical shapes (c) and (d), with buckling load indicated by the two lower dashed lines in (a).[Clau16]

-T.pfeifer et. al (2016), one of the most common Additive Manufacturing (AM) technologies is Fused Filament Fabrication (FFF), more commonly known by the trademarked name "Fused Deposition Modeling™" (FDM™). As FFF continues to gain popularity as a method of manufacturing, an understanding of all factors involved in the FFF process becomes essential.

Four primary printing parameters studied to understand, and the effects on part quality, solidity, and strength also studied. These printing parameters are extrusion rate, nozzle travel speed, layer height, and path width. A recommendation for the determination of optimal extrusion temperature and feed rate was found. A theoretical relationship be-tween the four print parameters was developed. The resulting solidity was found to vary throughout a printed part, which has effects on the predictability of part strength. Micro computed tomography was proven valuable in this analysis as well as being an effective tool for investigating the bead structure[PKHC16].

-T.zegard et. al (2016), showed that Additive manufacturing, a rapidly evolving field, fills the gap between topology optimization and application. Additive manufacturing has minimal limitations on the shape and complexity of the design, and new materials has been currently evolved, higher precision and larger build sizes. Two topology optimization methods addressed: the ground structure method and density-based topology optimization. The results obtained from these topology optimization methods require some degree of post-processing before they could be manufactured, some inherent issues of the optimization technique might be magnified resulting in an unfeasible or bad product. In addition, these work aims to address some of the issues and propose methodologies by which they might be alleviated. The proposed framework has applications in a number of fields, with specific examples given from the fields of health, architecture and engineering. In addition, the generated output allowed for simple communication, editing, and combination of the results into more complex designs. For the specific case of three-dimensional density-based topology optimization, a tool suitable for result inspection and generation of additive manufacturing output was also provided[ZePa16].

-O.gutnichenko (2016), indicated that Intermittent turning the slotted work pieces was always accompanied with a high impact load of the machine tool during the entry phase of the cutting edge. A strong dynamic response of the system leaded in the process and results in vibrations arose and potential tool life and surface finish issues. The present study addresses the modeling of cutting force build-up process with further optimization of cutting edge geometry where tooltip overshoot during the tool entry was selected as an objective function. The model takes into consideration the interaction between three units of the machine tool such as a tool, tool post, and work piece as well as an influence of the process on the system's dynamics[GuAS17].

-E.ceretti et. al (2017), showed that one of the most applied strategies in tissue engineering consists in the development of 3D porous scaffolds with similar composition to the specific tissue. In fact, the microstructure of the scaffolds influences the final structure of the in growing tissue. Multi-layered PCL scaffolds were produced with modified FDM printer in order to analyze the influence of the extrusion technology (filament or powder extrusion head) and of the process parameters on the deposited material. In particular, dimensions and uniformity of both deposited filament and grid of the scaffolds were analyzed to understand the influence of the process parameters so as to optimize the FDM production technology[CGNF17].

-S.barbiery et. al (2017), proved an overview methodology for the design of a motorcycle piston was presented, based on topology optimization techniques. In particular, a design strategy was preliminary investigated aiming at replacing the standard aluminum piston, usually manufactured by forging or casting, with an alternative one made of steel and manufactured via an Additive Manufacturing process. In this methodology, the mini-mum mass of the component was considered as the objective function and a target stiffness of important parts of the piston was employed as a design constraint. The results demonstrated the general applicability of the methodology presented for obtaining the geometrical layout and thickness distribution of the structure. A method for a computer aided steel piston design has been proposed. In particular, the presented methodology aimed at finding more efficient layout solutions for the piston framework feasible with Additive Manufacturing techniques. The authors employed topology optimizations to define the optimal structural topology. Special care has to be taken in setting up the optimization process since the choice of the constraints, i.e. the performance targets, of the mesh size and quality and of the optimization parameters directly affect the outcome of the process[BGMM17].

-J.lopez-castro et. al (2017), indicated that DMLS (Direct Metal Laser Sintering) Additive manufacturing allows building topological optimized geometries with good mechanical properties and low weight. These features are appropriated for the aeronautical industry because the reduction of weight involves saving costs per trip. However, the manufacturing cost using SLM (Selective Laser Melting) or DMLS, is also high since titanium alloys powder is expensive. Therefore, this work point to explore the possibility of using 15-5PH stainless steel powder to balance the mechanical properties, weight and cost of the part[LMGB17].

-G.allaire et. al (2017), This article addresses one of the major constraints imposed by additive manufacturing processes on shape optimization problems – that of overhangs, i.e. large regions hanging over void without sufficient support from the lower structure. After revisiting the ‘classical’ geometric criteria used in the literature, based on the angle between the structural boundary and the build direction, a new mechanical constraint functional proposed, which mimics the layer by layer construction process featured by additive manufacturing technologies, and thereby appeals to the physical origin of the difficulties caused by overhangs. This constraint, as well as some variants, is precisely defined; their shape derivatives were computed in the sense of Hadamard's method, and numerical strategies were extensively discussed, in two and three space dimensions, to efficiently deal with the appearance of overhang features in the course of shape optimization processes[ADEF17].

-A.verma et. al (2017), showed that Additive manufacturing (AM) was considered as the standalone production house for customized parts of different varieties. AM has found applications in various industries including medical and aerospace for both prototyping and functional part fabrication. With rapid development in additive manufacturing technologies, the future of US manufacturing and economy clearly looked bright, process sustainability of such AM devices were not well studied. This paper addresses much needed sustainability aspects of additive manufacturing processes. More specifically, material wastage and energy consumption are two major concerns of the AM processes that requires immediate attention. Both process at layer and part level enabling additive manufacturing process towards sustainability was formulated and optimized. Numerous real world examples were demonstrated and compared against conventional approaches to demonstrate the applicability of the developed approach. The models formulated here for selective laser sintering (SLS) process could be easily extended to other additive manufacturing technologies with little or no modification. Limitations of proposed research were also discussed[VeRa17].

-S.jahan et. al (2017), This work presents a systematic and practical finite element based design optimization approach for the injection tooling adaptive to additive manufacturing (AM) technology using stereo-lithography (SLA) and powder bed fusion (PBF). First a thermos mechanical optimization of conformal cooling was implemented to obtain the optimal parameters associated with conformal cooling design. Then, a multiscale thermos mechanical topology optimization was implemented to obtain a lightweight lattice injection tooling without compromising the thermal and mechanical performance. The design approach was implemented to optimize a real design mold and the final optimal design was prototyped in SLA and the manufacture ability in PBF has been discussed[WJZZ17].

-J.liu (2017), showed that Hybrid additive-subtractive manufacturing was gained popularity by making full use of geometry complexity produced by additive manufacturing and dimensional accuracy derived from subtractive machining. Part design for this hybrid manufacturing approach has been done by trial-and-error, and no dedicated design methodology exists for this manufacturing approach. To address this issue, this work presents a topology optimization method for hybrid additive and subtractive manufacturing. To be specific, the boundary segments of the input design domain were categorized into two types: (i) Freeform boundary segments freely evolve through the casting SIMP method, and (ii) shape preserved boundary segments suppress the freeform evolvement and were composed of machining features through a feature fitting algorithm[LiTo17].

-W.guilan et. al (2017), indicated The improvements of surface quality and dimensional accuracy were critical for Wire and Arc Additive Manufacturing (WAAM). Multi-objective optimization process for Bainite steel additive manufacturing explained. The welding design matrix for conducting the experiments was made by using the Box Behnken design of response surface methodology (RSM). The input process parameters were varied at three levels which result in 46 experimental trials. The responses were measured during or after conducting the experiments. A second-order response surface model was developed and then multi-objective optimization was performed to obtain the desired surface appearance. The acceleration and staggered deposition processes were used to decrease the head dimension of single weld bead. The results show that the optimized sample surface appearance was smooth which has little spatters and no visible defects. Compared with the traditional processes which rely on overlapping rate adjustment but weaken the single weld bead morphology optimization, the process of this paper has comprehensive considerations of droplet transfer, heat input, and shaping coefficient. It enables the capacity of fabricating metal parts with high accuracy and lays a good foundation for Bainite steel additive manufacturing[YGHL17].

-A.aboutalib et. al (2017), explained Manufacturing parts with target properties and quality in Laser-Based Additive Manufacturing (LBAM) was crucial toward enhancing the “trustworthiness “of this emerging technology and pushing it into the main- stream. Most of the existing LBAM studies did not use a systematic approach to optimize process parameters (e.g., laser power, laser velocity, layer thickness, etc.) for desired part properties. a novel process optimization method proposed that directly utilizes experimental data from previous studies as the initial experimental data to guide the sequential optimization experiments of the current study.

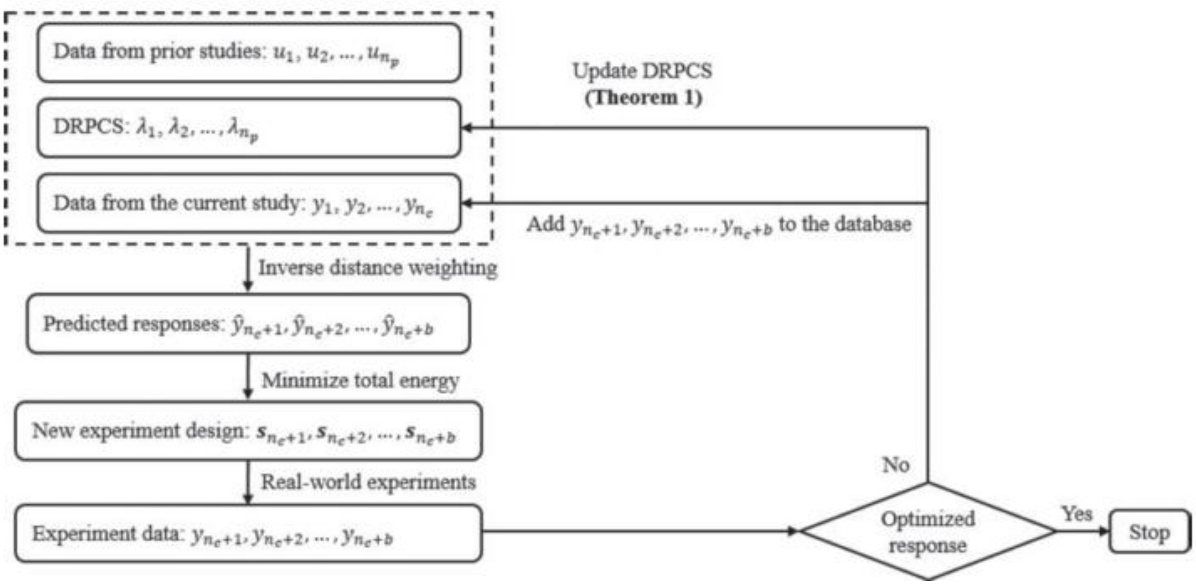

Fig 6 :-Framework of the proposed accelerated process optimization method[ABES09]

Total number of time- and cost-intensive experiments reduced. Method and test verified to performance via comprehensive simulation studies that test various types of prior data. The results showed that their method significantly reduced the number of optimization experiments, compared with conventional optimization methods. And also conduct a real-world case study that optimizes the relative density of parts manufactured using a Selective Laser Melting system. Combination of optimal process parameters was achieved within five experiments[ABES17].

-C. dapogny et. al (2017), A new functional of the domain proposed, to be used in shape and topology optimization problems as a means to enforce the manufacturability of structures by additive manufacturing processes. The main idea has to be build a piecewise affine approximation of the cost function and of its shape derivative by using the derivative of the elastic displacement with respect to the height of the intermediate structure[ODFM17].

-R.weldman et. al (2017), a method was presented for combining topology optimization with an approximate additive manufacturing process model so as to reduce thermal distortions induced during the build process. Thermal distortions were detrimental in any manufacturing process, though in some additive manufacturing processes these distortions might cause a build to completely fail. Here, 2 approximate manufacturing models were used in conjunction with a compliance minimization topology optimization problem. First, a quasi-static thermos mechanical model was used that approximates distortions induced by the cooling of the material. Second, an element birth model was used in which elements were activated in turn, and a similar quasi-static thermos mechanical problem was used at each step. The overall algorithm used a compromise objective function to weight the 2 goals: thermal displacement minimization and compliance minimization. These models were compared along with a strict overhang constrained method[WiGa17].

-G.allaire et. al (2017), the goal of these constraints was to take into account the thermal residual stresses or the thermal deformations, generated by processes like Selective Laser Melting, right from the beginning of the structural design optimization. In other words, the structure was optimized concurrently for its final use and for its behavior during the layer by layer production process. It was well known that metallic additive manufacturing generates very high temperatures and heat fluxes, which in turn yield thermal deformations that may prevent the coating of a new powder layer, or thermal residual stresses that may hinder the mechanical properties of the final design. The target was to avoid these undesired effects, Shape derivatives were computed by an adjoin method and were incorporated into a level set numerical optimization algorithm. Several 2-d and 3-d numerical examples demonstrate the interest and effectiveness of their approach[AlJa17] **.**

-C.dapogny et. al (2017), The article used to contribution of the effect of modelling proper-ties of the constituent material of structures fabricated by additive manufacturing technologies, and of how they influence the design optimization process. On the one hand, emphasizing on the case where the particular material extrusion techniques were used, a model proposed for the anisotropic material properties of shapes depending on the (user-defined) trajectory followed by the machine tool during the assembly of each of their 2d layers. On the other hand, advantage of the potential of additive manufacturing technologies for constructing very small features checked , and trying to consider the optimization of the infill region of shapes with the goal to improve at the same time their lightness and robustness. The optimized and constrained functional of the domain involved in the shape optimization problems in these two contexts were rigorously analyzed, notably by relying on the notion of signed distance function. Eventually, several numerical experiments were conducted in two dimensions to illustrate the main points of the study[DEFM17].

-A.qattawi et. al (2017), explained how The Additive Manufacturing (AM) technology initially was developed as a rapid prototyping tool for visualization and validation of designs. The recent development of AM technologies, such as Fused Deposition Modelling (FDM), was driving it from rapid prototyping to rapid manufacturing. However, building end-user functional parts using FDM proved to be a challenging task. The difficulty arises from the large number of processing parameters that affect the final part design such as: building direction, extrusion temperature, layer height, infill pattern and more. The processing parameters of FDM influence the quality of the parts and their functionality. In addition, a more systemic understanding is required to elaborate on the impact of the FDM processing parameters on the final part's mechanical properties, dimensional accuracy and building time. The presented paper provides an experimental study to investigate the independent effect of each processing parameter on the mechanical properties and dimensional accuracy repeatability of FDM parts. A total of 18 test specimen samples were printed using varying processing parameters. In order to investigate the repeatability and resulted tolerances, the dimensions of these specimens were measured and compared with a 3D CAD model. The presented work utilizes a tensile test per ASTM D638 standards to obtain the mechanical properties of each fabricated sample. In addition, the work provides a Finite Element Analysis (FEA) model for AM parts. The work suggested to simulate their behavior under mechanical loads for future investigation on the coupled effects of processing parameters[AQAG17].

-S.mantovany et. Al (2017), showed how Topology Optimization (TO) methods optimize material layout to design light-weight and high-performance products. However, TO methods, applied for components or assembly with high complexity shape or for structures with copious number of parts respectively, do not usually take into account the manufacturability of the optimized geometries, then a heavy further work was required to engineer the product, risking to compromise the mass reduction achieved. Within an Industry 4.0 approach, manufacturing constraint to evaluate since early stages of the conceptual design to perform a TO coherent with the manufacturing technology chosen. Several approach of TO with different manufacturing constraints such as casting and extrusion were proposed and each solution was compared. The optimum conceptual design was determined in order to minimize the component weight while satisfying both the structural targets and the manufacturing constraints; a case study on a high- performance sport car dashboard was finally presented,(see fig 6.)[MPCB17].

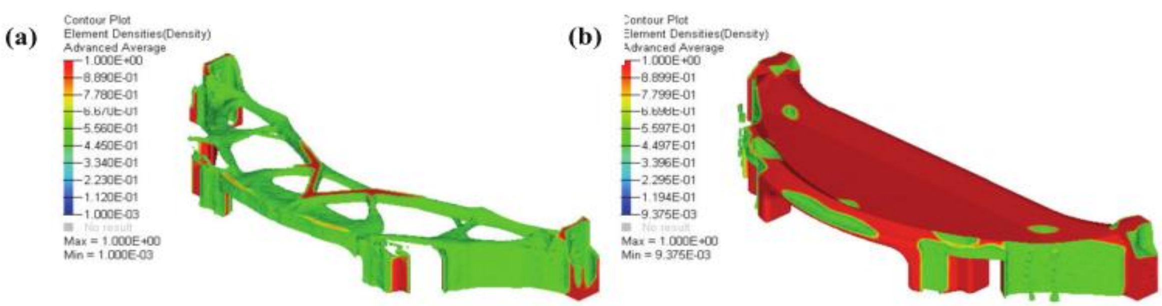

Fig 6:-Topology results with constrained mass 20% (a) and 80% (b) considering single draw constraints.[MPCB17]

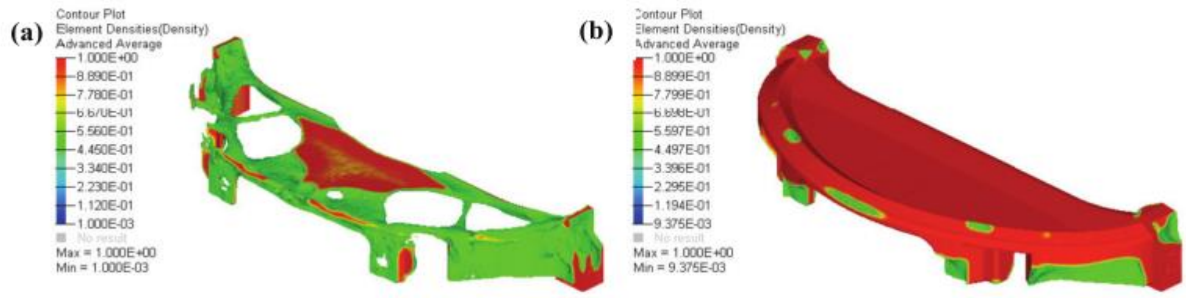

Fig 7.Topology results with constrained mass 20% (a) and 80% (b) considering double draw constraints[MPCB17]

-D.walton et. al (2017), showed how investigates a design and development process for Electron Beam Melting (EBM) which incorporates a simulation-driven design process called topology optimization. Research consists of a review of EBM design principles and validation of mechanical properties for Ti-6Al-4V ELI. Findings were applied to a case study whereby a pair of suspension uprights are redesigned and manufactured by EBM with the objective of mass reduction. Previous studies indicated that optimization shape controls could potentially minimize the number of supports required for EBM. Mean-while, a parametric solid/surface modeling approach can allow for greater control of design intent when designing for larger assemblies or structures. Application of the proposed strategy resulted in the case study having a 36 % reduction in mass in comparison to a CNC aluminum design. Whilst the EBM alternative design also yields an 86% reduction in raw material use, there was a sevenfold increase in cost for manufacture alone. There work is an example of topology optimization being a suitable approach when designing for AM (DfAM). But, the cost and time constraints associated with EBM limits application of the process to high-performance industries such as motorsport, aerospace, or tooling solutions[WaMo17].

-D.coupek et. al (2018), indicate that Optimization and path planning methods for multi-axis additive manufacturing presented with conventional three-axis systems. There includes an adaptation of the building direction and an algorithm for the special case of cylindrical axes. These methods can reduced the production time drastically by avoiding support structures and by using the integration of predefined building blocks to substitute the infill. Those limitations could be overcome by multi-axis FDM including more than three axes in machine kinematics. There allows to replace the work piece infill by assembled elements. The resulting base body serves as starting point for the surface printing, which requires new methods for path planning in order to exploit the full potential of multi-axis systems. However this technology will explore new application domains and industrial products[CFBR18].

-S.liu et. al (2018),showed how A powerful design approach which was Topology optimization used for determining the optimal topology in the form of discrete densities or continuous boundaries to obtain desired functional performances. The filter method was used to ensure the characteristic preserving. After their process, the distribution of the nodes in the boundary of the topology optimization results is denser, which benefits the subsequent curve fitting. By using the curvature and it was derivative of the uniform B-spline curve, an adaptive B-spline fitting method was proposed to get a parametric CAD model with fewest control points[LLLC18].

Chapter 4

Conclusions

Conclusions

This study is about literature review consist of 3 chapters, it generally emphasizes on additive manufacturing (AM) about optimizations and modeling techniques. In the chapter one 16 references was used and gathered in this study, that emphasize on extrusion, powder, and resin based 3D-Printing.

In the second chapter 50 studies were used that accentuate modeling in AM punctuating from 2003 to 2018. Our survey has concluded that most of the studies had been published in 2016 and 2017.

The third chapter concentrated on the optimization. Totally, 49 studies were used chronologically published from 1999 till 2018. Most of the researches on optimization were published in 2017. This indeed showed the increasing importance of 3D-Printing. As the result more than 100 studies were gathered that helps professionals get more information in a shorter period of time as most of the results are listed in this project.

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