INTERNATIONAL JOURNAL OF R&D IN ENGINEERING, SCIENCE AND MANAGEMENT
Vol.10, Issue 3, pp.1-13, ISSN 2393-865X

Design and additive manufacturing of different components with FDM 3-D printing by high strength high temperature glass fiber filament

Sachin Kumar, Mechanical Engineering Department, UIET, MDU Rohtak, India
lm.ssk.sachin@gmail.com

Abstract

FDM (Fused Deposition Modeling) 3-D printing, also known as fabricating process is transforming the outlook of additive manufacturing. This modern specialized craze is furthermore uniform in hugely supervised production, such as agile tooling, quick prototyping and automotive industries. Working on the studies foreground, 3-D printing technology is developing latest ideal in research departments, like defence, implanting cells, tissue engineering moreover in dynamic robots interconnected subject. 3-D printing is first & foremost focused at mini ratio of tailor-made & made to order while traditional machining is twisted to stack productivity. Additive manufacturing (AM) in mini-scale extent is besides inexpensive in contrast to traditional manufacturing method, where cutting operations, guiding & planning technique initial to bona fide mass-productions are exhaustive & overpriced. In this paper we study the design prospects of knurling bolt to fit in a 3-D scanner with tripod stand. Design and additive manufacturing of device holder with FDM 3-D printing by HSHT (high strength high temperature) glass fiber filament used as working filament. Functional 3-D model of gear terminology used in industries & additive manufacturing of crutch tip used in standard aluminium crutches for handicapped person.

Keywords: Additive manufacturing, HSHT, Fiber filament, FDM

1. Introduction

In 3-D printing technology, FDM 3-D printer is a type of additive manufacturing which is used to manufacture product by adding layer by layer when extrusion nozzle temp reached to a critical temp where filament begin to melt and flow outside through nozzle and becomes hard under 5 seconds from the time it came outside of the hot nozzle. 3-D printing technology has the scope to manufacture complicated shape, competent of intensifying the potential of their relevant applications. One similar paradigm is the production of grid or criss-cross type of formation used in the rocket, propellers, jet engines & wind turbine blades planned to amplify the automatic collision feedback with an wholescale depletion of mass. The calibre of 3-d printing technology in granting duplicating & repeating, regeneration of outcomes lead through the inception of brand new & brush-up products. On the other

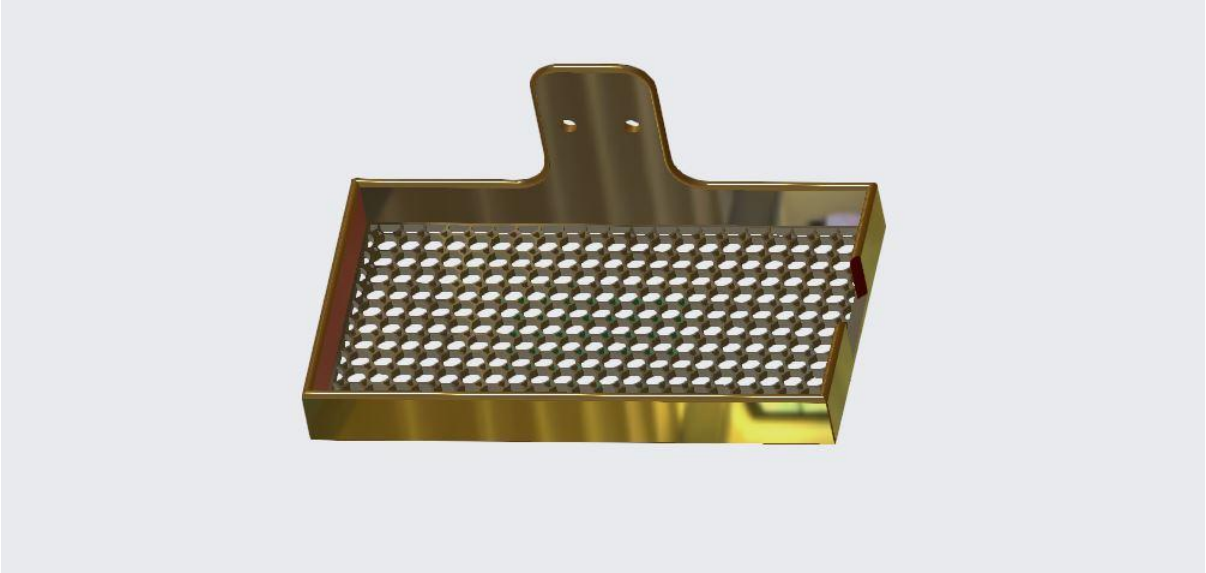
hand, there are restrictions to the quantity of module entanglement when one desires to manufacture in under a feasible resources and standard through traditional techniques. Some examples are device holder for travelling where you often don't get a table to put your device like your handset your PB (power bank). We can also customize its base to more like a net-shaped structure. So that air can pass through it and when your handset or device becomes hot during the charging process then the temperature can be reduced by a natural convection process. Its potential to fabricate complicated formation of almost lattice-shape in materials that are traditionally inflexible to machine has acquired this fabricating methods tremendous popularity. The enhancement & expansion of materials used in 3-D printing techniques have been exposed to remarkable swift progress. Primarily every material can be generate by one or separate 3-D printing techniques today. These materials can be split into four major class's plastics, ceramics, metals and composites. In case of fdm 3-D printer recent advancement in the use of composites(a mixture of ABS and PLA into metal powder), HSHT glass fiber & carbon fiber materials has gain popularity due to its strength to the plastic filaments.

2. Materials And Methods

We have used composite(contain a ratio of 60% to 70% of plastic material and 30% to 40% of the metal powder) and HSHT(high strength high temperature) fiber glass filament and carbon fiber material for fdm 3-D printing of crutch tip, knurling nut & bolt, gears and device holder. Carbon fiber is used in the additive manufacturing of gears.

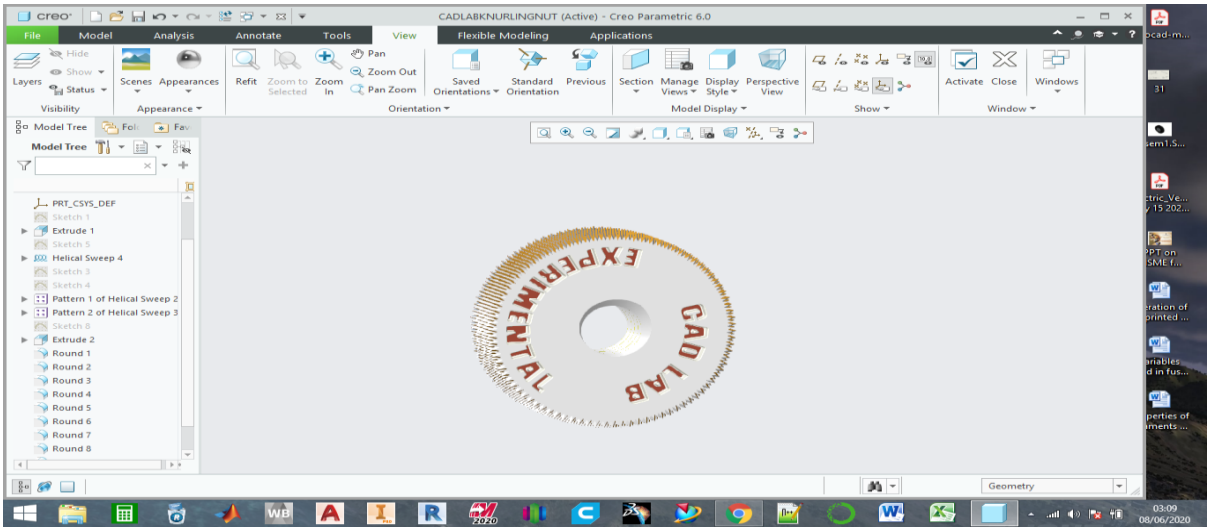
2.1 Device Holder

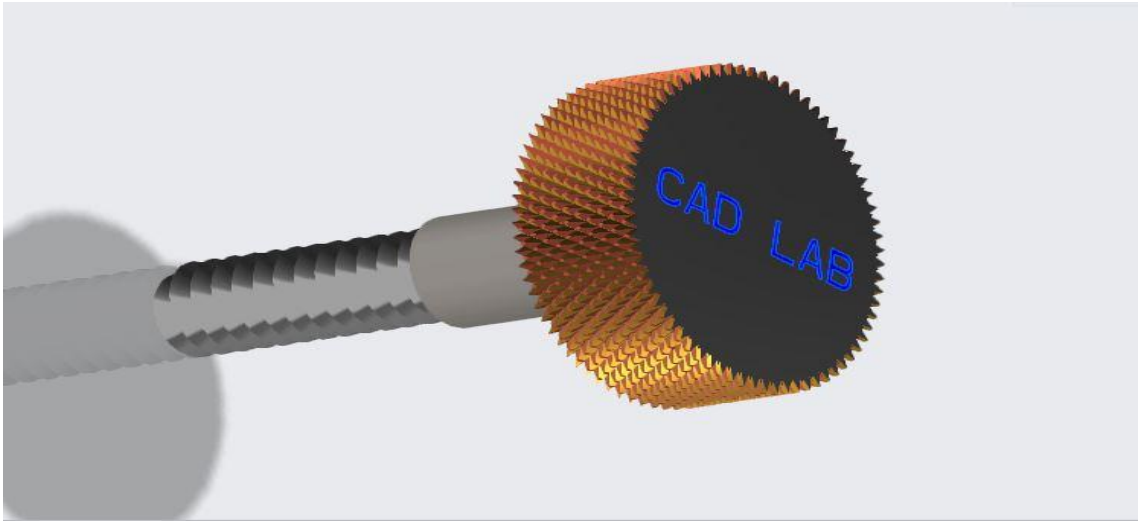
To design device holder we have used ptc creo cad software. Length, breadth and height is taken as 165mm, 95mm, and 25mm. A gap is provided at the right corner of device holder so that a cable of charger can enter and connect inside the device port. Two pin hole of Φ 5.2mm dia for the charger socket pin is equally spaced at 20mm with the centre of collar. Height and breadth of the collar is 50mm & 40mm. We have provided a net shaped at the base of the device holder. Lattice type used is 2.5D in X-direction, lattice cells are multiplied and placed within the volume is set to regular, representation of the lattice is set to full geometry, cell type selected as octagonal. Cell size in x,y,z direction is 7.20mm, skewing angle taken zero, wall thickness of the cell structure is 0.72mm. Width and length is 6mm & 15mm and spacing is 45mm.



2.2 Knurling Nut & Bolt

We have designed a knurling nut & bolt to fit tripod stand to sense-RS 3-D scanner OEM of 3DSYSTEMS. We have measured the pitch value of internal thread from scanner with thread gauge. Major dia inside the scanner is way to small to be measured by a vernier calliper. So we have taken major diameter of ¼'' standard value from ASME chart table which is associated with corresponding pitch value of 20G. To apply these value in CAD system we have to convert it into metric units, first of all we have to convert 20G(gang/t.p.i) into milimeter so 1/20 is equal to 0.05 inches, it'll be multiplied by 25.4mm because 1 inch is equal to 25.4mm and the total value of pitch is calculated as 1.27mm. We have taken 19G and 22G pitch value as well because we notice that pitch gauge fit nicely in the internal thread of the scanner b/w these numbers. In 19G it was close fit & there was no gap b/w the teeth of gauge and thread, and in 22G it was loose i.e we can saw some minor gap so



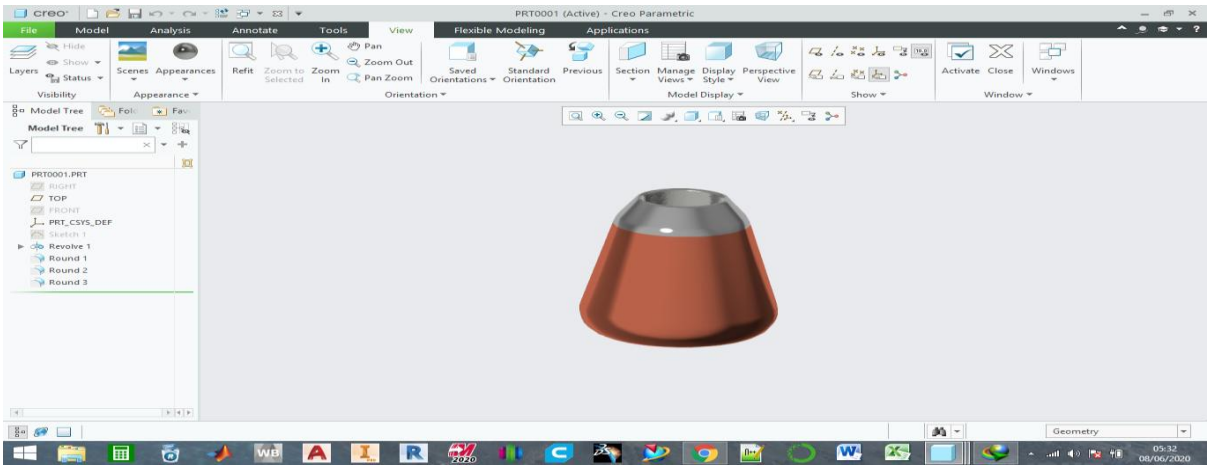


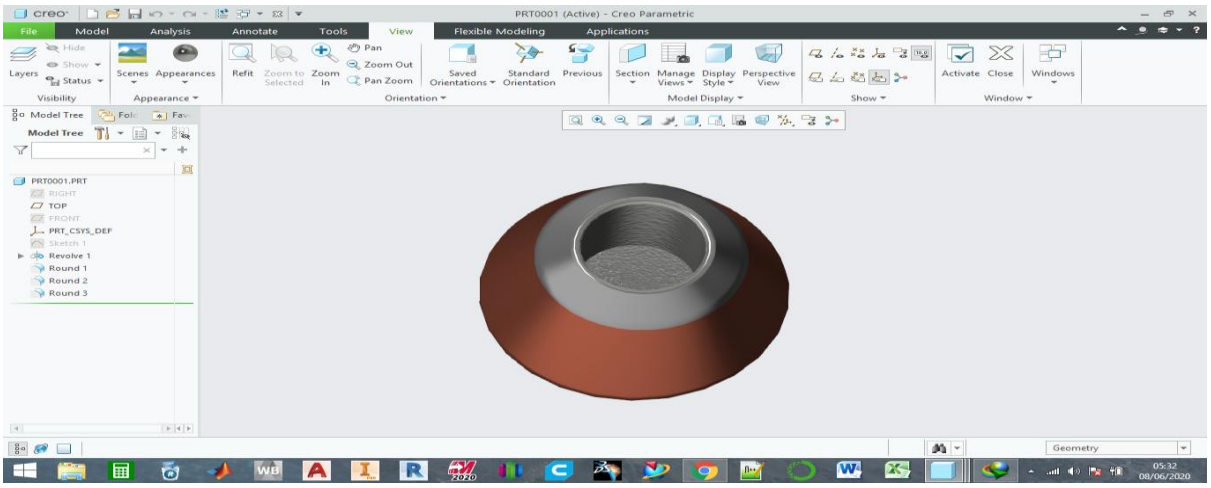
we have considered 20G as the pitch value. The major thread dia of I.T(internal thread) from scanner is converted into metric unit, obtained value is 6.35mm. To find the pitch dia we need to subtract 1 from 6.35mm and to get the minor dia we have to subtract 1mm from pitch dia. In thread profile flank angle is taken as 60 degree. This is the angle b/w a flank and thread axis of bolt. It is sometime called as half angle of a thread but this can be only applied if neighboring flank has angle symmetric to each other. An unified screw thread have a 30 degree flank angle and are symmetrical, this is why they are commonly referred to as 60 degree angle thread. To set the bolt with scanner and tripod we have to make a nut as well so to make a nut that can perfectly fit in bolt we have to designed it by keeping some important fact in mind. An international clearance is originate b/w coupling thread when nut & bolt are to be fabricated. This clearance is acknowledged as the allocation, possessing an allowance make sure that when the threads are fabricated in that place will be a effective room b/w them. For fasteners, the allowance is normally put to the exterior thread. The tolerance is the distinction b/w the extreme and lowest permitted control. Thread fitting is a coalescence of allowances and tolerances, a estimate of closeness or slackness b/w them. A clearance fitting is one that allow a unbound working assembly and tamping fit is one that has a definite interference thus essential tools for the earliest wornout of the nut. For unified thread standard inch screw thread there are six type of standards to fit 1B, 2B, 3B for interior threads, and 1A, 2A and 3A for exterior thread. Standard 1A and 1B is contemplate as immensely free tolerance thread fit. This type of standard is more suitable for fast & uncomplicated assembly & dissembly, 2nd type is 2A and 2B is a balance b/w the fastener it won't be loose and tight, 90% of the industries fastener uses this type of standard. 3A and 3B are befitted for narrow tolerance, these fastener are considered for assistance where protection is a censorious design concern. This type of standard has limiting tolerances and no allowance. Moving on to the main subject, major dia of nut is considered as Φ 5.54mm, and pitch value is same as we used in bolt i.e

1.27mm. Thread direction is clockwise in both bolt and nut. According to the UNF (fine thread) minimum clearance hole diameter for ¼'' size of bolt is for normal fit 0.281 inches, close fit is 0.266 iches, for loose fit is 0.297 inches, these value will be converted in metric unit by multiplication with 25.4mm and we get the value of 7.1374mm, 5.2324mm & 7.5438mm after subtracting these numbers with 2 we can obtain minimum clearance hole diameter for the nut.

2.4 Crutch Tip

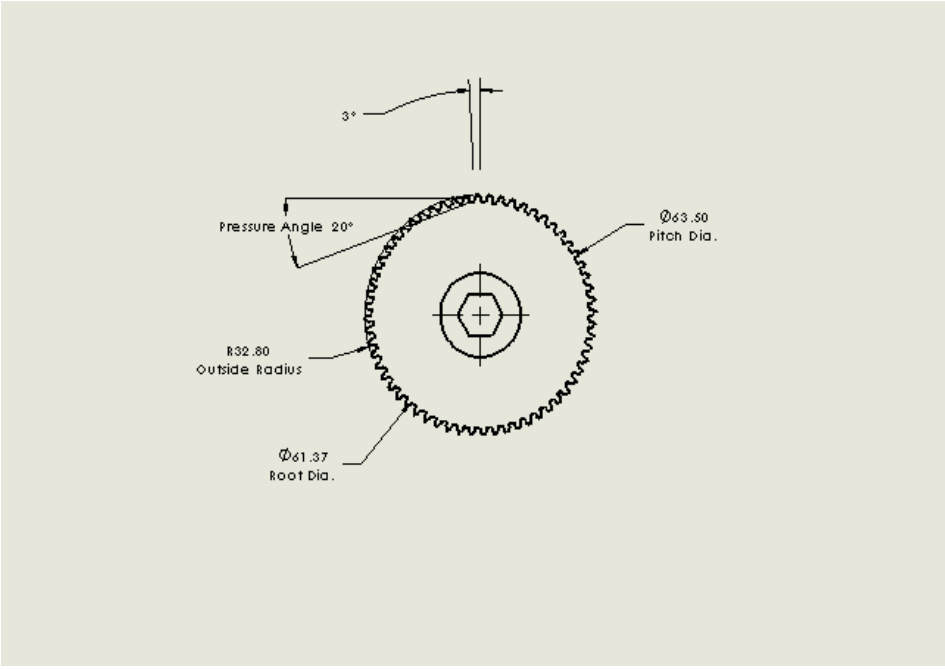
We have measured the rod dia of standard aluminium crutch with vernier caliper, exact measured value is 21mm on main scale reading , vernier scale reading is 4*0.02mm is equal to 0.08mm, diameter of the rod is equal to 21mm + 0.08 = 21.08mm. We have considered the internal dia(I.D) of Φ 22.5mm for crutch tip because if we take the exact 21.08mm then crutch tip won't fit on the rod so we need clearance b/w 1.5 mm and 1.7 mm. Base height of tip is taken 10mm. Total height of the crutch tip is 60mm, base dia of the crutch is considered as Φ 60mm, angle with the crutch top and outside base is taken as 200 degree.





2.5 Gears (spur gears)

In this, we are going to design a 60 tooth gear and a 36 tooth gear (pinion spur gear), pitch value of the both gear is taken as 24mm, no. of teeth is 60 in major size spur gear & 36 in case of spur pinion gear, pressure angle of both gear is taken as 20 degree. Face width is 0.250'' for both gears, pitch circle is obtained after dividing no. of teeth on gears to the pitch, calculation of root dia or circle is done after subtracting 2 from no. of teeth of gears and divided to the pitch, we can find outside circle diameter when we add 2 in no. of teeth and divide it to no. of teeth on spur gear. Now coming to the next point in the process of designing a pair of spur gear we draw a vertical centreline from the center point to a point outside of the circle. Layout circular thickness angle of 3 degree to the left of the vertical centreline, angular momentum for the circular thickness is calculated when 360 degree devided by no. of teeth and then divide by 2, this value is completely depen no. of teeth in a gear and the value 360 degree and 2 can't be changed, it is necessary to divide by 2 since there are always an equal no. of teeth and spaces in each gear. Pressure line is drawn through the pitch point at an angle of twenty degree with a line peripheral to the crown of the pitch circle, withdraw a line that bisect the round width angle. This line mean to divide or bisect far away the outermost circle. Base circle is tangent to the 20 degree pressure line. The base circle will have nearly the same dia as the root circle. This will not be the case with spur gear having different number of teeths and different number of pitch. We have find out that the tooth form circle by creating circle whose radius can't be obtained after dividing pitch dia by eight, although we wlll take pitch point as a centre of this small circle, create another circle (2) of the same radius whose radius lies at the intersection of circle (1) and the base circle, this



circle will form the top right curve of the gear tooth, whose one end is coincident on dedendum end face and another end of arc is coincident on addendum end face. Erase circle (1) and trim away all of circle (2), except the tooth from which is curve is form and connecting this curve to dedendum and addendum, tooth form is generated from the pitch point.

3. Result & Discussion

In first project we have designed and manufactured a device holder with 3-D printing technology using fdm 3d printer and HSHT glass fiber filament. After additive manufacturing(AM) of device holder we can carry smart phones, power banks, Bluetooth speaker e.t.c during the charging process. When we don't get a table to put our accessories while charging it, although we can buy something from market but it is not necessary that we can customized it, to do that we need a 3-D printing technology like fdm 3d printer which is cheaper than other 3-D printing technology like SLS or DLMS & SLA. So we have innovate a device holder which have a net-shaped structure at the base that can naturally cool down our devices by convection process when power is supplied, as we know that heat is transferred from high temperature to lower temperature. In second project we have designed and manufactured knurling nut and bolt using fdm 3d printer and with composite filaments as main material, we have designed it to fit tripod stand with 3-D scanner. So that scanner can be stable during scanning process, in this type of scan, object is moving while scanner position fixed. In CAD design we have added knurling feature to the simple nut & bolt so that it looks more appealing and asthetics also we can't buy something like this from store, and finding a knurling nut & bolt can't be possible because wrench won't fit on it and no industry wants to manufacture a product that can't be used. Coming to the next point we have learned that while designing nut & bolt pitch value of the both part is kept the same while clearance is changed for nut so that it can assemble and dissemble easily. In the

third project we have re-engineered the crutch tip by fdm 3-D printer using composite fillament to fit in standard aluminium crutch. Original rubber crutch tip base dia was Φ 40mm and there was some flaw in this design because it was round from the bottom end of crutch tip and it can easily sink in the sand which make it looks dirty so we have modified the new design and make some changes like we have increased its base diameter to Φ 60mm and increase the flat surface area from the bottom face. In the 4th project we have study the terminology used in spur gear design, we have designed it & fabricated it using fdm 3-D printer technology by carbon fiber filament as main material, our purpose for manufacturing spur gear to fit it in wall clock. In this study we have find that the tooth form circle which give a gear shape of tooth on the outer periphery of root diameter of the gear can't be obtained after dividing pitch dia to eight because if we do that then acquired circle will cross the centreline of gear & if we plot it then the arc formed for teeth will cross the centre and tooth of the gear won't be complete.

4. Conclusion

The discussed projects and the designing methods in this literature can significantly improve the complex customization of the product. The potential of additive manufacturing by fdm 3-D printing technology by adding layer by layer cannot able impact on manufacturing at any place. In conclusion fdm 3-D printed parts using composites, HSHT fiber glass and carbon fiber material can tremendously turn 3-D printing from a prototyping method to a more functional manufacturing technology and it have gained enormous advantage when comparing it with conventional manufacturing technology. One of them is adding material to the part and another is manufacturing of complex structure like net-shaped & knurling pattern in single manufacturing operation, so that the product weight and manufacturing time can be reduced.

Reference

1. Abrol, Sanchita, and Deepak Chhabra. (2017) "Harvesting piezoelectricity using different structures by utilizing fluid flow interactions." International Journal of R & D in Engineering, Science and Management 5, no. 7: 24-36.
2. Ajay Kumar, Ashwani Kumar and Deepak Chhabra (2014) "Analysis of smart structures with different shapes of piezoelectric actuator." International Journal of R&D in Engineering, Science and Management,. 1(2): 60-71

3. Ankit Singroha and Deepak Chhabra (2017). "Analysis of Piezo Polymer Energy Harvesting in Different Applications via Diverse Circuits." International Journal of R&D in Engineering, Science and Management 5(7): 121-135.
4. Ashwani Kumar and Deepak Chhabra (2016) “Fundamentals of Piezoelectric Energy Harvesting” International Journal for Scientific Research & Development, Vol.4 , Issue 5: pp.1168-1171.
5. Ashwani Kumar and Deepak Chhabra (2016) “Recent Developments in the Field of Piezoelectric Energy Harvesting & Advanced MEMS: An Overview” International Journal for Scientific Research & Development, Vol.4 ,Issue 4: pp.1536-1540.
6. Ashwani Kumar and Deepak Chhabra (2016). “Study of PEH Configurations & Circuitry and Techniques for Improving PEH Efficiency” International Journal for Scientific Research & Development, Vol.4 , Issue 3: pp.2098-2102
7. Ashwani Kumar, Deepak Chhabra (2018) “Mehanobiological Aspects of Biosensors Applications In Personalized Healthcare” International Journal of Latest Trends in Engineering and Technology, Volume: 9 Issue: 4 pp.229 – 231 ISSN: 2478-621X.
8. Budhwar, Anmol, and Deepak Chhabra. (2016) "Comparison of energy harvesting using single and double patch pvdf with hydraulic dynamism." International Journal of R&D in Engineering, Science and Management 4, no. 1: 56-67.
9. Chhabra, D., Bhushan, G., Chandna, P. (2016) “Optimal placement of piezoelectric actuators on plate structures for active vibration control via modified control matrix and singular value decomposition approach using modified heuristic genetic algorithm.” Mechanics of Advanced Materials and Structures, 23 (3), pp. 272-280.
10. Chhabra, D., Deswal, S., (2020). “Optimization of significant factors for improving compressive strength of ABS in Fused Deposition Modeling by using GA & RSM.” IOP Conference Series: Materials Science and Engineering 748(1),012007.
11. Chhabra, Deepak, Gian Bhushan, and Pankaj Chandna. (2014) "Optimization of collocated/noncollocated sensors and actuators along with feedback gain using hybrid multiobjective genetic algorithm-artificial neural network." Chinese Journal of Engineering 1-12.
12. Chhabra, Deepak, Gian Bhushan, and Pankaj Chandna.(2014) "Multilevel optimization for the placement of piezo-actuators on plate structures for active vibration control using modified heuristic genetic algorithm." In Industrial and Commercial Applications of Smart Structures Technologies 2014, vol. 9059, p. 90590J. International Society for Optics and Photonics, 2014.

13. D. Chhabra, K. Narwal and P. Singh, (2012) "Design and analysis of piezoelectric smart beam for active vibration control." Int. J. Adv. Res. Technol. 1(1), 1-5.
14. D. Yadav, D. Chhabra, R. K. Gupta et al.,(2020) "Modeling and analysis of significant process parameters of FDM 3D printer using ANFIS." Materials Today: Proceedings. https://doi.org/10.1016/j.matpr.2019.11.227
15. D. Yadav, D. Chhabra, R. Kumar Garg et al., (2020) "Optimization of FDM 3D printing process parameters for multi-material using artificial neural network." Materials Today: Proceedings. https://doi.org/10.1016/j.matpr.2019.11.225
16. Deepak Chhabra (2016) "Optimization of an Automotive Rear Dead Axle using CAE Tool" International Journal of R&D in Engineering, Science and Management,. 4(2): 18-24.
17. Deswal, S., Narang, R., Chhabra, D. (2019) "Modeling and parametric optimization of FDM 3D printing process using hybrid techniques for enhancing dimensional preciseness" International Journal on Interactive Design and Manufacturing. 1-18. https://doi.org/10.1007/s12008-019-00536-z.
18. Dinesh Yadav and Ravin Sehrawat. (2018) "A Review on Recent Enhancement in Greenhouse Drying System." International Journal of R&D in Engineering, Science and Management 7, no. 5: 82-90.
19. Dinesh Yadav and Ravin Sehrawat. (2018) "Artificial intelligence integration in healthcare and Medicine." International Journal of R&D in Engineering, Science and Management 7, no. 3: 16-22.
20. Dinesh Yadav and Ravin Sehrawat. (2018) "Healthcare and Artificial Intelligence: Image Processing An Emerging tool." International Journal of R&D in Engineering, Science and Management 7, no. 3: 9-15.
21. Dinesh Yadav and Ravin Sehrawat.(2018) "A Review on Recent Enhancement In Hybrid composite." International Journal of R&D in Engineering, Science and Management 7, no. 3: 16-22.
22. Gupta R. K., Chhabra D., (2019). "Reliability assessment on assembly line due to random failure of mechanical component: A case study in an automotive ancillary unit." International Journal of Advanced Science and Technology, Vol. 27, No. 1,pp. 251-258.
23. Jyoti Yadav, Dinesh, DP Goyal (2016) "A Review on Advance Piezoelectric Energy Harvesting and their Circuitry System." International journal of R&D in engineering, science and management, vol.04, No.7, pp.8-17.

24. Kumar, Amit, and Deepak Chhabra (2013) "Design of Neural Network Controller for Active Vibration control of Cantilever plate with piezo-patch as sensor/actuator." Int. J. Mod. Eng. Res 3, no. 4: 2481-2488.
25. Mohit Kumar, Deepak Chhabra and Suresh Kumar. (2014) "Intelligent controllers/adaptive controllers for active vibration control in different structures/systems-a review." International Journal of Latest Technology in Engineering, Management & Applied Science 3(5): 13.
26. Mohit Yadav, Dinesh Yadav, Surendra Kumar, Ramesh Kumar Garg and Deepak Chhabra(2019) "Experimental & Mathematical Modeling and Analysis of Piezoelectric Energy Harvesting With Dynamic Periodic Loading." International Journal of Recent Technology and Engineering, Volume-8, Issue-3, 6346-6350.
27. Mohit, Deepak Chhabra, and Suresh Kumar, (2015) "Active Vibration Control of the Smart Plate Using Artificial Neural Network Controller," Advances in Aerospace Engineering, vol., Article ID 137068, 20 pages, 2015. doi:10.1155/2015/137068.
28. Narwal, Kapil, and Deepak Chhabra. (2012) "Analysis of simple supported plate for active vibration control with piezoelectric sensors and actuators." IOSR Journal of Mechanical and Civil Engineering 1, no. 1: 2278-1684.
29. Naveen Kumar, Deepak Chhabra (2016) "Implementation of Fire Fighting and Safety in Warehouse" International Journal of R&D in Engineering, Science and Management,. 3(7): 193-207.
30. Neeraj Sehgal and Deepak Chhabra (2014) "Modeling and Simulation of a Plate with Piezo-Patches as Sensors/Actuators Using LQG Modal Control & Comparison with Classical Controller" International Journal for Scientific Research & Development, , Vol.2 , Issue 6: 4-13.
31. Neeraj Sehgal, Monu Malik, Deepak Chhabra, (2014) "Meta-heuristics Approaches for the Placement of Piezoelectric actuators/Sensors on a Flexible Cantilever Plate: A Review" International Journal of Enhanced Research In Science Technology & Engineering, Vol. 3, Issue 6, June, , pp: (7-16),ISSN: 2319-7463, .
32. Nitin Yadav, Deepak Chhabra "Design and Analysis of Closed Flow System with Varying Various Parameters of Hydrodynamics for PEH" Journal of Control & Instrumentation, (2018) Volume: 3 Issue: 10 pp.41 – 48 ISSN: 2454-4248.
33. Rajan Narang, Deepak Chhabra (2017) "Analysis of Process Parameters of Fused Deposition Modeling (FDM) Technique" International Journal on Future Revolution in Computer Science & Communication Engineering, Volume: 3 Issue: 10 pp.41 – 48 ISSN: 2454-4248.

34. Rani, Pooja, and Deepak Chhabra. (2016) "Piezoelectric energy harvesting from fluid flow dynamism using pvdf." Int. J R&d Eng. Sci. Manag. 4, no. 1: 23-36.
35. Sanchita Abrol, Deepak Chhabra (2018) “Experimental Investigations of Piezoelectric Energy Harvesting with Turbulent Flow” International Journal of Mechanical and Production Engineering Research & Development, Volume: 8 Issue: 1 pp.703 –710 ISSN: 2449-8001.
36. Sandeep Kumar, Deepak Chhabra, & Pawan Kumar. (2014) “Design and Stress Analysis of Steering Rack Using CAE Tool”. International Journal of Advances in Engineering Sciences,. 4(3), 12-15.
37. Sandeep Kumar, Deepak Chhabra and Pawan Kumar (2014). "Design and optimization of steering rack using cae tool." International Journal of Enhanced Research in Science Technology & Engineering 3(6): 106-110.
38. Sandeep, Deepak Chhabra, (2017) "Comparison and analysis of different 3d printing techniques", International Journal of Latest Trends In Engineering And Technology, Volume 8 Issue 4-1 - 264-272.
39. Vashistha, R., Yadav, D., Chhabra, D., & Shukla, P. (2019). “Artificial Intelligence Integration for Neurodegenerative Disorders.” In Leveraging Biomedical and Healthcare Data (pp. 77-89). Academic Press.
40. Vikram, Deepak Chhabra, (2017) "Design and analysis of mechanism to apply periodic dynamic load on PVDF" International Journal Of Latest Trends In Engineering And Technology, Volume 8 Issue 4-1, 250-257.
41. Yadav Dinesh, Jyoti Yadav, Rajat Vashistha, Dharminder P. Goyal, and Deepak Chhabra. (2019) "Modeling and simulation of an open channel PEHF system for efficient PVDF energy harvesting." Mechanics of Advanced Materials and Structures 1-15.
42. Yadav, Dinesh, and Ravin Sehrawat. (2019) "A Review on 3D printing Technology Application in Healthcare." International Journal of R&D in Engineering, Science and Management 8, no. 6: 01-06.
43. Yadav, Dinesh, and Ravin Sehrawat.(2019) "Green Energy Generation using Single and Double parallel circuit configuration of PZT piezoelectric patch by application of Hydro Dynamism." Inter. J. R&D Eng. Sci. Manag 9.2: 25-38.
44. Yadav, Dinesh. (2018) "Comparison of Green Energy harvested using PZT piezo patch in different series configuration and Optimization of circuitry system." Journal of Emerging Technologies and Innovative Research 5, no. 8: 974-984.

45. Yadav, J. and Yadav, D. (2017). "Design of an open channel fluid flow system for piezoelectric energy harvesting." Int. J. Latest Trends Eng. Technol 8, no. 4-1: 244-249.
46. D Chhabra, G Bhushan, P Chandna (2013) “Optimal placement of piezoelectric actuators on plate structures for active vibration control using modified control matrix and singular value decomposition approach” International Journal of Mechanical, Industrial Science and Engineering 7 (3), 1-6.
47. S Adlakha, D Chhabra, R Vashistha (2020). “Efficacious Study of Specific Co-Creation Policies in the Healthcare Ecosystem: The Synergy Between Healthcare Providers, Policymakers, and Seekers.” Technological Innovations for Sustainability and Business Growth, 199-220.
48. Yadav, Jyoti, Dinesh Yadav, Rajat Vashistha, D. P. Goyal, and Deepak Chhabra. (2019) "Green energy generation through PEHF–a blueprint of alternate energy harvesting." International journal of green energy 16, no. 3: 242-255.
49. Yadav Mohit, and Yadav Dinesh. (2019) "Micro Energy Generation in Different Kinds of Water Flows on Lead Zirconium Titanate/PVDF.” International Journal of R&D in Engineering, Science and Management 9, no. 5: 1-8.
50. Kumar Ashwani, Dinesh Yadav, Ramesh Kumar Garg, Ravikant Gupta, and Deepak Chhabra. (2020) "Design and Optimal Placement of PVDF Patches Over a Shoe Transducer for Efficient Energy Harvesting." *Design Engineering* : 08-22.
51. V Kumar, D Chhabra (2013) “Design of fuzzy logic controller for active vibration control of cantilever plate with Piezo-Patches as sensor/actuator.” International Journal of Emerging Research in Management &Technology 2, 34-44.
52. B Pratap, R K Gupta, D S Yadav, A. Yadav, D Chhabra, M. Nag (2020). “Physical and mechanical characterization of nanoalumina filled resin based dental composites.” Materials Today: Proceedings doi.org/10.1016/j.matpr.2020.04.162.
53. M Khare, R K Gupta, S S Ghosh, D Chhabra (2020). “Effect of carbon black on mechanical properties of Al7075/Al_2O_3/B_4C reinforced aluminum composite.” Materials Today: Proceedings doi.org/10.1016/j.matpr.2020.04.803.
54. SK Vashist, D Chhabra (2014). “Optimal placement of piezoelectric actuators on plate structures for active vibration control using genetic algorithm” Active and Passive Smart Structures and Integrated Systems 2014 9057, 905720.