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Additive Manufacturing for Design of Personal Protective Equipment's to combat against COVID-19

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Abstract:*. More than 220 nations have reported COVID-19 cases, raising fears about the disease's worldwide spread. Due to the sudden effects of the second wave of COVID-19 in many countries, there is a sudden scarcity of personal protective equipment for front-line healthcare professionals as well as a lack of medical instruments. This work considers how the Additive Manufacturing (AM) industry has played an important role in preventing the spreading of the Corona virus by providing a customized parts quick on-demand and locally produced, reducing the waste and reducing or eliminating the need for extensive manufacturing processes. Also, we have designed the personal protective gears and equipment using AM technology-3D printing and performance analysis is carried out and found to be very useful.

Index Terms – **Additive Manufacturing, COVID-19, Face marks, Face shield, Personal Protective Equipment, 3D printing**

I. INTRODUCTION

Since the dawn of time, mankind has experienced several pandemics, some of which were more horrifying to the populace than others. Novel coronavirus, commonly known as COVID-19, has caused a global emergency since it was first discovered in China's Wuhan area. There is currently no confirmed COVID-19 vaccination, however multiple ongoing clinical preliminary studies are evaluating anticipated medications. Compared to traditional subtractive or formative manufacturing processes, 3D printing is fundamentally a novel way to create parts. The part is manufactured directly onto the constructed stage layer-by-layer in 3D printing, which results in a new arrangement of benefits and limitations; we'll cover this below. With the use of 3D printing, doctors can treat more patients while maintaining high standards of quality. As a result, just like any other breakthrough, 3D printing has created a number of favorable conditions and potential results in the field of medicine [1]. AM is now used in and being researched for usage in sectors like the medical, automotive, aerospace, and marine industries, as well as industrial replacement parts. AM is described as a manufacturing process where customization or complexity are unrestricted [2]. In contrast to mass producing the same type of components, this needs labeling and tracing of each individual part. However, AM provides a far larger possibility for customizations and complicated geometries as compared to conventional production. However, if the geometry is created for mass production and simply the manufacturing cost is considered, additive manufacturing is typically not less expensive. The complete product design and an assessment of the economics over the course of the product lifecycle would be sufficient[3]. By rapidly prototyping and refining designs for the fabrication of various medical devices and protective equipment, 3D printing technology advances to address this challenge and provide solutions to patients, medical professionals, and other groups who are experiencing a shortage of PPE and medical devices [4]. The ability to produce complicated items more quickly than with traditional subtractive manufacturing is the main benefit of 3D printing. The lead time for sending a small batch of parts is nearly nonexistent. As a result, 3D printing is extremely important in creating emergency supplies during the COVID-19 pandemic[5]. The spread of this hazardous infection is caused by the critical need for these medical gadgets. A proof of concept (PoC) and prototype are displayed, showing how a reusable, individually designed face mask may be created using 3D printing and 3D imaging materials that are widely available.

OBJECTIVES OF WORK

- To investigate the Additive manufacturing and covid-19 challenges
- To understand the role of AM in medical application COVID-19 scenario
- To investigate role of 3D printing in the protection of surgical and critical care professionals in the COVID-19 pandemic.
- To understand the uses of 3D printing for production of PPE for COVID 19 like situations
- To design and analyse the PPE using SolidWorks /3D printing

II. AM TECHNIQUES APPLIED DURING THE COVID-19 PANDEMIC

The COVID-19 epidemic is by far the worst and worst incident in humankind's control over Earth to yet. Not only has it claimed over a hundred thousand deaths since then, but it has also caused many sleepless nights for medical and investigative professionals throughout the world. The health disaster brought on by COVID-19 was largely prevented because to the AM industry. For healthcare professionals and everyone else affected by the current dilemma of medical equipment shortages, 3D printing technology offers real alternatives. Hospitals all throughout the world had to deal with alarming shortages of essential clinical equipment including face shields and coverings, testing swabs, ventilators, and more[6]. The COVID-19 key goods that are in limited supply worldwide have been listed by the World Health Organization and are divided into three categories: personal protective equipment (PPE), diagnostic equipment, and critical care equipment. Governments from all across the world are asking manufacturers to temporarily repurpose their assembly lines to fill this gap. Depending on the intricacy of the products, several levels of repurposing are often necessary to create COVID-19 fundamentals. The assembly sector is being prompted by COVID-19 to reexamine its traditional production methods, advancing digital transformation and smart manufacturing over the production lines[7].

In this COVID-19 pandemic, personal protection equipment (PPE) includes protective clothes, helmets, gloves, face shields, goggles, surgical masks, respirators, and other items. For the welfare of society, this article discusses some of the gear needed by the general population. Many of the PPE designs presented here are works in progress, thus it is important to carefully consider if locally produced alternatives to these devices are viable.

Figure 1: 3D printing applications for fabrication of PPE [8]

The numerous medical tools and equipment required to battle the COVID-19 are made using 3D printing, an AM technology, as depicted in Figure 1. Traditional supply chain models take a while to respond to high demand, while 3D printing firms may launch items with fleeting interest and meet high demand in a shorter amount of time. Even though most 3D printers can't make stocks as quickly as alternative assembly methods like injection moulding, they can nevertheless manufacture a greater range of designs without the use of new moulds. People from the 3D printing community have banded together to form a sort of assembly hive mind during this epidemic by exchanging design files and pooling resources[9].

The AM technology uses the digital files for the producing required vital medical parts, which essentially required during the COVID-19 crisis. Going ahead, the 3D printable clinical model resources are described here will be possibly be extended in various centralized model warehouses with new inventive open-source models. Government, semi-government agencies, individuals, corporations and universities are working in organized form to quickly develop the various 3D-printed materials and products especially when established supply chains system are under distress, and supply chain system cannot keep up with required demand [10].

Most of the parts manufactured by the 3D printing technology to meet the COVID-19 challenges were made of polymeric materials. Major AM techniques to print polymeric parts have been listed in Figure 2.

During the COVID-19 pandemic, the fundamental processes of the five main AM methods were employed to produce a variety of 3D printed products depicts in Figure 2.

1. Stereolithography apparatus (SLA) is the most commonly used vat photopolymerization process. The basic principle of the technique is that a UV-light source is used to selectively polymerize (cure) a photosensitive polymer resin layer by layer which ultimately builds the desired 3D part.
2. MultiJet (or PolyJet) printing is also based on the photopolymerization principle which follows the inject printing method to build a 3D part.
3. Selective laser sintering (SLS) is one of the most common 3D printing techniques that belong to the powder bed fusion family of the AM classification. In this technique, laser energy is used to selectively fuse and sinter pre-polymers (mainly thermoplastics) layer by layer to ultimately form a 3D part.
4. Multi jet fusion (MJF): MJF is another type of powder bed fusion 3D printing technology
   MJF technique, an ink (as a fusing agent) is first dispensed on the powder to promote the infrared light (IR) absorptivity and a detailing agent is simultaneously printed near the edge of the part to inhibit sintering in these areas. Then a high-power IR energy source is applied to scan over the building platform to only fuse the inked areas which bonds the polymer powder together.
5. Fused deposition modeling (FDM): FDM, also known as the fused filament fabrication (FFF), uses preform thermoplastic materials in the filament form to print 3D parts [11].

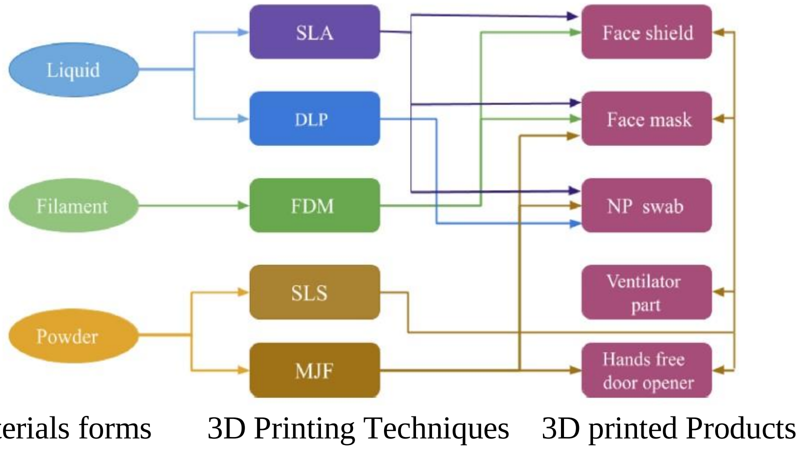

Figure 2 flowchart for interrelation of different AM techniques for manufacturing of PPE[11].

III. Fused Deposition Modeling 3DP Process

The most popular 3D printing method is fused deposition modelling (FDM), which is a type of material extrusion and is by far the most extensively utilised because of how simple, inexpensive, and versatile it is. The FDM process used to create PEEs is shown in Figure 3. Plastic wire is utilised as the raw material in fused deposition modelling (FDM/FFF), which is heated, extruded via a nozzle, and then deposited layer by layer. The following steps are necessary to create a 3D model: Creating a 3D CAD model is the first stage in creating a 3D printed object. The 3D CAD model is then divided into millions of tiny individual layers using specialised software like as Cura, Simplify 3D, etc. Any 3D model must have its 3D printing settings established based on the printing process and machine capabilities before being cut into slices. The machine codes necessary for the tool path will be automatically created for each slice after slicing is complete[12].

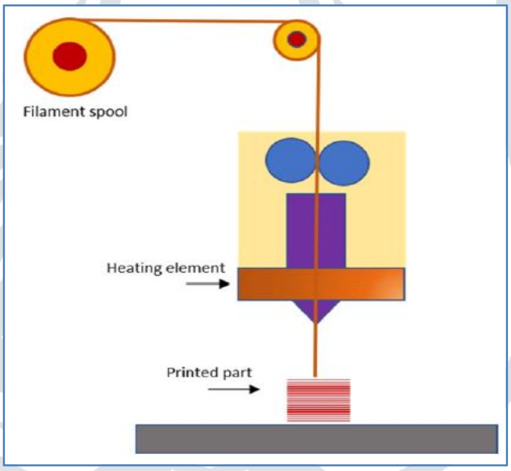

Figure 3 Fused deposition modeling (FDM) Technique[11]

In FDM, a heated nozzle is used to extrude beads of semi-solid material, which rapidly solidify upon extrusion. The extruded material is then successively deposited to create the component layer by layer[13]. Material is supplied to an extrusion nozzle head in the form of thermoplastic filament coiled on a coil and unreeled. A resistive heating filament located in the nozzle head warms the material to its maximum flow rate. The substance is consolidated and in a condition that allows for flow. The extrusion head and flow are moved by stepper or servo motors. Both horizontal and vertical movements of the extrusion head are possible[14].

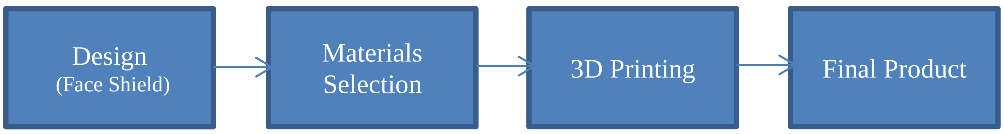

Figure 4 Fused deposition modeling 3DP process of a face shield

The process carried out to manufacture face shield in depicted in figure 4. First the 3D model for face shield is designed and the materials are selected. After this process the 3D printing process is carried out and then the final face shield product is obtained[15].

IV. Design and Analysis

Two 3D-printed reusable polyamide composite parts (a face mask and a filter membrane support) and two disposable parts make up the customised 3D protective face mask (a head fixation band and a filter membrane). The reusable parts of the 3D facemask were created using computer-aided design (CAD) based on unique facial scans that were obtained using a modern smartphone equipped with two cameras and a face scanning software. Two reusable 3D-printed parts (a face mask and a filter membrane support) and two disposable parts were combined to create a specially constructed 3D protective face mask (a head fixation band and a filter membrane). The CAD designer at 3D Infinity created the STL virtual templates for the two reusable parts of the 3D personalised face mask using a 3D modelling procedure using CAD software (SolidWorks): the 3D face mask and Filter membrane support. To enable optimal tightness after applying the filter membrane, the connection between the two components was created as a screw fixation type (Figure 10). The CAD designer used Netfabb additive manufacturing software to perform a Boolean calculation between the STL file of the individual face scan and the 3D face mask virtual template after downloading the OBJ file of the individual face scan in order to get an accurate best-fit of the individual 3D face mask on its corresponding facial mask.

Figure 5 (a) reusable 3D-printed face mask (b) 3D image of the prototype.

Using AM technique the intricate parts are designed quickly on a computer (CAD) and then it has been printed out on a 3D printer. Figure 6 shows how a mould was made in Solidworks using the solid body of a 3D printed mask as a starting point. This was accomplished by creating a solid block around the mask's contour, hollowing down the inside to match the mask's form, then cutting the block in half.

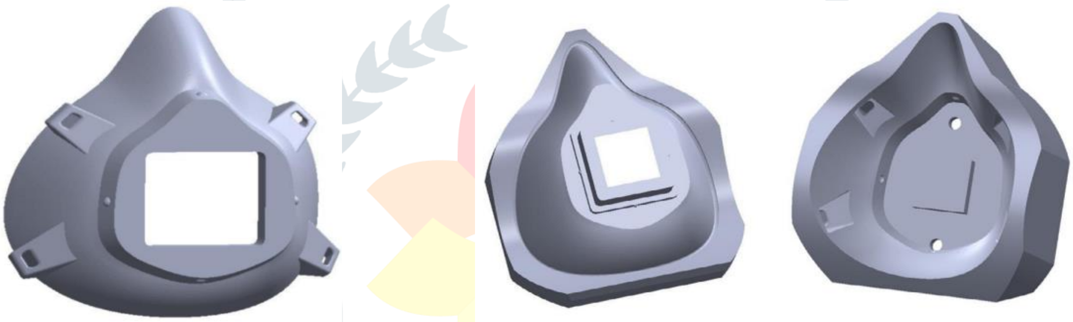

Figure 6. (a) Solid model of mask (b) Mold design

Figure 6 shows both halves of the mask as designed with CAD

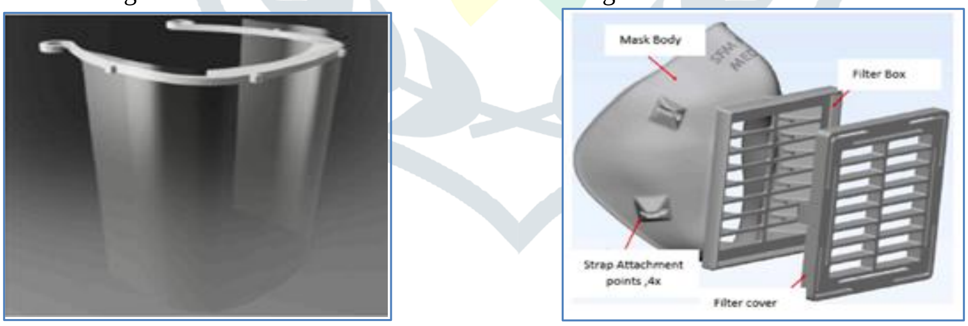

Figure 7 depicts 3D Printable (a) Face shield and (b) Stopgap Face Mask

The face shields and stopgap face mask are created with the use 3D Printers is as shown in figure 7

The 3D printed mask adjuster and swab as shown in figure 8. This mask adjuster is useful for hospital staff as they need to wear face marks for an extended period. The 3D printing can be used to design the swabs and it has a well-designed tip for efficacy in sample collection for a medical professional, and also for patient comfort and safety.

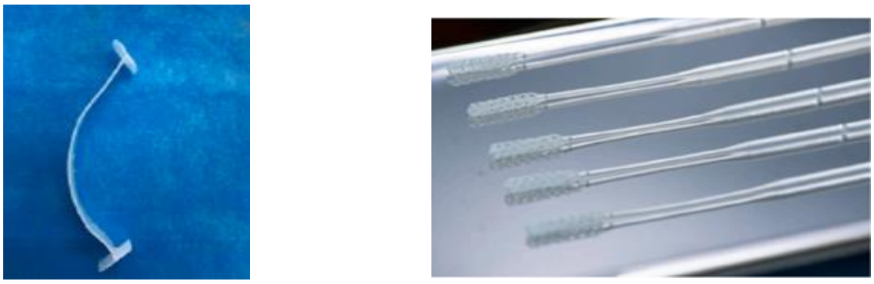

Figure 8: 3D Printable (a) mask adjuster (b) swab

A designer is fabricating thousands of 3D printed buckles to improve comfort and alleviate associated ear pain for medical workers treating coronavirus patients. Further With the use of HP 3D printing the ventilator parts can be printed in only 24 days. The hand free door opener can be created with the use of 3D printing. 3D printing can be used to design quarantine booths *(isolation wards) and in a single day* 15 coronavirus isolation wards can be prepared. 3D printed drone structures (indoor drone) can be designed to fight the spread of the COVID-19 contamination with a 99 % cleansing rate.

V. CONCLUSION

We have investigated the Additive manufacturing and covid-19 challenges and understood the role of 3D printing in the protection of surgical and critical care professionals in the COVID-19 pandemic. Also we have identified the potential applications of 3D printing for production of PPE for COVID 19 like situations. Finally we have designed and analyse the PPE using SolidWorks /3D printing. 3D printing has proven to be a boon and revolutionized technology to supply medical devices and tackle the situation caused by the COVID-19 pandemic. The diverse designs were produced and are currently used in hospitals by patients and frontline healthcare doctors

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