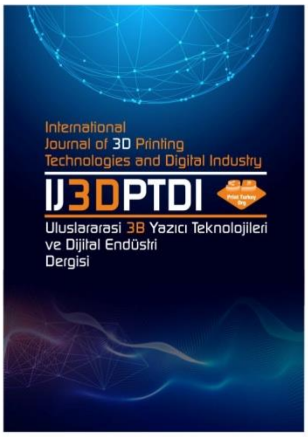

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EXAMPLE OF USING 3D PRINTERS IN HOSPITAL BIOMEDICAL UNITS

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ABSTRACT

Along with the developments in the industry, the Three-Dimensional (3D) printer technology, which came to the fore at the end of the 1980s, has started to be used in many areas and has taken an important place in our lives. The prototype of the final version of a product designed with the help of Computer Aided Design (CAD) programs can be easily produced. 3D printers; They are involved in areas such as automotive and machine production in order to develop prototypes in the industry, developing course materials in education, planning of surgical operations in the field of health, production of artificial organs and orthotic prosthesis applications in biomedicine. In this study, 3D printers in the biomedical units in hospitals, the production of new ones instead of the broken parts, and their usage areas are included. In this context, the static analysis of the broken keypad of the ultrasound device was made. Accordingly, the model was created using computer software and the production was carried out with a 3D printer. An example of the usage areas of 3D printers is presented. In addition, the cost of the keypad is reduced by manufacturing it one by one instead of replacing it as a whole.

Keywords: 3D printer, Biomedical, Ultrasound, Keyboard, Static Analysis.

1. INTRODUCTION

Three-dimensional (3D) printers print any object in solid form using a computer aided design (CAD) program [1]. Although three-dimensional printing technology has entered our lives since the 1980s, it has become widespread in the market in a short time. The first working 3D printer was produced by Chuck Hull in 1984 [2]. Figure 1 shows a script invented by Hull. In 1986 Charles (Chuck) Hull patented one of the earliest 3D printers, a stereolithography machine.

Figure 1. The first 3D printer invented by Charles (Chuck) Hull [4].

In 1988, another 3D printing technology named Scott Crump, Fusion Deposition Modeling (FDM) was produced [3]. As seen in Figure 2, the RepRap (do it yourself, develop it yourself) project started in 2005 and open source printers became able to produce their own parts [5,6]. Consumers founded MakerBot in 2009 and had one of the first 3D printers available to consumers [7].

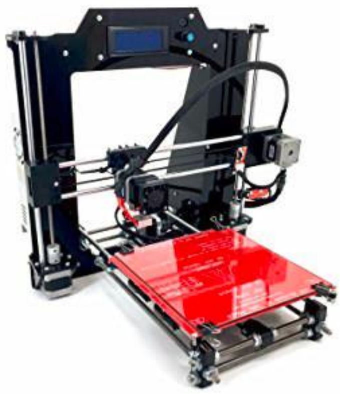


Figure 2. RepRap Prusa 3D printer [8].

3D printers, which are rapid prototyping technology, use different methods and different raw materials. The most common working principle for design is to divide a three-dimensional object created in the computer environment into layers, convert it to STL format, and then create a real object by creating a layer by layer [9]. 3D printers have multiple manufacturing technologies. These technologies are Fused Deposition Modeling (FDM), Shape Deposition Manufacturing (SDM), Selective Laser Sintering (SLS), Direct Laser Metal Sintering (DLMS), Selective Laser Sintering. Laser Melting (Selective Laser Melting-SLM), Objet Polyjet, Multijet and ColorJet [10]. Today, the most widely used FDM method in the production process is to obtain a three-dimensional product by stacking the layers of a two-dimensional object with a three-dimensional model on the computer. These technologies use different materials such as ABS (acrylonitrile butadiene styrene), PLA (polylactic acid), metal, plastic, iron powder [11,12].

Ultrasound is one of the medical imaging methods used to examine organs in the body. Ultrasound is used in procedures such as diagnosis, treatment, biopsy and to monitor fetal development in pregnant women. Since it does not emit any radiation, it is not likely to harm the baby. Ultrasound sends sound waves to the body at frequencies greater than 20kHz, which is a high frequency that the human ear cannot hear. The sound waves are produced by the piezo crystals inside the probe, which is part of the ultrasound, and their return is detected. When a sound wave hits a dense object in the body, such as an organ or bone, it is reflected back or creates an echo. These resulting echoes are reflected back to the probe, producing electrical signals. The echoes and the distances between them are measured by a computer and create a moving image containing different densities of tissue, fluid and air in the body [13,14].

3D printers are used in many fields. They are involved in the production of parts in the automotive industry in the industry, in the production of food in the food field, in the production of miniatures of architectural structures in architecture, in the construction of construction structures in engineering, in the development of course materials in education, in the planning of surgical operations in the health field, in the production of artificial organs, in the completion of missing bone fragments and in orthotic prosthesis applications in biomedicine. [15].

Some studies using 3D printers in the healthcare field are as follows. Ayoub et al; created a model of the mandible from computed tomography images and enabled it to be used in surgical operation planning [16]. AbouHashem et al; They modeled human bone structures using 3D printers due to ethical issues in the supply of bone for anatomy education [17]. Van Koevering et al; modeled the fetal facial deformity displayed on ultrasound at the 30th week of pregnancy with a 3D printer. This study is the first to model prenatal fetal anomalies [18]. Lioufas et al; created 3D-printed models of children with cleft palate deformity. They created a 3D model using magnetic resonance image data. In this way, they obtained models of incomplete soft palate deformity, incomplete anterior palate deformity, and complete cleft palate [19]. Souzaki et al. produced a liver model with 3D technology in a three-year-old boy who was diagnosed with hepatoblastoma and was planned for surgical intervention, and in their study on this model, they reported the successful results of the planned surgical application and the surgical intervention they performed [20]. Biglino et al.; A training was organized for cardiology nurses and it was observed that the 3D models of the nurses were more educational in this training. Nurses stated that they gained general anatomy skills more quickly with 3D models and that the models helped to analyze anatomical complexity after treatment. These 3D models contributed positively to the learning process [21]. Palousek et al; They set an example for its use in this area with its wrist orthosis design [22]. Celebi et al.; In his study, he carried out a study on skull fabrication and implant design using a 3D printer of a damaged skull. In this study, using the computerized tomography image of the patient, the damaged skull structure was printed with a 3D printer and an implant suitable for use in the damaged area was designed and manufactured. Thanks to this study, 3D printouts were obtained from the computed tomography data, and it was seen that the necessity of the surgical operation to be performed for the purpose of examination before the implant design could be eliminated and the process could be improved in favor of the patient [23]. With the increase in the need for organ transplantation in recent years, Akpek; The tricuspid heart valve, located between the right atrium and the right ventricle, was modeled and produced with a 3D printer. With this study, the production of organs with biocompatible printers was encouraged [24].

Figure 3. Broken key image.

3D printers are used in many areas and their applications in the health sector are developing day by day. In this study, a study was conducted on the production of the deformed keypad of the ultrasound device, as an example of the usage areas of 3D printers in hospital biomedical units. The broken keypad button is shown in Figure 3.

2. MATERIAL AND METHODS

2.1. Static Analysis

In order to analyze the cause of the broken keypad, first a model of the broken part was created using the Solidworks program. Then static analysis was performed. The points where the key is connected are determined and fixed. A standard mesh model was created. A force of 1N was applied as the force of a person turning the button. The minimum stress amount is 7.21e-004 (MPa). This tension is formed where the key is held and turned. The maximum amount of tension is 4.22e-001 (MPa). This tension occurred at the points where the key was fixed. Fixation points are indicated by pink arrows. At this stress point, deformation and fractures occur. Accordingly, it is seen that the stress is intense at the fixation point, as shown in Figure 4.

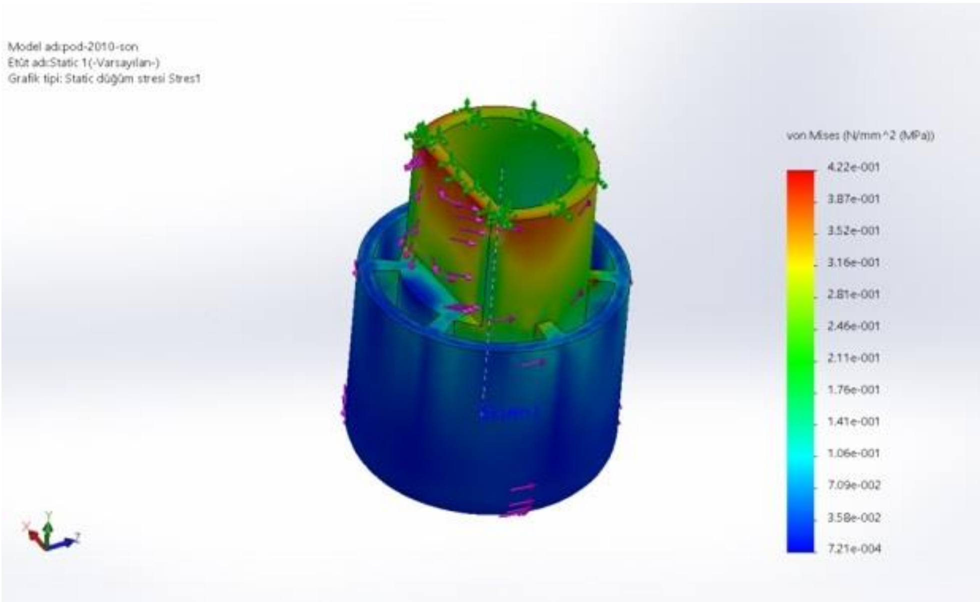


Figure 4. Stress graph of the broken key model.

The design has been changed to avoid this breaking point. Accordingly, the thickness of the breaking point has been increased in the new model. The ports on the inside are filled. A 1N force was applied by creating a standard mesh model. Accordingly, the minimum stress amount is 4.47e-003 (MPa). This tension is formed where the key is held and turned. The maximum amount of tension is 1.89e+001 (MPa). Figure 5 shows the stress graph of the newly designed keypad model. It is seen that the amount of voltage at the connection point decreases under the same conditions. In this way, a more durable design was created compared to the previous one.

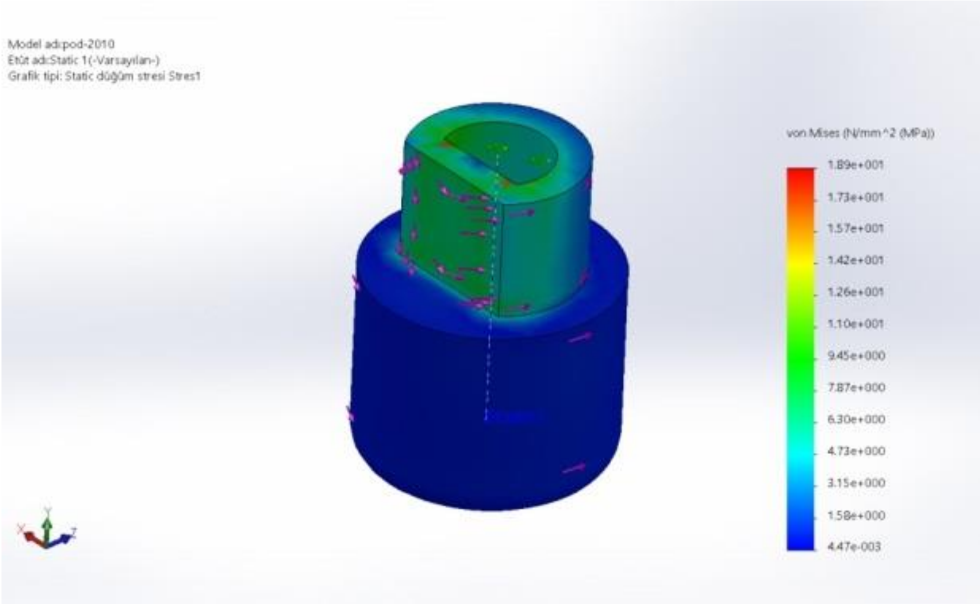


Figure 5. Stress graph of the generated key model.

2.2. Modelling

First, the three-dimensional drawing of the part to be prototyped must be made by means of CAD software. Computer software such as AutoCAD, SolidWorks, Google Sketchup and Rhino3D are available to create 3D models. Apart from computer software, there are web-based software that works with cloud computing technologies infrastructure. Or, if the 3D model of the model to be produced is shared on the internet, it can be obtained from here. Here, the 3D model was created by making the necessary physical measurements of the broken key of the ultrasound device using SolidWorks computer software. The thickness of the broken piece at the breaking point was measured as 2mm. This is drawn as 4mm to be more robust. In addition, the connection points on the inside are filled. It is shown in Figure 6.

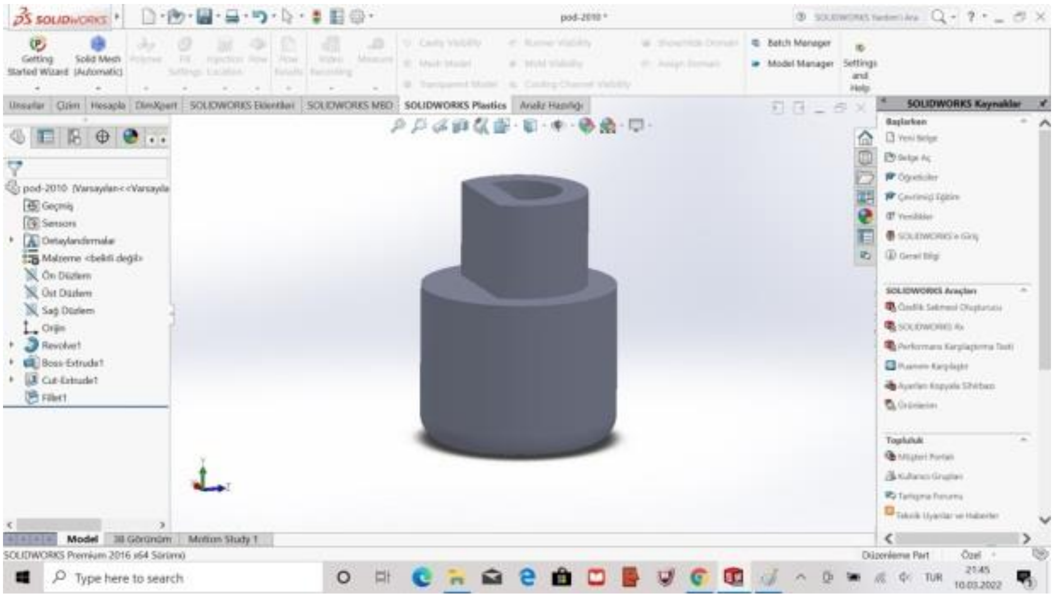


Figure 6. SolidWorks 3D model.

In order to take the output of the drawn model from the 3D printer, it is exported as an STL file that slicing software will detect.

2.3. Slicing

The model drawn in the slicing process is translated into G code, a language that the 3D printer can understand. In other words, the model obtained as an STL file for slicing software is divided into layers. The layer thickness, filling pattern, filling amount, speed and temperature parameters required during production with a 3D printer are adjusted with these software. With these parameters, the quality of the model to be created is determined. The parameter values used for this study are given in Table 1.

Table 1. 3D printer manufacturing parameters.

Layer Height	0.20 (mm)
Shell Thickness	0.8 (mm)
Press Speed	40(mm/sn)
Bottom/Top Layer Thickness	0.8 (mm)
Occupancy Rate	20 (%)
Table Temperature	50 (℃)
Nozzle Temperature	210 (℃)
Print Tip	0.4 (mm)
Filament Amount	0.22 (m)
Dimensions [W,D,H]	15,4 – 15,4 - 19.9 (mm)
Manufacturing Time	≅11 (min.)

Ultimaker 2+ printer was used for the output of the 3D model. The technical features of the Ultimaker2+ 3D printer used for printing are given in Table 2 [25].

Table 2. 3Ultimaker2+ 3D printer technical features.

Printing Field	23 x 23 x 20.5 cm
Technologhy	FDM
Layer thickness	20 micron
Raw material	PLA/ABS/CPE/NAYLON/FLEX an all special flements(open flement system)
Raw Material Diameter	2,85 mm
Nozzle Diameter	0,25/0,4/0,6/0,8 mm (Changeable nozzle system)
Structure	Metal
Dimensions	35 x 35 x 49 cm
Weight	9 kg
Platform	Heated
Power supply	221 W
Data input	SD card / USB Cable
Print Software	Cura

As shown in Figure 7, G code conversion was performed with the parameters determined by the Cura software belonging to this printer.

Figure 7. Cura software image of the 3D model.

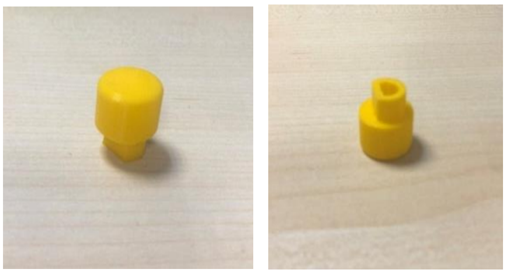
2.4. Printing and Production

The model, which was converted to G code with the slicing software, was produced with a 3D printer. Here, the production time may vary depending on the parameters determined in the slicing software. PLA (Polylactic acid) filament was used in this study. Because this material has much better mechanical properties than materials such as polyurethane, polypropylene and plastic. Therefore, it is the most preferred filament type. PLA filament parameters are given in Table 3.

Table 3. Technical specifications of PLA filament.

Tensile Strength	65 MPa
Maximum Operating Temperature	52 °C
Coefficient of Thermal Expansion	68μm/m-°C
Density	1.24 g/cm3
Extrusion Temperature	190- 220 °C
Table Temperature	45- 60 °C

No surface treatment was done after the print was taken from the printer. Figure 8 shows the 3D printing model of the model created for the broken ultrasound keypad.



(a) (b)

Figure 8. Keypad 3D printer output (a) top view (a) bottom view.

3. RESULTS

In parallel with today's technological developments, 3D printers are developing. With this development, it has begun to take place and be used in many parts of our lives. As mentioned before, it is used to produce and model various products in many fields from industry to education and health. It has even entered our homes for hobby purposes. In this study; The ultrasound device, which is used in various parts of the hospital to view the internal organs of the human, was produced from a three-dimensional printer by modeling the same instead of the broken keys that were deformed due to use or time. The keys produced and put into use are shown in Figure 9. Instead of replacing the entire keypad with the breakage of a single key, or in cases where parts cannot be supplied, a solution has been produced using 3D printer technology. Thanks to rapid prototyping and printing, the active use of the ultrasound device has been ensured. Since this model data can be stored in digital environment, it is possible to print repeatedly when desired. This will ensure rapid production and continuity in the era of digital transformation. In this way, an example of its use in the medical field is presented. It also provides an advantage in terms of cost. According to the make and model of the ultrasound device, the replacement cost of the entire keypad is approximately $600. Even if you want to buy a single button, it costs $ 15. It was produced for approximately $ 0.5 using a 3D printer and profited.

Figure 9. Ultrasound view of the 3D printed keypad.

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