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COMBATING COVID-19: WORKFLOW AND DISTRIBUTION OF THREE-DIMENSIONALLY PRINTED FACE SHIELDS

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Abstract- On 11 March 2020, the World Health Organization declared the "coronavirus disease 2019" (Covid-19) a global pandemic. This novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) epidemic outbreaks emerged in December 2019 from Wuhan City in Hubei Province, China. It spread to the rest of the world [Guo, Cao, Hong et al. 2019]. This pandemic has led to the shortages of personal protective equipment (PPE) at a global level, especially in Malaysia. This paper presents the alternative process of producing face shields using fused deposition modelling (FDM) in three-dimensional (3D) printing. The 3D file for the face shield was obtained from an online portal, the file 'sliced' using Cura software, 3D printed using Ultimaker 2+, and the finishing includes attaching a transparent PVC rigid sheet with holes punched along its side. A quickly fabricated and low-cost solution, this face shield proved to be feasible to be used for Malaysian front liners in combating the pandemic.

Keywords: Covid-19, fused deposition modelling (FDM), personal protective equipment (PPE), severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)

I. INTRODUCTION

On 12 December 2019, a continuous occurrence of an unknown acute respiratory tract infection originating from the Hunan South China Seafood Market was reported in Wuhan City, Hubei Province, China [Guo, Cao, Hong et al. 2019]. It became an outbreak and starts to spread to the whole world. On 11 March 2020, the World Health Organization declared the "coronavirus disease 2019" (Covid-19) a global pandemic. As of 17 April 2020, a total of 2,230,439 cases of COVID-19; 150, 810 cases of deaths and 564,210 recovered cases have been reported throughout the world (worldometers.info/coronavirus/).

In Malaysia, the first case of COVID -19 was detected on 25 January 2020. It was traced back to three Chinese nationals previously had close contact with an infected person in Singapore [The Borneo Post, 2020]. On 4 February, a 41 years old man was the first Malaysian who was confirmed COVID-19 positive. 17th March 2020, Malaysia confirmed 2 COVID-19 related deaths, a 60-year-old man from Kuching, Sarawak, and a 34-year-old man from Johor Bahru, Johor [Ang, 2020 and Elengoe, 2020]. To this date 18 November 2020, a total of 49730 cases detected with 318 deaths was reported by Ministry of Health (MOH). Number of cases which was going down at one time now is rising.

Doremalen in 2020 indicate that aerosol and fomite transmission of COVID-19 is plausible, since the virus can remain viable and infectious in aerosols for three hours and on surfaces up to 72 hours which make wearing a personal protective equipment (PPE) compulsory to every medical staff in the field. The rising cases also lead to the shortage of PPE worldwide and support is badly needed [Tino et al, 2020, Swennen et al, 2020, Wesemann et al, 2020]. In Malaysia the shortage of PPE has been report as early as April 2020 base on online survey by Dr Timothy Cheng and team [Lim, 2020]. 83 percent of the respondents in the survey reported having experienced shortage of PPE supplies at their workplace resulting 60 percent of the respondents opt to use their Do-It-Yourself (DIY) PPE. This shortage sparks the initiative by Prusa Research which suggesting alternative production of PPE parts such as face shield to be printed in house using rapid prototyping technology also knows as three-dimensional (3D) printing [Gomes, 2020]. This initiative was getting a substantial respond worldwide including Malaysia.

II. 3D PRINTING MOVEMENT IN MALAYSIA

In Malaysia the awareness to find an alternative way to produce parts for PPE already spark as early as March 2020. Lim has report that on 19 March 2020, a Facebook user name NurfaizFoat has created group to coordinate his idea in which to mobilise Malaysians to print the face shield using 3d printer for distribution to frontlines, using a face shield design that being adapted from Josef Prusa's original design. On 25 March 2020, Adrian Wong has launch the Facebook group TeaMa for COVID-19 together with the official website https://faceshield.site/ with the aim not just printing the face shield but also other medical equipment as parts such as connector for intubation box and Dmask .

III. TEAMA FOR COVID-19 (TEAMA)

Initiate by Adrian Wong, this group consist of 143 entities coming from various background such 3d printer enthusiast, business owner and higher education body. TeaMa offer a platform where everybody can contribute; donating money or materials, becoming a volunteer as runner or printer team or even to request for PPE parts and medical equipment. To date, TeaMa has received a RM 42 865.00 sum of donation in order to cater 43 839 orders of face shields. Even though TeaMa overseeing the whole process of accepting donations and delegating the order, every state group is in touch with their respective Covid-19 screening hospitals.

Figure 1 Face shield by TeaMa for Covid-19.

IV. PRINTER

For this initiative, we are printing using Ultimaker 2+ and Ultimaker 2+ Extended. This printer was design and build by Ultimaker, a Netherland base company which office and assembly line are in United State. These printer**s** currently hosted in Interface Design 3D Printing Workshop in the Faculty of Creative Multimedia, Multimedia University.

Figure 2 Ultimaker 2+ and Ultimaker 2+ Extended

The build volume for this printer is 223 x 223 x 205 mm for Ultimaker 2+ and 223 x 223 x 305 mm for Ultimaker 2 Extended+. This printer is using a Fused Deposition Modelling technology (FDM). Fdm printer

being choose due to low cost price and maintenance, easy to operate [Liu et al, 2019, Park et al, 2016, Redwood et al, 2017], and able to print is shortest of time [Seol et al, 2014, Gomes et al, 2020]. The process was described as;

"A spool of filament is loaded into the printer and fed through to the extrusion head. Once the printer nozzle has reached the desired temperature, a motor drives the filament through the heated nozzle melting it. The printer then moves the extrusion head around, laying down melted material at a precise location, where it cools down and solidifies. Once a layer is complete, the build platform moves down and the process repeats building up the part layer-by-layer (essentially resembling a very precise hot-glue gun)."

[Redwood et al, 2017]

V. WORKFLOW

These face shields require 4 phases as same as suggested by Amin in 2020; design, digital preparation, printing and assembly.

In the first phase, instead of design we only acquired the face shield 3d file in. stl format that being shared by TeamA in their portal. Standard Triangle Language (STL) is a file format native to the stereolithography CAD software created by 3D Systems [Roscoe, 1988].

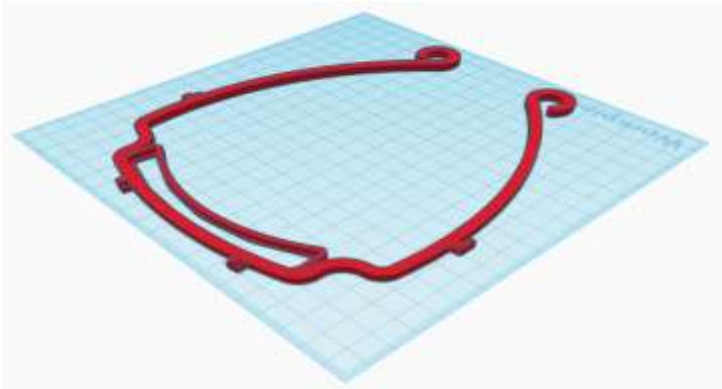

Figure 3 Face shield in stl file, view in TinkerCAD software.

For the second phase, the stl file needs to be digitally converted to Gcode format in order to print. Gcode is the language that being use by computer to communicate with the 3d printer (Amin, 2020). Here, we are using Ultimaker native slicer software Cura in order to convert the slt file to gcode file. In this software, the nozzle size is set to 0.8mm to make printing process faster. The layer height is set to 0.03mm as a draft quality as this model is simple and no detailing or intricate parts. The wall thickness is set to 2.1mm with the infill of the model being set as 10% of the density. With this set up, the material usage can be save while still maintaining the strength of the frame. We also able to place two pieces of the face shield together and later will be printed as a pair. Once sliced, the face shield 3d file the printing time is 1 hour 1 minute and 30 gram or 3.80m of material as shown in figure 4.

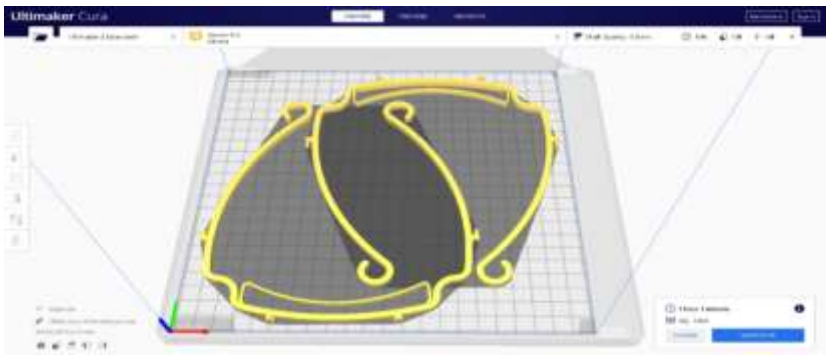

Figure 4 Position of the face shield in Cura.

We also stack 10 pieces of face shield with 2 mm gap filled with support structure. For this setting, 13 hours printing and 366g or 46.26m material is needed.

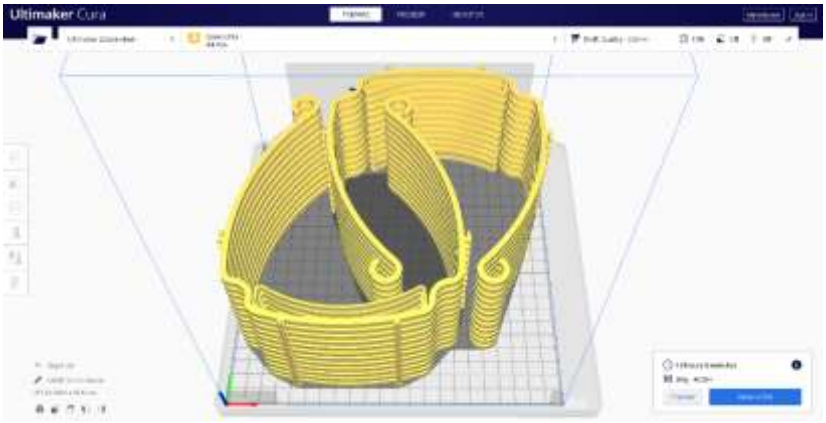

Figure 5 Face shields are stack together.

These Gcode file is saved into the secured digital (SD) card which contain information such as printer setting (nozzle diameter, nozzle and build plate position), print setting (layer height, support structure and printing) and filament setting (type, diameter and density). These Gcode file is transferred from the computer to the 3d printer via SD card.

Third phase is printing the face shield. The poly lactic acid (PLA) is used as a material for the face shield. The PLA is punch through the feeder and the feeder will roll the PLA to the heated nozzle. The nozzle and the build plate are heated to 200 Celsius and 60 Celsius respectively. The heated nozzle will melt the PLA and lay melted PLA on top build plate while being cooling off by side fan until it's hardened. A new layer of melted PLA later being lay on top of the harden PLA again and again forming a face shield. To increase the production speed, the printing time is being double to from 40 mm/s to 80mm/s. This however only being applied when printing a pair of face shield, the 20 pieces printing hour still remain the same as the support structure will be compromise if using higher speed. During day time, we are able to print 10 pieces per printer given the time to remove the face shield from the build plate, heating up and cooling down the nozzle and the build plate. 20 pieces at the night time thus accumulate as 30 pieces of face shield per 24 hours. Once the printing is done, we need to separate the stacks and clean up the support structure using plyers and art clippers.

Figure 6 Plyer, art clippers and paper puncher.

Figure 7 Stack of face shield and the process of removing the support structure.

Final phase of the process is to assemble the face shield. Two corner of the transparent PVC rigid sheet is cut into round to avoid the pointy end. Four holes are punched through the transparent sheet using the paper puncher. Each hole is 7-8 cm a part base on the hook at the face shield. The transparent sheet later is attached to the face shield. This process however only being done base on request. Some of the recipient already has the transparent sheet. They will attach the transparent sheet rite before the user wears the face shield.

VI. DISTRIBUTION

The distribution of the face shield is being administrated by TeaMa admin. The request is being made to the TeaMa Face Shield official website and being cascade to the satellite printers nearby the requester. The volunteers who tasked as a runner will pick up the face shield from the satellite printers and delivered them to the requester. As our 3d printing workshop is located in Cyberjaya, we respond to the request from any entity around Cyberjaya such as Putrajaya Hopsital, Putrajaya Health Clinic and Seri Kembangan Clinic. If the requester is far from the printers or in remote area, or the closes printers are unable to full fill the request due to any reason (out of materials or printer's down time), support will be delivered from the nearest printer. Runner also will collect the face shield, repacked and currier the face shields to the remote area or the area where no satellite printer is available. The satellite printers also sometime will deliver the face shield directly to the requester.

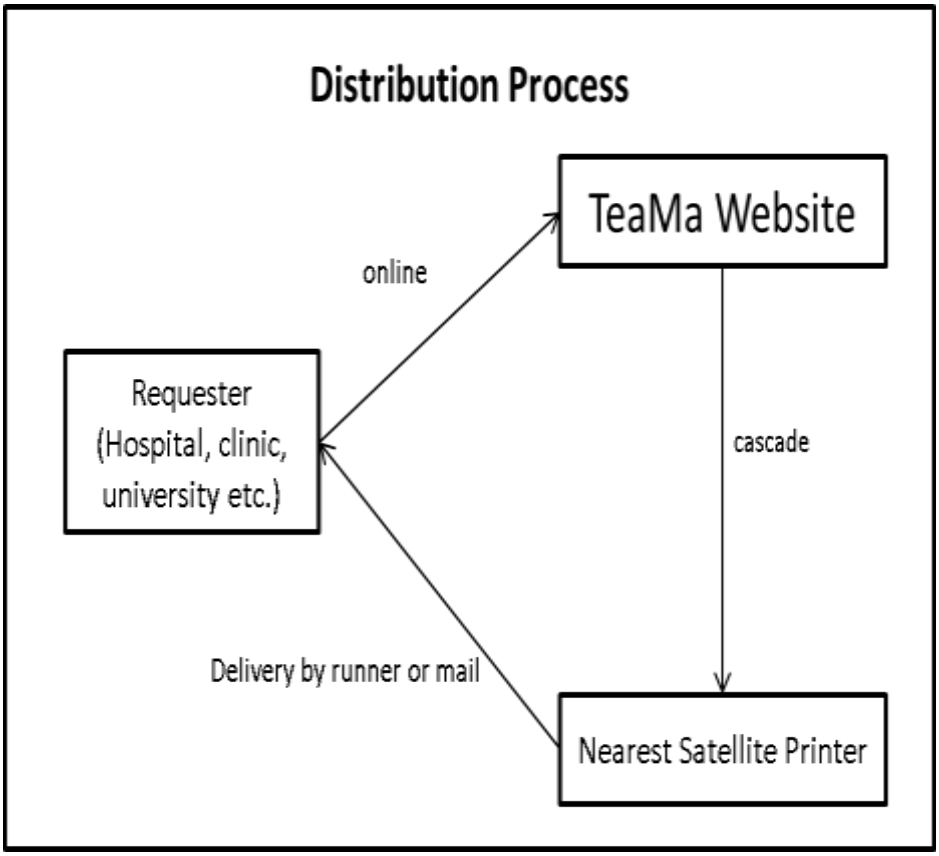

Figure 8 Distribution Process

VII. COST

In this paper we only calculate the raw material cost as we do own the printers and the stationaries (plyer, art clipper and paper puncher) prior to the pandemic. We are using eSUN filament which cost us RM120 perspool. As one kilogram of spool is able to produce 70 pieces of face shield, our cost is RM 1.74 per piece. Adding up with the transparent sheet. Our average cost is RM 2.00 per face shield.

Table 1 Equipment, material and cost

Material	Preparation	Cost
Printers	Na	Na
PLA	Na	RM120 per spool
Transparent PVC rigid sheet	4 punched holes, 2 round corners	RM00.28 per pieces
Plyer, art clipper and paper puncher	Na	Na

VIII. MAINTENANCE

The face shield set can be disposed or recycle. All parts need to be clean using soap, water and disinfect using 70% alcohol wipes. Let it dry properly and store in closed compartment with a room temperature. PLA material tends to react to heat so avoid direct sunlight or hot source object such as dryer, heater or the back side of refrigerator.

IX. Discussion and Conclusion

Covid-19 pandemic is still a treat to our live. During this pandemic, a lot of medical devices and PPE part can be printed using 3d printer such as D mask and incubators chamber's connector. However not every parts of this printed device will provide the same fluid barrier and air filtration protection as Food and Drug Administration–cleared PPE [Amin, 2020].

These face shields have been sent to various front liner stations and the feedback have been positive cite Wong. Wong also mention that these face shield is good enough to be used at low risk areas or operations (screening areas at hospitals/clinics, normal clinics, quarantine stations, or as extra protection at normal wards which are non-COVID related). This will ensure that the high-grade PPEs that are coming in from the government can be fully utilized at high risk areas such as wards that house COVID-19 positive patients.

Using our printers, we are able to 1500 pieces of face shield to date. Accumulatively this movement have produced 46,650 pieces of 3d printed face shield to being distributed to the front liners. This movement and study also have sparked the interest of more multinational company such as Petronas, HICOM and Proton to contribute. (BERNAMA,2020)

As a conclusion, our quickly fabricated and low-cost solution face shield proved to be feasible to be used for Malaysian front liners in combating the pandemic. This result of this study have shared, discussed and decimated among the satellite printer to ramped up the production of the face shield. We hope that this paper will help and guide any parties that have an access to 3d printer and willing to contribute in this fight over Covid-19 pandemic.

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