



KAUNAS UNIVERSITY OF TECHNOLOGY
FACULTY OF MECHANICAL ENGINEERING AND DESIGN

Brijesh Munishami Gowda

**PRINT QUALITY IMPROVEMENT BY MODERNIZATION OF 3D
PRINTER “ULTIMAKER 2+” PRINthead**

Master’s Degree Final Project

Supervisor
Lecturer. Dr. Darius Mažeika

KAUNAS, 2017

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Master’s Degree Final Project
Mechatronics Engineering (code: 621H73001)

Supervisor

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PRINT QUALITY IMPROVEMENT BY MODERNIZATION OF 3D PRINTER “ULTIMAKER 2+” PRINthead

DECLARATION OF ACADEMIC HONESTY

2017

June

08

Kaunas

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MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT

Study programme MECHATRONICS

1. Title of the Project

The main aim of this project is “Print Quality Improvement by Modernization of 3D Printer “Ultimaker 2+” Printhead”

Approved by the Dean Order No. V25-11-8, 21 April 2017

2. Aim of the project

The aim of the thesis is to modernize the Ultimaker 2+ to increase the quality of printing parts.

3. Structure of the project

Summary, Introduction, Literature review (history about printer, previous researches, 3D printer parts, nozzle details, 3D printing technologies, problems, conclusion), Ultimaker 3D printers comparison, Ultimaker 2+ (Dimensions, requirements, hardware parts, steps how to use, materials we use), CURA, Microscope (NIKON DS-Ri2) (key features), printed parts quality analysis, 3D printer head design with PZT-5A, hot tip and nozzle, ultrasonic welding, analysis (nozzle movements, frequency calculations, temperature calculation), conclusion.

4. Requirements and conditions

- Designing Piezoceramic(PZT-5A) and inserting in to the previous model.
- Calculating higher frequency and temperature, ultrasonic plastic welding, nozzle section.

5. This task assignment is an integral part of the final project

6. Project submission deadline: 2017 May 08th.

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Brijesh Munishami Gowda. PRINT QUALITY IMPROVEMENT BY MODERNIZATION OF 3D PRINTER “ULTIMAKER 2+” PRINthead. *Master's Final Project / supervisor Lektorius Darius Mažeika; Faculty of Mechanical Engineering and Design, Kaunas University of Technology.*

Research field and area

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SUMMARY

The main aim of this project is “Print Quality Improvement by Modernization of 3D Printer “Ultimaker 2+” Printhead”. We have many 3D printers with good and low surface quality, if the surface quality is low or medium we will not get the better result in final, so to overcome this disadvantage with the low cost we can develop a good printer head for the better quality of the surface. In this project, we analyze the printer head design for the better quality of the 3D prints because its application is numerous in social, geopolitical, industries and in all the places where we use the 3D models. First, we analyze many technologies which are present now and also consider what are the disadvantages with the present technologies mainly in technical specifications. By considering all the past decade results we decide what are changes to be made and we start implementing. We have consumer 3D printer which is varied on the production qualities of prints due to various factors such as layer thickness, line spacing, nozzle temperature, among others. Until today, a very light interest is given to the 3D print filament quality, and research about how the filament quality could affect the print quality. Here I consider mainly the nozzle temperature we can see many examples the prints which are printed in the low-temperature results the low-quality prints. We can see on the internet that Fused Filament Fabrication technology is the major technology which is used in 3D printing to print the parts. Here my idea is to design the 3D printer Ultimaker 2+ head and insert the piezoceramic (PZT 5A) at the nozzle and to calculate the frequency of the assembly, the frequency will be increased. Here I choose 0.4mm nozzle and also the with the help of increased frequency we use ultrasonic plastic welding to make layer strong, then calculate the temperature at the contact point of nozzle and plastic plate, the temperature must increase than the standard value because we are increasing the frequency. Here the prints are printed layer by layer of the size 0.06mm and we use ultrasonic plastic welding to connect the two layers to make the part stronger, with all these specifications the designed part is printed to check the surface quality.

Keywords: *3D printer head design, Movement of Nozzle, Frequency calculation, Ultrasonic welding, Temperature calculation.*

Brijesh Munishami Gowda. Spausdinio kokybes tobulinimas modernizuojant 3D spausdintuvo „Ultimaker 2+“ spaudinimo galvute, Magistro baigiamasis projektas / vadovas Lektorė dr Darius Mažeika, Mechanikos inžinerijos ir dizaino fakultetas, Kauno technologijos universitetas.

Kaunas, 2017. 51 psl.

SANTRAUKA

Pagrindinis projekto tikslas yra „Spausdinimo kokybės gerinimas, modernizuojant trijų dimensijų spausdintuvo „Ultimaker 2+“ galvutę. Yra daug trijų dimensijų spausdintuvų, pasižyminčių gera ir prasta paviršiaus kokybe. Jeigu paviršiaus kokybė prasta arba vidutinė, negausime gerų rezultatų, todėl norint išvengti šio trūkumo, neišleidžiant daug lėšų, galima sukurti gerą spausdintuvo galvutę, suteikiančią geresnę paviršiaus kokybę. Šiame projekte analizuojame spausdintuvo galvutės dizainą, reikalingą geresnei paviršiaus kokybei pasiekti, nes trijų dimensijų spaudiniai plačiai naudojami socialinėse, geopolitinėse, pramonės šakose ir visose vietose, kur naudojami trijų dimensijų modeliai. Pirmiausia analizavome daug šiuo metu egzistuojančių technologijų, svarstėme jų trūkumus, aptinkamus pagrindinėse techninėse specifikacijose. Apžvelgę paskutinio dešimtmečio rezultatus, nusprendėme, kokių pokyčių reikia ir pradėjome juos įgyvendinti. Turime vartotojams skirtą trijų dimensijų spausdintuvą, kurio spausdinimo kokybė skiriasi priklausomai nuo įvairių veiksnių, pvz., sluoksnio storio, tarpų tarp eilučių, purkštuko temperatūros ir pan. Iki dabar trijų dimensijų spaudinių plaušelių kokybei buvo skirtas nedidelis dėmesys. Čia atlikome tyrimą, kaip plaušelių kokybė gali paveikti spausdinimo kokybę. Daugiau dėmesio skyriau purkštuko temperatūrai. Matome daug pavyzdžių, kai žemoje temperatūroje atspausdintų darbų kokybė yra prasta. Internete pateikiama informacija, kad jungtinių plaušelių gamybos technologija yra dažniausiai trijų dimensijų spausdinimui taikoma technologija. Mano idėja buvo sukurti trijų dimensijų spausdintuvo „Ultimaker 2+“ galvutę ir prie purkštuko pridėti pjezo keraminę dalį (PZT 5A) bei apskaičiuokite viso bloko dažnį, kuris turėtų išaugti. Pasirinkau 0.4mm purkštuką. Dėl padidėjusio dažnio galime naudoti ultragarso plastikinį virinimą. Taip sluoksnis tampa stipresnis. Tada apskaičiuojame temperatūrą purkštuko ir plastikinės plokštelės kontaktiniame taške. Temperatūra turi viršyti standartinį dydį, nes padidinome dažnį. Spaudiniai spausdinami po 0.06 mm sluoksnį. Dviem sluoksniams sujungti naudojame ultragarso plastikinį virinimą – taip dalys sustiprėja. Paviršiaus kokybei patikrinti atspausdiname dalis su nustatytomis specifikacijomis.

Reikšminiai žodžiai: *trijų dimensijų spausdintuvo galvutės projektavimas, purkštuko judėjimas, dažnio apskaičiavimas, ultragarsinis virinimas, temperatūros apskaičiavimas.*

ACKNOWLEDGEMENT

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Regards

Brijesh Munishami Gowda

Table of Contents

INTRODUCTION	5
1. Literature Survey	7
1.1 History	7
1.2 Previous research about 3D printers	8
1.3 3D printer parts	10
1.3.1 Mechanical parts	11
1.3.2 Electric part	12
1.3.3 Control unit in 3D printing.....	14
1.4 Nozzle	15
1.4.1 Which 3D printer nozzle should choose	15
1.5 3D printing technologies.....	17
1.5.1 Stereolithography	17
1.5.2 Fused deposition modelling	18
1.5.3 Selective laser sintering (SLS)	18
1.5.4 Selective laser melting (SLM).....	19
1.5.6 Laminated object manufacturing (LOM)	19
1.5.7 Binder Jetting (BJ)	19
1.5.8 Multi-jet modeling (MJM)	20
1.5.9 Material jetting (MJ)	20
1.6 Problems example images of printing process.	20
1.6.1 Problem of lift-off parts.....	20
1.6.2 Bad printing little plastic came out:	21
1.6.3 Holes in the parts.....	21
1.7 Conclusion about printed quality	22
1.8 Conclusion about literature survey	22
2. Ultimaker 3D printer comparison.....	23
3. Ultimaker 2+.....	26
3.1 Dimensions and weight of ultimaker2+ and ultimaker2 extended+	27
3.2 Build volume.....	28
3.3 Printer and printing types.....	29
3.4 Requirements for Ultimaker 2+	30

3.5 Hardware components	31
3.6 Steps how to use Ultimaker 2+	31
3.7 Materials used in 3D printer ultimaker 2+	32
3.7.1 Nylon: Abrasion-resistance and durable	32
3.7.2 ABS: Tough and durable.....	33
3.7.3 CPE Family: Chemical resistant and tough.....	33
3.7.4 PLA: Water soluble.....	34
3.7.5 PC: Strong, heat resistant and tough.	34
3.7.6 TPU 95A: Wear and tear resistant.....	35
4. CURA.....	36
4.1 Steps to work in CURA	36
4.2 Model designed to print in ultimaker 2+	38
4.2.1 Table and graph for time v/s material v/s nozzle dimensions	38
5. Microscope (NIKON DS-Ri2)	40
5.1 Key features	40
5.1.1 High-resolution images	40
5.1.2 Excellent color reproduction	41
5.1.3 High-speed live display	41
5.1.4 High sensitivity, low noise.....	41
5.2 Specifications	41
6. Printed part quality analysis	42
7. 3D Printer Head Design.....	44
7.1 PZT-5A (Piezoceramic).....	44
7.2 Specifications of PZT-5A	45
8. Hot tip and Nozzle.....	46
9. Ultrasonic welding.....	47
10. Analysis	49
10.1 Vibration and frequency study.....	49
10.1.1 Results of frequency analysis.....	51
10.2 Temperature Study.....	52
10.2.1 Results of Temperature analysis	53
14.3 Conclusion about analysis	54
16. Conclusion	55
17. References	56

List of Figures

Figure 1 History of 3D printing from origin to till date	7
Figure 2 3D Ultimaker 2+ printer head	10
Figure 3 Design of extruder body of Ultimaker 2+	11
Figure 4 Hot tip designed part in solid works with all standard dimensions	12
Figure 5 Controlling parts in 3D printing.....	15
Figure 6 Design of nozzle.....	16
Figure 7 Nozzle with 0.4mm hole dimension	17
Figure 8 Printed parts in where we can see lift-off parts problem	21
Figure 9 Printed parts in where we can see bad prints and under construction problems.....	21
Figure 10 Printed parts in where we can see full holes [22]	22
Figure 11 Ultimaker 2+ head from front and right side view.....	26
Figure 12 Ultimaker 2+ head nozzle located region	27
Figure 13 Ultimaker 2+ outer body model [23]	27
Figure 14 Ultimaker 2 extended+ outer body model [23]	28
Figure 15 Ultimaker 2+ inner body model [23]	29
Figure 16 Ultimaker 2 extended+ inner body model [23]	29
Figure 17 Ultimaker 2+ hardware components front and back [24]	31
Figure 18 Nylon printed examples. (a)Designed to versatility meets reliability, (b)Designed to resist humidity (c)Excetionally durable [25]	33
Figure 19 ABS printed examples Example, (a)prototype, (b)Fit testing, (c)Versatile capabilities [25]	33
Figure 20 CPE printed examples, (a)Chemical resistant, (b)reliable parts, (c)complex geometrics [25]	34
Figure 21 PLA printed examples, (a)Smoother, (b)complex geometries, (c)Endless possibilities [25]	34
Figure 22 PC printed examples, (a)Stable dimension, (b)Tough and strong, (c)Optically translucency [25] 35	35
Figure 23 TPU 95A printed examples, (a)Flexible and durable, (b)Chemical resistant, (c)Great for end-use parts [25].....	35
Figure 24 view of CURA software.....	36
Figure 25 (a) Object is designed in solid works software, (b)Import designed file to CURA, (c)3D printing the designed model using ultimaker layer by layer [26]	37
Figure 26 Model designed to print in Ultimaker 2+	38
Figure 27 Pictures of microscope (NIKON DS-Ri2) with camera.....	40
Figure 28 3D printer head design done in solid works.....	44
Figure 29 PZT-5A (Piezoceramic) design.....	45
Figure 30 Design and Assembly of nozzle and hot tip.....	46
Figure 31 Geometric fixtures, the green coloured marks on the above diagram are considered as fixed.....	46
Figure 32 Ultrasonic plastic welding steps, (a) part in fixture, (b)horn contact, (c) pressure applied, (d)weld time, (f) hold time, (g) horn retracts [28]	48
Figure 33 Movement of Nozzle at frequencies in Hz, (a) 17129, (b) 18414, (c) 32824, (d) 37461, (e) 45625, (f) 49509, (g) 51883, (h) 57508 and (i) 63060	50
Figure 34 Study of the temperature at the contact point of plastic plate and nozzle.....	53

List of Tables

Table 1 Ultimaker 3D printer comparison.....	23
Table 2 Time v/s Material v/s Nozzle dimensions	39
Table 3 Printed part quality analysis	42
Table 4 Specifications of PZT-5A.....	45
Table 5 Results of frequency analysis	51
Table 6 Results of temperature analysis	53

List of Graphs

Graph 1 Time v/s Material v/s Nozzle dimensions.	40
Graph 2 Results of frequency analysis	53
Graph 3 Results of temperature analysis	55

INTRODUCTION

The first printed solid model was studied and published from Nagoya Municipal Industrial research institute by Hideo Kodam, in 1981, with the help of “additive manufacturing”, “3D printing technology” or “rapid technology”. Later on, this technology has gradually increased but till now many technologies have made much research on the printed model surface quality, even now this process is continuing.

3D printing is a rapidly increasing in all areas, with the respect and uses for 3D printers rising every day. In this project, It leads effort to give an introduction to the large range of technologies in 3D printers, a contrast of the most mutual 3D printers on the market, an indication of materials that can be used to print, online services and communities that proposal 3D models or 3D printing services, and an intro to designing and printing your first model.

The present 3D printing technology consists of three main steps – the modelling, the printing and the finishing of the product:

- In the first step that is in modelling phase, the machines which we used to print models uses the virtual blueprint of the object in order to obtain the printing model and processes them of thin cross sections in a series that are being used successively. Now we get the identical model of the virtual model to physical one.
- In the next printing phase, in order to build the product first the 3D printer should read the design with all cross sections and later should deposit the layer of the material. Each layer should fuse with the previous (here in this case in my project we use ultrasonic plastic welding) based on the virtual cross sections, finally the object will be obtained after printing all the layers. Using this technique, we can create many shapes using variety of material (metal, Powder, ceramic, liquid, thermoplastic, paper etc...)
- In the next step that is final phase is finishing the product, we use standard resolution in many cases, in order to print in the increased conditions, this may be the more advantages if we want to print the larger size models that the desired one, finally we to remove the additional material we apply subtractive process at a greater resolution.

Depending on the above-explained phases many more additional improvements can be implemented in the printing process so that one model can use multiple material or multiple colors. But maintain the printing quality is very important because while using much material there are chances of bad quality or other problems.

So from the above paragraph it is clear that how 3D printing is necessary for various fields, the printing quality depends on the surface of the printer and the head which is the part of 3D printing which we are used to printing, we will not be satisfied completely when the result of print is in low or medium quality, only when the quality is excellent then we will be satisfied, So now we are the main part of discussion to get the output of print in good quality we have to increase the surface quality of the printer head then automatically the printing will be in good quality, this is the main idea of my project and introduction about project.

If we think why we wanted to increase our surface quality is best quality has more value and their printed model might use in many different places for production and other purposes to get the better result, the quality of used materials plays a very important role and some applications are explained below.

3D printing can be used to prototype, create spare parts, and is even multipurpose enough to print prostheses and medical grafts. It will have a growing influence on our world, as more and more people gain access to these astonishing machines.

The next industrial rebellion is all about personal fabrication, and it's happening now. 3D printing is poised to unlock the potential in every person to create, innovate and fabricate. It's already transforming manufacturing; soon it will change the world and also used in schools, colleges, space, art making and also in robotic & computing fields.

Tasks:

- Choose Ultimaker 2+ and study CURA software.
- Choosing best nozzle.
- Design PZT-5A.
- Design 3D printer head with PZT-5A.
- Analysis is made to check vibration modes (Nozzle movements), Calculate the frequency of the assembly and ultrasonic plastic welding and finally to Calculate the temperature when the nozzle is in contact with plastic.

1. Literature Survey

1.1 History

The initial 3D printing knowledge early developed evident to us in late 1980's, at which time they were termed this as Rapid Prototyping (RP) technologies.

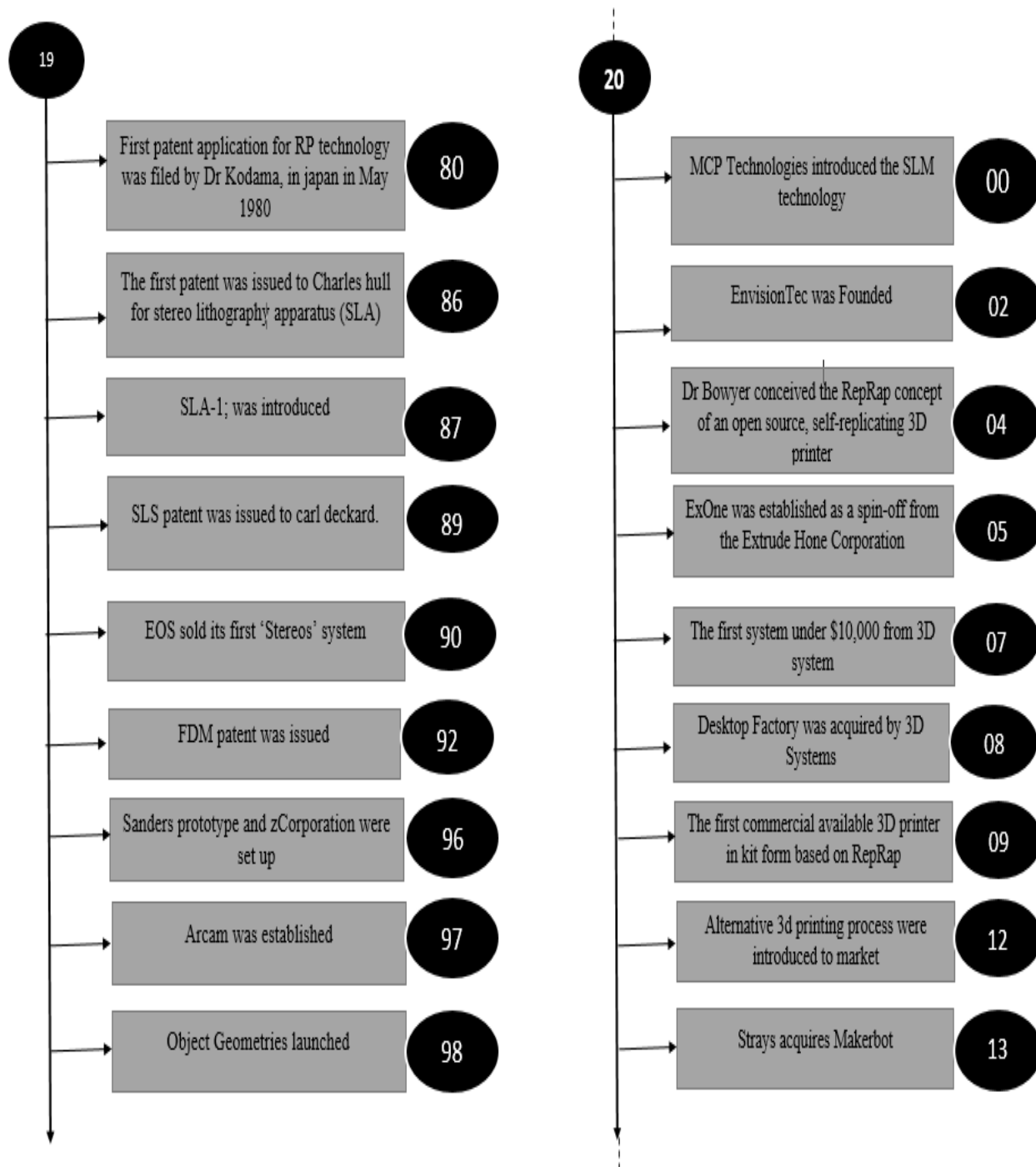


Figure 1 History of 3D printing from origin to till date

1.2 Previous research about 3D printers

Gubson, D.W Rosen, B. Sucker topic “Extrusion-Based Systems”, it is Improver Manufacturing Technologies, They looked at prototyping knowledge which customs extrusion that is layers of materials to form objects and also mainly on how the extruder performs, also on generating supports for overhanging which is not normally possible, brief study about FDM machines how it works for 3D bio-plotter systems to create something to help head trauma, from this paper it is clear for me what type of extrusion-based systems we have to use in my project [1].

Vik Olliver, “Construction of Rapid Prototyping” the year 2005 from this we can understand information about materials. The report covers an investigation using a rapid prototyping machine using recycled high-density polyethylene and also the paper inspects the proper deposition, speed and the temperature that the plastic must be put down on the outward surface. Here the main device which we are used for extrusion is modified so now it is clear what type of construction should be in my project [2].

Ian Gibson, David W. Rosen, Brent Stucker, “The Use of Numerous Materials in Improver Manufacturing year 2009. Almost from the beginning, we are used only one material so to overcome this problem in this Ian Gibson used multiple materials for manufacturing. In detail, numerous materials is a important benefit to how approximately technologies work, like plastic-coated object manufacturing technology works, here he used porous multiple material process that is multiple heads, material, and colors this paper clearly explains about the material and use of multiple material [3].

Colby Leider, Douglas Mann, Daniel Plazas “personal modified tools to control” before for controlling we were using one joystick similar shaped that was modified to the user’s exclusive hand shape, this has been used to control for sound dispersal in sound-reinforcement settings this was prototyped on 3D printing [4].

Branka Lozo, Maja Stanić, Sonja Jamnicki, and Sanja Mahović Poljaček, “Three-Dimensional Ink Jet Prints- Influence of Infiltrates” from this we can clearly understand how three-dimensional are usually finished by an infiltrated agent prior to the final use. Epoxy mastic, cyanoacrylate, and a polyurethane-based executive are often used. The impact of infiltrating type on the selected mechanical properties and surface appearance of 3D inkjet prints was the focus of the study. The type of infiltrate agent used greatly contributes to the discussed final properties of the prints. As a case study, the application of 3D printing in conventional printing technology was studied. The 3D prints can be used as an undesirable matrix for conservative photopolymer flexographic printing plate production. It is important that the applied infiltrate

does not influence the 3D print dimensions, as well as provide the optimum combination of mechanical and surface properties and observing at using 3D printing to brand a flexography printing plate [5].

B. Lenman, M. Vermeulen, T Clasesens, P. Van Ransbeeck, "Towards Cost-efficient RPM Technology for Patient Specific PIV Models" The article discusses the uses of the RepRap from a biomechanical viewpoint, and how the RepRap can be used as a knowledge tool, for problem-solving purposes, and surgery preparation. Models are done from scans of a cystic fibrosis a patient's inferior lung and then modeled, this paper clearly explains about cost [6].

Ed Sells and Adrian Bowyer, "Directly Including Electronics into Conservative Rapid Prototypes" This paper discusses the potentials of printing circuit panels by uniting rapid prototyping and straight writing technology. The impression is to print a panel made of ABS plastic and to use Wood's metal as conductors for the circuit. The metal was animated and clasped into place by a syringe. A syringe pouch was printed by the RepRap to keep the metal from chilling. After this was perfected, a way of inputting a chip into the system was design as well as a battery holder, so it is clear how the electronic design and rapid prototyping should be in my project [7].

Till Bovermann, Risto Koiva, Thomas Herman, Helge Ritter, "TUI-Modular Substances for Palpable User Interfaces" In this paper, we describe the plan and building of TUImod, a modular system of bodily substances with different features. TUImod supports fast prototyping of palpable user interfaces by providing a broad range of elements that can easily be assembled into a variety of objects showing different topographies. The forte of this system lies in its modular structure, letting an enormous number of object designs, from this paper I have understood how the design should be in my project [8].

Juan Gonzalez-Gomez, Javier Gonzalez-Quijano, Houxiang Zhang, Mohamed Abderrahim, "To the intelligence of touch in snake modular robots for hunt and release operations" this paper is about the use of snake's modular robots to be used in City Search and Release, and also industrial uses for the robot, such as removing gravel from in front of a trapped victim that proposes RepRap can figure portions for this machine to so it inexpensive, from this I have understood what type of necessary sensors I have to use in my project [9].

Lawrence Sass, "Materializing Palladio's Perfect Community: Computational Renovation finished Corporeal Symbol of Digital Data" this topic is on digital project and manufacture group that use 3d printing to reduce 3d models of architectural sketch the CAD sketches for this specific project are dispatched available and can be used by schools, organizations and many useful places where 3D printers

are necessary to print their own 3d model (though possibly a little too thorough for the RepRap as well there would be projections) from this I understood what type of material I have to use for my project [10].

Kirk Hausman, author of 3D Printing for Dummies, “First let us know when is first patent for the 3D printer that is in the year 1980’s, but minimum it took 30 years for the fair rate of change. 3D printers are used in Labs and research departments earlier for rapid prototyping systems for quick mock-ups production. But British researcher Adrian Bowyer are looked after these things and started to create the first self-replicating rapid prototyping (RepRap) system using salvaged an electric supply to stepper motors and by getting common material from local hardware store” [11].

1.3 3D printer parts

The main parts of 3D printer used to print is extruder also it is called as head of the printer, the only job of this is printing, so now better to detailly about all the parts of head because in my project I am doing research and development about the printer head this details will help me if we want to change any changes in the head design.

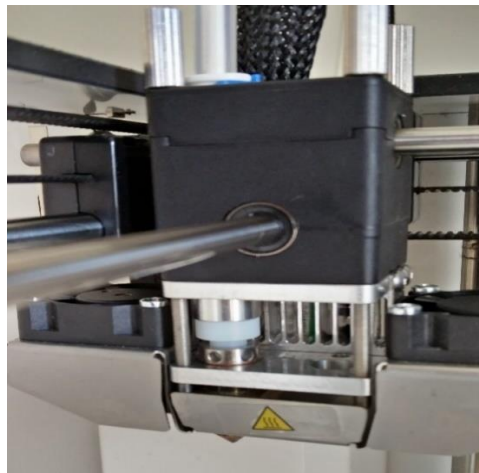


Figure 2 3D Ultimaker 2+ printer head

This head is further linked to the other parts for the proper movements mainly here we do back and forth movements for the deposition of the material on the described place, Extruder parts mainly contain two important parts which help in printing: the hot tip and the extruder body.

The 3D printer head or 3D printer extruder is a part in bodily extrusion-type printing responsible for raw material caring and forming it into the never-ending profile. Here in this process, we have mechanical, electrical and control components.

1.3.1 Mechanical parts

In 3D printer head, extruder body and hot tip are the two important which are considered as mechanical parts, if the changes are required in this design are made using solid works and other designing software, in this project we use solid works.

1.3.1.1 Extruder body

The extruder is the part which determines the failure or success of the print, proper working of extruders signifies the printing will be the success. As I said the extruder is the important component of the 3D printer which acts as filament feeder till the hot tip in the correct amount, hot tip is the place where it is melted and extruded out from the nozzle end to form thin layers. Here it's very important to note that extruder and hot tip are not same, the extruder is called as "cool end" because when the filament is moved to the hot tip the extruder becomes "cold".

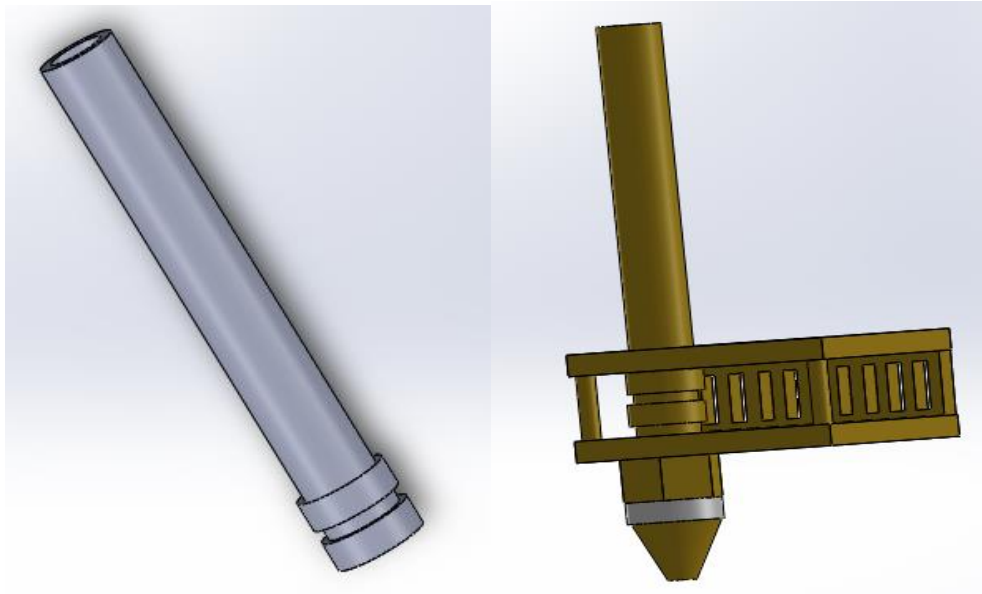


Figure 3 Design of extruder body of Ultimaker 2+

Currently in extruder basically we have two types- Bowden and Direct, if we go deeper there is lot of other information about these two types of extruder, the main difference is "Bowden extruders cannot handle filament which is flexible and also they have too much of strings inside", "Direct extruders are very slow compared to Bowden extruder and they have too much backlash" now I think we got confusion which extruder to use, so let's go bit deeper to clear this problem and choose which extruder is perfect to print our selected part, but both extruders are good in their own specification.

This extruder body contains other parts, we can clearly say that extruder is interconnected to other small parts, the drive gear is the part linked to the block/axis of the stepper motor, like a stunned or

furrowed rim pulley. Its purpose is to apply grip to push the filament as the stepper motor turns. As the stepper motor turns the drive gear rotates and the filament is moved till the hot tip.

In some cases, reduction gears are used because a gear larger than the one protected on the motor axis is used to raise the force applied to the filament. In our project, that's the gear that makes direct contact with the filament itself. So the motor turns in forward direction then the reduction plays the good role here.

1.3.1.2 Hot tip

Hot tip is the another important mechanical part of 3D printer which is mainly used for printing, before we saw the action of extruder and it working, the filament is moved till the hot tip by the extruder body, hot tip is the end part of extruder or printer head, here hot tips should get enough hot so that it can melt plastic or other materials, in some case like if we use thermoplastic the hot tip should remain cold so the temperature is varied, hot tip can withstand the temperature up to 240 degree Celsius, as I said hot tip is referred as tip of the 3D printer extruder/head where it should be more hottest. This hot tip has two subcategories – Diamond hot tip and RepRap interface standard. Here the main process is melting depends on the material which we select.

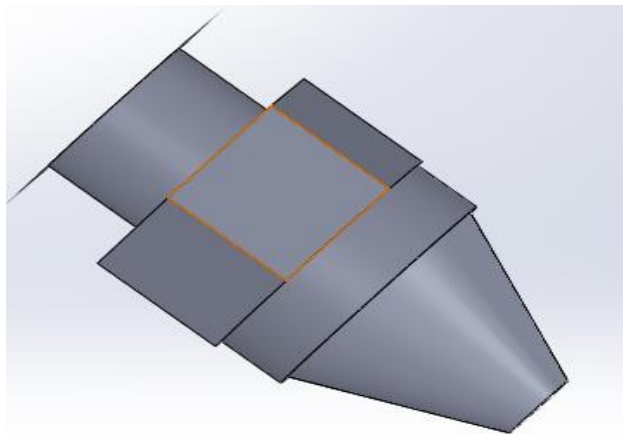


Figure 4 Hot tip designed part in solid works with all standard dimensions

This is followed by nozzle; nozzle diameter plays a very important role in my project so it will be explained later detailly.

1.3.2 Electric part

Here we have only a few electrical parts, stepper motor is one among them

1.3.2.1 Stepper Motor

Depending on the printer which we use the stepper motor plays a very important role, as I explained in the extruder stepper motor is mainly used for the movement of the extruder, indirectly it helps for the movement of the filament. And also, to move the printer head on the build platform in all possible X, Y and Z directions [12], also stepper motor has another feature to pull the filament into the extruder when it is needed.

Stepper motor is unique in this 3D printing because they can move to the known dimensions and also can hold in the mentioned positions. Their stepper motors are frequently used in many fields like robots and 3D printers.



Fig5: Stepper motor in Ultimaker 2+

3D printer stepper motors are divided by National electrical manufacturers association (NEMA) based on their standard size and measurements, the most popular size stepper motors used in 3D printers are NEMA 14, NEMA 17, NEMA 23 and NEMA 24[13], these also refers to the frame size of the motor. Do not consider that just because the stepper is size is large the torque will be more, torque is not depended on the size of motor it's on the capacity of the motor.

Stepper motor is a kind of electric motor used in many industries especially in robotics and 3D printer manufacturer companies. We use stepper motor because it moves in the specified interval for each of the pulse power, these pulse power are provided by the motor driver.

The main properties of stepper motors are

Step angle- Full 360 degree is divided into steps by the mentioned angle gives the number of steps per revolution.

Micro stepping – Here the stepper motor will have fixed number of steps, micro stepping allows stepper motor in 3D printing to run more accurately and smoother.

Bipolar – Bipolar is the internal connecting parts of the stepper motor, this varies for different stepper motors, depending on this stepper motor moves.

Unipolar – The important beauty of the unipolar is the step can be changed without reversing the current in the coil, this makes the simple electronics.

Holding torque – Here we have position control because in 3D printing we need extruder to hold in some place while building this helps to do that.

Wiring – Depending upon the number of wires we have different stepper motors, most commonly we have 4, 6 and 8 number wires. But in RepRap, we use 5 wires because 5th wires connect to both coil center.

Heat – Depending on the temperature which we use for 3D printing we have different stepper motors, some works in low temperature some works in higher temperature.

Power and current – Power and current is an external supply for the stepper motor to work, they have their own standard values.

1.3.2.2 Thermistor

The thermistor is the component in charge of calculating the temperature and forwarding the information obtained to the printer's control structure, making sure that the temperature of the extruder is achieved correctly, as this will be the temperature that the filament will be at when departure the nozzle.

1.3.2.3 LED

The two LEDs on the controller unit display the state of the heating system. The blue LED stays lit until the wanted temperature is touched, then the red LED lights up and the blue LED will turn off. Now the print head is prepared to start and you can start printing. Earlier each run, the filament must be increased with reasonable forward jogging of the 4th axis until a fresh thread is printed out. We call this process "exhausting". Eliminate the thread, e.g. with a pair of tweezers, and then turns printing on. If you take a print break, bleed the system again before any further printing. Print breaks are useful for filament change (color change), for the insertion of mechanisms (e.g. square nuts into the bags printed for them) or for the glance of the workpiece. The modification for the filament pinch roller is continuously set to maximum pressure [15].

1.3.3 Control unit in 3D printing

Subsequently swapping on the control unit, the real temperature of the print head is displayed in degree Celsius. The filament from the reaches the hot tip then the heating of the hot tips directly starts

heating the filament and the print nozzle to the mentioned set point. The control unit has two buttons for temperature modification. By pressing one of two buttons, the display shifts to the setpoint or target value.

This can now be reduced with the left button by 1 degree Celsius, or increased with the right button by 1 degree Celsius. If we do not press any button for 3 seconds, the displays shift back to the actual value. You can change the set value always; the last set value remains protected until it is altered [16].

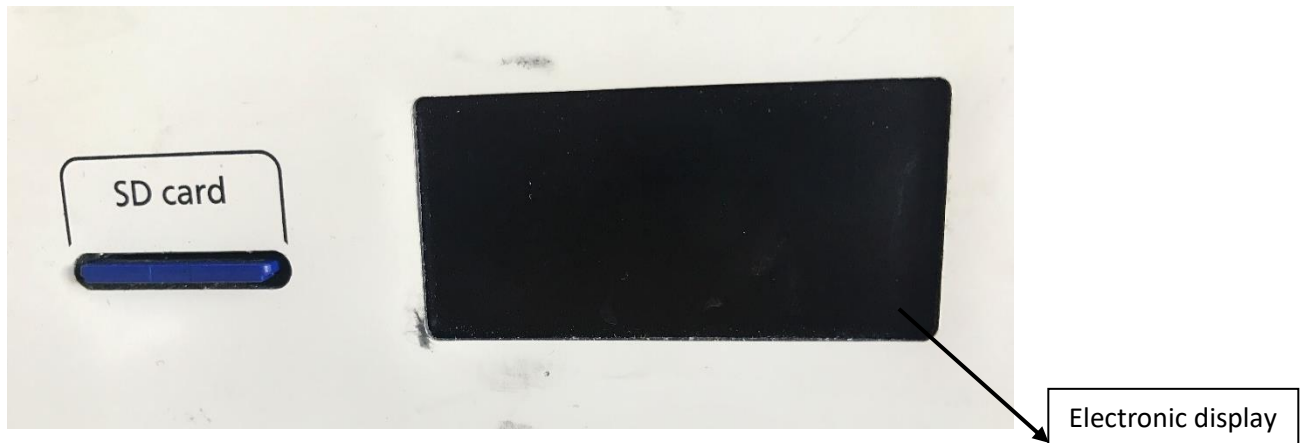


Figure 5 Controlling parts in 3D printing

1.4 Nozzle

Where ever if we search on the internet related to the improvement of the surface quality we will find the details related to the nozzle, changes in the nozzle will make the difference in quality it seems. The nozzle is at the end part of the 3D printer which is like a diamond shape at the end will have a small hole to for the filament to come out from the hot tip, here the discussion started because depending upon the whole size we have 4 types of nozzles. Nozzle with the size 0.25mm, 0.4mm, 0.6mm and 0.8mm[14]. many have proved that with the smaller size nozzle the filament flow will be slow and the quality will be good. So, for the same reason in my project, we use 0.4mm nozzle. Now you can ask y can't we use 0.25mm nozzle everywhere for better quality, yes, we can but the time taken to print with the nozzle 0.25mm is very high compared to another nozzle, now it's clear that 0.4mm nozzle is the best one and it's more clearly explained further.

1.4.1 Which 3D printer nozzle should choose

This is one of the major question which arises when we come for the printing, for better quality we have to use small size nozzle, if we consider time that the printing takes we can go for the best one, that is 0.4mm nozzle which is proved as best for the good quality and the time taken to print is satisfied.

This changing of the nozzle is not done in all the printer its done in the very selected printer so we have to choose that printer first, for example in my case I have chosen ultimaker 2+ where the nozzle can be removed easily and changed.

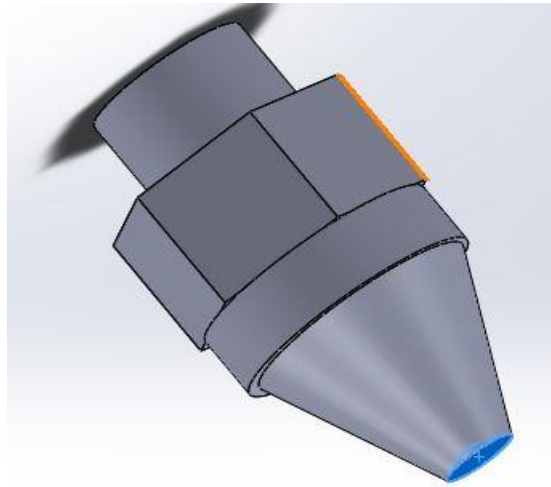


Figure 6 Design of nozzle

Now let's take a look of various nozzles details which are commonly available, the most common used nozzle is which has 0.4mm sometimes it might be considered as 0.35mm by most of the printers, the reason for this is very simple it has very good all round size and many have proved that the models which are printed with this nozzle have good quality compared to another, if we are printing models for the business then we can take more time which is required by the 0.25mm nozzle, because it takes more time to print the model. So, all the business-related printing companies use 0.4mm then the quality will be good and time will be saved.

Another common smaller size nozzle is 0.25mm, even some printer offering 0.2mm, 0.15mm and mass portal related are trying to experiment with 0.1mm nozzles they might create some unbelievable results for FDM.

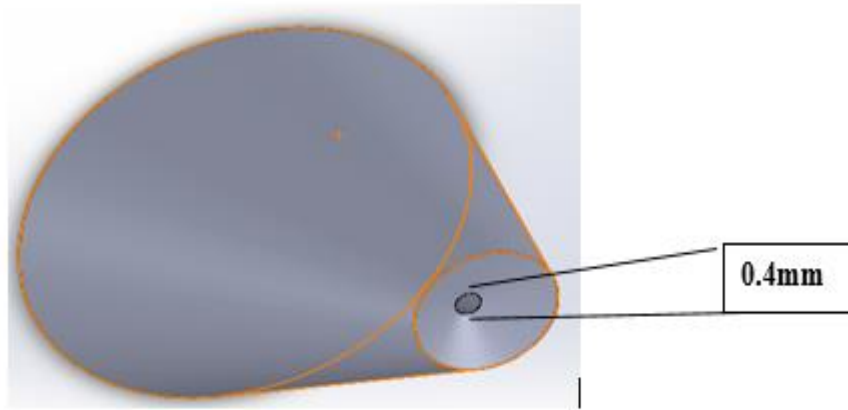


Figure 7 Nozzle with 0.4mm hole dimension

In many research, we can see that small nozzle allows us to achieve better quality. But in the case of small printers or old model printers and also especially in lower priced printers unless they support higher resolution they are not going to make any difference.

Even in some cases we use 0.8mm nozzle it is also called as the thicker nozzle, the main reason is as follows in order machines these nozzles were very commonly used now they are making come back to the present world by knowing what we need, what they have to do and much more. Now in the present printer if we see normally there will 0.4mm nozzle, as we know even this 0.4mm nozzle takes more time to print and printed parts will not be that stronger.

If we want to overcome this problem and make sure our prints should be stronger, the fast process then 0.8mm or sometimes even 1.0mm nozzle will be the best option. Finally, we can say all the nozzle are best in their own specification in my case I use 0.4mm to improve the printed quality because as we seen in many cases researchers have proved 0.4mm nozzle is the best to improve the quality.

1.5 3D printing technologies

Here till now as per my reference, we have 9 different basic types of technology which are best in their own fields any all the 9 types are used in one or the other ways, which are as follows:

1.5.1 Stereolithography

Stereolithographic 3D printers (known as SLAs or stereolithography apparatus) location a punctured platform just underneath the surface of a vat of fluid photo treatable polymer. the first slice of an object on the surface of this liquid is suggested by the UV laser, producing a very tiny layer of photopolymer to strengthen.

The pricked platform is then dropped very slightly and another portion is traced out and toughened by the laser. Another slice is then created, and then another until a complete object has been printed and can be detached from the vat of photopolymer, exhausted of excess liquid, and cured.

SLA is named that this is one of the oldest in all technologies invented by Chuck Hull in 1983, here in this we want the resin to be harder and become solid so we expose photosensitive liquid resin to an ultraviolet laser beam. Advantages of SLA is, it creates the smooth surface object with full detailed, it is more popularly used in the cosmetic dentistry and jewellery industry for creating excellent moulds [17].

1.5.2 Fused deposition modelling

Think we already used the term FSD before now let us explain briefly, in desktop 3D printing technology we commonly use FDM, here first thermoplastic filament is heated and then extruded through an extrusion head or extruder with the help of stepper motor to deposit that molten plastic in X and Y coordinates and layer by layer is done in the Z direction.

Here the object is built from bottom to top if there is any overhanging in the while printing they can be removed later when printing is done in the finishing section. The Fairly robust object is done by when a hot thermoplastic is extruded from a temperature-controlled print head to a high degree of accuracy. Fused deposition modelling technology type of 3D printers is a money-making means for product growth and rapid prototyping in minor occupational and education sectors since it's accomplished of fabricating robust parts quickly and reliably [18].

1.5.3 Selective laser sintering (SLS)

SLS is almost similar to SLA, but there is difference in SLA we use some resin here we use powdered material, later laser is used to selectively sinter a layer of grains which further fixes the powdered material to make solid structure altogether, now the object is completely formed now we have to leave the machine to cool then we can remove the printed part.

SLS is most commonly used everywhere for product development and also in rapid prototype in the huge range in commercial industries and mainly in the production of end-use parts. In this, the laser is used to build the objects to selectively fuse composed consecutive layers of a cocktail of powdered wax, metal, Nylon, ceramic or one of a range of other materials.

This SLS type of 3D printer needs the use of classy high-powered lasers, though, which puts it a bit outside the reach of the average customer with the exclusion of specialized 3D printing services like Outline ways, Sculpted, and immaterialize.

1.5.4 Selective laser melting (SLM)

SLM technology sometimes we call it as subcategory of Selective Laser Sintering (SLS) 3D printer type, here in this SLM we use high power laser beam to make full metallic powder into 3D solid parts.

We use some typical materials here they are aluminum, cobalt chrome, titanium and stainless steel, for some applications like medical or aerospace industry, we have any complex geometry in the parts then we use SLM to print the complex parts and also thin walled structures. Even it's used in the fabric gas turbines energy industry.

1.5.5 Electron Beam Melting (EBM)

EBM is indirectly related to temperature, it can work up to temperature 100 degree Celsius when it is used by high vacuum to melt the metallic powder fully at this stage the EMB technique will use the computer controlled electron beam to operate it.

This EBM technology used metals like Inconel718, Inconel625, and pure titanium to fabricate aerospace parts and in medical fields, this 3D printing applied technology is currently very slow and very expensive.

1.5.6 Laminated object manufacturing (LOM)

Lom uses the material which has a quality of fusing under the heat and pressure they are used for making layer's metal laminates, plastic and adhesive coated paper, we used computer controlled laser or knife to make the shape of the printed model by cutting.

Later this process is continued by machining and drilling methods. Here printing is done layer by layer then later excess material is removed by cutting process with the help of computer-controlled laser for perfect finishing, finally, the printed object will be sanded or it can be sealed with the sand.

Now finally if we consider the dimensional accuracy of the 3D printer type compared to other technologies SLS or SLA, LOM will be considered as the most lovable and fast 3D printing in the available one which is mainly used to create the larger models. It also helps us to get full to get full colored models or parts [19].

1.5.7 Binder Jetting (BJ)

Binder Jetting 3D printers are invented by an institute called MIT. We have seen many 3D printing technology names they are known as "inkjet 3D printing", "Power bed printing", "drop-on-power printing" or most commonly as "binder jetting". Binder jetting is a preservative industrial process. In this type of

printers, we commonly use two types of materials one is powder based material (often gypsum) and also, we use the bonding agent to make a proper bonding between the layers.

In my project, I use ultrasonic plastic welding between the layer to make them stronger. The binder which we are present in the liquid form which is extruded from the printer head this is similar to the regular inkjet 2D printers when the printing is finished the printed part is removed and the process repeats for other parts. In this technology, we commonly used materials are metal, sand, plastic and ceramic.

These printers are with more advantage we can print the parts with color option we can fill the color to the parts by adding the pigments to the binder, normally used colors are black, white, cyan, yellow and magenta. This coloring makes the parts more attractive and popular, here we have some drawback in this technology that is structural integrity of the object where we cannot get a high resolution but we have more expectations on this technology so better hope to overcome the drawbacks.

1.5.8 Multi-jet modeling (MJM)

It is also a type of inkjet where we use successive layers of powder to build the objects, with an inkjet-like print head used to spray on a binder solution that glues only the obligatory granules together [20].

1.5.9 Material jetting (MJ)

As the name says in the title it is related to wax, this technology is commonly called as “wax casting” we do not have any researchers for this technology, this technology is used from many years in jewelry industries which makes the material high quality.

A different type of wax with a lower melting temperature is placed below projections in your creation, acting as a provision material. When production is finished, they are placed in a heated immersion that dissolves away provision material. Casting wax is very delicate and should be touched carefully. It will begin relaxing around 60 degree Celsius and melts at 80 degree Celsius. It can slowly distort and fail over time, so improved to be fast [21].

These are some of the technologies which 3D printer has and many are using their specifications or qualities they have.

1.6 Problems example images of printing process.

1.6.1 Problem of lift-off parts: Here the layer is slightly lifting away/off from the glass and also the edges some time do not stick properly and also parts might come out of the glass plate, reason is glass may be oily/dirty.

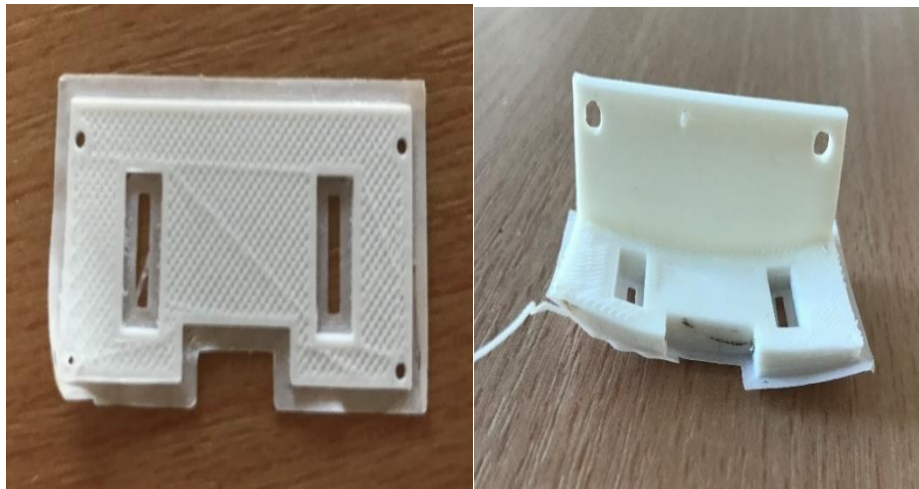


Figure 8 Printed parts in where we can see lift-off parts problem

1.6.2 Bad printing little plastic came out: The printer is under-extruding plastic and the printed parts contain many holes and spaces, there are many reasons behind this/ possible causes feeding plastic might not be done properly, clogging in the nozzle, the print temperature is too low or other issues.



Figure 9 Printed parts in where we can see bad prints and under construction problems

1.6.3 Holes in the parts: In some printed parts, plastic may not be sprayed properly so we may get many holes in parts even this is the major problem we face.

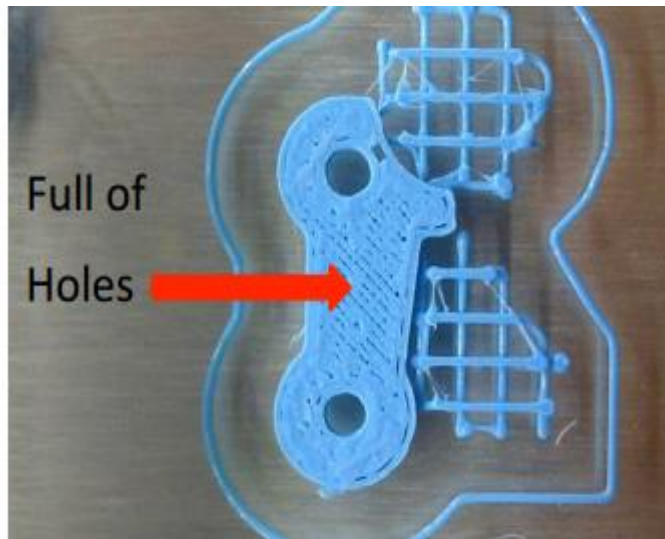


Figure 10 Printed parts in where we can see full holes [22].

The above explained clearly states that we have some or the other problems with the printed model, in this project I consider the main problem is surface quality and further we are going to explain detailly about changes in the design and solutions.

1.7 Conclusion about printed quality

These are some problem which we face in printing to overcome this and increase the quality, so I do modernization in the 3D printer head by inserting the piezoceramic under the nozzle and calculated the frequency of the assembled part, further with the increased frequency the temperature is calculated the temperature which is calculated should be higher the standard one, then if we print with the increased temperature then the quality must increase then the problems will be solved, this is completely explained further with design and calculations.

1.8 Conclusion about literature survey

In the previous part that is in literature survey, we have seen past and present about 3D printer head, previous research about the 3D printer and also the problems which we have, so now by considering all these previous let's take project deeper in the modernization of the printer head to overcome the printing quality problem

2. Ultimaker 3D printer comparison

Now let us discuss some ultimaker printers and decides which ultimaker printer is more useful to my project.

Table 1 Ultimaker 3D printer comparison [14]

	Ultimaker 3	Ultimaker 2+	Ultimaker 2 Go	Ultimaker Original+
Summary	Designed for efficiency, precision and reliability, it is the most industrial used desktop 3D printer.	It supports many materials, used for many applications from prototype to customized tools.	It is bit compact design, this is best one for the starters on 3D world. High capable, reliable and powerful.	It is open-source gives endless freedom for modification and changes to our needs. Accurate and consistence printer
Features	<ul style="list-style-type: none"> -Material- matching -Dual extrusion -Water soluble -Wi-Fi, Ethernet and USB connectivity -Active leveling -Optimized CURA -Optimized cooling 	<ul style="list-style-type: none"> -Nozzle swapping -35W heater -Optimized airflow -Geared feeder -Heated build plate -Large build volume -Up to 20-micron layer resolution 	<ul style="list-style-type: none"> -Compact yet-power -Includes travel case -High layer resolution -Fast process 	<ul style="list-style-type: none"> -DIY kit -Heated build plate -Modification is easy -Expandable by adding extra
Size	Ultimaker 3 342 x 380 x 389mm Ultimaker3 extended 342 x 380 x 489mm	Ultimaker 2+ 342 x 357 x 388mm Ultimaker2 extended+ 342 x 380 x 489mm	Ultimaker 2 Go 255x280x287mm	Ultimaker original+ 342 x 357 x 388mm Ultimaker original 342 x 357 x 388mm
Build volume	Ultimaker 3 215 x 215 x 200mm Ultimaker3 extended 215 x 215 x 300mm	Ultimaker 2+ 223 x 223 x 205mm Ultimaker2 extended+ 223 x 223 x 305mm	Ultimaker 2 Go 120x120x115mm	Ultimaker original+ 210 x 210 x 205mm Ultimaker original 210 x 210 x 205mm

Head speed	30 to 300mm/s	30 to 300mm/s	30 to 300mm/s	30 to 300mm/s
Layer resolution	0.40 mm nozzle: 200 to 20 microns	0.25 mm nozzle: 150 to 60 microns 0.40 mm nozzle: 200 to 20 microns 0.60 mm nozzle: 400 to 20 microns 0.80 mm nozzle: 600 to 20 microns	0.40 mm nozzle: 200 to 20 microns	0.40 mm nozzle: 200 to 20 microns
Material	Ultimaker 3 Nylon, ABS, PVA, CPE, PLA Ultimaker3 extended Nylon, PLA, PVA, CPE, ABS	Ultimaker 2+ Nylon, ABS, CPE+, CPE, PLA, PC, TPU 95A Ultimaker2extended+ Nylon, ABS, CPE+, CPE, PLA, PC, TPU 95A	Ultimaker 2 go PLA	Ultimaker original+ PLA, CPE, ABS Ultimaker original PLA
Temp in C	180 to 280	180 to 260	180 to 260	180 to 260
Nozzle diameter	0.40 mm	0.25 mm 0.40 mm 0.60 mm 0.80 mm	0.40 mm	0.40 mm
Build plate	Ultimaker 3 20 to 100 °C heated glass build plate with active leveling Ultimaker3 Extended 20 to 100 °C heated glass build plate with active leveling	Ultimaker 2+ 50 to 100 °C heated glass build plate Ultimaker2 Extended+ 50 to 100 °C heated glass build plate	Ultimaker 2 Go Glass build plate with blue tape	Ultimaker Original+ 50 to 100 °C heated glass build plate Ultimaker Original Acrylic build plate with blue tape

Connectivity	Ultimaker 3 WiFi, LAN or USB port Ultimaker3Extended WiFi, LAN or USB port	Ultimaker 2+ Control panel with SD card Ultimaker 2 Extended+ Control panel with SD card	Ultimaker 2 Go Control panel with SD card	Ultimaker Original+ Control panel with SD card Ultimaker Original Optional control panel with SD card
Price	Ultimaker 3 € 2.995 *excl. VAT Ultimaker3Extended € 3.695 *excl. VAT	Ultimaker 2+ € 1.895 *excl. VAT Ultimaker2Extended+ € 2.495 *excl. VAT	Ultimaker 2 Go € 1.195 *excl. VAT	Ultimaker Original+€ 995*excl. VAT Ultimaker Original€ 795*excl. VAT

From the above comparison table, all the printers are good in their own specifications. But the Ultimaker 2+ has many Nozzle options and features of this printer is, more importantly, useful for my project so I use Ultimaker 2+ in our project, now let's study deeper about ultimaker 2+.

3. Ultimaker 2+

Ultimaker 2+ is one of the types in 3D printers suited to larger 3D prints. Got released in April 2015, this product also contains other printers called Ultimaker 3 family, ultimaker 2 family and ultimaker originals. Many open-sourced are started by many companies. Ultimaker 2+ is the upgraded version of ultimaker 2+. Now a day it is used in many schools, industries and other educational and research places, the ultimaker 2+ is efficient, reliable and user-friendly. First, we must thank the developer because this ultimaker 2+ supports many materials which are explained detail in further, as I said this is used in many applications.

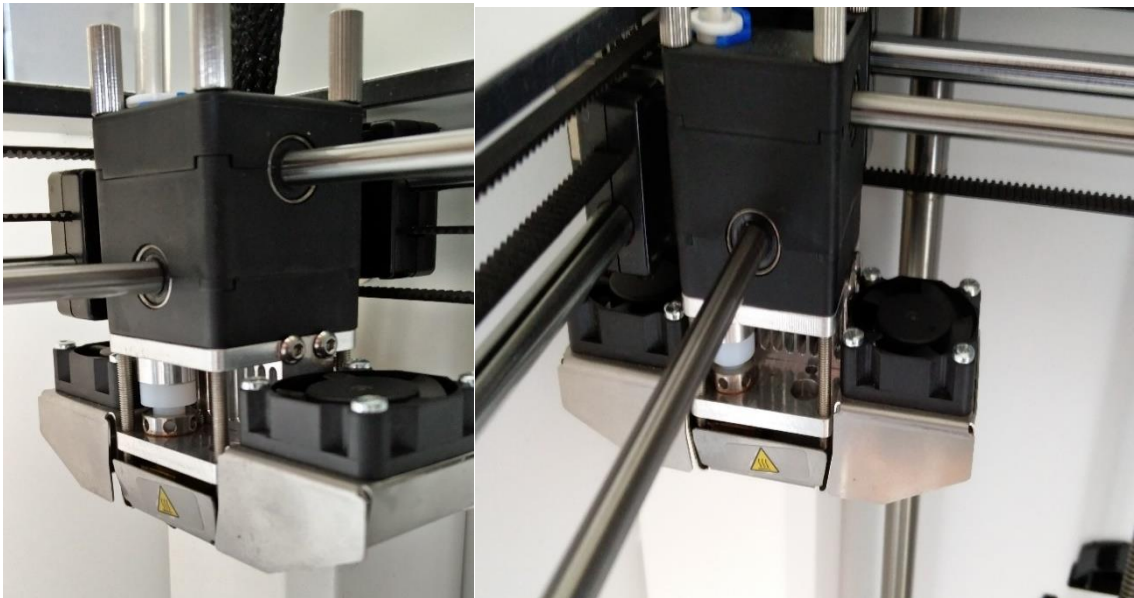


Figure 11 Ultimaker 2+ head from front and right side view

There are some important features about ultimaker 2+ they are augmented by our world-wide open source communal.

They are augmented Dependability and geared feeder, for better quality or for some good features swapping the filament are necessary so this advanced feeder lets us to switch the filament easily and the pressure which we choose for the filament should be correct this is done in reliability.



Figure 12 Ultimaker 2+ head nozzle located region

Swappable nozzle for greater control: In 3D printer nozzles, we have four different types depending on its dimensions 0.25, 0.4, 0.6 and 0.8 mm nozzles this can be switched between them for greater output and for fast printing speed.

Enhanced airflow, smoother prints: Here we use new fancaps to confirm the perfect aimed airflow under the nozzle and also done similarly from both the sides.

3.1 Dimensions and weight of ultimaker2+ and ultimaker2 extended+ Ultimaker 2+

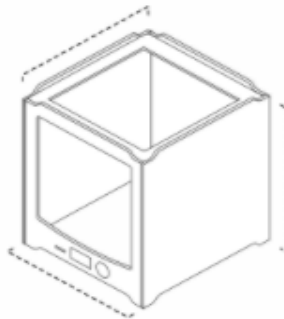


Figure 13 Ultimaker 2+ outer body model [23]

Standard Outer body dimensions:

342 x 357 x 388 mm (13.5 x 14.0 x 15.3 inches) [14]

Here the ultimaker 2+ also contains **Bowden tube and spool holder** along with the model then the dimensions will be:

342 x 493 x 588 mm (13.5 x 19.4 x 23.1 inches) [14]

Weight:

11.3 kilograms (399 ounces)

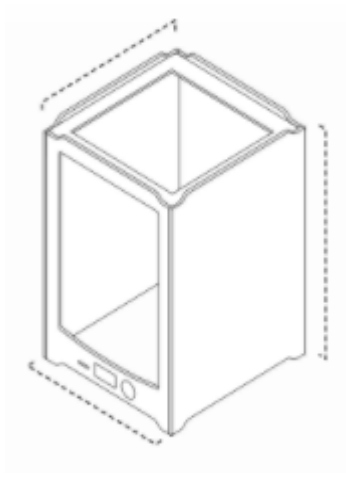
Ultimaker 2 extended+

Figure 14 Ultimaker 2 extended+ outer body model [23].

Standard Outer body dimensions:

342 x 357 x 488 mm (13.5 x 14.0 x 19.3 inches) [14] similar to previous but there are some changes in height, this has larger height compared to previous.

Dimensions with Bowden tube and spool holder:

342 x 493 x 688 mm (13.5 x 19.4 x 27.1 inches) same here difference in height compared to previous.

Weight:

13.3 kilograms (434 ounces)

3.2 Build volume

Ultimaker 2+ contains build space where the models are printed that space is called as build volume. So with the wide build volume compared to its size., the ultimaker 2+ is built to give us a good high degree of elasticity [14] which can impact on the final better output.

Ultimaker 2+

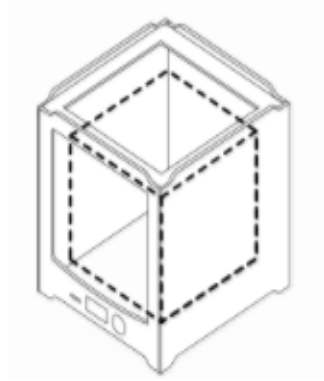


Figure 15 Ultimaker 2+ inner body model [23]

Standard Inner build space dimensions:

223 x 223 x 205 mm (8.8 x 8.8 x 8.1 inches) [14]

Ultimaker 2 extended+

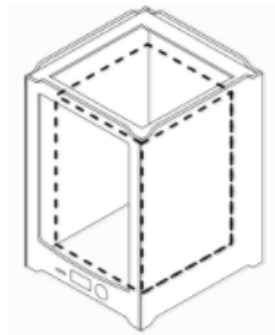


Figure 16 Ultimaker 2 extended+ inner body model [23]

Standard Inner build space dimensions

223 x 223 x 205 mm (8.8 x 8.8 x 8.1 inches)

3.3 Printer and printing types

Ultimaker 2+ is a Pre-assembled type (This whole printer is built before in factories, so the transport can be done easily)

As we mentioned before there are four types of nozzles and their layer resolution is as follows:

0.25 mm nozzle: 150 to 60 microns

0.40 mm nozzle: 200 to 20 microns

0.60 mm nozzle: 400 to 20 microns

0.80 mm nozzle: 600 to 20 microns

Note: Here in our project we use 0.40 mm nozzle for better time saving and good quality.

Build plate and levelling:

Here we use 50 degree Celsius to 100-degree Celsius heated glass plate and assisted leveling process.

Build speed depending on the nozzle

0.25 nozzle has a capacity to build up to $8\text{mm}^3/\text{s}$

0.40 nozzle has a capacity to build up to $16\text{mm}^3/\text{s}$

0.60 nozzle has a capacity to build up to $13\text{mm}^3/\text{s}$

0.80 nozzle has a capacity to build up to $24\text{mm}^3/\text{s}$

Along with these we use Fused Deposition Modeling (FDM) with XYZ accuracy as 12.5, 12.5, 5 microns, print level speed from, 30 to 300 m/s, Standard nozzle temperature from 180 degree Celsius to 260 degree Celsius with nozzle heat up time approximately 1 minute and build plate up time should be less than 4 minutes, finally the operating speed should be 50 DbA.

3.4 Requirements for Ultimaker 2+

- Here we require some software called CUA, our free print preparation software.
- Supported operating system is Free on MacOS, windows, and LINUX.
- Supported file types are STL, OBJ, and AMF
- File transfer is done to standalone 3D printing from the SD card which is included in ultimaker.
- Operating ambient temperature should be from 15 degree Celsius to 32 degree Celsius and nonoperating temperature should be 0 degree Celsius to 32 degree Celsius.
- Electric input should be from 100 volts to 240 volts, 4 Amperes, 50 to 60 Hertz and 221 Watt Maximum, the output will be 24-volt DC and 9.2 amperes.

3.5 Hardware components

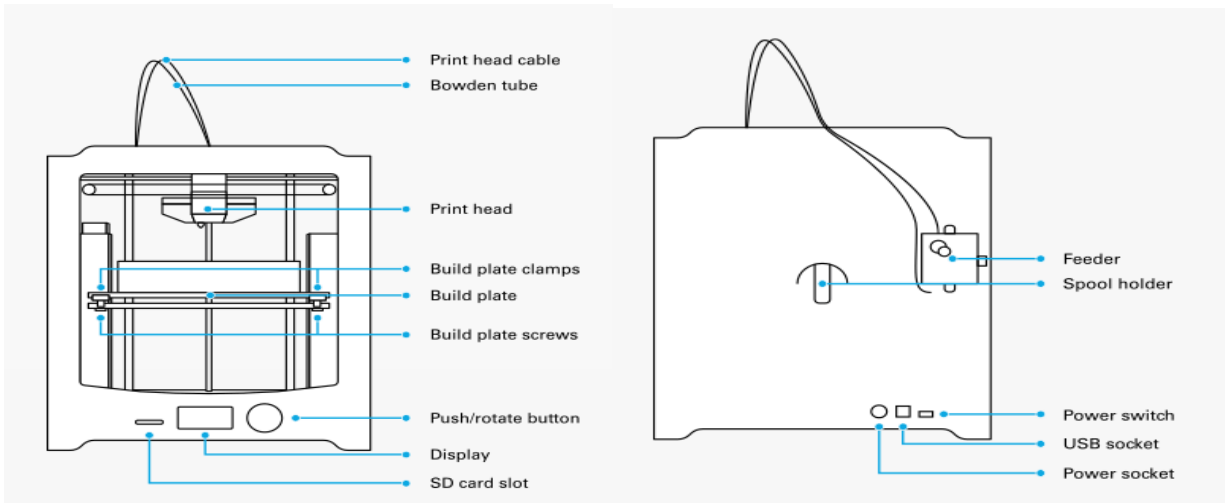


Figure 17 Ultimaker 2+ hardware components front and back [24].

3.6 Steps how to use Ultimaker 2+

1. Both Clamps from the glass plate is removed first by using screwdriver.
2. To remove the glass plate from the back clamps, pull glass plate back.
3. Using soap and water clean the plate and dry it using paper towel.
4. Glass plate should not touch with the bare hands after drying. Oil which contains in our hands can prevent plastic sticking so use proper paper towel to hold it.
5. Now the glass plate is pushed from back to inserted back on the Ultimaker and lock the glass build plate by using the front clamps.
6. Using where turn to go to maintenance option and push the wheel to select the option next in similar way go to build-plate and select, now select continue for the levelling process.
7. Now we have to use 1mm thickness object to check the levelling of the build plate. Use the wheel to change the distance between the nozzle and the build plate, up and down the build plate until we get the small amount of resistance the on the object which we want to build.
8. Now to change the distance between the nozzle and the build plate use screws and make it in perfect place for building.

9. To test the levelling of the build plate, use the single piece of paper, now start rotating the until we get the small amount of resistance on the paper and start moving the paper back and forth to check whether a nozzle is contacting the paper.

10. Rotate all the four screws for the proper resistance of nozzle on the paper. Following this the bed levelling process is complete.

11. Preparation using CURA software, design model and insert in CURA to select material, nozzle and to note the printing time.

12. Now to print the parts which are in CURA is transferred to SD card by clicking the toolpath to SD option.

13. Now insert SD card to slot available in ultimaker and select print from the menu and to find the part to be printed which is available in SD card scroll the wheel by turning and select the part which is saved in STL file and push the button to select.

14. Now the printing will start observe the printer for 5 minutes till first 2-3 layers are printed and make sure that its printing well, if its working good then we can leave the printer to print object for the time required and return when printing job is done.

15. When printing is started, the temperature should be adjusted by turning the wheel it can be increased or decreased in the temperature settings and select the desired temperature of the nozzle and press the wheel.

16. After selecting return option will appear select return option then the process is done, printing work will be done successfully.

3.7 Materials used in 3D printer ultimaker 2+

3.7.1 Nylon: Abrasion-resistance and durable

Many manufacturers worldwide are using this material, important reasons to choose nylon are as follows high strength-to-weight ratio, corrosion resistance, impressive durability, low friction and humidity absorption is less compared to other. The mechanical stress plays very important role.

Some example 3D prints printed using nylon

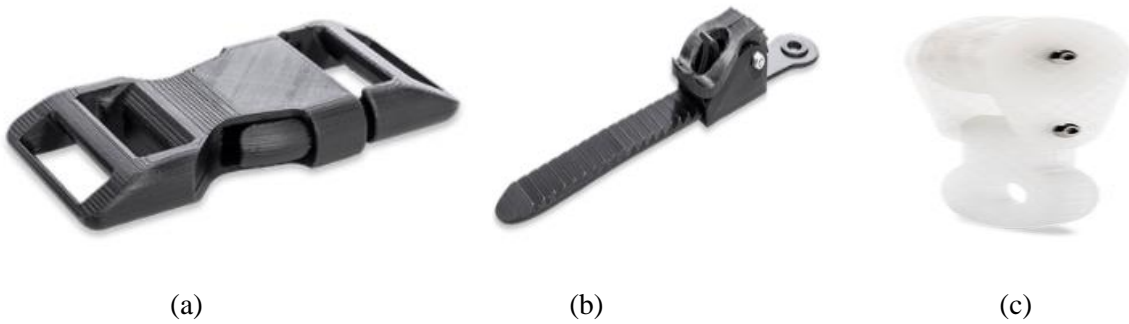


Figure 18 Nylon printed examples. (a) Designed to versatility meets reliability, (b) Designed to resist humidity, (c) Exceptionally durable [25].

3.7.2 ABS: Tough and durable

Ultimaker ABS are fast in process, reliable and safe, ABS can handle temperatures up to 85 degree Celsius, so if we want to print in this temperature zone then we can use ABS and also ABS is good impact resistant which makes good choices for parts (mechanical), important reasons to ABS are as follows even ABS has high durability and strength as nylon, plays good role for printing end parts and strong prototypes, achieve nicer and mainly excellent mechanical properties.

Some example 3D prints printed using ABS

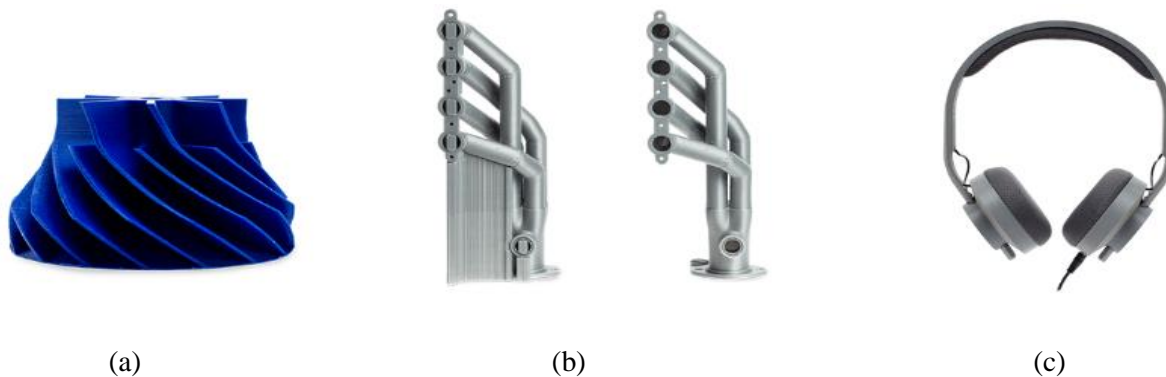


Figure 19 ABS printed examples Example, (a) Prototype, (b) Fit testing, (c) Versatile capabilities [25].

3.7.3 CPE Family: Chemical resistant and tough

CPE material can resist temperature up to 100 degree Celsius, the main reason to select CPE is toughness, dimensionally stable, good interlayer adhesion, used for low-level ultrafine particles, good at volatile organic compounds and chemical resistant. The main reason the transparent option is available so if we want to print any transparent material this material can be used.

Some example 3D prints printed using CPE family



Figure 20 CPE printed examples, (a) Chemical resistant, (b) Reliable parts, (c) Complex geometrics [25].

3.7.4 PLA: Water soluble

To print water soluble parts PLA plays very important role and also for complex material. Reasons to choose PLA are moisture sensitive is less compared to other, excellent adhesion for both PLA and Nylon, safe dissolution in tap water and thermal stability is good.

Some example 3D prints printed using PLA family



Figure 21 PLA printed examples, (a) Smoother, (b) Complex geometrics, (c) Endless possibilities [25].

3.7.5 PC: Strong, heat resistant and tough.

Here parts can be printed in temperature up to 110 degree Celsius. Reasons to choose PC are it gives good print quality, good temperature resistant, toughness, dimensionally stable, good bed adhesion, strong interlayer, allows printing parts for lighting applications and good mechanical strength.

Some example 3D prints printed using PC



Figure 22 PC printed examples, (a)Stable dimension, (b)Tough and strong, (c)Optically translucency [25].

3.7.6 TPU 95A: Wear and tear resistant

This material can elongate up to 580% at the break with shore-A hardness, the reason to choose TPU are chemical resistant, high impact strength, good corrosion resistance used most common in oil industries and chemical fields, durable and flexible.

Some example 3D prints printed using TPU 95A

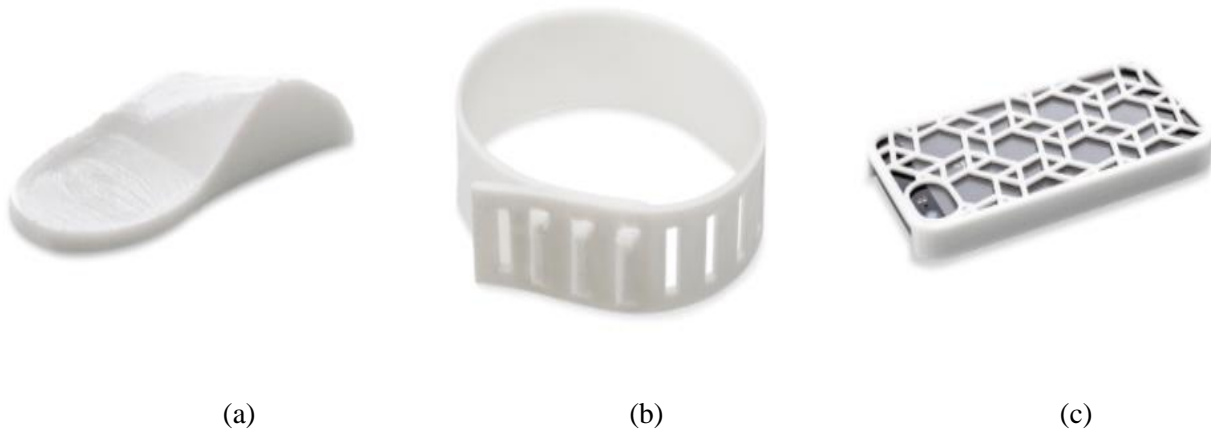


Figure 23 TPU 95A printed examples, (a) Flexible and durable, (b) Chemical resistant, (c) Great for end-use parts [25].

4. CURA

CURA is a software which is used to prepare our model for printing. It helps to select the material which is required and also to choose the nozzle for better quality and can note the time which is required to print the model. This software makes us easy understanding and for experts, there are 200+ settings options to use for their needs. It is open source.

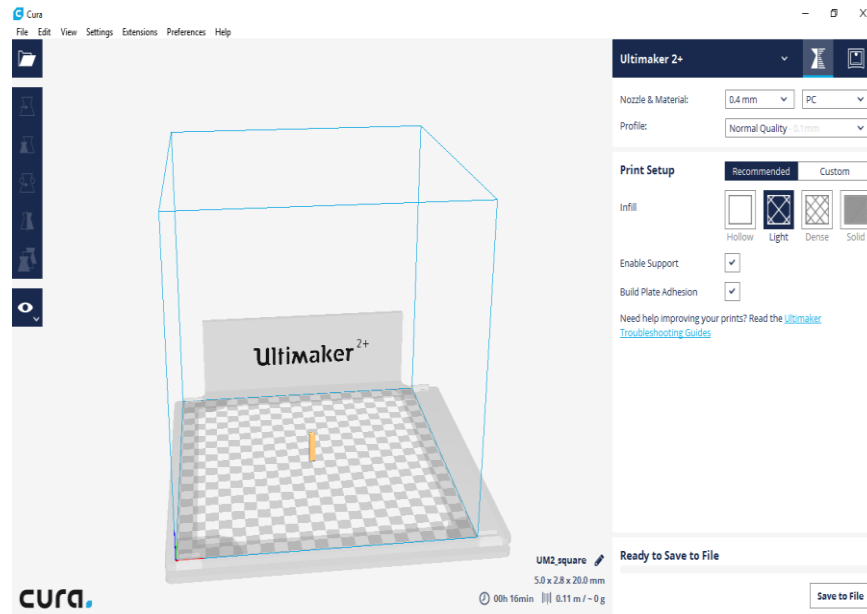


Figure 24 view of CURA software.

The world's most advanced 3D printer software in CURA

CURA creates a unified combination of software, hardware, and materials for the best printing experience. It is supported by the global network of Ultimaker certified service partners. This software is completely free can easily download from the internet or from ultimaker official websites. It supports only STL, OBJ and 3MF file formats.

4.1 Steps to work in CURA

1. Download CURS software from the internet and launch. Then after successful installation go to expert option which is present in top right corner the change option to full settings to modify the print
2. The part which we want to design should be saved in our computed in the STL format. Now go to load option to select the part and upload. Load icon will be on the top of the screen

3. Now the part will be in the ultimaker, check whether part is in proper orientation or not if not use rotate option to place it in proper position and restart button will be available we can use whenever we need it for proper orientation
4. The parts are printed layer by layer so we have select layer thickness and also material depending on the thickness and material the time required to print the object is calculated, that is explained further

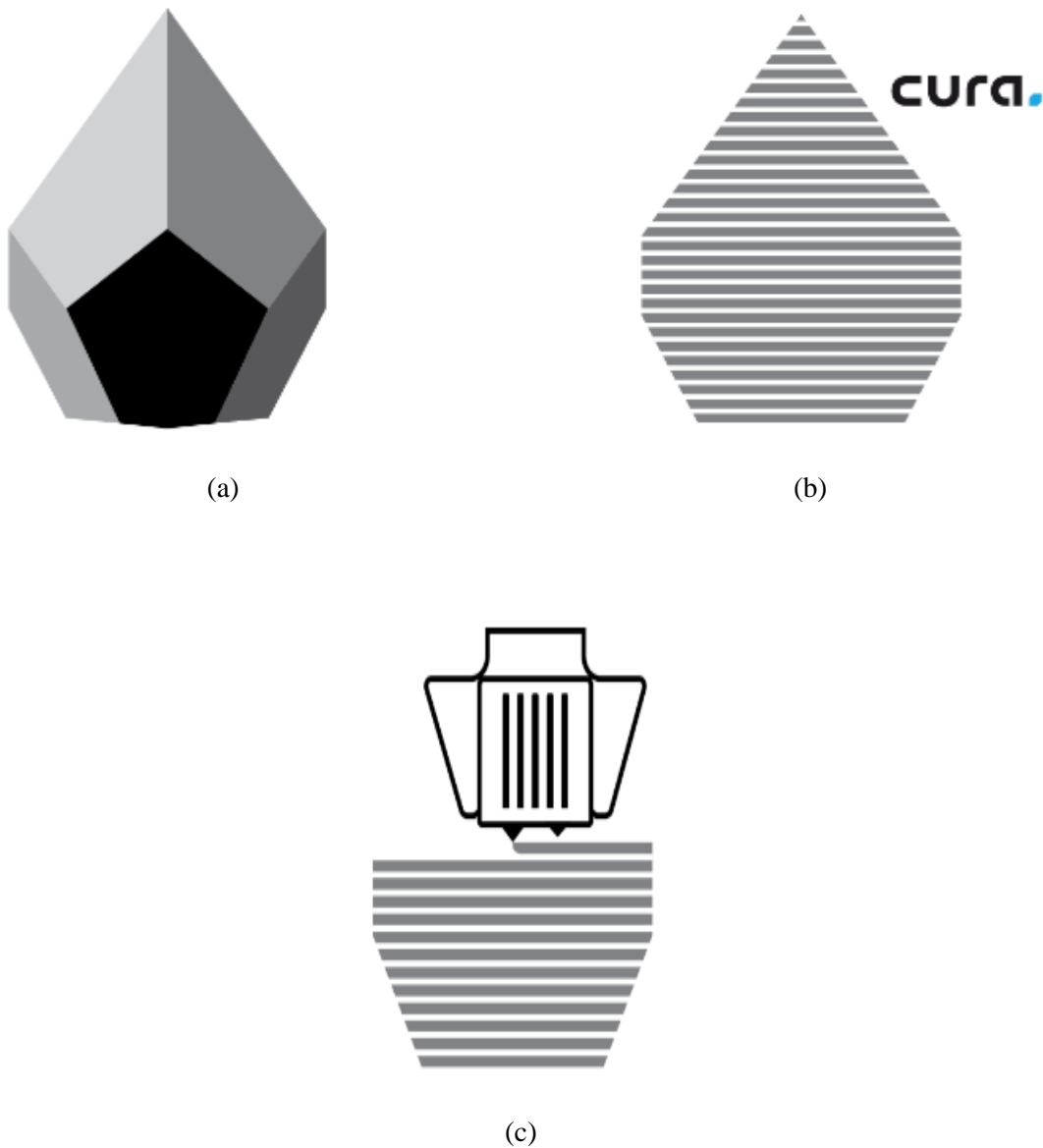


Figure 25 (a) Object is designed in solid works software, (b)Import designed file to CURA, (c)3D printing the designed model using ultimaker layer by layer [26].

4.2 Model designed to print in ultimaker 2+

Square model is designed using solid works software with the dimensions 10mm Height, 10mm Base and 5mm Width and saved in STL format to use in CURA.

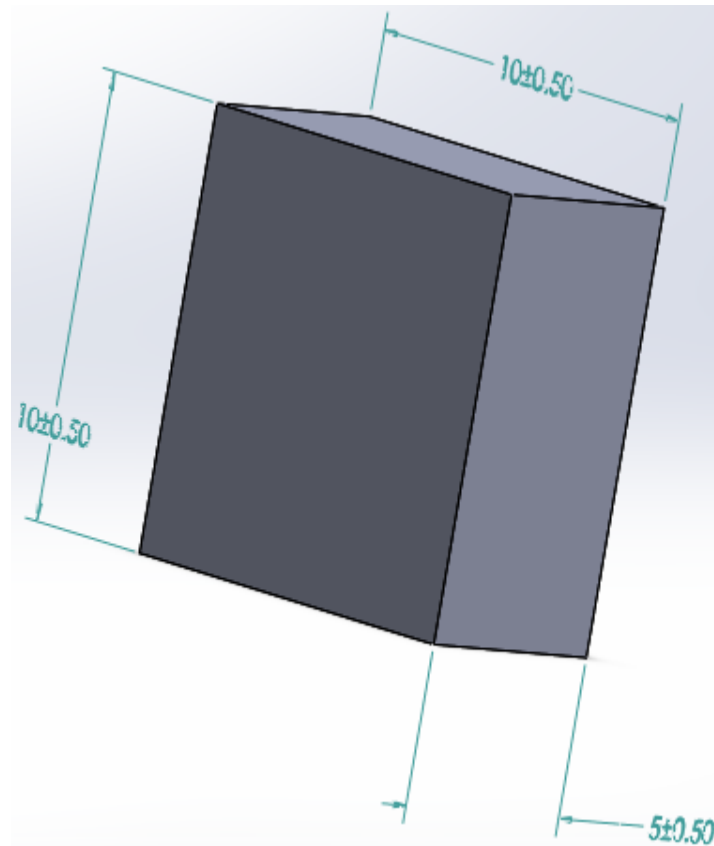


Figure 26 Model designed to print in Ultimaker 2+

This model is inserted in CURA software and time required to print the model is calculated for different material and different nozzle (0.25mm, 0.4mm, 0.6mm and 0.8mm [14])

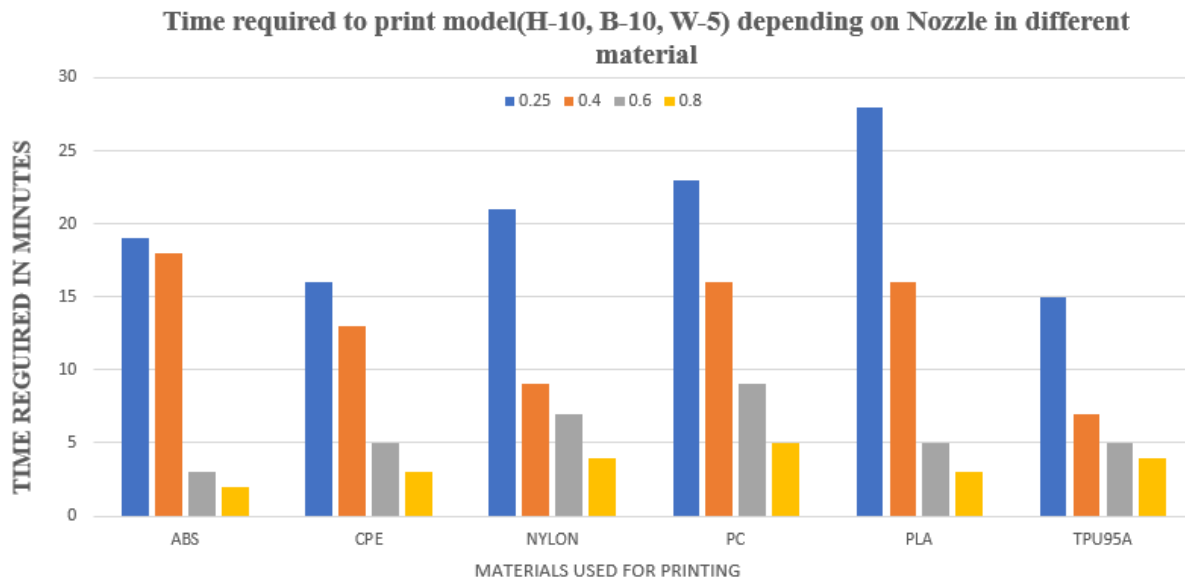
4.2.1 Table and graph for time v/s material v/s nozzle dimensions

- Here we calculate the time required to print the above mentioned diagram.
- Calculated for all the material by selecting all the types of nozzle individually.
- Analysis of the calculations is explained below in table and graph.

Table 2 Time v/s Material v/s Nozzle dimensions

		TIME REQUIRED TO PRINT IN MINUTES			
MATERIALS	NOZZLE	0.25	0.4	0.6	0.8
	ABS	19	18	3	2
	CPE	16	13	5	3
	NYLON	21	9	7	4
	PC	23	16	9	5
	PLA	28	16	5	3
	TPU95A	15	7	5	4

Graph 1: Time v/s Material v/s Nozzle dimensions



From the above table, it's clear that for all the material time required to print material with 0.25 nozzle is more, less time for 0.8 nozzles.

5. Microscope (NIKON DS-Ri2)

The printed model surface quality is analyzed by the checking the printed model quality with the microscope (NIKON DS-Ri2)

This microscope camera is 16.25 megapixels offering fast, the one-shot capture of ultra-high resolution color images and fast storage of images as high 4908 x 3264 pixels, but without pixel stepping or pixel shifting. The printed model is placed under this and the images were taken, this microscope contains four cameras but we use TU plan Fluor 5x/0.15 An OFN25 WD23.5 because this is best one among all.



Figure 27 Pictures of microscope (NIKON DS-Ri2) with camera

5.1 Key features

5.1.1 High-resolution images

This microscope camera is 16.25 megapixels CMOS sensor for better image quality, in photomicrography this pixel density is ideally used for ultrafine structure or some better patterns at low or high magnifications used in industry or biological samples.

5.1.2 Excellent color reproduction

As the name says Nikon is most wanted camera microscope used for reproducing color at the eyes just to see it very clearly, this is done based on the Ds model's they are extensive data storage for many years for the developing microscope digital color cameras, this results in the excellent reproduction of colors.

5.1.3 High-speed live display

We have Supra-HDTV-class live images with a high-speed display this is done using the Nikon microscope, maximum pixel capacity NIKON DS-Ri2 can display is 4908 x 3264 pixel this range is full pixel range at 6 fps, or we have other range 1636 x x1088 pixels this is for 3 x 3 averaging image sat 45 fps. So, with this fast-live frame rate can make fine focusing that leads easily to perform.

5.1.4 High sensitivity, low noise

Here we use the high signal to signal noise ratio for the fluorescent color image capture, we should use the sensitivity settings range from ISO200 TO ISO12800 which allows for the capture of vivid fluorescent color images [27].




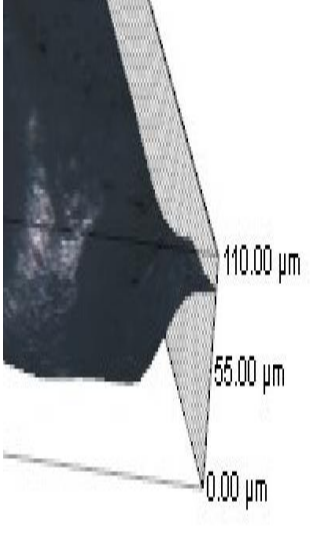


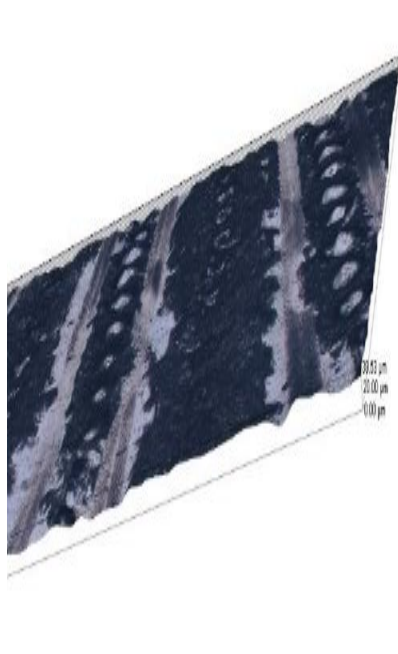
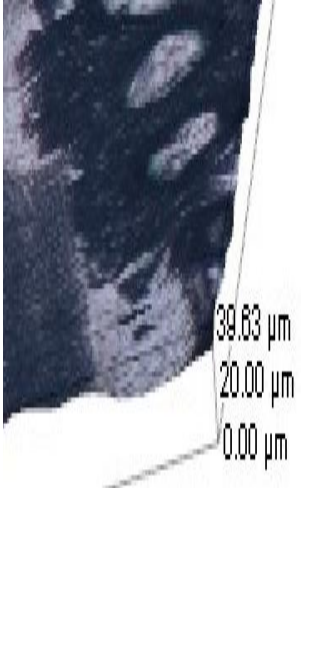
5.2 Specifications


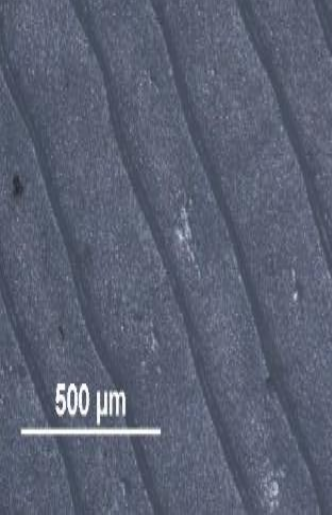




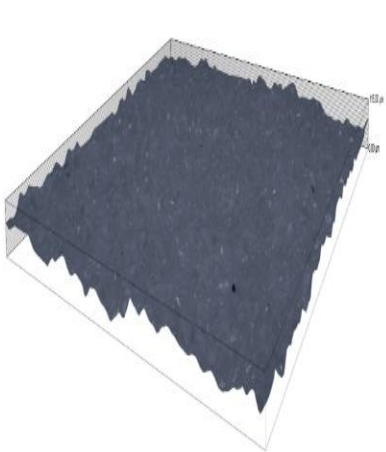
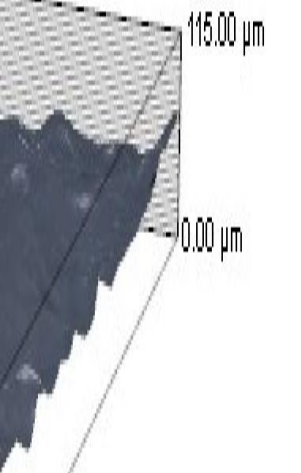
Nikon has image sensor of type Nikon FX-format, color CMOS sensor, and the size is 36.0 x 23.9mm, more importantly, its effectively 16.26 megapixels. Lens mount is F mount, the exposure time is 100 microseconds to 120 microseconds, image formats are TIFF, JPEG, BMP, etc... they are selectable in NIS- elements. Interface is USB3.0 computer control connection and external sync input/output. The power supply is AC 100 volts to 240 volts 50/60HZ and power consumption is 13W. the dimension of the model is 105W x 134 D x 153 H mm and weight is 1200 grams, environmental operations are 0-30 degree Celsius, 80% RH max, 30-40 degree Celsius, 60% RH max.

6. Printed part quality analysis

When printing is done using the ultimaker 2+ now we check the printed parts and analyses what are the problems which we have in the printing parts. So here are some examples of printed parts with supporting structures are highlighted. Will compare all the mode quality and analyze the result.

Table 3 Printed part quality analysis

Printed part	2D View in Microscope	3D View in Microscope	Layer thickness
			
			

Printed part	2D View in Microscope	3D View in Microscope	Layer thickness
			
			

Here in the above table, we can see some printed parts which layer thickness is checked under the microscope which I mentioned before, each part layer has different thickness in micrometre. As per my project mentioned before if the layer thickens is less then the quality will be good. From the above table, 3 second part has less layer thickness so we can consider that part has good quality compared to other parts. So, this process is done after the parts are printed in the ultimaker 2+ to conclude which printed part has better quality. So, in the next chapter will discuss the new implementation in the design and analysis.

7. 3D Printer Head Design

Here we design the 3D printer head with all the standard sizes for further new implementation of the project.

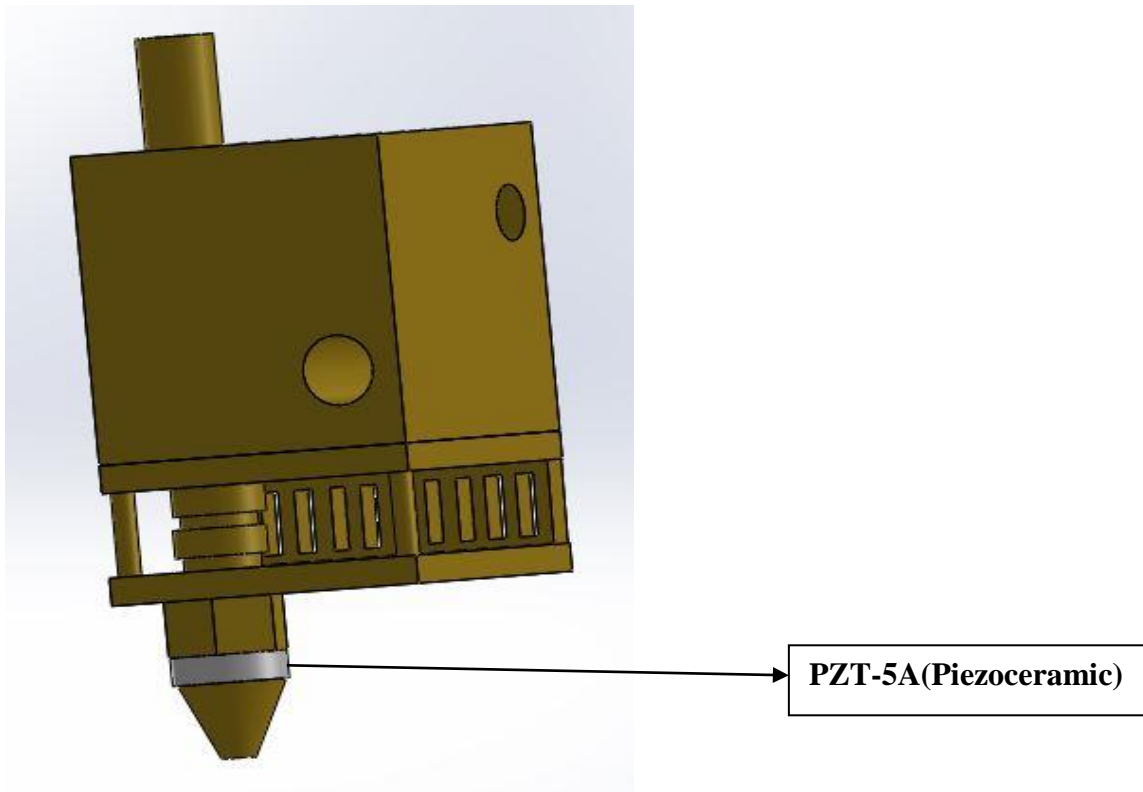


Figure 28 3D printer head design done in solid works

Here is the 3D printer head design with standard size, designed is done to check the vibrations of the assembly and to calculate the frequency of the assembly. So, we use PZT-5A(Piezoceramic) to check the vibrations of the design with standard values of piezoceramic.

7.1 PZT-5A (Piezoceramic)

As I mentioned we use piezoceramic to check the vibrations of the printer head, here PZT-5A is inserted as shown in the above figure between the hot tip and nozzle for the movements of the Nozzle and to calculate the frequency.

Here this PZT-5A is designed using solid works or comsol software the material properties are specified next detailly with the design

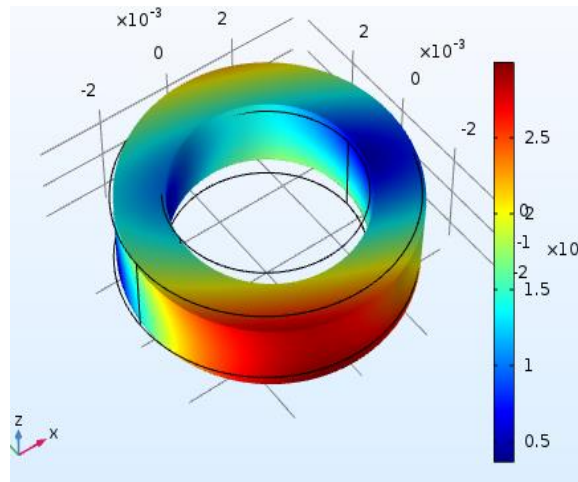


Figure 29 PZT-5A (Piezoceramic) design

7.2 Specifications of PZT-5A

Table 4 Specifications of PZT-5A

Model	PZT-5A
Material No	5A18
Coupling factor (kp)	0.62
Dielectric constant	1800
Dissipation factor (%)	1.5
Frequency constants(Hz.m)	
Thickness	1800
Diameter	2010
Young's modulus (N/m)	5
Mechanical Q	65
Poisson's ratio	0.35
Curie point (°C)	310
Density (10 ³ Kg/m ³)	7.6

The above mentioned Piezoceramic is designed and specified with the values which are mentioned in the table1. The piezoceramic is designed with dimensions' thickness is 2mm and diameter of the outer circle are 7mm and the inner diameter is 3.5mm because the extruder body hole to pass the filament is 3.5mm so PZT must match with it.

8. Hot tip and Nozzle

Here we have considered hot tip and nozzle assembly to calculate the vibrations of the nozzle and also with the vibrations to calculate the frequency of the assembly. Here to calculate the vibration we are fixing the geometries, in printer head, we will have two holes where the rods are attached to the movements, that two portions are fixed.

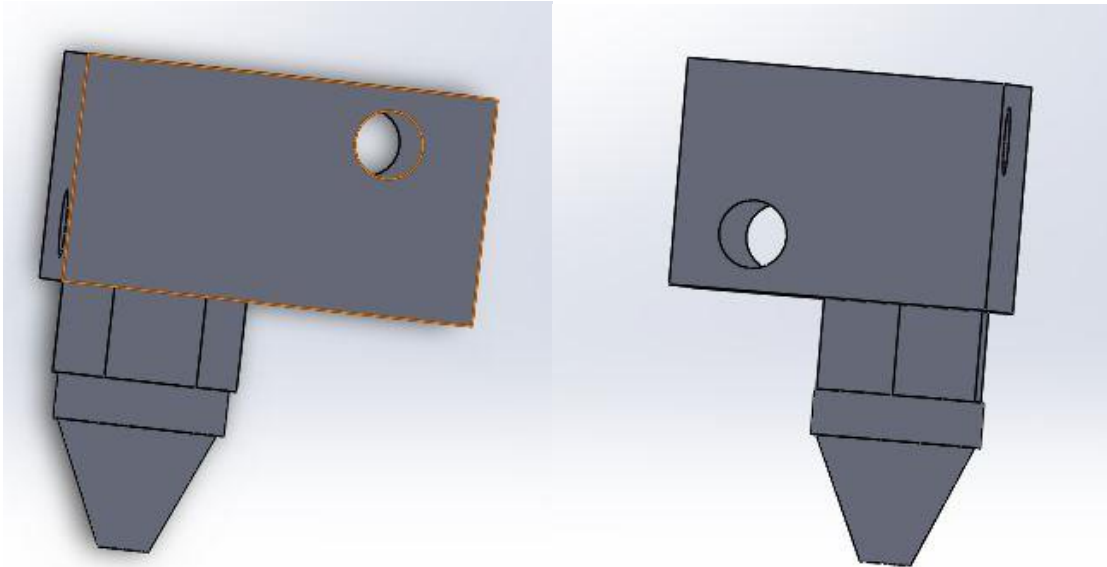


Figure 30 Design and Assembly of nozzle and hot tip

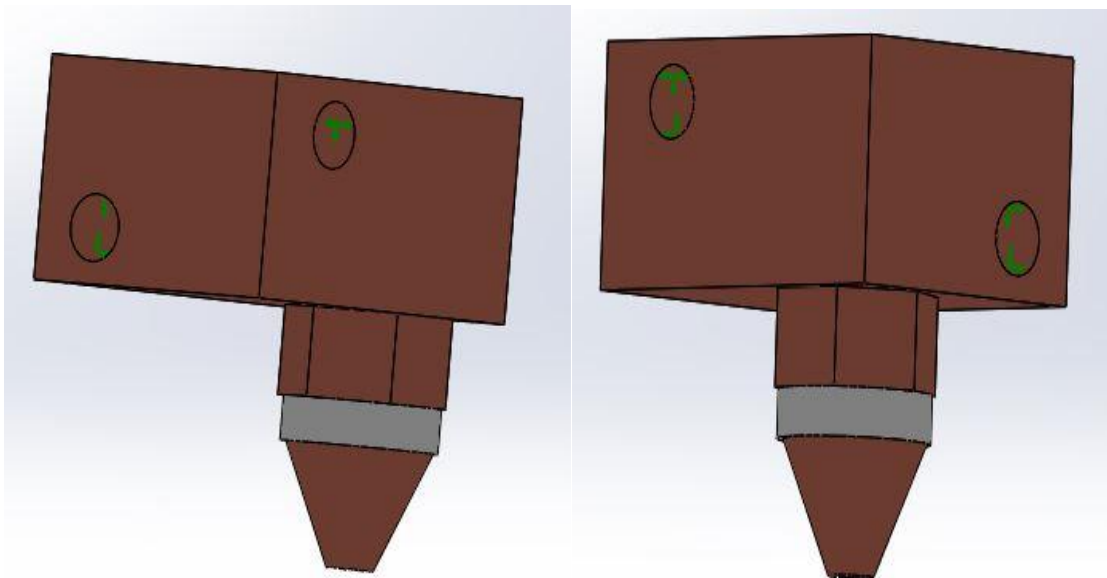


Figure 31 Geometric fixtures, the green coloured marks on the above diagram are considered as fixed

9. Ultrasonic welding

When layers are printed its subjected to ultrasonic plastic welding so let's brief about ultrasonic plastic welding.

Ultrasonic plastic welding can be done between the layers through blending or amending of plastic plates which are thermal in nature using as an energy from sharp frequency mechanical drift. This task is attained by conversion of electrical segment energy to mechanical motion which is at very high frequency. Molecular bonding between parts is attained by applied mechanical drift and employed force which intern creates grating heat at joining function of components.

The following steps and pictorial representations explain the basic ideology of ultrasonic welding:

Step 1: Parts in fixture

The fixture is defined as a hollow block that supports for holding two thermoplastic parts together, which are assembled together.

Step 2: Horn contact

Horn is depicted as the titanium or aluminum component. The top plastic part is in proximity with the horn.

Step 3: Pressure applied

Applying of pressure to parts is essential in order to hitch them to fixture.

Step 4: Weld time

- The vibrations of the horn are done vertically at the frequency of 20000Hertz or 40000 Hertz.
- Weld time is predefined for the distance being calculated in thousands of an inch.
- Designing of parts as to be taken care in order to make sure that vibratory mechanical force is used for limited points for contacting two parts.
- Friction heat is generated by mechanical vibrations that are passed through thermoplastic substances, on reaching the melting point plastic melts stopping the vibrations and cooling process of plastic begins.

Step 5: Hold time

- Due to the nature of plastic that forms into solid after cooling, a prefixed time is set in order to hold the clamping force, this is referred as holding time.
- Dual pressure is used in strengthening the joints by application of force at hold time.

Step 6: Horn retracts

- Horn is recanted as soon as plastic which is in melted state turns its states into solid and clamping force is withdrawn.
- Port this procedure, joining of two plastic parts is obtained and taken out from the fixture as the individual part.
- Assembly of plastic is one of the energy efficient methods as it is quick and clean
- Additional requirements like solvents, adhesive material, mechanical fasteners are not required.
- Final, obtained assembly is strong and clean.

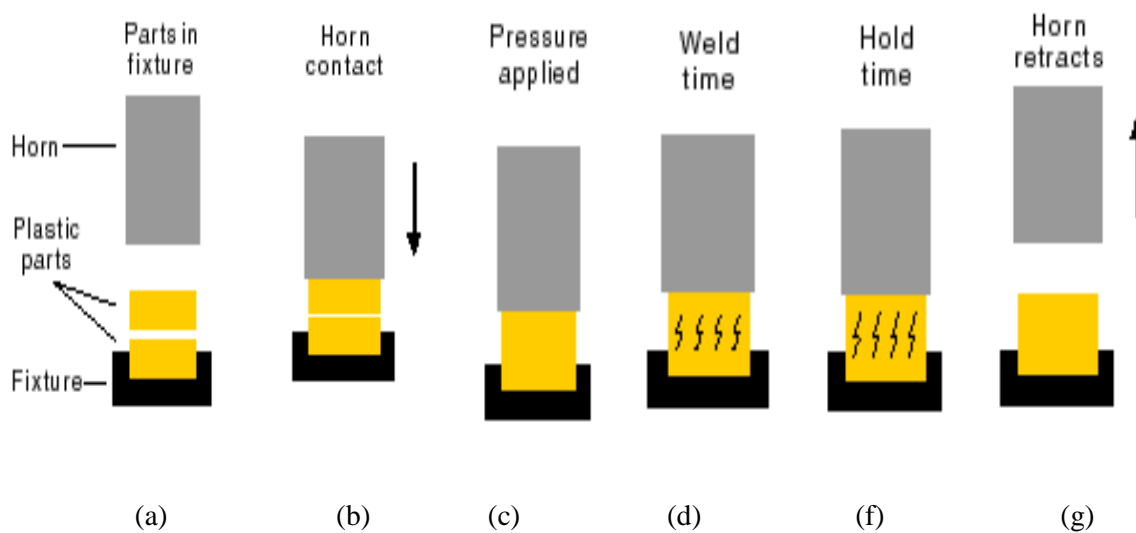
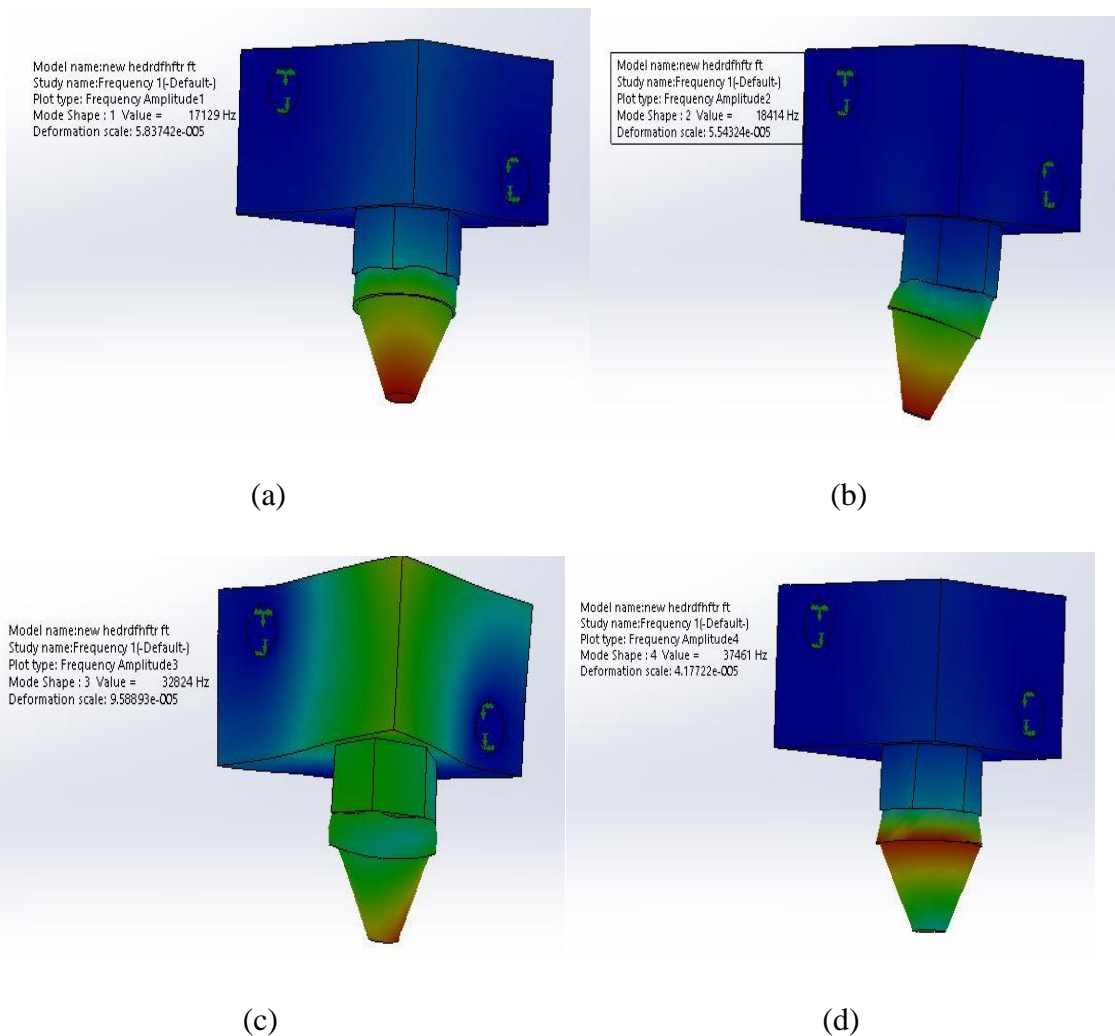


Figure 32 Ultrasonic plastic welding steps, (a) part in fixture, (b)horn contact, (c) pressure applied, (d)weld time, (e) hold time, (g) horn retracts [28].

10. Analysis

10.1 Vibration and frequency study

The PZT-5A is inserted between the Hot tip and Nozzle and the standard frequency of the PZT-5A is applied to calculate the frequency of the printer head assembly. Simulation is done by adding the specified material to the head, the frequency has to increase and nozzle movement should be done, only nozzle part should be moved rest all the body parts of the head should be fixed, this process is done by calculating the frequency on in the nozzle and hot tip part because we need only the movement in all possible vibrations, the movement of nozzle at various increased frequencies are as shown in the following figure



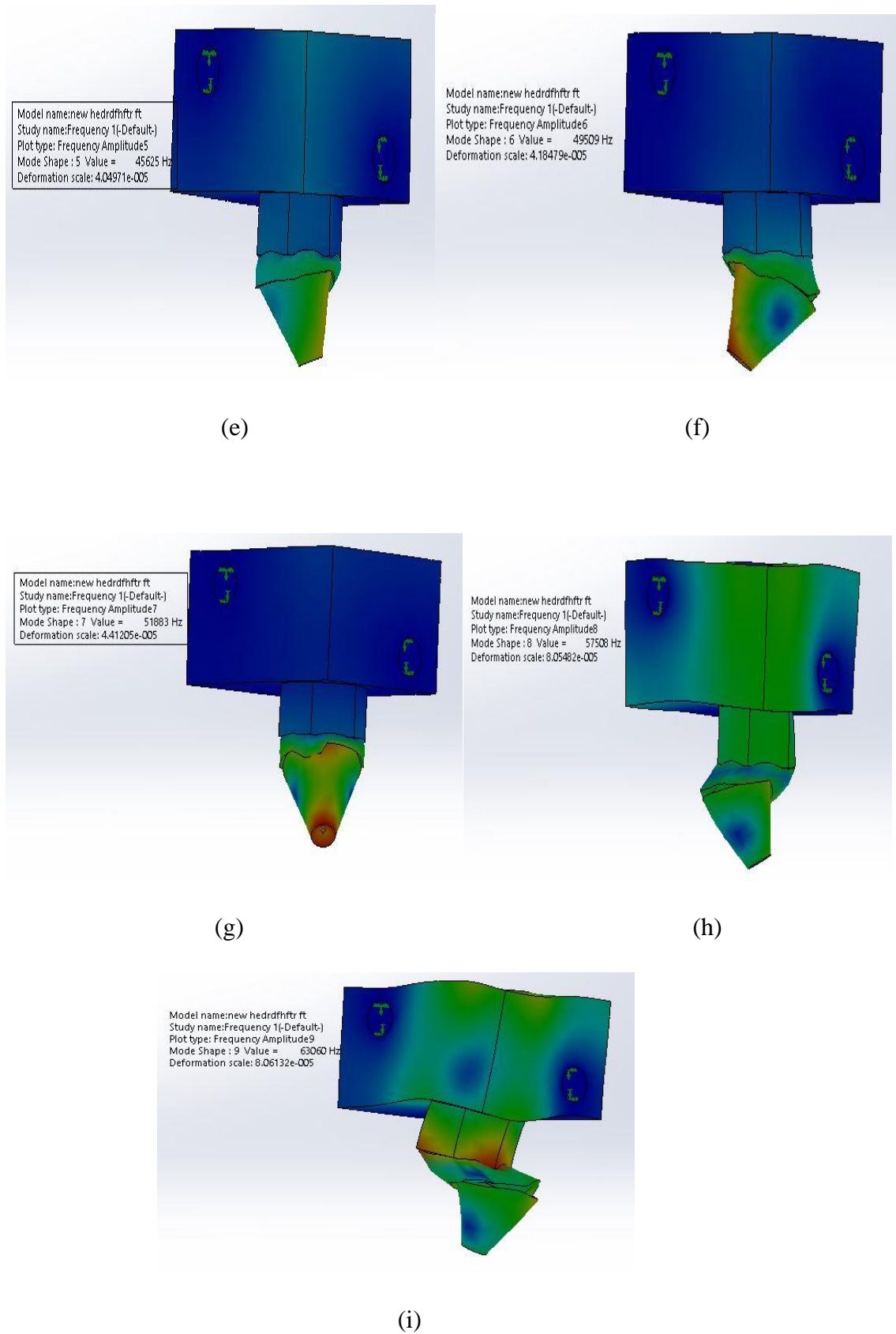


Figure 33 Movement of Nozzle at frequencies in Hz, (a) 17129, (b) 18414, (c) 32824, (d) 37461, (e) 45625, (f) 49509, (g) 51883, (h) 57508 and (i) 63060

By doing simulation the vibrations of the nozzle are calculated. When there is a movement in the nozzle the frequency will suddenly increase to the greater value that should be noted because that frequency will be used to calculate the temperature at the contact of the nozzle with the plastic material.

10.1.1 Results of frequency analysis

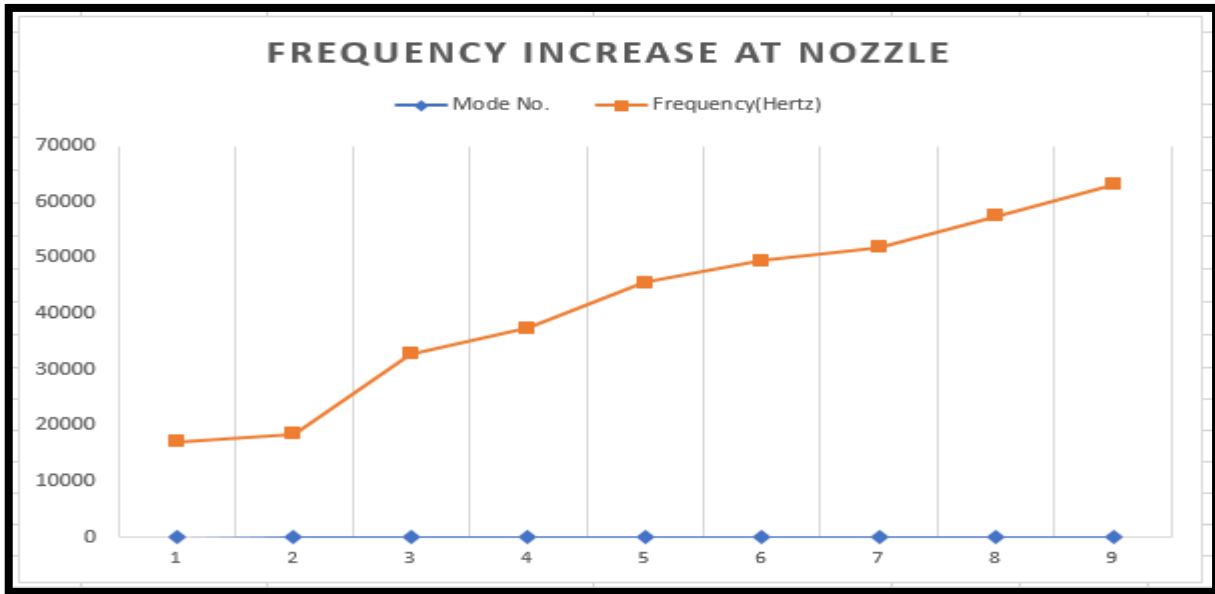
Now for the above design that is for the nozzle and hot tip we calculate the frequency, we have to get the frequency in higher value so that it will be helpful for the ultrasonic plastic welding which explained before that we need frequency till 40000 Hertz. Here we calculated for all the 9 simulation models for the nozzle movement.

As we saw previous our main aim is to increase the frequency to a larger level, we have done that successfully here are some results for an increase in the frequency. The frequency is an increase from 17129Hz to 63060 Hz at 9 modes in required time as shown in the table.

Table 5 Results of frequency analysis

Vibration shapes	Frequency(Hertz)	Period(Seconds)
a	17129	5.84E-05
b	18414	5.43E-05
c	32824	3.05E-05
d	37461	2.67E-05
e	45625	2.19E-05
f	49509	2.02E-05
g	51883	1.93E-05
h	57508	1.74E-05
i	63060	1.59E-05

Graph 2: Results of frequency analysis



The above graph and previous tables clearly state that the frequency is increased for the nozzle vibrations. Now we can conclude that the with the increased frequency at the nozzle if we make the nozzle end to contact with the plastic material and to calculate the temperature at the contact point.

So, from the analysis, we got higher frequency which will be used for ultrasonic plastic welding to make layer stronger.

10.2 Temperature Study

1. In the previous section, we have seen the vibration and frequency calculations of the nozzle, now we discuss about the calculation of the temperature.
2. First, we design the plate of thickness 2mm and make it as plastic by adding material.
3. Next, we make the contact of plastic material which we created with the nozzle (0.4mm) end.
4. After making the contact start the thermal simulation to calculate the temperature at the contact point.
5. Now apply the thermal loads such as the heat power of 10W and convection from 200 to 500W/(m².k) and select the contact parts where the temperature should be calculated.
6. Now run the study to calculate the temperature.

10.2.1 Results of Temperature analysis

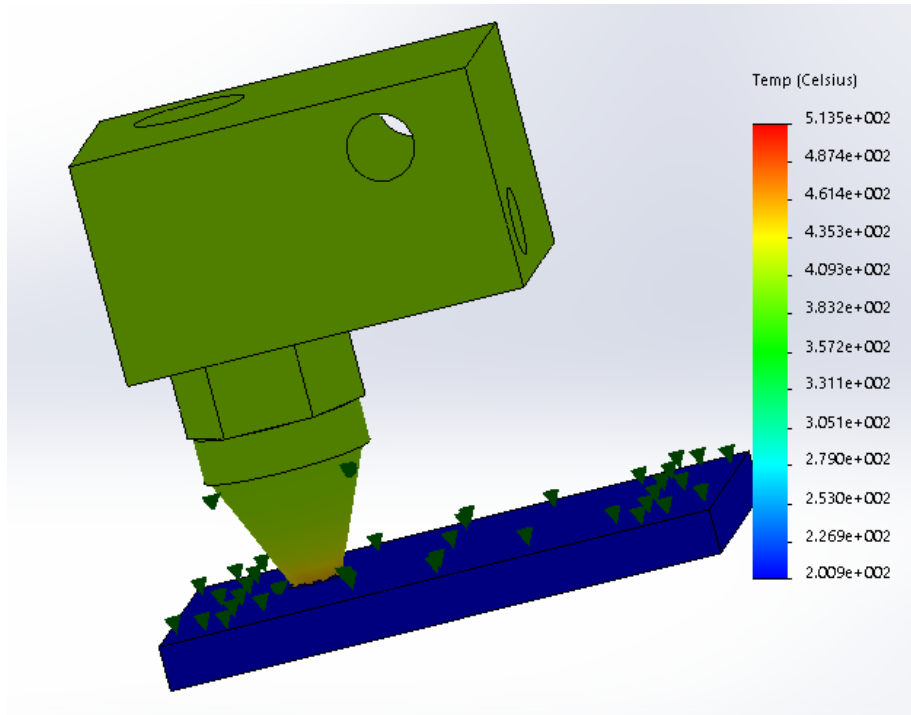


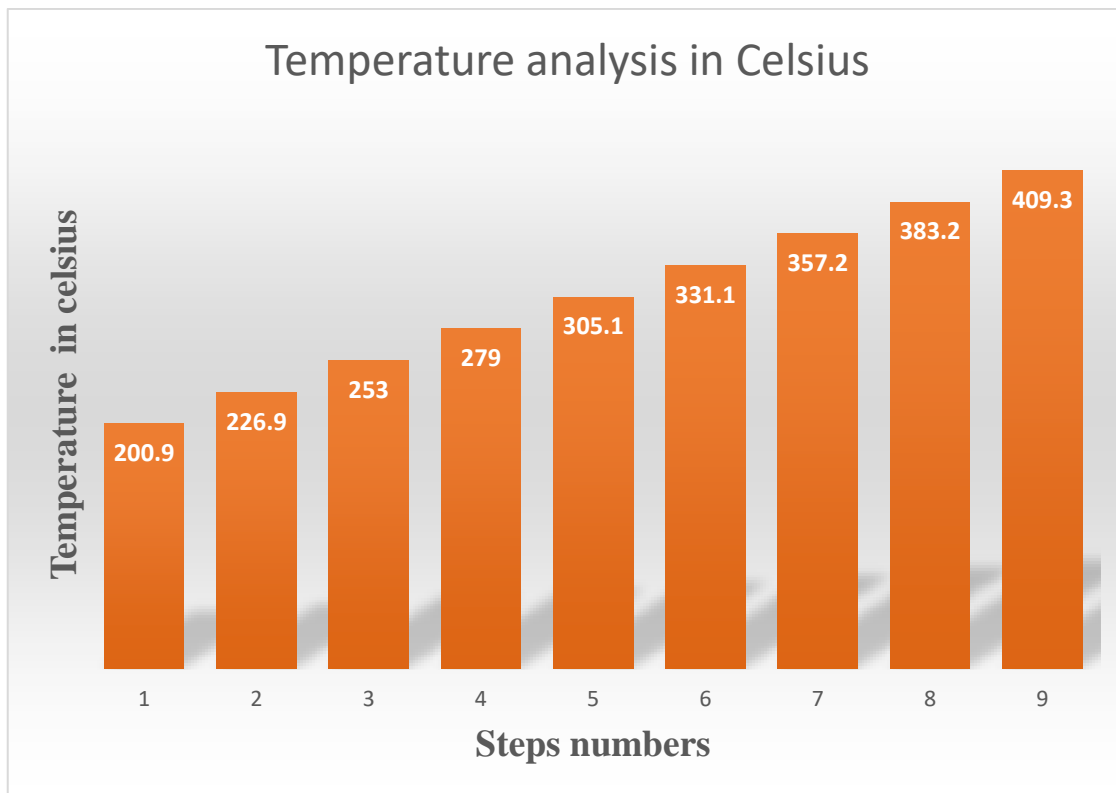
Figure 34 Study of the temperature at the contact point of plastic plate and nozzle

From the above analysis diagram, it is clearly understood that the temperature at the contact point of nozzle and plastic material is increased from 200.9 Celsius to 409.3 Celsius for all the vibration and frequency shape steps. Which is little greater than the standard Ultimaker 2+ temperature.

Table 6 Results of temperature analysis

Step No.	Temperature (Celsius)
1	200.9
2	226.9
3	253
4	279
5	305.1
6	331.1
7	357.2
8	383.2
9	409.3

Graph 3: Results of temperature analysis



From the previous table and above graph its clearly understood that the temperature of the nozzle at the contact point is increased.

Note: If PZT-5A cannot afford the increased temperature then we have to make an alternative option for cooling the piezoceramic by designing the alterative to cool the Piezoceramic

14.3 Conclusion about analysis

We have seen many problems in the printed parts which are printed in low temperature, from this analysis first we calculated the vibrations of the printing nozzle it has many movements so that its understood that nozzle can move in all possible ways to print the material and with that vibrations we calculated the frequency of the assembled parts we have seen the increment in the frequency range the we designed the plastic plate and made the contact with the nozzle to check the temperature in standard conditions and temperature is calculated and we noticed that the temperature is increased to greater extent. Now from this theoretical calculation we can conclude that we can print the model with the more temperature range.

16. Conclusion

We have discussed briefly about the 3D printing technology and also about main aim of this project that is to increase the quality by modernization of Ultimaker 2+ head.

- First, we compared all the Ultimaker printer and choose Ultimaker 2+ is the best and started modernising, then designed 10 x 10 x 5mm solid model and analysed in CURA software the required time to print part in all possible material.
- From the CURA software analysis we came to know that 0.4mm is the best to print parts in good quality because the printed parts in 0.4mm nozzle will have thin layers.
- After choosing the nozzle we moved to designed part, here we design the Piezoceramic (PZT-5A) and placed between the nozzle and hot tip to check the movements or vibrations of the nozzle, finally we save the movement of nozzle in all the possible ways so the nozzle can move to the end parts to print.
- Then we design the Ultimaker 2+ printer head with all the standard dimensions and PZT-5A (piezoceramic) is inserted to it, which is used for further analysis.
- With all the previous tasks modernization in the printer head by inserting the PZT-5A between the nozzle and hot tip is done to check the vibrations and frequency, here we got high range of frequency which is a very good result. High frequency will be used for ultrasonic plastic welding to make layer stronger. later we designed the plastic plate and contacted with the nozzle end, the temperature is calculated at the contact point and we saw the temperature increase, so when working with the larger temperature the material which we use to print start melting and it becomes thinner layer.

Now the printer starts to make the layers thinner, now its concluded that the building of the part is done with all the thin layer, now the part contains many layers. Finally, the part which is printed with the many layers has good quality than the part which has less layers or thick layers.

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