Innovation in Agriculture Accelerated by FAB

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Agriculture is truly a complex system which consists of meteorological system, ecosystem, and farming. Only to control plant growth in filed, or to breed new cultivars, we need enormous time series data such as air temperature, soil moisture, soil temperature, and plant growth rate. So we have been developing an IoT device, Field Server for monitoring fields. Recently we developed open source hardware version, Open-FS (open field server), using open source hardware, Arduino. Now components of Open-FS, UAV (drone) and new sensing devices for tailor-made breeding can be fabricated instantly by FAB (personal/digital fabrication).

We are constructing a platform (CLOP: CLoud Open Platform) to create the agricultural big data integrating open data and sensor data collected by IoT and M2M. The given objective in the project is to make farmers' income twice by optimal combination of farming technologies and cultivars, so we are developing "Income Doubler (ID)" on CLOP. Under this mission, we learned that the ID can be quickly created and improved utilizing open source technologies. Open source works as a kind of collective intelligence, and it will be accelerated by FAB with evolution in NGS (Next Generation Sequencer), Robotics, AI, and Quantum computing. The big wave of open source reached to open source seeds for DIY breeding and hand-made agricultural machines. Now, anyone may create not only foods but also new cultivars in in their own fields or plant factories (i.e. FabFarms).

Sooner or later farmers will be able to produce crops without working. That is, farmers will live on only unearned income like as the landed class. Simultaneously amount of jobs will be decreased in industries and population of the unemployed will be increased. However, it might not be serious problem, since they can feed themselves in FabFarms.

Center of Innovation on Global Fab Society- from '3D Printer' to 'IoT Fabricator'

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The Keio University Social Fabrication Center is leading a new research project called "Center of Innovation on Global Fab Society – for Kansei-oriented digital manufacturing", funded by COI: Center of Innovation (National Funding). One of main topics is developing "IoT Fabricator", based on current 3D printing technologies.

Functionally Graded Materials through Laser Engineered Net Shaping

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Functionally graded materials are a special class of heterogeneous materials in which the composition is gradually varied, over the component volume. This allows gradual variation of physical and mechanical properties within the component, with several potential advantages such as (a) tolerance to high thermal gradient due to gradual variation in thermo-physical properties and (b) improvement in the weight compensated mechanical property such as bend modulus of a cantilever beam, etc. Thus the structure and hence the properties can be tailor made. Digital manufacturing processes such as Laser Engineered Net Shaping (LENS) allow fabrication of such functionally graded materials by using multiple material powder feeders with controlled feed rates of powders on a moving substrate under a focused high power laser beam. The LENS process incorporates features from stereolithography and laser surfacing, using computer aided design file cross sections to control the forming process.

Recent work in the authors' laboratory has demonstrated that graded 3-D samples of functionally graded SS316 stainless steel – IN625 nickel base super-alloys could be successfully produced to near full density with good mechanical properties. A composite disc with IN625 powder (rim portion) and SS316 powder (disc portion) was deposited successfully. It is found that there is a good integrity between two materials at the interface. An integral turbine rotor could be realized from this composite disc with different functional properties at different locations. This technique is generic in nature that can be applied for producing composite cylinder/disc with any two metallic materials. In order to understand the microstructure evolution, thermal behaviour associated with LENS deposition of SS316 alloy is also numerically simulated, and the predictions are experimentally validated.

Another interesting work that is progressing concerns deposition of FGM panels of IN625 nickel base super alloy coated with layer- wise increasing contents of yttria stabilised zirconia as thermal barrier coating. Initial trials had problems like macro cracking, spalling of the deposit etc. Like plasma spray coatings, a bond coat is considered necessary to ensure adherence of the coating to the substrate, and Ni-Cr is found to be better as bond coat than Ni-Cr-Al-Y. Thermo physical properties of separately made 3-D cylindrical deposits of IN625-YSZ composites corresponding to intermediate layers of an FGM showed the properties to be intermediate to those of the alloy and the ceramic species. Presence of microscopic cracks in layers with higher YSZ contents is nonetheless observed, though the coating adheres well to the substrate even after 200 Nos. thermal cycles between RT and 1000 °C. Further work to reduce and to favourably re-align the cracks is in progress.

Efficient Process Planning Strategies for Additive Manufacturing

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Digital fabrication is a very promising technology being developed worldwide which enables direct fabrication of complex 3 D parts from their digital models using Additive Manufacturing (AM) processes. It significantly compresses product development time, particularly for small volume, intricate part production. AM processes however, have some limitations like relatively poor productivity, low part quality and production in the nonfunctional material. Researchers worldwide are thus, addressing these issues to improve productivity, accuracy and efficiency of AM processes.

This talk will focus on presenting our research work on the efficient process planning strategies for the fabrication of complex parts using AM processes. In particular, two important issues will be focused viz. Optimum Part Orientation and Hollowing. Part orientation directly governs the production time and part quality, while hollowing affects the material utilization.

Intelligent software has been developed which provides optimum orientation of a CAD part model for AM fabrication. A genetic algorithm based Multi objective optimization strategy has been used considering a weighted objective function of build time, part quality and material requirement. Novel strategies for 2 D and 3 D part hollowing have been proposed and analyzed to recommend a new optimum strategy called Auto filling. Algorithms have been developed for automatic generation of support structures for hollowed parts, if required. The software has been rigorously tested for several complex CAD part models which were actually fabricated. Results of these case studies will be presented.

3D Printing as an Enabler of Innovation

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3D Printing has made design and development of new products faster, cheaper, better and smarter. Not only it has cut down product development costs and times, but has enabled new innovation possibilities which are limitless. The talk will cover three such cases covering teaching, research and innovation. First one covers an industrial case study to design and manufacture hydraulic manifolds. The second case is about a social innovation which has potential to benefits millions of people. The third case pertains to making teaching-learning more effective in presently changing phase of education. In summary the talk will cover diverse application areas of additive manufacturing and role it can play in advancing and accelerating *Make in India*.

Digital Fabrication of Sheet Metal Components

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Societal changes impacted manufacturing including other engineering fields. Earlier industrialized economies were on mass production; however a combination of advances in technology and information is making it increasingly possible to manufacture the customized products. For mass-customization, manufacturing processes have to be flexible with minimum change over time and tooling costs. Manufacturers worldwide, now attempt to grow by competing on product differentiation as much as on price. This trend leads to short product life cycles, low volume of a chosen product model, and profitability is as much dependent on the speed at which new models and products are introduced as on the control of direct cost. This trend in manufacturing sector led to development of flexible manufacturing technologies for digital fabrication, and particularly in the area of machining and deposition to changeover between different products with the help of fully automated systems. However, developments in the area of forming have not kept pace with machining mainly because of the requirement of component specific tooling in many of the operations. This presentation is going to cover some of the attempts made worldwide to develop forming processes suitable for digital fabrication with emphasis on incremental sheet metal forming carried out by our group. Digital fabrication of sheet metals is not just digitizing the design, but digitization of material behavior and process mechanics.

The Disruptive Influence of 3D Printing

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3D Printing has been widely considered as game-changer in the way we manufacture products. Closely linked to digital design processes and many internet businesses, 3DPrinting has been described as an enabling technology that can turn anyone into a designer. This presentation will take a look at this claim and try to provide some grounding that allows us to take stock of where we are and what we may expect from 3D Printing.

Digital Fabrication in Defense Product Development

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Defense systems are typically characterized by small batch size production requiring complex design. They use special materials of unique specifications and require advanced manufacturing techniques. They often have long cycles and obsolescence level is also high.

Challenge is develop the product in short span of time without compromising on cost and quality. During the development phase designer requires to manufacture functional prototypes for validation of the design as well as end use components, form-fit applications and composite toolings.

Digital fabrication sometimes also called Additive Manufacturing/Direct Digital Manufacturing leads to a window for realizing the new products in shorter span of time. Additive Manufacturing describes multiple techniques to build solid parts by adding materials in layers. Additive manufacturing reduces waste because it only uses the materials needed to produce a product. The process also reduces the need to maintain large inventories of component parts because they can be produced using just-in-time concept. Additive manufacturing is fundamentally going to change the way traditionally material removing manufacturing works. It requires different approach and processing stages to produce the final component. An additive manufacturing machine can produce multiple types of products without re-tooling. This has potential to benefit Defense Industries, which demands a continual light weighting of components. Designer is not constraint to design component with limitation of fabrication processes. Designer can optimize the components and reduce the product weight.

New technologies are driving development of faster and more accurate Additive Manufacturing Machines to ensure quality control of products. Components manufactured by Additive Manufacturing are having major applications in Automobiles, Aerospace, Medical, Entertainment Industry etc. Defense industry is also using metal components made by additive manufacturing. Efforts are being made to improve the processes, speed, quality control and variety of materials.

It is expected that additive manufacturing will focus on producing high-value components and products, along with those requiring complex internal geometrics that cannot be made using traditional manufacturing techniques. Additive Manufacturing machine will continue to improve building more types of materials, parts, and eventually whole products with increased speed and precision.

Digital Fabrication Today

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As well as our business concept and activities, and our latest product involving open source hardware and communications & interactive devices that are booming today, we would like to go over user testimonials to introduce how our products are being incorporated in the local market of India, such as in industrial and education fields. Though social engagement, we also thrive to discover new approaches in the globally growing digital fabrication. Our very recent project with Institution of Advanced Media Arts and Science will include the details of how the Monozukuri movement influences socially and how digital fabrication is not limited to manufacturers but for individuals.

Metal Additive Manufacturing using Arc/ Laser Cladding

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Additive Manufacturing (AM), formerly known as Rapid Prototyping (RP), has revolutionized the way products are designed and manufactured today. Popularly known today as 3D Printing (3DP), its influence is felt in all walks of life starting from fashion to medicine. It is considered an important enabler in the ongoing Third Industrial Revolution triggered by the Internet. Laminated Manufacturing (LM), Powder-Bed Technologies and Deposition Technologies are the most popular AM processes for metals, each having its complementing domains of applications. Deposition technologies make use of cladding to build the 3D object in layers. Arc cladding using GMAW, GTAW and PAW heads and laser cladding are used currently. Electron Beam also can be used although no process is commercially exists now. While powder feedstock is popular in metallic AM, its yield is poor in deposition technologies, as low as 10-15%,. So, wire/strip feedstock is preferable. Arc cladding invariably uses wire/strip feedstock; even laser cladding can also use wire/strip as the beam can be shaped into a thin strip or a rectangle. While deposition technologies are ideal for realizing Functionally Gradient Matrix (FGM), they cannot use a sacrificial support. The authors have overcome the need for support by using 5-axis kinematics. In order to achieve smooth finish, traditional AM uses thin slices which makes it slow and expensive. Hybrid Layered Manufacturing (HLM) developed by the authors is a retrofitment of a CNC machine with a cladding system. HLM uses material addition in thick layers, focusing on integrity at that time. The near-net shape thus achieved is finished on the same machine. While HLM started with GMAW cladding, it has been expanded to GTAW and laser cladding will be used very soon, each finding its own complementary applications. HLM will have to incorporate preheating and Stress relieving operations for hard materials. In-situ inspection will make it more reliable. To cater to these needs, an integrated multi-station and multi-axis HLM is under development. An overview of HLM will be discussed in this paper.

Industry Perspectives to Additive Manufacturing

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Additive Manufacturing is touted as the future of the way in which goods will be produced, and with good reason. While it is a favorite with engineers for the fact that functional goods can be produced, designers also thrilled with the prospect of being able to make anything they can conceptualize. The Green brigade is also pleased, for fewer materials are consumed and hence the world is being saved. And the business leaders are also reaping benefits, commercial and otherwise! At Cyient, we are interested not just in the process of Additive Manufacturing, but in the enterprise which encompasses it. Additive Manufacturing requires special skills in the preparation stage, like part suitability analysis and design. At the post-build stage, the parts need to be subjected to special processes in order to be deemed functionally ready. At both these stages, tacit knowledge of the specific industry for which the part is intended to be used, is very crucial. This Presentation, at the International Symposium on Digital Fabrication, covers the industry perspective of Additive Manufacturing and the Industry aspirations on this disruptive technology. Some key elements that will be covered are: (1) Nature of the market for additive manufacturing, (2) relevant technologies and applications, (3) future trends that will impact industry.

Smoothing Algorithm to Improve Accuracy of STL File for RP Bio-Applications

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Bio-fabrication of accurate human components from Computed Tomography (CT) or Magnetic Resonance Imaging (MRI) data is the challenging task. These bio-models have been performed primarily on voxel based data. Further these data were transformed into Stereo Lithography (STL) files (triangle based data). These STL files are widely used for fabrication of human components with Rapid Prototyping (RP) technologies. However there are always chances of having some dimensional error. In this paper, we develop an algorithm to produce accurate human components by using smoothing algorithm. In this proposed work, the human component is primarily divided into an equal thickness of slices along the Z-axis direction. In each slice, contour data information was created as a Common Layer Interface (CLI) file. These contours are smoothening and increase the accuracy by using the interpolation algorithm. In the next step these smoothened contours are transformed into the uniform thickness surfaces. These surfaces are arranged one on another along the Z-axis direction further developed an STL file. Finally by applying this algorithm an accurate component can be produced.

Deformation Machining

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Deformation machining (DM) is a combination of two emerging manufacturing processes-thin structure machining and single point incremental forming (SPIF) or single point

incremental bending. Firstly, the bulk raw material is machined to get thin monolithic structures (vertical or horizontal) depending upon the application. Thereafter, the thin machined structure is formed incrementally using a single point forming tool into the desired shape. This hybrid process, in one setup, allows the creation of lighter weight components with novel and complex geometries which otherwise require complex tooling and equipment, can now be fabricated using much simpler tools and conventional machines without compromising with the quality.

First aspect of DM is the creation of thin structures out of the bulk raw material by thin structure machining. Thin structure machining is different from conventional machining due to the lack of stiffness of machined structure. Therefore, it requires different machining techniques, like the use of long slender end mills, employing high speed machining to reduce the contact time of the tool cutting edge with the thin structure. Relieved shank tooling can also be used in the machining of thin vertical geometries, so as to provide a relief for vibrating thin machined geometry coming in contact with the tool. This process is extensively used in aerospace and marine industries replacing assembled part with thin monolithic parts. Thus, reducing the Second aspect of DM is forming the machined thin structure into the desired shape on the same setup and machine. For this single point incremental forming (SPIF) or single point incremental bending technique is used. SPIF is a die less forming process where a hemispherical shaped single point solid tool is used to deform the thin structure to a desired shape incrementally using computer numeric control. In this process, a thin structure or sheet metal is deformed locally into plastic stage, enabling creation of complex shapes according to the tool path generated by a CNC machining center. SPIF has enabled flexibility in creation of symmetric, asymmetric and random shapes. Incremental forming has the application in the diverse fields of engineering: customized medical products, sandwich panels. The potential of thin monolithic parts with complex geometries in aerospace industry (e.g. mold lines of fuselage, avionic shelf, impellers, pressurized bulk heads), biomedical engineering (cranial plate, bone and joint support, prosthetics), heat transfer and dissipation (irregular, curved fins) is a close possibility. Deformation Machining is classified into two modes: (i) Bending and (ii) Stretching, based upon the orientation of the deforming tool and the component.

Digital Fabrication in Sheet Metal Forming: Incremental Forming

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Incremental forming became a potential process for low volume production and rapid prototyping of sheet metal products. This process requires very simple tooling and the entire manufacturing cycle is under computer control. This makes the process as a “Digital fabrication” technique. There was significant number of studies to understand behavior of aluminum alloys in incremental forming, however the studies related steel sheets are very limited. Thus, the present paper discusses some of the important results related to incremental forming of steel sheets.

The formability of the material in the incremental forming is superior over the conventional stamping and deep drawing due to localized deformation in the process. The maximum wall angle that can be achieved without fracture is the primary parameter to assess the formability of material in incremental forming. The maximum formable wall angle for Extra Deep Drawing (EDD) steel was predicted using varying wall angle conical and pyramidal frustums. Further the formability of varying wall angle frustums have been analyzed using analytical fracture forming limit curve and finite element simulations.

The maximum allowable thinning is one of the important parameter to form the blank without fracture. The thickness distribution of varying wall angle frustums have been simulated in LS-DYNA and validated with the experimental results.

The process parameters have significant effect on surface roughness of parts produced in incremental forming. To get the proper quality of parts for functional applications, it is important to select the optimum process settings. Another drawback with this process is the long processing time. Mathematical models have been developed to understand the effect of process parameter on surface roughness and manufacturing time. Further, optimum process parameters have been obtained for minimum surface roughness and minimum manufacturing time using multi objective optimization algorithm NSGA-II.

The drawback with limiting wall angle in single stage incremental forming can be overcome with multi stage incremental forming (MSIF). The conical frustums beyond the limiting wall angle have been formed successfully in MSIF. However, the manufacturing time increases drastically with MSIF. To show the potentiality of MSIF, a steep wall angle scaled model of CRT dome shape has been formed without fracture.

A Comparative Study of Machining related material characteristics of Wrought and Sintered Titanium alloy Ti-6Al-4V

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Machinability of a material depends on the inherent properties of a material which include microstructural phase, chemical composition, bulk hardness, modulus of elasticity and thermal conductivity. Work hardening has direct and indirect influence on machinability. Titanium alloys, in particular Ti-6Al-4V are often considered as difficult to machine materials due to work hardening ability and poor thermal conductivity. These properties of titanium alloy leads to high cutting forces and heat accumulation in the deformation zones that results in rapid tool wear and poor surface quality.

Recently, additive manufacturing (AM) has gained attention amongst manufacturing industries as it enables fast, flexible and cost efficient method of manufacturing. Among the AM technologies, Selective Laser Melting (SLM) is one of the most promising and emerging technique that is being used widely. Even though complex parts can be manufactured using this technology, a finish machining is much desired to meet the dimensional accuracy and tolerance. To ensure proper tool and parameters selection, it is necessary to understand the machinability of AM components.

This paper aims at comparatively studying the machinability of wrought Ti-6Al-4V (produced by conventional manufacturing method) and SLM fabricated Ti-6Al-4V component by analyzing its material properties. The experimental design consists of material characterization using bulk hardness testing, tensile testing and chemical composition using spectrometry of wrought and SLM Ti-6Al-4V. The results show that the SLM Ti-6Al-4V has higher yield strength, hardness, and ultimate tensile strength as compared to its wrought counterparts. In addition, SLM Ti-6Al-4V was porous and brittle in nature whereas wrought Ti-6Al-4V was dense and highly ductile. Thus, a hypothesis can be generated that the machinability of SLM Ti-6Al-4V is comparatively poor taking in to account the yield strength, ultimate tensile strength, hardness and porosity. The brittleness of SLM Ti-6Al-4V may slightly improve the machining characteristics due to less frictional force as a result of brittle fracture of chips as compared to the highly ductile wrought Ti-6Al-4V. However, previous studies in chip formation of titanium alloys has shown that very least sliding of chip material on the tool rake face. Thus, ignoring the effect of brittleness on machinability seems legitimate.

Self-organization for Manufacturing Process- Digital Fabrication Method with Encoding Information based on Physical property and Geometric Form of Components

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Introduction: Human manufacturing systems typically require high complexity that can be achieved only by top-down or laborious manual assembly. As technologists pursue smaller and more complex structures, traditional manufacturing schemes will not be able to meet such demands, because they are limited in their scalability, robustness, and complexity. As a solution to this problem, applying “self-organization”, which is the autonomous organization of components into pattern or structures, to human manufacturing process has been a long sought goal in many fields of both academia and industry. As related works, self-organization has been used to create structures at the nano- and micro-scales using techniques such as chemical bounding, geometric interactions, and magnetic field. Even at the meso- and macro-scales, many techniques and basic theories to design self-organization and self-reconfigurable systems has been proposed and implemented in the field of robotics. Although these robotic systems are impressive and are approaching functionality, they offer little hope in terms of scalability for large applications or complex structures, because of its high application cost, failure of electronics and miscommunication between machines. Therefore, this proposal focuses on physical properties and geometric forms of units.

Implement: We have implemented "self-organization folding system" which can form arbitrary two-dimension shape applying self-organization folding approach to assembly processes. In detail, we implemented simple designed components encoding information and an assembler. And then we constructed a mathematical model based on this designed components in order to overcome restricts which analog system has. Consequently, self-organization folding system was proposed and implemented. Moreover, some potential applications based on our system such as "PHYSPLAY" and "self-organization electronic circuit" have been proposed.

Conclusion: The self-organization folding system attains scalability to enable the assembler to print an object even if the scale is bigger than the size of the assembler in theoretically. In practical, our system has been limited with physical forces such as a gravity and a friction force, so we will try to control them as a future work. The system also alleviates the need for complex and accurate movements of assembler compared with top-down human manufacturing system. As our future work, we will develop the self-organization system which can construct arbitrary three-dimensional forms. And also, we will apply this system for constructing small and complex structures of electronic circuit boards without highly-precise-assemblers and consider the engineering potentiality of self-organization electronic circuit system as a new type of fabrication.

Direct Metal Laser Sintering (DMLS) for Digital Additive Manufacturing (DAM) of Precision and Intricate Nuclear Power Reactor Core Components – Structure Property Correlation

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Digital Additive Manufacturing (DAM) refers to any manufacturing process where parts are built up from raw material (generally powders, liquids, or molten solids) micro layer by micro layer rather than cut out of a stock material such as a block of wood or metal. One of the most unique advantages of DAM technologies is the ability to create complex geometrical shapes that would be impossible to do with any other method of manufacturing. The technology has been successfully implemented for manufacturing components of aerospace and defense industry, namely rotor blades, nozzle guide vanes, flame tube & combustion chambers. The present research project aims at exploring and then developing DAM process parameters for manufacturing nuclear power reactor components. The nuclear power and fuel cycle program in India is expanding rapidly. In this context there would be a need to manufacture special components made of materials like stainless steel, aluminium alloys, Inconel, Cr-Mo alloys and zirconium alloys. For the first time, we will explore the possibility of fuel assembly components for nuclear reactors using Direct Metal Laser Sintering (DMLS). To start with, isotropic materials like stainless steel would be utilized. Component examples are as follows: tools and fixtures for 19 and 37 element fuel assemblies for pressurized heavy water reactor (PHWR), integrated finger bulge and bottom tie plate component for Advanced Heavy Water Reactor (AHWR) fuel assembly, gripper springs and other SS components for fuel and blanket assemblies for sodium cooled Fast Breeder Reactor (FBR). A trial piece of the orientation fixture for the 19 element fuel assembly has been made and SS316 powder was used as the raw material. This is part of a collaborative effort between Engineering Staff College of India (ESCI), Nuclear Fuel Complex (NFC) and industry.

Mathematical Modeling, Numerical Simulation and Multi-Objective Optimization of Fused Deposition Modeling (FDM)

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Additive manufacturing (AM) technologies enables the manufacturing of parts or products directly from 3D CAD models. In distinction to the traditional methods of manufacturing where in the raw material is fabricated to the final product based on subtractive principles, these AM processes are based on additive principle for the part manufacturing. Fused deposition modeling (FDM) is one among those most popular AM technologies where in the filaments are added one beside other forming a layer, and then layer upon layer to build the final product. The strength and dimensional stability contributed by the neck formation resulted due to bonding is studied.

A mathematical modeling technique was adopted using the principles of sintering operation. The theoretical strength as obtained from the mathematical model as contributed due to the neck growth has been validated by conducting experiments on specimens manufactured using FDM process. The results of neck growth are also validated through FEM of filaments. Different orientations were experimented to find the variation in neck formation between the filaments and hence its contribution to strength.

A multi-objective problem, namely maximization of strength and minimization of volumetric shrinkage, has been formulated and solved for optimal solutions. Pareto's plot has been obtained that arrives at the optimal set of the process parameters. Based on the mathematical modeling it was learnt that the neck formation between the filaments is a very important factor in determining various properties. Based on the study it was found that part orientation plays a very important role in all the properties chosen for the study. From the present work, the following key conclusions can be concluded:

1. In FDM process, the time required for the two adjacent cylindrical filaments for finally coalescing completely into one single filament is not available before complete solidification and cooling to the chamber temperature occurs.

2. The neck formation results in increase in strength as well as change in dimensions. From the SEM micro-graphs, it is clear that the cylindrical filaments convert into elliptical cross-section filaments after solidification.

3. From the experimental studies, it can be concluded that the process parameters bear a conflicting relation with the responses chosen namely strength and volumetric shrinkage.

4. From the Pareto's plot, it can be concluded that the best possible strength that can be obtained using any of the combinations is found to be 35.83 MPa. Also any improvement in the shrinkage cannot be obtained beyond 0.77%.

5. From the tribological studies, it can be concluded that cracks are formed in the specimens when the specimens are tested at high load, high speed and low orientation angle of the part during its manufacture using FDM process.

6. For uniform wear, the layers are to be deposited vertical to the build platform of the FDM system so that the intra-layer takes the maximum load.

Micro-Macro Stereolithography and UVLED Fabrication for Microfluidic Applications

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The aim of the work is to device a simple mixer for easy mixing of liquid samples in microscale system. To achieve this, a fabrication technique where micro structures of micro and nano features for fluidic applications is presented. 1, 6- HexaneDiol DiAcrylate (HDDA) and Benzoin Ethyl Ether (BEE) of suitable volumetric proportions are used as monomer and photo initiator respectively to prepare precursor liquid polymer. Scan based microstereolithography setup and UVLED apparatus has been developed in-house for processing polymer structures. Chemical parameters and Microstereolithography (MSL) build parameters were fine tuned for fabricating components suitable for micro fluidic applications. Based on the parameters thus chosen, a vortex flow fluidic channel was designed, developed and analysed for flow properties.

Modelling and Analysis of Optimal Scaffold Design for Biomedical Applications

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Additive manufacturing (AM) is an advanced process for building a component layer by layer, with one layer of material bonded to the previously laid layer using 3D design data. Bio medical engineering is one of the fastest growing wings in AM. In field of Bio medical engineering, AM is one of the useful technique to develop a bone scaffold. Scaffold is a artificial structure, which can replace diseased or damaged human organs and tissues. In the current study, scaffold models were developed using Computer Aided Design (CAD) software. The porosity and strength of scaffold is optimized by considering different structures. Designed parts are analyzed under static loading conditions for optimal structure. The novel structures made of Acrylonitrile Butadiene Styrene (ABS) plastic material were fabricated using fused deposition modelling (FDM) machine. In this work, optimal design was considered on the basis of porosity and strength.

Rapid prototyping and thermal gradient method applied to fabrication porous structure for application in biomedical field

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The fundamentally different features of Rapid prototyping (RP) from that of conventional sintering offer us some new approaches to develop materials with excellent properties. Applying this method, porous Hydroxyapatite (Hap) ceramics, as well as the HAp-zirconia composites have been fabricated successfully. Porous hydroxyapatite (Hap) is expected to have desired mechanical and biological properties for biomedical applications. However, due to material processing problems, to date, this material can only be prepared by conventional techniques. Fuse deposition Machine is modified to fabricate Hap conventional support structure is not required three nozzle system is utilized for fabrication. Main nozzle is provided with heating arrangement. Two nozzles provided for transient Hap and solvent. Three stages heating with two lasers arrangement for gradual temperature change so transformation is faster. Primary result shows mechanical properties and porosity is as per bone structure. The micro structural characterizations such as phase purity and composition of porous BCP granules were performed and verified by X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FT-IR) analysis. The chemical and the microstructure information of the Fabricated Hap were investigated by FT-IR (Fourier Transform Infra-Red), SEM (Scanning Electron Microscopy), X-ray Diffraction (XRD). Result shows interconnected regular pores and uniformly distribution of Hap. There is covalent boding makes stronger adhesion to prosthetic. Using this technique, it is possible to produce scaffolds with mechanical and structural properties

close to those of the natural bone and teeth. The prepared scaffold has an open, regular pattern and uniformly interconnected porous structure. Some extent problem of small nanoparticle aggregate together is called balling and product of different temperature solidify on the layer is called recasting is dominates the process. By optimizing the operating parameter these problem can be minimized.

Role of additive manufacturing in tissue engineering: Scaffold to 3D organ printing

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In recent years, the field of tissue engineering has witnessed a steady shift from conventional 2D research-based cell culture models to application-oriented 3D microenvironments. The novelty of additive manufacturing or three-dimensional (3D) printing lies in printing layer by layer of biological tissues with respect to either their complex shapes or their non-uniform nature of biological constituents. The 3D printing in tissue engineering, also called bioprinting, has given rise to novel approaches for printing porous scaffolds with controlled geometry, chemistry, interconnected porosity, and high reproducibility. The process helps in faster non-destructive processing of products without the need for specific tooling or dies as used in conventional subtractive manufacturing process. An additional advantage is the choice of a wide range of materials that can be 3D printed, such as polymers, metals, and ceramics. In addition, it is also possible to 3D print tissue components, such as cells and extra-cellular matrix materials, with site specific growth factor/drug delivery abilities. The ability of these processes to produce customized products would enhance their demand in the future. Although present techniques help us fabricate tissue-analogous structures, the future trend in this research is to print a fully functional organ.

Manufacturing of Functionally Gradient Materials by Using Weld-Deposition

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When the inherent inhomogeneity of Additive Manufacturing techniques is carefully exploited, the anisotropy transforms into the desired distribution of the properties paving the way for manufacture of Functionally Gradient Materials. The present work focuses on using weld-deposition based Additive Manufacturing techniques to realize the same. Mechanical properties like hardness and tensile strength can be controlled by a smaller degree through control of process parameters like current, layer thickness etc. A wider control of material properties can be obtained with the help of tandem weld-deposition setup like twin-wire. In tandem twin-wire weld-deposition, two filler wires (electrodes) are guided separately and it is possible to control each filler wire separately. The investigations done on these two approaches are presented.

A Simulation Based Approach for Understanding the Effect of Melt Pool Behavior on Solidification Microstructure in Beam-Based Solid Freeform Fabrication of Thin-Wall Structures

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Beam-based (laser and electron beam) solid freeform fabrication processes are under consideration for aerospace applications. However, their success will ultimately depend on the ability to control microstructure because of the strict guidelines that aerospace applications have on microstructure and mechanical properties. This research, aims to understand the effect of melt pool behavior (primarily in the vicinity of a free edge) on solidification microstructure in beam-based deposition of 2-D thin-wall geometries. The analytical Rosenthal solution for a moving point heat source is used for presenting thermal finite element results for cooling rates and thermal gradients in dimensionless form. Numerical results are also interpreted in the context of a solidification map for predicting trends in solidification microstructure in laser-deposited Ti-6Al-4V.

Structure and Properties of Laser Deposited NiCrAlY-YSZ Composites

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Laser Engineered Net Shaping (LENS) is a laser additive manufacturing process for fabricating near net shaped components directly from powders using Computer Aided Design (CAD) solid models. It involves deposition of alloy powders onto a moving substrate which is locally melted under a focused laser beam. Coordinated movement of the substrate results in deposition of overlapping lines and layers leading to a fully dense part. One of the unique features of LENS technique is its ability to control the layer composition, thus realising functionally graded materials (FGMs). Functionally Graded Materials (FGMs) are a class of advanced materials whose composition and/or microstructure are made to change in a controlled manner from one location to the other, resulting in corresponding changes in the properties.

NiCrAlY-YSZ FGM is a candidate material for thermal barrier coating application. Conventional thermal barrier coating fails at the metal-ceramic interface due to large mismatch in the coefficient of thermal expansion. The proposed NiCrAlY-YSZ FGM

whose composition is varied layerwise from pure NiCrAlY to that of pure YSZ is proposed to minimize the thermal expansion mismatch; thus improving the coating life. The intermediate layers that constitute the FGM are composed of composites made using a combination of NiCrAlY and YSZ. In order to understand the structure and properties of FGM, the structural features and properties of individual layers of YSZ-NiCrAlY composites are to be studied. Therefore, the structure and thermo-physical properties of NiCrAlY-YSZ composites deposited on Inconel 625 substrate were investigated and the results are presented herein.

Composite blocks of NiCrAlY-YSZ (15 mm x 15 mm square builds) with varying volume percent of YSZ (25%, 50% and 75%) in NiCrAlY were deposited using LENS process. The process parameters employed during the deposition are 250W laser power (LP), 16mm/s scan velocity (SV) and 19g/min. powder feed rate. Microstructural features of the deposits were examined using optical, SEM and EBSD tools, and correlated it with the measured thermo-physical properties. Micrographs (Fig.1) revealed that YSZ was dispersed in the metallic NiCrAlY matrix and is segregated predominantly at the layer boundaries because of its low density. Phase analysis was carried out using XRD and complemented with EBSD technique. It showed that YSZ is predominantly tetragonal with a small volume fraction of cubic phase. Variation of thermal conductivity with increasing volume percentage of YSZ was measured using laser flash technique. With the increase in YSZ content, the thermal conductivity was found to decrease significantly. Thermal conductivity of the NiCrAlY-YSZ composites was observed to increase with the increase in temperature. However, this raise in the thermal conductivity is less steep for higher content of YSZ in NiCrAlY.

Spallation of the NiCrAlY-YSZ composites from the substrate was observed beyond 25vol% of YSZ after laser deposition. This could be due to increased mismatch in the thermal expansion of NiCrAlY-50%YSZ with the substrate compared to that of NiCrAlY-25%YSZ. However, no spallation of YSZ coating was observed when deposited in a gradient fashion with an increament of 25%YSZ in each layer. Hence, it is possible to control the structure and properties of NiCrAlY-YSZ composites by varying the constituents accordingly.

Digital Modeling and Fabrication of Indian Traditional Ornamental Product

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This paper presents the integrated product development of various Indian traditional ornamental products (carved jewelry, Filigree jewelry, Jali's and furniture carvings) using parametric computer-aided modeling and fabrication. Integrated product development approach brings innovative designing and agile fabrication into contact by transferring and converting the product information and data among CAD/CAM tools. The objective is to produce computer compatible digital models having a wide modeling range and supported by diverse fabrication such as CNC machining, laser cutting and layered manufacturing. The motivation is to automate the generation of user specific designs of traditional Indian ornamental products.

Ornaments are the aesthetics products which involve artistic skill, effort, time and imagination. This paradigm incorporates traditional aesthetic senses into CAD system so as to facilitate even the persons having least imaginative and artistic skills. It also capitalizes the advantages of computer over hand by freeing from repetitive tasks and considerably reducing the effort and time required for designing and creating the ornamental products.

Electrospinning: A New Nanoscale 3D Printing Technology for Polymers and Carbon

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Additive manufacturing, also popularly known as three dimensional (3D) printing is currently a talk of the town. Fabrication of 3D objects has drawn a considerable attention in recent time and a lot of research is currently underway. Challenges becomes paramount when size of these 3D objects is reduced to nano or sub-micron domain. Manufacturing of 3D objects at nanoscale is currently a major challenge in this field.

Electrospinning is a method to produce nanofibers in which polymer solution is ejected through a nozzle in the form of a charged jet under the influence of high electric field. As shown in schematic (Figure 1), due to instabilities and whipping motion, solvent evaporates continuously resulting the thinning of charged polymer jet and finally depositing on a collector in the form of nanofibers. Although the process of electrospinning was first patented long back in 1900, however it drew attention to fabricate non-woven fabrics for numerous applications since early 1990s. However we now propose electrospinning a potential tool for nanoscale manufacturing for 3D objects. Key aspect of this technology for 3D printing is developing control on electrical instabilities and thus guiding the nanofiber deposition in a controlled manner. In this poster, we will discuss some of these recent work on using electrospinning for fabrication of 3-D structures. We can convert the same 3-D polymer structures in 3D carbon structures simply upon pyrolysis under controlled atmosphere.