IMPROVING ON-SITE ENGG SP USING 3D PRINTING TECHNOLOGY

Maj Viksit Sachdeva

"We have 3D printing, a machine which can print spare parts, print models, print toys, print pistols, print body parts, organs; print things which can make a difference to our lives."
-Mr Lee Hsien Loong, Prime Minister of Singapore

***Abstract*— 3D printing is a technology used to print three-dimensional objects using a specially designed 3D printer. The technology has seen numerous developments, advancements and applications since its inception. It has been one of the most talked about developments in the digital world and has involved millions of investment and funding in R&D establishments by big commercial and defence players around the globe enabling creation of almost everything from tiny human body parts to construction of buildings today. However, the most challenging aspect involved in the 3d printed objects is the reliability factor that will impact the future of this technology. This article aims at study of the 3D printing technology and recommend the way forward for its utility in improving on-site engineering support as the function of Corps of EME.**

INTRODUCTION

1. 3D printing is a printing technology that involves a distinct technique of combining several kinds of materials and processes to create solid three-dimensional objects. The first ever accepted patent in this technology is by the name of Mr Chuck Hull of 3D Systems Corporation, California (US), who invented the first 3D printing process called 'stereo lithography' by contributing an Stereolithography file format (STL) in 1983, which emerged as a break through in the proliferation of the technology and is widely common in many 3d printing processes today. The STL format is a digital file capable of storing data with respect to three-dimensional printing process.

2. The production line process involves different methods to manufacture objects. The 3d printing involves Additive manufacturing (AM) which signifies addition of materials in successive layers and phases to create objects. Additive manufacturing in 3D printing enables fast production as compared to traditional manufacturing methods. Combination of a variety of materials and processes with different permutation and combinations, capable of handling simple to complex geometries, are printed based on the 3D model to serve objects for different industries, as is available in the world today.

3. The objects created from this technique are created using a 3d printer that reads a digital file (STL format) as input and produces successive layers of materials such as metals, plastics, concrete, resins, or sand, until the entire object is created.

4. Today, like the successful e-commerce websites incl Amazon, Flipkart and Alibaba, there are websites which offer products related to 3d printing. The available products are 3d models of thousands of objects, slicing softwares, materials used and 3d printers. There are websites like makexyz.com and treatstock.com which seek 3d model of desired objects and provide on-demand 3d printing and delivery with accuracy and precision. Google Trends report as on 19 Oct 2018 shows the increase in interest of people across the world for 3d printing rising for more than 1000 percent from 2011, which is the clear indication of the exponentially increasing popularity of the technology in present day global market.

5. Recently, an article on *'Aerospace 3d printing'* by Sarah Saunders of 3DPrint.com on Apr 4,2018 reveals that one third of General Electric Aviation's new turboprop engine for aircrafts will consist of 3d printed metal components. This indicates the far developments, which the technology has undertaken in the past decade moving leaps forward towards bringing a reliability factor in the 3d printed objects.

THE 3D PRINTING TECHNOLOGY

6. 3D printing technology involves series of phases in the overall printing process. The first phase is to create a Computer Aided Design (CAD) model of the object to be created. This is of course the key issue in the adoption of 3D printing technology. 3D models can be created in some of the famous three dimensional object designing softwares namely, AutoCAD, Google Sketchup, Blender and Autodesk Fusion 360. These applications provide easy user interface and multitude of functionalities to enable the user to design 3d models. Today, 3d models are also commercially available on popular websites like Thigiverse.com and MyMiniFactory.com, which have thousands of 3d models available in their cart which can be purchased suiting the requirement.

Fig: 3D model designing (CAD)

7. The first phase post designing a 3d model generates an .STL format file, which is a digital file fed to the 3d printer as input. This digital file is further processed in a slicing software like MakerWare, Cura and Simlplify 3D which provide layer slices and tool path details to the printer enabling it to print the object accurately using movements and directions data which the head and the nozzle need to follow for printing the object completely.

8. Once the file is fed to the printer, the choice of numerous COTS available processes and materials (liquid/ paper/ powder/ sheet) enables the printer to create 3d objects with high precision and complicated geometry. A 3d printer is specially designed to have a platform where the object starts building with the heads and nozzles of the printer, which carry out the additive manufacturing process in the form of layers of materials (polymers/ metals) one over the other in series of cross sections, moving the platform vertically up/ down untill the complete object is created. Materials usually used in one of the widely used processes, the Fused deposition Modelling (FDM) technology, are called as filaments and are used in printers as rolls of thermoplastic materials like ABS (Acrylonitrile Butadiene Styrene) or PLA (Polylactic Acid) – which are completely different kinds of thermoplastic made from corn starch or sugar cane. The resolution of the printed object hence describes the thickess and X-Y resolution in dpi or micrometers.

Fig: 3D Printer

ADVANTAGES OF 3D PRINTING

9. 21st century has seen rapid development in the materials and the printers available commercially off the shelf for creating 3d printed objects. The technology has seen rapid proliferation of the use of 3d printed objects in the medical, toys and aviation industries owing to its number of advantages. Following are the major advantages which 3D printing processes have over the traditional manufacturing processes:-

(a) Fast manufacturing. A complex geometry 3d printed object of 12 square inch of the famous MakerBot printer takes 16-24 hours to print, which is much lower than the traditional manufacturing process. However, the capability to print mass objects directly depends upon the complexity and selection of printers.

(b) Reduced transportation time. An object can be printed in-house based on the customised specification of the required object, thus reducing transportation time and costs for forward delivery of objects.

(c) Lower costs. The printing process is 20-30% cheap as compared to the traditional manufacturing process owing to the use of material, less required machinery and transportation cost etc. The costs are likely to reduce in future due to rapid continuous developments in the technology making it more available in the open market.

(d) Environment friendly. The process is environment friendly as it omits the use of toxic chemical processes and emissions. Also, the materials like PLA, ABS, Nylon, Carbon Fiber etc are biodegradable.

(e) Reduced wastage of material. As the digital file provides specific data, the heads and nozzels spread the material selected on the respective location and layers, thus reducing wastage of material. Also, unlike traditional subtractive manufacturing, 3d printing is an additive manufacturing resulting is curbed wastage.

(f) Procurement delays. Specifically to Army, the technology can help in fast availability of required goods or products, as they can be developed and created in-house thereby eliminating all sort of procurement and procedural delays.

GLOBAL FOOTPRINT

10. As per a study, by 2023, the global market of 3D printers and their services is estimated to be worth $32.78 billions at a Compound Annual Growth Rate (CAGR) of 25.76% during 2017 and 2023. Based on a forecast by China Industry Information Institute, the figure of 3D printing Industry of India's neighbor, China is expected to become the proud stake holder of one-third of the global market by 2020 by reaching mark of a magnificent $7.68 billion in output value.

11. During the past decade, the capability of 3D printers have increased 100 times faster, thereby inducing a competitive market leading to corresponding decrease in the cheapest available 3D printer from $18,000 to $400. Globally, multiple applications of 3D printing in civil sector which have made news, are the major shoe companies like Nike for printing shoes, China for building a six storey 3D printed office building, Communication giants for research in introducing 3D scanning in mobile phones, use of 3d printing in printing human body parts using body tissues and cells and huge expansion of General Electric Aviation's 150,000-square-foot Additive Technology Center (ATC) in Cincinnati, which has become one of the largest and most advanced Additive Manufacturing research R&D and development centre.

PRESENT STATE IN INDIA

12. The experience of India in the technology was at a nascent stage in 2014, when the overall market comprising of commercial companies and the workforce was just 300-500 including engineers, dedicated companies and graphic designers with 3D printing experience etc. However, with the current escalated trend, the market is expected to expand to a workforce of 50000 by 2019. This will further lead to higher growth of the 3D Printing industry and shall provide wide job opportunities in electronic, manufacturing and retail sectors.

13. Keeping in view the vast void of 3D printing in India, the current business models of 3D Printing industry in India are:-

(a) Reselling premium brand 3D printers like MakerBot and XYZ Printing imported mainly from the US and Europe.

(b) Transfer of Technology (ToT) partnerships by foreign collaborators with Indian entrepreneurs.

(c) Hi-tech companies and startups involved in designing and manufacturing of indigenous 3D Printers and providing services.

14. In India, cost of 3D printers ranges between Rs 75,000 to Rs 1.5 lac, marketed mainly by Bengaluru and Chandigarh based companies. Market applications in India include fields of architecture and industrial construction, manufacturing production tools and parts, dental technology and jewelry business etc.

USE IN DEFENCE

15. 3D Printing has in due course of time proved to be an innovative and revolutionary technology with potentially significant applications for the defence. Its applications till date have been tried and test by some of the militaries of the world. The prominent development in the military has been the development of a grenade and a grenade launcher named RAMBO (rapid additively manufactured ballistics ordnance) by US Army's Armament Research, Development and Engineering Center (ARDEC). Both completed the testing phase and fired successfully in May 2017. As long ago as 2014, the U.S. Navy also installed this technology on ships to create spares (critical and obsolete) for both the ships and weapons carried onboard. In addition, both the Air Force and the Marine Corps of US have created roadmap and laid policies to explore 3D printing for use in the respective domains. In India, Indian Space Research Organization (ISRO) has started use of the technology post successful launch of a 3D rocket into space on May 25, 2017 by New Zealand, that has posed competition to India and China in terms of low cost launch services.

16. The reason for which the 3D printing technology is mustering attention, R&D and funding by the forces of the world is the major benefit which the technology offers for the defence sector. It speeds up the supply chain and reduce costs since some supplies can be printed in the forward field locations with cheaper raw materials. Obviously, all components/ tools/ spares, especially the complex and IP protected types, cannot be 3D printed, however, the technology can be successfully used in equipment intensive operations under critical scenarios which have direct implication on battle efficiency, since the defective parts can be replaced on the spot in quick time.

17. From the developments till now and based on the military's experience, 3D printing so far has highlighted a couple of key benefits which can be imbibed and get to a stage of implementation in the Indian Armed forces also :-

(a) It can simplify logistics by only transporting the technology and raw materials, rather than every conceivable spare part or weapon. This will lead to reduction in logistics, procurement and procedural delays.

(b) Training imparted to soldier technicians in 3D printing will enable a corpus of a workforce that can be able to produce customized parts for unique situations/ critical or obsolete eqpt.

(c) 3D maps are in use by militaries all over the world which can also be imbibed in India.

IMPROVING ON-SITE ENGINEERING SUPPORT

18. In Indian Army, the Corps of Electronics and Mechanical Engineers (EME) has the role to achieve and maintain the operational fitness of all the equipment less signal equipment of Indian Army. For this, the Corps is structured into various repair and recovery echelons to provide engineering support to the equipment of fighting arms of the Army. Though the structuring of repair echelons has been able to provide deliverables at forward locations since years, but these require presence of the must, six pillars of sustainment to enable the technicians to carry out their tasks successfully. These include the availability of required spares/ tools and machinery to revive the functionality of the equipment. In forward locations, stocking of the entire range and depth of spares and tools for all the equipment is a difficult task, hence the spares are stocked in central locations (rear echelons) keeping in view the accessibility and financial factors which induce numerous delays with regard to transportation and procurement thereby impacting the equipment readiness at critical times.

19. To overcome various factors impacting the equipment readiness, 3D printing can be utilized to print spares/ tools as forward as possible thereby enhancing the capability of the Corps in providing the overall engineering support to the forward formations. Though the composition of materials used to provide the desired strength to the spares/ tools will vary from object to object, the availability ratio of the spares will substantially increase. The concept has been proved by use of 3D printed protective covers and support struts in Royal Air Force's (RAF) Tornado fighter jets. Also, the US Army's Rapid Equipping Force (REF), has deployed an Expeditionary Lab-Mobile (ELM) in Afghanistan which is a 20-foot container equipped with a 3D Printer and other workshop equipment allowing production of items including replacement spare parts.

20. 3D printing of critical spares. Availability of critical spares in field is of paramount importance to maintain the mission reliability of the equipment. 3D printing technology can prove to be a deciding boon in field, where a small part going dysfunctional can render a critical weapon or weapon system non functional. 3D printing of critical spares in forward location will have a direct impact on the overall mission readiness of the formation. This is highly possible with the use of portable 3D printers available in the world today, which can be used to print on-demand spares/ tools at lower prices than the traditional manufacturing and transportation costs combined.

RECOMMENDATIONS

21. Creation, establishment and training of a corpus workforce in the Corps to proliferate the 3d printing technology and further design as also collect 3D models of equipment, spares and tools specially which are critical in nature.

22. Signing of an MoU with corporate giants/ startups to carry out required R&D, ToTs, indigenously develop 3D printers and sources of materials for the overall requirement of Army.

23. The forward deployment of 3D Printers in Division/Corps EME Battalions, Corps Zonal Workshops in the Area of Operations, that will enable the technicians to manufacture components for immediate use in field. This can thus help reduce the overall load that is carried by the repair and recovery echelons, which in turn shall reduce the logistics tail.

24. Installation of 3D printers for on-demand manufacturing of obsolete components in Army Base Workshops to reduce the overall manufacturing time consumed to manufacture spares/ tools and machinery using traditional methods. This will enable a long-term maintenance gain for maintaining the vintage fleet of equipment possessed by the Indian Army.

CONCLUSION

25. The increasing development and popularity of 3D printing technology is further making the technology available for the global open market. From the study it can be deduced that 3D printing technology / additive manufacturing has immense potential for military applications as other armed forces of the world have already taken leaps ahead in the same. The benefits of using such a technology in Indian Armed forces specially in the Corps of EME can lead to mass benefits in terms of overall budget as also to the battle worthiness of the equipment. 3D printed weapons like pistols, guns, bombs, rocket launchers, rockets and drones are already reality and available, with missiles under development. The technology can be widely used for surveillance, training, maintenance of weapons and weapon platforms in field which include replacing spares/ parts / making new parts and new equipment thereby improving logistics and battle-readiness as also reducing costs. Hence, there is a need to device a planned roadmap for the implementation of 3D printing in the Indian Army at the apex level so as to reap the major technical benefits it has to offer.

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Author Profile

Maj Viksit Sachdeva, an alumnus of IMA was commissioned into the Corps of EME on 08 Jun 2013. The Officer is OACT qualified. He has a varied experience of undertaking EME tasks in Field & Peace locations and is presently posted as Instructor, Class 'B' in MCEME, Secunderabad.