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Application of additive manufacturing in challenges posed by COVID-19

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ABSTRACT

COVID-19 has brought a lot of turbulence and instability among manufacturing organizations. This pandemic has affected all types of manufacturing operations- subtractive, additive and forming manufacturing processes. In this paper we have discussed how additive manufacturing has played a role in this time of crisis. There has been an increased adoption of additive manufacturing to overcome the demand created by this pandemic. The number of actors in additive supply chain have reduced and thus in the time of epidemics that has been a boom and has helped manufacturers relying on additive manufacturing to be agile and react in nearly no time to the requirements. The same has been found its use primarily in manufacturing healthcare facilities in short notices along with producing parts of medical equipment like ventilators.

1. Introduction

COVID-19 is a communicable disease caused by coronavirus and is transmitted through droplets from an infected person to healthy person. The way to prevent is wearing masks, practicing social distancing, avoiding physical contact, practicing good hygiene, etc. If someone is infected and is severely infected then for treatment ventilators and oxygen masks are needed. Along with this, the medical professionals and the staff taking care of these infected patients need to wear PPE kits. Thus, the need is to produce in large scales and that too locally all these equipments. Additive manufacturing has addressed all the challenges faced by the industry producing these and has come to the rescue.

1.1. Additive manufacturing

Additive manufacturing is a highly innovative technology having various advantages over conventional manufacturing processes. It helps in producing parts on demand without the need for setup and tooling [1]. Additive manufacturing is considered as a game changer [2]. Additive manufacturing technology impacts supply chain performance considerably [3]. Additive manufacturing is used across industries i.e. aerospace, automotive, construction, medical equipment, healthcare, bio-medical, fashion, food, etc. But during this time of crisis its major usage has been in the healthcare, bio-medical and medical equipment. Some of the main advantages of additive manufacturing include:

- Freedom to design and innovate
- Saves energy costs
- Support green manufacturing initiatives
- Easy to revise or change versions of a product
- De-centralizes production
- Reduces lead times
- Easy to design and produce complex products
- Faster time to market

1.2. Additive manufacturing and its supply chain

Additive manufacturing offers the following features- mass segmentation, mass customization, mass complexity, mass variety, mass modularization, and mass standardization. In order to meet these requirements, once requires a different supply chain. Additive manufacturing has changed the way supply chain works i.e. from push based to pull based. Additive manufacturing has resulted in reducing costs- inventory and transportation along with reducing capital expenditures on warehouses, factories, etc.
Along with this, it has decentralized production along with reducing inventory holding cost in the entire supply chain. This has resulted in reducing supply chain steps as their will be lesser need of warehouse, transportation and IT systems.

Some of the features of additive manufacturing supply chain as discussed by various researchers are

- Additive manufacturing involves innovative design and also on-demand manufacturing process. The requirement of warehousing and transportation can be significantly reduced. With proper supply chain configuration, it is possible to increase cost efficiency [4].
- In aircraft spare parts supply chain, additive manufacturing has helped in reducing the inventory as parts can be printed as and when needed at site, instead of maintaining inventory. This has helped in reducing inventory holding cost and saving money for the industry [5].
- In consumer goods industry, additive manufacturing is helping consumers to become creators. Thus, consumers can buy designs and print locally whatever is needed. In some cases, a hybrid approach is being implemented where shift is happening from centralized to decentralized supply chains [6].
- A major shift includes a move from centralized to decentralized supply chains [7].

2. Need of additive manufacturing in COVID-19

The COVID-19 pandemic is a global health crisis and the utmost challenge being faced by world today. Nations are trying their best to test and treat patients along with slowing down the spread of the virus by detecting contact, prohibiting/limiting travel and abandoning large ceremonies. World Health Organization reached out to the industry to increase manufacturing of medical appliances and healthcare needs by around 40%, so as to meet the demand created by this crisis [8]. Across the world, there has been news along with advisory to industrialists to produce ventilators, Personal Protective Equipment (PPE) kits and other urgently required medical equipment. PPE is used to protect health professionals from getting infected by germs and acting as a shield. A lot of mass production facilities were being repurposed to meet this demand. But will take weeks-to-months to establish these facilities and will be able to address this in long term and not short term. But this was the time, when we needed these critical items in span of days along with the necessity to mass produce these locally along with being cost-effective [6,8]. Additive manufacturing was the first responder to this crisis. It demonstrated one of its strengths in this crisis due to its ability to deliver parts quickly and locally, because it needs no tooling along with shorter lead times. Fig. 1 shows how additive manufacturing may be useful in response to COVID-19.

3. Use of additive manufacturing during COVID 19

Some of the uses of additive Manufacturing are

- **Ventilators:** The first prototype was produced using meeting all the requirements and functionalities expected of such a device [9]. Also, it helped in producing parts of the ventilator in a very short time [10–12] (Fig. 2).
- **Swabs for testing:** In order to carry out throat swabs for COVID-19 test, first fully automatic robot has been developed by robotics researchers from the University of Southern Denmark. The 3-D printed robot swabs the patients so that the risk of infecting healthcare professionals is reduced [13].

![Fig. 1. Schematic of procedure of utilizing additive manufacturing in response to COVID-19.](image)

![Fig. 2. Part of ventilator produced from AM.](image)
Face shields: As part of PPE kit, face shields are one of the most important component. Additive manufacturing helped in producing prototypes along with producing face shields.

Splitter multiplying ventilator capacity: In order to use the same ventilator machine among various patients, there was a need to prepare splitter. Additive manufacturing has been used to produce the same.

3-D Bioprinting: A company in Russia, 3-D Bioprinting is utilizing bioprinted tissues to model pathologies, predict toxicity and develop therapeutics for COVID-19-associated illnesses. The same is used in their research for coming out with a drug for COVID 19.

Antimicrobial polymers in the COVID-19 pandemic: An antimicrobial polymer is a class of polymer that control the growth of microorganisms such as bacteria, fungi or protozoans. In the COVID-19 pandemic, additive manufacturing played an important role in the development of critical medical devices by printing antimicrobial polymers [14].

Hand sanitizer holders: In the COVID-19 scenario, the demand of hand sanitizer is increasing by public, health worker, hospital. The mass production has been fulfilled by additive manufacturing [15].

Non-invasive positive end expiratory pressure (PEEP) masks: Brigitte de Vet developed a solution to deliver oxygen along with creating high positive pressure. This solution was by designing a 3-D-printed connector that holds together standard medical equipment, a filter, non-invasive mask and a PEEP valve [16].

Oxygen valves: Frontline Hospital in Italy took help of FabLab Milan to design and print a replacement valve in just a couple of hours. The valve was needed for for Venturi oxygen masks [17].

3-D lung models for use in surgical planning & understand COVID-19: In COVID-19 severe cases, the requirement is to treat respiratory illness, which requires specialist respirators to take over the functionality of lungs. The same were 3-D printed. Along with this, in order to study it was necessary to keep human cells alive for at least two hours. Deshane lab created facility for the same so that research can be done on human lung tissue [18].

4. Conclusion

Additive Manufacturing has been on the forefront of fight against COVID 19. The need of the hour was to mass produce locally at low cost and that too rapidly. Conventional manufacturing had a lot of limitations and was difficult to produce in the time available. The use has been across countries and the major reason for its success has been the supply chain of additive manufacturing. The supply chain has helped in reduction of various supply chain actors along with reducing lead time. The application of Additive Manufacturing has been in ventilators, splitter multiplying ventilator capacity, face shield, swabs for testing, 3-D bioprinting, antimicrobial polymers, non-invasive positive end expiratory pressure (PEEP) masks, oxygen valves, lung models, etc. All this has helped in the fight against COVID-19. Thus, we will see increased adoption of Additive Manufacturing in the times to come. As a next step, researchers can take this research forward by focusing on two aspects. Firstly, the researcher can take each of the areas (ventilators, face shield, etc.) where we have seen usage of additive manufacturing during COVID 19 times and then do a detailed research. Secondly, the researcher can do a survey based analysis and look at the barriers for adoption of Additive Manufacturing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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