Developments in 3D Printable Composite Material

Senthil Kumar S1,*, Gundluru Mahammad Wahab2, Lekkala Yuva Srinivas 3, Aumalasetty Jaswanth 4, Guddeti Rama Thulasi Reddy 5

1Associate Professor, Department of Mechanical Engineering, RMK College of Engineering and Technology, Puduvoyal.

2,3,4,5Final year Students, Department of Mechanical Engineering, RMK College of Engineering and Technology, Puduvoyal.

*Email: senthilkumar@rmkcet.ac.in

Abstract: The generic printing materials based on the filament with the proper unique properties In recent years 3-D technology has become one of mostly used prototype methods for various applications. 3-d printing technology was now adopted in many areas of research and development sectors these technology was increasing the demand of improvement and this properties of verifying and by blending the materials exhibited using varies properties to for manufacturing high performance composites. In day-to-day-life composites have already utilized as a wide range of applications which included in manufacturing of the biomedical components, mechanical components and electrical. The 3-D printed composites were manufactured till the ability range of manufacturing complex-shapes and the geo-metrical shapes in the low cost production and the advantages in the prototypes this review causes all the recent developments, reports and properties of developing the 3-D printable materials have been modifies either by the nano-particles, fibres and other polymers in the field of mechanical and electrical sectors.

Keywords: 3d printer, composite material, polymers, carbon nanotubes

1. Introduction:

3-D printing technology is a term used to describe the 3-D printing technology used for the prototyping of the objects from a digital module to the 3-D printer and it allows the objects to be manufactured from bottom to top in the vertical direction. This process makes the prototype without moulding or milling the process begins with the print command from the compute and by sending the digital CAD FILE [1], will be printed using the printer. The difference that was observed in the 3-D printer was the molten ink was deposited in the thin layer on the top surface in order to manufacture a solid proto-type. These successive layers were designed in software that makes a series of cross-sectional elements through the computer-aided-design. These process constructs the respective layer according to the cross section, these cross-sectional layer were constructed in several ways by the 3-D printer used in constructed to the fabrications of individual parts to make a complex structures. The prototype structure is manufactured by assembling of the parts and the 3-D printing process was held in the layer-by-layer process. The printing of desired
slices were designed for desired objects, and this process results in the rapid manufacturing process used the 3-D printing in a over whelmed based on single material with a boundary range of commercial and proletariat design and there is a relatively inter range of printable materials comparable with printer technology are type of commercial printers and hence they are in limited varieties.

In parallel to these printing technological developments, this technology also brought interest to several based on preblending of materials and bringing the fillers into the printable resins, this also exhibiting special characteristics and properties of 3-D printer representing a technology with huge potential of interest and bringing that to a low cost, prototyping compared among with the traditional procedure for fabricating of composite materials and objects.

In the present work, we summarize the recent developments and discussing the latest process for developing a 3-D printable composite materials and the fabricating methods, advantages, disadvantages, applications and limitations regarding the 3-D printable composite materials.

2. 3-D Printable composite material with proper mechanical properties

3-D printable materials with essential durability and mechanical strength have been collaborated with the help of fillers in order to establish composites with good performance in these specific areas and in these materials have been developed mainly for applications in aero-space, automobile industries and wind energy.

An example by Ning, Who mixed carbon fibres with a thermoplastic matrix to fused filament fabrication printing to develop a replacement for printable composites by following many mechanical properties, including the tensile strength and durability the were examined composite material with the 5W % carbon fibres (150mm) and this process resulted in flexural toughness, flexural modulus with a rise of percentage(11.82%, 16.82%, 21.86%) compared with a rise of percentage compared with a polymeric material, In this study the composite shown worst tensile properties because of bulk porosity values when they are compared with other composites.

3. 3D Printed Electro-active Composite Materials:

Electrically active composites which are manufactured by combining filler with carbon nanotubes containing electrical and mechanical to matric, this incorporation of nanotubes present will be challenger in the upgrading of such composites in comparison with modern techniques such as deposition and fibers spinning. 3-D printing was used as a substitute for fabrication of the manufacturing of in expensive and eco-friendly electronics developed from the composite materials minor issues in a traditional method can be circumvented by 3-D printer.

To increase the dispersion of carbon nanotube (CNT) in common solvents, and widely used in biopolymers are combined with the solvent nor chemicals modifications in the nanotubes are performed. For Example, carboxylation of carbon nanotubes to allow the required efficiency at dispersion in water has been described and also provide several advantages which include an ecofriendly and low cost. To overcome the poor dispersion of carbon nanotubes arranged a biopolymer dispersant in this process, including Gallen and the Gallen. To bring excellence in dispersion and stabilization of carbon nanotubes in aqueous solutions were reached by the help of biopolymer. By the help of ultra-small quantities of these dispersants they are considered for preparing an electrically conducting composite filament.

4. Conductive material developed for 3D printable electrodes:

There are various materials which were assigned for 3-D printing in various sectors particularly for developing the electronic components.
There are bulk number of studies were developed by electrodes with the help of 3-D printable methods have involved the printing of different metals. In the above studies, 3-D printed stainless steel electrodes were manufactured and they were electroplated with elements like gold, bismuth, nickel etc. and with iridium oxide to make these electrodes convenient for hosting of some analytical applications. However, this process manufacturing of metal materials needs expensive equipment, and In most of the cases it needs an additional fabrication steps for making them, where the materials like stainless-steel electrode are electroplated along with an another metal for preparing the electrodes suitable material for sensing. Certain posited metals may also not be suitable for process of environmental monitoring. Metal electrodes also offer with a limited electrochemical potential window and this leads to reducing their purpose of use as sensors.

For the above mentioned, carbon based materials are mostly preferred for the development of 3-D printable electrodes. To manufacture conductive carbon filaments and to manufacture composite materials are produced from conductive materials such as carbon-nanotube, graphene, and carbon-black mixed with thermoplastic materials such as polylactic-acid and acrylonitrile, butadiene styrene. Printing a carbon composite filaments may offer some significant advantages in developing of conductive electrodes when they were compared to carbon based paste and carbon-nanotube epoxy composite electrodes based on the appropriate in conductivity for the printable electrode. At this point of time we have reports on conductive 3-D printable polymer material based on the polypropylene/carbon black filament, poly butylen/carbon, poly butylene/carbon nano tube and composite filaments.

The recent Studies have proven that printing along with the carbon based composites material should be carried out with a special care, the anisotropy and orientating of printing the materials can result in significant variations in the electrochemical performances of the printed sensor. These studies concentrates on highlighting the importance of understanding the key parameters in printing the elements and their influence using on the conductivity of composite electrodes, as the factors can influence the conductive pathways used in composite materials.

5. High performance of 3-D printable concrete enhanced with nanomaterials

Nanoparticles are a type of particles with a diameter of less than 100 nm. Due to their small size, their behavior is influenced by atomic, molecular, and ionic interactions. Research on nanoparticle addition to concrete concludes that increased mechanical strength is obtained as well as improved rheological behavior, specifically yield stress and cohesion. These effects are largely attributed to increased pozzolanic reactivity. A well-dispersed nanoparticle microstructure has the further benefit of increasing re-flocculation of particles e.g. after shearing induced by pumping, hence increasing thixotropic behavior that is ideal for 3DPC purposes.

HPC is defined as concrete having high strength or improved durability properties, however, a wide range of strengths (60 – 130 MPa) are defined as HPC depending on the era and institute. For 3DPC purposes, an HPC must demonstrate thixotropic behavior to yield acceptable buildability. Thus, an HPC for 3DPC consists of a hybrid model: firstly improved rheology and secondly increased mechanical or durability properties. Typical HPC employs very low w/c ratios, which results in incompatible workability in terms of printability for 3DPC. With the use of nanoparticles, higher w/c ratios can be used to obtain concrete rheology suitable for 3DPC, while also conforming to the hardened property requirements for HPC. In this research, the silicon carbide and silica nanoparticles were added to make a reference HPC material that is suitable for 3DPC. Its effect on rheology is depicted by means of novel static yield shear stress evolutions of curves, which encompasses the statics and dynamics yield strength, re-flocculation and structuration rates that characterize the degrees of thixotropy of a materials. Its effect on mechanical properties, in particular compressive and flexural strength and the Young’s Modulus, are examined. The interlayer bond strength between successive filament layers with and without nanoparticle addition is determined by the help of 4-point bending test. This is a crucial test for 3DPC, as the interlayer bond strength is typically weaker than the concrete itself. Adequate rheology can result in filament layers were
merged in order to form a homogenous concrete section and it leads to resulting in stronger structures without weak interlayer bonds.

6. Conclusion:

3D printing technology is one of revolutions in the field of science. The main potential regarding the 3-D printer for fabricating of composite materials is a hurry of modern developments and the possibilities present in the applied material sciences and it leads to a sparking of new research into the quick prototyping’s of complex prototyping with the material properties.

References

[1] L. S. Dimas, G. H. Bratzel, I. Eylon and M. J. Buehler, Adv. Funct. Mater. 2013, 23, 4629–4638.
[2] S. Waheed, J. M. C. Canyelles, N. Macdonald, R. M. Guijt, T. Lewis, B. Paull and M. C. Breadmore, Lab Chip, 2016, 16, 1993–2013.
[3] N. Bhattacharjee, A. Urrios, S. Kanga and A. Folch, Lab Chip, 2016, 16, 1720–1742. 5 O. Ivanova, C. Williams and T. Campbell, Rapid Prototyping J., 2013, 19, 353–364.
[4] S.H. Masood, W.Q. Song, Development of new metal/polymer materials for rapid tooling using fused deposition modelling, Materials & Design 2004, 25, 584-94.
[5] J. Wang and L. L. Shaw, J. Am. Ceram. Soc., 2006, 89, 3285–3289.
[6] J. Jyoti, S. Basu, B. P. Singh and S. R. Dhakate, Composites, Part B, 2015, 83, 58–65
[7] A. E. Jakus, E. B. Secor, A. L. Rutz, S. W. Jordan, M. C. Hersam and R. N. Shah, ACS Nano, 2015, 9, 4636–4648.
[8] R. Matsuzaki, M. Ueda, M. Namiki, T.-K. Jeong, H. Asahara, K. Horiguchi, T. Nakamura, A. Todoroki and Y. Hirano, Sci. Rep., 2016, 6, 23058.
[9] D. W. Lipke, Y. Zhang, Y. Liu, B. C. Church and K. H. Sandhage, J. Eur. Ceram. Soc., 2010, 30, 2265–2277.
[10] T. N. A. T. Rahim, A. M. Abdulllah, H. M. Akil, D. Mohamad and Z. A. Rajion, J. Reinf. Plast. Compos., 2015, 34, 1628–1638
[11] P. Jeong Hun, J. Jin Woo, K. Hyun-Wook and C. Dong-Woo, Biofabrication, 2014, 6, 025003
[12] C. Bergmann, M. Lindner, W. Zhang, K. Koczur, A. Kirsten, R. Telle and H. Fischer, J. Eur. Ceram. Soc., 2010, 30, 2563–2567
[13] S. Kumar and J. P. Kruth, Mater. Des., 2010, 31, 850–856
[14] P. Calvert, Chem. Mater., 2001, 13, 3299–3305
[15] J. M. Taboas, R. D. Maddox, P. H. Krebsbach and S. J. Hollister, Biomaterials, 2003, 24, 181–194
[16] M.D. Symes, P.J. Kitson, J. Yan, C.J. Richmond, G.J.T. Cooper, R.W. Bowman, T. Vilbrandt, L. Cronin, Integrated 3D-printed reactionware for chemical synthesis and analysis, Nat. Chem. 2012, 4 349–354.
[17] Q. Sun, J. Wang, M. Tang, L. Huang, Z. Zhang, C. Liu, X. Lu, K.W. Hunter, G. Chen, A new electrochemical system based on a flow-field shaped solid electrode and 3Dprinted thin-layer flow cell: detection of Pb2+ ions by continuous flow accumulation square-wave anodic stripping voltammetry, Anal. Chem. 2017, 89, 5024–5029.
[18] J.L. Erkal, A. Selimovic, B.C. Gross, S.Y. Lockwood, E.L. Walton, S. McNamara, R.S. Martin, D.M. Spence, 3D printed microfluidic devices with integrated versatile and reusable electrodes, Lab Chip. 2014, 14, 2023–2032
[19] C.L. Manzanares Palenzuela, M. Pumera, (Bio) analytical chemistry enabled by 3D printing: sensors and biosensors, TrAC Trends Anal. Chem. 2018, 103, 110–118.
[20] E.H.Z. Ho, A. Ambrosi, M. Pumera, Additive manufacturing of electrochemical interfaces: simultaneous detection of biomarkers, Appl. Mater. Today 2018, 12, 43– 50.
[21] J. G. Korvink, P. J. Smith and D.-Y. Shin, Inkjet-based Micromanufacturing, John Wiley & Sons, 2012.
[22]. D.Y. Shin, M. Jung and S. Chun, J. Mater. Chem., 2012, 22, 11755–11764
[23]. D. Engstrom, B. Porter, M. Pacios and H. Bhaskaran, J. Mater. Res., 2014, 29, 1792–1816
[24] J. Mueller, K. H. Matlack, K. Shea, C. Daraio, Adv. Theory Simul. 2019, 2, 1900081.