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A Review Paper on Material, Applications and Future Perspectives of 3D Printing Technologies

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Abstract:
3D-printing technology has revolutionized the manufacturing industry by reducing the lead time and production cost in addition to the fabrication of customized and complex parts. Presently, this technology uses a limited type of materials as compared to conventional manufacturing due to constraints of mechanical and chemical properties. An intensive literature survey has been performed in this paper to study the applications the advantages and disadvantages of different kinds of materials used for 3D printing. The study also explored the methods of composite material fabrication for 3D printing and its scope of implementation for end-use applications. The study also focuses on future applications of this technology along with challenges to be faced ahead of the implementation of this technology for mass production.

Keywords: *3D printing, Additive process, phases of 3d printing, principles of 3d printing, applications of 3d printing, fused deposition modelling (FDM), benefits & limitations of FDM, materials used in FDM, application of FDM*

INTRODUCTION

3D printing is an added substance assembling process for building a three-dimensional object of the ideal or required shape from a real (3D) model or different sources (electronic information) through added substance forms. In this added substance process different layers of material are set down under the PC controls [1].

The main strong and very first item was printed by Hideo Kodama from the Nayoga Municipal Industrial Research Institute. The credit for initial three-dimensional printer goes to Charles Hull who planned it while working in his very own organization in 1984. [2]

Generously act of spontaneities made in this innovation makes it great advanced helpful instrument.This have been an interesting topic for very long time for producers, creators, specialists, architects and researchers. [2]

Itbegan from a computerized model which uses an added substance process. In this the item was to be worked from the base to its top by adding it to the layers of the characterized material in a well-characterized or consecutive way to make the desired material. [1]

In the advancement of 3D objects materials that are used are plastic, metals of different sorts and natural issues like carbon and its subsidiaries.

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Most of the customary assembling forms, the material of an underlying shape article are evacuated until the ideal shape is acquired. [1]

Since 1984, the innovation has advanced and 3D printing machines have turned out to be increasingly well known, valuable and become progressively reasonable when their cost has been brought down. [2]

These days, prototyping has a wide scope of uses in different fields of human exercises, for example, restorative industry, look into, building, military, design, development, PC industry, style, instruction, and so forth [2].

Phases of 3D Printing Technology:

The 3D printing innovation comprises of three primary stages - the displaying, the printing and completing of the item [3].

1) In the demonstrating stage, a progression of flimsy cross-areas is utilized by the methods for virtual diagrams of the article by the machine and handling them.
2) In the printing stage, to manufacture the item, the printer stores the layers of material by perusing the structure. Each layer depends on a virtual cross-area by combining with the last ones, in the wake of printing every one of these layers, the ideal item has been acquired.
3) The last stage comprises completing the item.

Principle of 3D Printing

3D printing takes a shot at the standard of is ***stereo lithography***, one of the most broadly utilized arrangements in 3D printing is STL (stereolithographic).

As per this guideline, any 3D article can be produced by utilizing CAD programming by the methods for the 3D scanner. First, it divides it into layers and then these layers are subsequently printed by the machine.[1]

By programming a STL record is produced. Different customization as per requirement is done, for example, the thickness of layer, external completion and temperature can be made. When the STL record is Produced STL record, at that point the article is prepared to be print.

For part printing, the changed over STL record is to be encouraged into the printer and as shown by the subsequent layers we have made, then the machine starts spreading out the plastic layer by layer. The material need not be plastic but rather it tends to be anything extending from fluid, powder, paper or sheet material. The layers are consequently combined to get the last shape.

Uses of 3D Printing:-

- Construction
- Medicine and Bioprinters
- Prosthetics
- Artificial Organs
- Domestic Usage
- Clothing
- Manufacturing

Future Work:-

- **Manufacturing:** The 3D printing industry is set to see uncommon development with market investigators anticipating a year on year 18 per cent development. As appeared in figure 5, it is anticipated that the 3D printed part market will develop to an 8.4 billion dollar industry by 2025. Vehicle parts and aviation will lead to the parts deals estimate. [1]

- **3D printed organs:** The mix of Stem cell research and 3D printing will bring about transplantable body parts later on. Genuine useful body parts will almost certainly be 3D printed. [1]

- **Skin joining:** In skin joining sound skin from a piece of the body is utilized to cover a harmed piece of the body. The technique is very surely understood to be a difficult method. College of Toronto analysts has built up a technique for skin uniting by stacking skin cells and different polymers into the 3D printer to misleadingly make layers of skin.

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Establishment of Regenerative Drug researchers at Wake Forest University in Winston- Salem, North Carolina, roused by war exploited people intend to print skin legitimately onto consuming wounds. They saw that the vast majority of the losses of war were consume exploited people which needed to go the frightful activity of skin joining. Ideally, in the close future, this examination will transform into the real world. [1]

- **Commerce:** Amazon set up a 3D printer store. They imagine selling advanced 3D configuration records and the client at that point prints the item all alone. This will alter the supply side of items as shoppers will probably print whatever items they need. [1]

FUSED DEPOSITION MODELLING (FDM):-

In 3D printing or added substance producing, there is a section named as FDM. FDM alludes to Fused Deposition Modeling or having the second or another name melded fibre creation (FFF). In figure 2.1 below different types are shown. It is one of the, for the most part, utilized added substance fabricating innovation, similar to the others 3D printing or added substance producing it additionally works by keeping softened materials in the way of layers to assemble objects. [5]

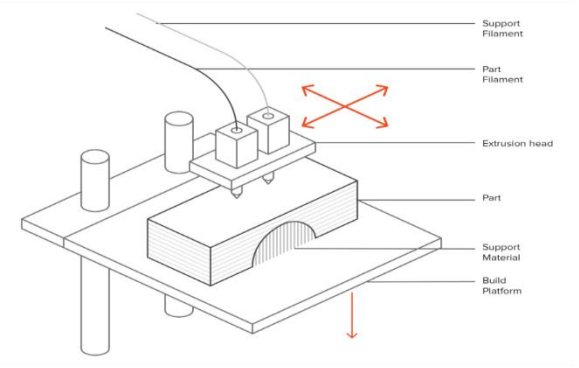

Fig. 2.1 (a) Procedure of FDM [4]

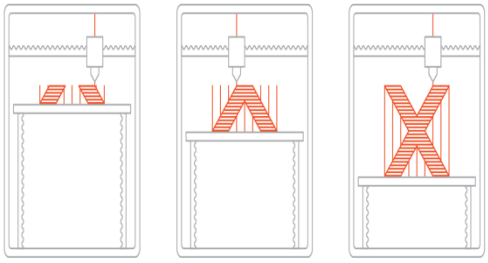

Fig. 2.1 (b) Procedure of FDM [4]

Advantages of FDM:-

- Thermoplastic parts and models delivered in a very practical manner.
- Lead times are short (speedy manufactural).
- Ease of accessibility and wide decision of crude material. **[5]**

Constraints of FDM:-

- Lowest goals and dimensional precision.
- Visible layer lines.
- Anisotropic parts. **[5]**

Material	Pros	Cons
ABS	• Good strength • Good temperature resistance	• More susceptible to warping
Nylon (PA)	• High strength • Excellent wear • Chemical resistance	• Low humidity resistance
TPU	• Very flexible	• Difficult to print accurately
PLA	• Excellent visual quality • Easy to print with	• Low impact strength

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PEI	• High strength • Fire and chemical resistance	• High cost
PETG	• Food Safe • Good strength • Easy to print	

Table 2.1 Materials used in FDM [5]

Applications of FDM in:-

- Creating prototypes
- Fit, Form and Function testing
- Rapid tooling patterns
- Mould inserts
- Creating and testing of parts (work under thermal loads)
- Production of parts having high preciseness and complex use [4]

HYBRID COMPOSITES

Hybrid composites were framed by strengthening the base lattice with more than one material having various properties. The composites which have a blend of at least two support of particles are equipped for improving the mechanical properties of the composite materials. The presentation of half breed composites is an aggregate impact of the individual constituents where there is a superior harmony between the inbuilt preferences and drawbacks. [8]

Almond Shell Based Composite Material

Matrix Material:

- Epoxy Resin CY-230
- Hardener HY-951

❖ **Water Absorption limit:** Water ingestion limit is found to be a critical factor for considering the impact of water on the composite material created. The produced parts were splashed into the water for 2 days and it was found that water retention or absorbing limit was found by the test distinction of beginning and last weight. [9]

❖ **Tensile testing:** Test on tensilewas done at strain paces of 0.1 mm/min. The characteristics and properties of the almond molecule of 10 wt %, 15 wt %, 15.13 wt % and 21.1 wt % strengthened composite demonstrates the UTS and rate stretching long individually for various wt% of almond fortified composite material. The example having 15wt % almond was demonstrating strange conduct from the general pattern. It very well may be seen that of all examples a definitive rigidity and most extreme rate stretching long was most elevated for the 15wt % of almond strengthened composite. It was seen that the expansion of almond particles essentially influences a definitive quality and rate stretching long. [9]

❖ **Compressive Testing:**From the study it was found that the properties like compressive strength of almond molecule filled with epoxy sap composite material was dictated by 100 KN ADMET made the servo-controlled general testing machine at 0.1 mm/min strain rate under dislodging control mode and the results shown in fig. 3.1(a). [9]

❖ **Hardness Testing:** Hardness infers protection from space, lasting or plastic distortion of material. In a crossbreed composite material, filler weight division altogether influences the hardness estimation of the mixture composite material. Hardness esteems estimated on the Rockwell HRR-Scale were demonstrating the impact of weight level of almond shell powder and the result shown in fig. 3.1(b). [9]

From study it was found that the hardness of slick epoxy tar (CY-230 + 8 wt % of HY-951) was 58 HRR. Created composite made of epoxy sap has hardness of 10 wt % and it was greatest and was found to be 57 HRR. The hardness was expanding with increment in almond wt %.

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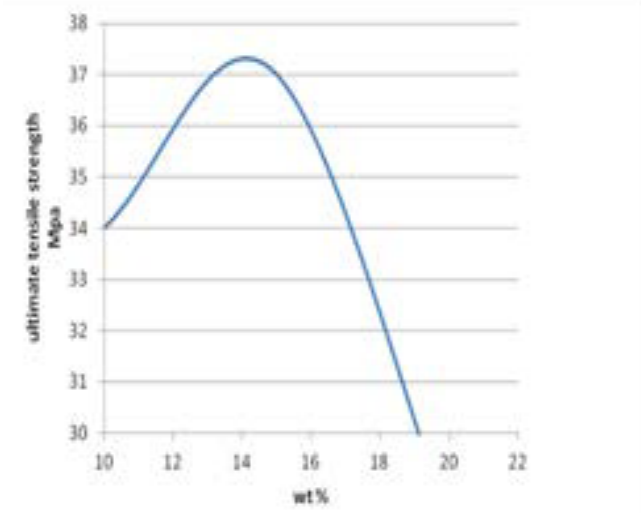

Fig. 3.1 (a) UTS variation for different wt% [9]

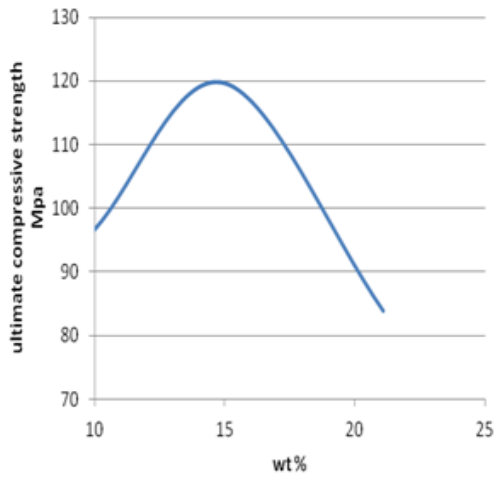

Fig. 3.1 (b) Ultimate Compressive Strength for Different wt% of Almond Reinforced Composite [9]

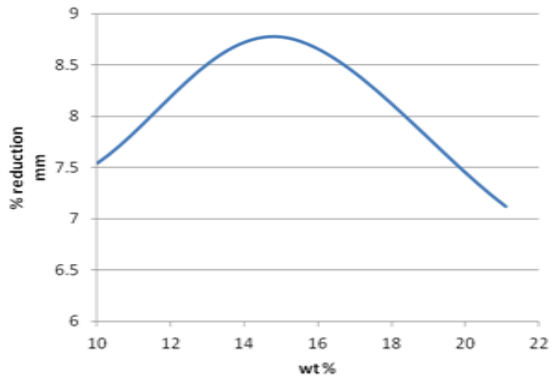

Fig. 3.1 (c) Percentage reduction in length for different wt% of almond reinforced composite [9]

Wood and plastic composites:-

Matrix Material

- Maple wood flour (about 177 μm)
- Cycolac& ABS resin

Reused ABS (acquired from obscure sources) contains different polluting influences, and it was found that its mechanical properties are poor and varies with time when it is contrasted with virgin ABS. When all this is said to be done in guidelines according to the utilization of recuperated ABS different high-esteem applications. Upon expansion of an adequate amount of flour made up of wood to ABS, it was found that the blending mechanical properties of body depends fundamentally on the content of wood and not on the properties of the polymer lattice. In this way, the mechanical properties of ABS containing 50 wt% wood fortification remain unaltered at the point when the virgin ABS in the lattice is supplanted by recuperated ABS. It should, notwithstanding, be noticed that reused materials can regularly have an unsavoury smell, and this must be indirect in some way. [13]

This basic arrangementis made to cover this composite with a refined layer of polymer preferably virgin for theprocedure of co-expulsion. The complicationswith above perceptions is that to reuse it high-esteem applications and the ABS recovered from post-purchase sources may not be important to undergo separation for the polymeric polluting influences for improving and institutionalizing the mechanical properties and particularly thecontrol quality and the malleability. Polymer recovered can be directly used for detailingthe plastic-wood composites that can competing WPCs made with virgin ABS. The results can be seen the fig 3.2 and fig. 3.4. These WPCs are likewise liable to be stiffer and more grounded than economically accessible WPCs which utilize polyolefin as lattice polymers. [13]

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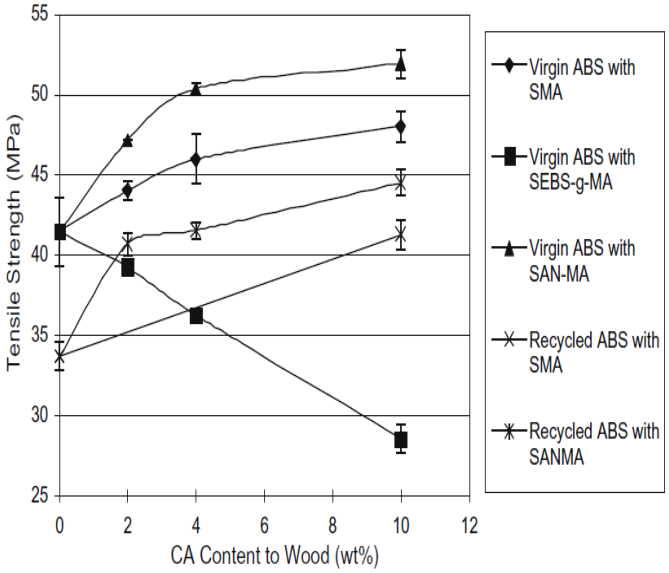

Fig. 3.2 (a) Tensile strength of ABS–WPCs having 50 wt.% wood as a function of the number of different coupling agents used. [13]

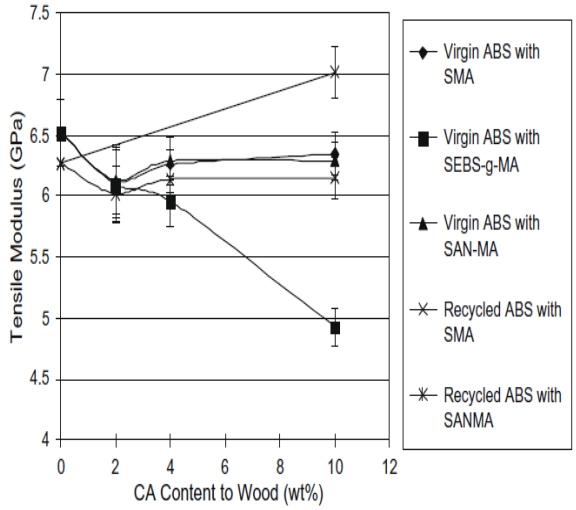

Fig. 3.2 (b) Tensile modulus of ABS–WPCs containing 50 wt.% wood as a function of the number of different coupling agents used. [13]

Graphene-based composite materials:-

Graphene sheets—one-iota are the thick and having two-dimensional layers with sp2-reinforced carbon—are tend to have an abnormal properties. Their thermal and electrical conductivity and their mechanical solidness may lead toremarkable in-plane qualities and characteristics for the graphite.Its crack quality tend to be equal to that of property with the carbon nanotubes. And can be compared for the kinds of imperfections and further the late examinations have shown that the individual sheets of graphene possess uncommon electronic and electric properties. One conceivable course to outfitting these properties as per the requirement for the applications is to fuse these graphene sheets into the composite material. The assembling of such composites requires not just that graphene sheets but also adequate scale is required. However when they are additionally fused, they are homogeneously dispersedinto different grids. [12]

Graphite is the modest and the most abundantly accessible, tragically does not prompt theoutbuildingfor yielding the individual graphene sheets. In a study a general methodology is present for the planning of graphene polymer composites using complete shedding of graphite and it was found that the sub-atomic level scattering of individual, artificially altered graphene sheets inside polymer hasPolystyrene–graphene composite. This was framed shown the permeation limit of 0.1 volume per cent for of electrical conductivity at normal room temperature and the most minimal detailed for incentive of any carbon-based composite aside from those including carbon nanotubes at just 1 volume per cent, this composite has a conductivity of 0.1 Sm-1, adequate for some electrical applications. In this approach of tuning the graphene sheet properties gives away to develop a very new class of graphene-based materials and their utilization as per the requirements of applications. [12]

Advanced Composite Materials:

The advanced composite material is made up of a different polymeric lamina material inserted in a tar grid, by and large, overlaid with filaments arranged in exchanging material and firmness. Polymeric and Stringy materials are not new, wood is the most normal powerful basic material known to man. A grid bolsters the strands and bonds them together in the composite material. The framework moves any connected problems to the strands, keeps the filaments in their position and picked a direction, gives the composite natural obstruction, and decides the most extreme administration temperature of a composite. [12]

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METHODS OF MAKING HYBRIDS:-

Single screw extrusion:

Single screw extrusion is one of the strategies utilized for preparing materials of manufactured plastics both in powder and liquid structure. It is mainly used to improve the nature of theliquefies just as increment its generation by making weight in the liquid polymer. This powers the extrusion of the polymer. Single screw extrusion is for the most part utilized for polymers that are pure. On the off chance that they are made of various materials, twin-screw extrusion is utilized. Single screw extruders can either be utilized as a major aspect of a huge extrusion framework or utilized as remain solitary machine for extrusion. [10]

The Process of Extrusion Using Single screw extruders:

The extruder comprises of the accompanying: barrel, screw, controls, drive component and game plan of tar feed. As the screw turns, it moves the pitch inside the hot barrel. Along these lines, it arrives at the required temperatures just as blends altogether to frame a liquefy that is homogenous. The weight which is developed by the single screw extruders at that point powers the soften from the extruder. It gets out moulded like a kick the bucket. The entire framework has a hindrance screw that ensures that the entire gum does not melt in fundamental extrusion screw. [10]

Favourable circumstances of Single Screw Extruders:

- Compared with twin-screw extruders, they are far much better at ejecting normal materials.
- Less expensive than other screw extruders.
- Less shear when compared with twin-screw extruders.
- Used in activities for a wide scope of various kinds of materials.
- High output.

Twin-screw extruders:

The Twin-screw extruders includemany intermeshing and co-pivoting fastens the mounted splined shafts on shut barrel. Because of this wide scope of these screw and the barrel structures, different screw profiles and procedure capacities can be set up as designated by procedure requirements. Thus, a twin-screw extruder can guarantee to ship, compacting, blending, cuisine, shearing, warming, cooling, tapping, moulding, and so forth with an abnormal state of adaptability. The real preferred position of intermeshing co-turning twin-screw extruders is their surprising blending ability which gives uncommon qualities to expelled items and increases the value of preparing units. [11]

In twin screw expulsion preparing, the raw materials might be solids (powders, grinds, and flours), fluids, slurries, and potentially gases. Expelled items are plastics mixes, artificially adjusted polymers, finished sustenance and feed items, fibre pulps, and so forth.

The advantages of twin-screw extrusion:

Twin-screw expulsion has turned into the standard after some time in a few businesses since it offers various focal points over single screw expulsion **[11]**:

- More stabilityon-going and control of item quality.
- Expanded profitability because of nonstop preparing, quicker start-up and shut down between item changes, sharp changeover and propelled robotization.
- More remarkable adaptability, with the capacity to process a wide scope of raw materials.
- Streamlined impression on account of vitality and water investment funds.
- Direct and simple to keep up and clean.

APPLICATIONS OF HYBRID COMPOSITE MATERIAL:-

- ✓ **In Aerospace:** Approximately half part of the aerospace is produced using composites. The essential advantages that composite parts are decreased weight and get together separating. The huge scale utilization of

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composites in the current program of the advancement of helicopters, military contender flying machine, little and huge common vehicle aeroplane, satellites, dispatch vehicles and rockets. Different segments of airship are manufactured by composites, for example, rudder, spoilers, airbrakes, lifts, LG entryways, motor cowlings, bottom shaft, back bulkhead, wing ribs, principle wings, turbine motor fan cutting edges, propellers, Interior parts etc. [6]

- ✓ **In Automotive:** Composites are being considered to make low weight, more secure and more eco-friendly vehicles. A composite is made out of a high-quality fibre (carbon or glass) in a lattice material (epoxy polymer) that when joined gives amplify properties thought about the individual materials without anyone else's input. Numerous segments like controlling wheel, dashboard, situate, rooftop, bring forth, mats, vitality safeguard, instrument group, inside what's more, outside board, leaf spring, wheels, motor spread and so on manufactured by composite materials. [6]

- ✓ **In Medical:** A composite is a nonviable material utilized in a therapeutic gadget and planned to associate with a natural framework. Composites as intersections, bone and joint substitutions, vascular joints, heart valves, intraocular focal points, dental inserts, pacemakers, biosensors, imitation hearts and so on generally utilized to supplant and additionally re-establish the capacity of exasperates or weakened tissues or organs, to improve work, to help in recuperating, to address inconsistencies and in this way improve the personal satisfaction of the patients. [6]

- ✓ **In Electrical field:** Composite materials have quality, high modulus; electronic composites underscore high warm conductivity, low warm development, and low dielectric consistent and high/low electrical conductivity contingent upon the specific electronic applications. Gadgets composites can utilize costly fillers, for example, silver particles, which serve to give high electrical conductivity. The utilization of composites in hardware incorporate interconnections, printed circuit sheets, interlayer dielectrics, kick the bucket connect, covers, warm interface materials, electrical contacts, connectors, heat sinks, lodgings etc. [6]

- ✓ **In Sports:** Composite materials are utilized in games hardware since they offer the simplicity of vehicle, obstruction, low weight, low upkeep and solidness. The composite material has qualities of weariness opposition break obstruction, prevalent thermos dependability, erosion obstruction, scraped area opposition and vibration constriction, and it has lightweight, high quality and high structure opportunity, and can be prepared and moulded effectively, so it is generally utilized in games gear. There are different products made of composite materials, including the arranging pontoons, cruising vessels, sailboards tennis rackets, badminton rackets, softball bats, ice hockey sticks, bows and bolts and so forth. [6]

- ✓ **In Chemical Industry:** Advantages of composites of imperviousness to fire properties, lightweight, shape capacity, and protection from synthetic compounds has made the material utilized in the substance business. Composites are broadly utilized in mechanical gratings, scrubbers, ducting, funnelling, exhaust stacks, siphons and blowers, auxiliary backings, stockpiling

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tanks, sections, reactors and so forth for antacid and acidic situations. A few applications are drive shaft, fan sharp edges, conduits, stacks, underground stockpiling tanks, housings, composite vessels and so forth. Globally, composites applications in synthetic industry are a generally little section in connection to the complete utilization of composites. [6]

✓ **Other:** Composites have for some time been utilized in the development for mechanical supports, structures, long length rooftop structures, tanks, connect parts and complete scaffold frameworks. With composites showing phenomenal protection from the marine condition. With the assistance of composite we make lightweight entryways, window, furniture, building, connect and so on for residential and development reason. [6]

CHALLENGES, OPPORTUNITIES & FUTURE TRENDS

A few difficulties must be overcome to increase the use of the Hybrid composites. A Plan, research and item improvement are required for endeavouring and improvingbusiness abilities that are required to defeat the challenges. In this interest, there is a need to study these accompanying issues.

- Science of essential preparing of half and halves should be seen all the more completely, particularly factors influencing the microstructural respectability.

- There is a need to modify the harm tolerant properties especially break strength and malleability in Hybrid Composites.

- Work ought to be done to deliver high calibre and low-cost fortifications from mechanical squander and results.

- Efforts are neededfor the advancement of Hybrids because of non-standard strands and lattices.

- There is a more noteworthy need to order various evaluations of half and halves dependent on property profile and assembling cost.

- There is a critical need to create straightforward, prudent what's more, versatile non-dangerous bags to measure.

CONCLUSIONS

In this paper, efforts have been made to analyse and present the applications and challenges ahead implementation of 3D printing technology on society. A brief history of 3D printing technologies along with the classification of processes has been discussed. Moreover, the advantages and disadvantages of the use of different kinds of materials havebeen presented based on an extensive literature review. The method of production of hybrid composites using 3D printing has been exploredalong with their practical applications. In the last section, future perspectives in the field of 3D printing have been elaborated based on the current status of technology. A lot of work is required to be done to develop the sustainable materials in addition to improvement in mechanical properties of the material used for aerospace and automobile applications. There is a need to reduce the cost of production through 3D printing technologies for mass production.

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