IMPROVISATION 3D PROTOTYPE'S TECHNICAL ISSUES FOR 3D PRINTER

BY

MD ALIK AKANDH
ID: 201-40-660

This Report Presented in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Multimedia and Creative Technology

Supervised By

Mr. Kazi Jahid Hasan
Lecturer
Department of MCT
Daffodil International University

DAFFODIL INTERNATIONAL UNIVERSITY

DHAKA, BANGLADESH

FEBRUARY 2024

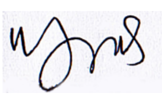
APPROVAL

This Project titled "**Improvisation 3d Prototype Modelling Technique for 3d Printer**", submitted by **Md Alik Akandh, Id: 201-40-660** to the Department of Multimedia and Creative Technology, Daffodil International University, has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Multimedia and Creative Technology and approved as to its style and contents. The presentation has been held on 17-02-2024.

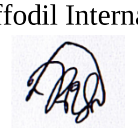
BOARD OF EXAMINERS

Md. Salah Uddin — **Chairman**
Assistant Professor & Head
Department of MCT
Faculty of Science & Information Technology
Daffodil International University

Professor Dr. Shaikh Muhammad Allayear — **Internal Member**
Professor
Department of MCT
Faculty of Science & Information Technology
Daffodil International University



Mr. Mizanur Rahman — **Internal Member**
Assistant Professor
Department of MCT
Faculty of Science & Information Technology
Daffodil International University



Professor Dr. Mohammad Zahidur Rahman — **External Expert**
Professor
Department of CSE
Jahangir Nagar University ,Dhaka

DECLARATION

We hereby declare that, this project has been done by us under the supervision of Mr. **Kazi Jahid Hasan, Lecturer, Department of MCT** Daffodil International University. We also declare that neither this project nor any part of this project has been submitted elsewhere for award of any degree or diploma.

Supervised by:

Mr. Kazi Jahid Hasan
Lecturer
Department of MCT
Daffodil International University

Submitted by:

Md Alik Akandh
ID: 201-40-660
Department of MCT
Daffodil International University

ACKNOWLEDGEMENT

First we express our heartiest thanks and gratefulness to almighty ALLAH for His divine blessing makes us possible to complete the final year project successfully.

We really grateful and wish our profound our indebtedness to **Mr. Kazi Jahid Hasan, Lecturer**, Department of MCT Daffodil International University, Dhaka. Deep Knowledge & keen interest of our supervisor in the field of **"*3D Printing*"** to carry out this project. His endless patience ,scholarly guidance ,continual encouragement , constant and energetic supervision, constructive criticism , valuable advice ,reading many inferior draft and correcting them at all stage have made it possible to complete this project.

We would like to express our heartiest gratitude to **Md. Salah Uddin,** Assistant Professor and Head**,** Department of MCT, for his kind help to finish our project and also to other faculty member and the staff of MCT department of Daffodil International University.

We would like to thank our entire course mate in Daffodil International University, who took part in this discuss while completing the course work.

Finally, we must acknowledge with due respect the constant support and patients of our parents.

ABSTRACT

This research not only contributes to advancing 3D printing methodologies but also provides a practical manual for practitioners, presenting precious insights for navigating the complexities of 3D printing to optimize strategies for enhanced accuracy, sustainability, and real-world applicability. The software program framework, incorporating Maya, Blender, 3ds Max, Meshmixer, and Cura Slicer, courses a scientific workflow. The selected Creality Ender 3 V2 Neo printer, chosen for its performance and mid-budget attraction, comprises numerous substances, with PLA diagnosed as the preferred preference for its eco-friendliness and superior end. Optimization strategies, starting from manual guide creation to infill systems, are systematically tested, with Final experiment identified as the premiere configuration, balancing energy, time performance, and material utilization. Navigating patron product prototypes and replacement elements, the have a look at information a three-step workflow encompassing modeling, slicing, and printing, where calibration complexity, temperature changes, and nozzle customization are paramount for reaching the preferred output fine.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER: 1
INTRODUCTION

The evolution of 3-d printing era has helped in a transformative technology in manufacturing, offering extraordinary opportunities for prototyping and alternative element manufacturing. This thesis manages a comprehensive exploration of the problematic interplay between software, hardware, materials, and optimization techniques to refine and decorate the 3-D printing workflow. The software program issue of this studies divides into three crucial categories: modeling the use of industry-fashionable software program along with Maya, Blender, and 3ds Max; mesh problem evaluation and correction facilitated via Meshmixer; and cutting and printing operations conducted through the versatile Cura Slicer. A judicious choice of hardware, exemplified by using the Creality Ender 3 V2 Neo printer, in addition complements the software program, aligning mid-budget concerns with heightened performance. The printer's compatibility with various materials is accentuated, with PLA emerging as the preferred material for its eco-friendly attributes, various color alternatives, and impeccable finish.

The research encompasses two pivotal model classes—consumer product prototypes and alternative components—reflecting the ubiquity of these items in ordinary existence. The workflow unfolds throughout 3 distinct ranges: modeling, cutting, and printing. Calibration intricacies, temperature modifications, and meticulous nozzle customization play a pivotal role in accomplishing the favored output fine. Optimization techniques shape a cornerstone of this investigation, delving into guide advent, layer peak choice, infill structures, and temperature changes. Last experiment emerges because the best configuration, showcasing a sensitive stability among electricity, time efficiency, and cloth usage.

As the technological panorama of 3-D printing continues to redefine manufacturing paradigms, this study contributes no longer only to the theoretical know-how of 3-D printing methodologies but also serves as a practical manual for practitioners. The insights derived herein provide a sturdy basis for navigating the complexities of three-D printing, emphasizing precision, sustainability, and realistic application within the dynamic realm of prototyping and alternative element production.

Motivation

This thesis is stimulated by the transformative ability of 3-D printing in reshaping contemporary manufacturing strategies. The motivation stems from the urgent want to bridge the space among theoretical knowledge and sensible utility, presenting a comprehensive guide for practitioners navigating the intricacies of 3-D printing. Recognizing the dynamic panorama of software program tools, hardware alternatives, and materials, the studies objectives to offer realistic insights into optimizing the workflow for green prototyping and alternative element production. The desire to attention on patron product prototypes and alternative elements is pushed by the pragmatic consciousness in their considerable use in everyday existence, emphasizing the direct effect of 3D printing on realistic eventualities. The motivation extends to the meticulous exploration of optimization techniques, with final experiment status as a testimony to the dedication to finding the appropriate balance between strength, time performance, and fabric utilization. In essence, this thesis is inspired via a commitment to advancing the sensible knowledge of 3-d printing, empowering people and industries to leverage its complete capacity within the hastily evolving panorama of present day manufacturing.

Research Objective

These concise research objectives aim to enhance understanding and application of 3D printing, providing practical guidance for both academic and industrial practitioners. Evaluate Creality Ender 3 V2 Neo for prototyping and implement printer calibration for precision in hardware selection and calibration. Examine PLA properties for environmental benefits and compare PLA products from various manufacturers in material selection and testing. Focus on consumer product prototypes and replacement parts in prototyping and replacement part production and develop a systematic approach for 3D printing challenges. Create a comprehensive comparison table for experimentation results and identify optimal settings for strength, time efficiency, and material usage in comparison and analysis. Validate optimal settings, especially Last Experiment, through practical experiments in validation through experimentation. Draw practical insights and offer recommendations for optimizing 3D printing processes in prototyping and replacement part production in practical implications and recommendations.

Expected Outcome

The expected results of this thesis embody a complete development inside the know-how and practical application of 3D printing generation for prototyping and alternative element manufacturing. Informed Hardware Selection and Calibration making sure its suitability for green prototyping and alternative element manufacturing. Fine-tuned calibration strategies guaranteeing precision and accuracy within the 3-D printing manner. In-intensity Material Selection and Testing: Clear know-how of PLA's precise houses, establishing it as an environmentally pleasant and incredible fabric for 3-d printing. Comparative evaluation of PLA products from diverse producers, supplying insights into material first-rate and its effect at the printing manner.

Effective Prototyping and Replacement Part Production: Practical packages of 3D printing in developing patron product prototypes and alternative components, addressing common demanding situations with a scientific technique.

Comprehensive Comparison and Analysis: Creation of a detailed comparison desk evaluating experimentation effects, guiding practitioners in deciding on most reliable settings primarily based on detail, speed, strength, and fabric utilization. Identification of settings, especially the ones in last experiment, as most useful for accomplishing a stability between electricity, time performance, and cloth utilization.

Validation thru Experimentation: Practical validation of diagnosed most advantageous settings, imparting real-international confirmation of their effectiveness in achieving desired results.

Practical Implications and Recommendations: Derivation of practical insights from research findings, supplying valuable pointers for practitioners seeking to optimize 3D printing methods in prototyping and alternative element production. These expected consequences together make a contribution to a refined and practical framework for leveraging three-D printing technology in diverse manufacturing packages, facilitating informed decision-making and superior performance for both educational and industrial practitioners.

Figure 1.1: The final model in separated parts (headphone stand)

Figure 1.2: The final model combined with all parts (headphone stand)

Report’s Layout

The document is structured into wonderful sections, commencing with an introduction presenting a background and motivation for the examination, culminating in a concise thesis declaration. The subsequent literature assessment encapsulates a comprehensive survey of 3D printing technology, elucidating present-day developments, applications, and the prevailing knowledge in software tools, hardware options, and materials. The methodology segment delineates the elaborate tactics concerned in software integration, hardware selection, material testing, and workflow optimization, providing a systematic approach to the study's research goals. Results are then meticulously presented, offering an in-depth evaluation of findings related to software, hardware, material checks, and practical applications in prototyping and alternative part production. The resulting discussion interprets these outcomes in the context of the research questions, exploring implications and unexpected consequences. A conclusive summary within the conclusion segment recaps key findings and their contributions, followed by practical guidelines for practitioners. Recommendations are supplied for future research areas, and the document concludes with a complete listing of references and appendices containing supplementary materials. This structured layout ensures a rigorous academic presentation of the researcher's methodologies, results, and implications, adhering to scholarly conventions.

CHAPTER: 2
BACKGROUND STUDY

Introduction

The evolution of additive manufacturing technologies, significantly 3D printing, has redefined traditional example in production, presenting unprecedented opportunities for precision, customization, and rapid prototyping. This transformative era has permeated numerous industries, starting from aerospace to healthcare, essentially changing how prototypes are conceptualized and the way replacement elements are manufactured. The surge in hobby and application of 3D printing technologies has prompted an intensified cognizance on optimizing its strategies to satisfy the needs of various packages. As the generation evolves, essential juncture emerges necessitating an in-depth exploration into the intricacies of software integration, hardware choice, material considerations, and workflow optimization for powerful 3-D printing. This history take a look at sets the degree for a complete research into those elements, aiming to bridge theoretical understanding with sensible software inside the domain names of prototyping and replacement part manufacturing. By analyzing the cutting-edge state of 3-d printing generation, general trends, and the prevailing frame of understanding, this examine seeks to make contributions to the continued discourse, giving valuable insights for practitioners navigating the dynamic landscape of additive manufacturing.

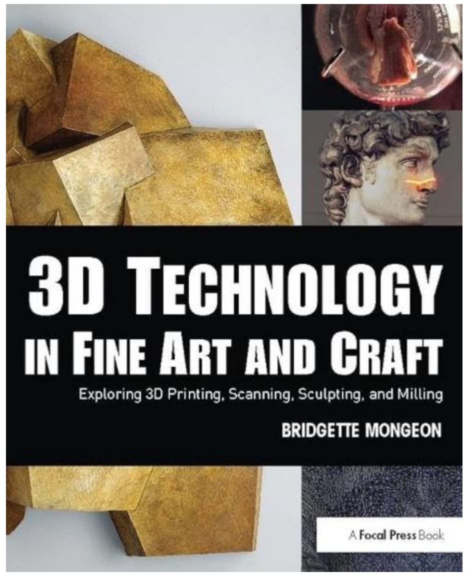


Figure 2.1: The book we followed for our research which helps us a lot for getting knowledge

Figure 2.2: Various types of printer models which are available in the market

Figure 2.3: Some printing material examples like, PLA, TPU & ABS

Figure 2.4: The cover that we made in home for avoid fume from ABS material and also save from dust

Literature Review

The literature overview explores the transformative evolution of 3D printing technology, tracing its historical development from rapid prototyping to its current widespread applications across industries, with key trends highlighting the technology's versatility in aerospace, automotive, healthcare, and consumer goods. Software tools such as Maya, Blender, and 3ds Max play significant roles in intricate 3D modeling, while Meshmixer addresses mesh issues crucial for successful physical reproduction. The Creality Ender 3 V2 Neo stands out in hardware selection for its efficiency and affordability, while PLA is extensively examined as the preferred material, considering its eco-friendly nature, color variety, and superior finish. Optimization strategies, including manual support creation and infill customization, form a vital component of the 3D printing workflow. The literature underscores the practical applications of 3D printing in prototyping and replacement part production, emphasizing its role in addressing real-world challenges. This brief review establishes a foundation for the study methodology, providing valuable insights for practitioners and researchers engaged in optimizing 3D printing techniques.

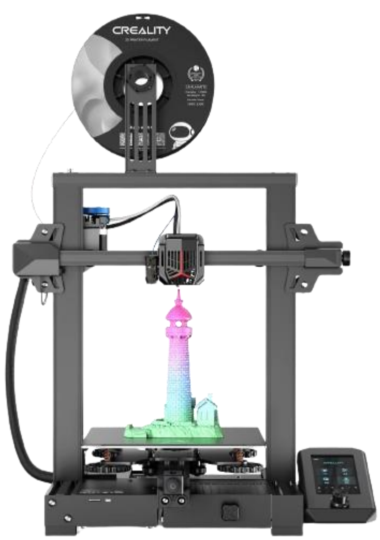


Figure 2.5: The printer model that we finally chosen for our printing machine (Criality Ender 3 V2 Neo)

Scope of the Problem

The scope of this thesis extends to the multifaceted challenges and possibilities embedded inside the realm of 3D printing for prototyping and substitute element manufacturing. Hardware selection, in particular comparing the Creality Ender 3 V2 Neo, turns into a focal point, necessitating an exploration of its suitability for green prototyping. Material concerns, mostly specializing in PLA, entail a comparative analysis of products from diverse producers, shaping the scope of fabric-related challenges and alternatives. Workflow optimization, enclose modeling, cutting, and printing tiers, Pivoting or persevering with venture ideas, with a focus on strategies which include manual aid creation and infill customization. The practical applications of 3-d printing in growing purchaser product prototypes and alternative components form an essential a part of the hassle space, emphasizing the need to navigate demanding situations essential in those programs. The optimization and improvement techniques, such as final experiment, make a contribution to refining the scope by using seeking most efficient stability between power, time efficiency, and material utilization. The energy problem and the need for non-stop printing via an inverter similarly make bigger the problem area, acknowledging real-international constraints. In essence, the scope encompasses the problematic demanding situations and capacity answers related to manipulating 3-D printing technology correctly within the dynamic domains of prototyping and substitute part manufacturing.

Challenges

The recognized challenges in the heritage observe revolve across the complex landscape of 3-d printing generation. The evaluation of hardware, especially the printer, introduces challenges in figuring out key criteria for efficient prototyping. Material choice, specifically in deciding on the optimum PLA version from diverse producers, presents a multifaceted situation thinking about environmental, coloration, and finish issues. Strategies for workflow optimization, real-international packages, strength dependency during printing, experimentation for optimization, and the vital for non-stop improvement make a contribution to the tricky challenges natural in leveraging 3-D printing successfully for creation, prototyping, and substitute part production. Successfully navigating these demanding situations is imperative for advancing the understanding and practical application of 3D printing technology.

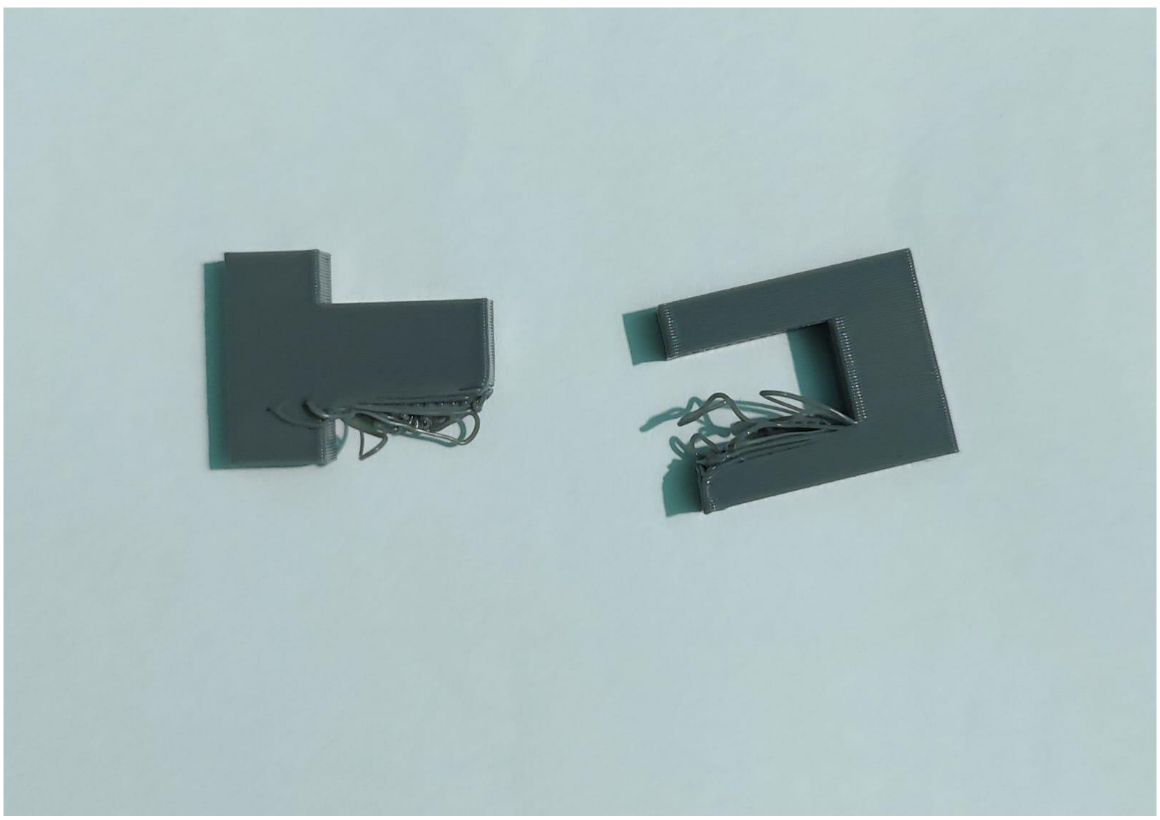


Figure 2.6: Stringing issue when we use 90 degree angle on the model

Figure 2.7: Stringing issue when we use more bevel on the model it causes stringing

CHAPTER: 3

PROPOSED RESEARCH MODEL

Introduction

The proposed research model centers on a comprehensive exploration of 3D printing optimization, utilizing a headphone stand as the focal model, weighing approximately sixty-eight grams, serving as a representative subject for experimentation. The research includes a meticulous process of iterative experimentation, performed seven times, wherein key parameters such as temperature, layer height, print speed, nozzle size, and others are systematically changed. Through these experiments, significant improvements have been achieved, showcasing the refining effect of parameter variations on the final product's usability. This iterative approach allows for a thorough understanding of the optimal settings for various models, unveiling unique insights into the interaction between parameter changes and model characteristics. The proposed research model not only provides a solid basis for exploration but also contributes to refining and enhancing 3D printing processes, establishing a valuable framework for future applications and advancements in this dynamic field.

Research Area and Construction's

This has a look at navigates the nation-states of 3D printing, emphasizing three key domain names—software program, hardware, and materials. Hardware exploration makes a specialty of the printer, assessing its skills in managing diverse substances. PLA emerges as the most advantageous material because of its color range, eco-friendliness, and printing precision. The research pioneers the categorization of fashions into prototypes and substitute components inside the purchaser products domain. The workflow, encompassing modeling, slicing, and printing, establishes a systematic approach for green model creation. Through iterative optimization, the look at refines important parameters, providing insights into accomplishing superior effects in element, velocity, and fabric consumption. The comprehensive assessment desk, providing a headphone stand model, encapsulates numerous outcomes, offering nuanced insights into 3-d printing processes. Overall, this studies extends the bounds of 3D printing understanding, imparting realistic recommendations for reinforcing modeling strategies and advancing packages in prototyping and substitute element production.

Figure 3.1: Replacement part examples like monitor mount, gears and screws

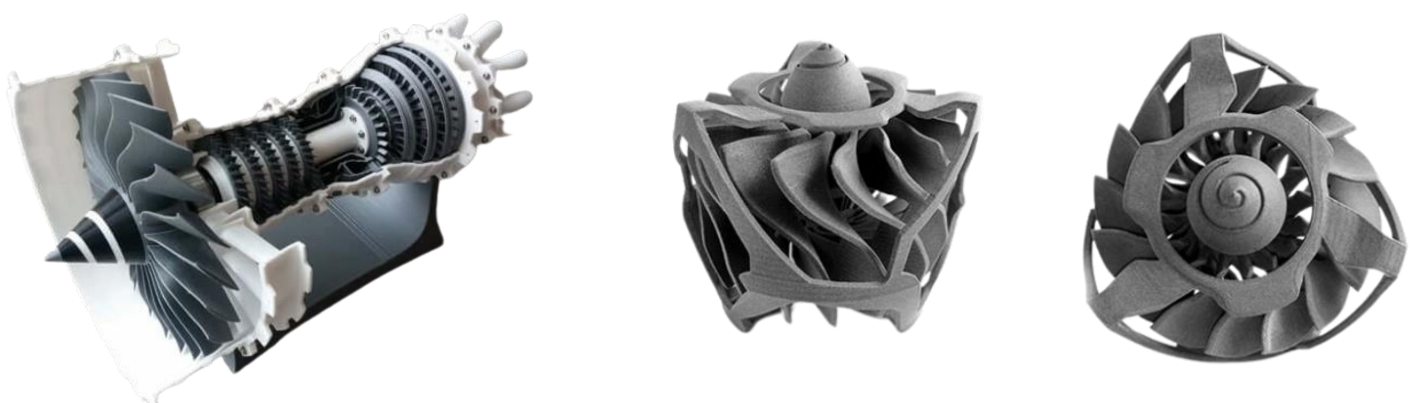
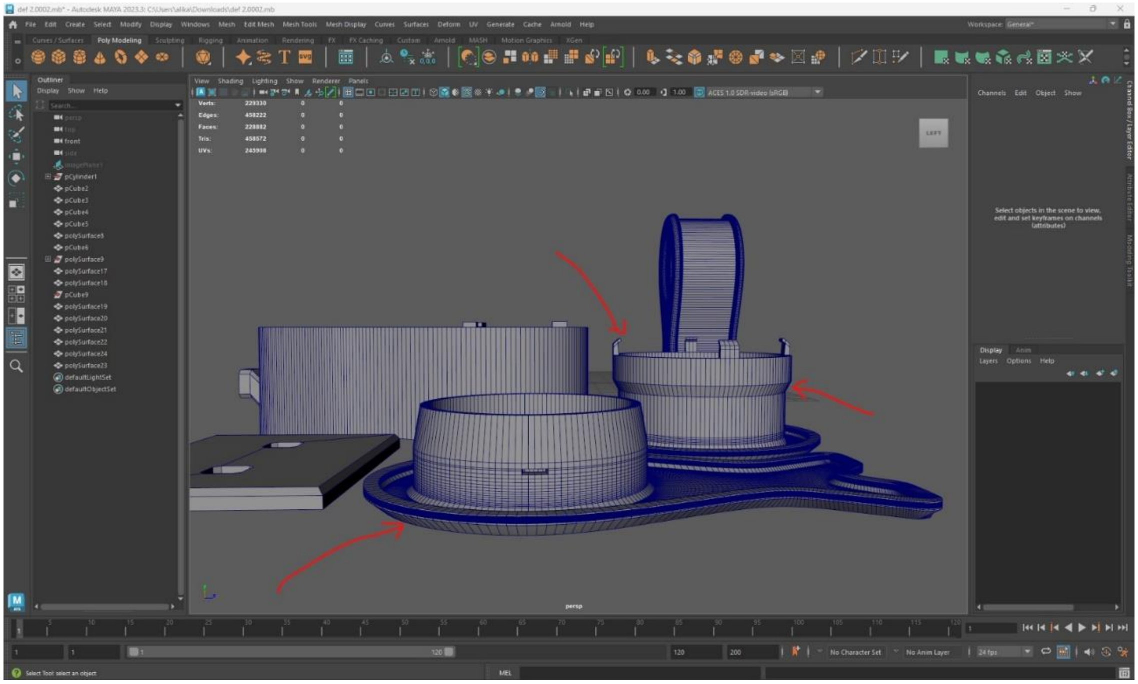


Figure 3.2: Prototype model examples like aerospace machines

Research Methodology

The research method adopts a systematic approach to investigating and optimizing 3D printing methods for prototyping and alternative part production, weaving in real-world applications, considerations of energy dependency, experimentation for optimization, and continuous improvement. The material exploration of PLA from various producers shapes the hardware and material assessment phases, while workflow optimization is navigated through strategies encompassing modeling, slicing, and printing stages. The proposed research model offers an established framework to address challenges, contribute insights, and enhance the understanding and application of 3D printing technology in construction, prototyping, and replacement part manufacturing.



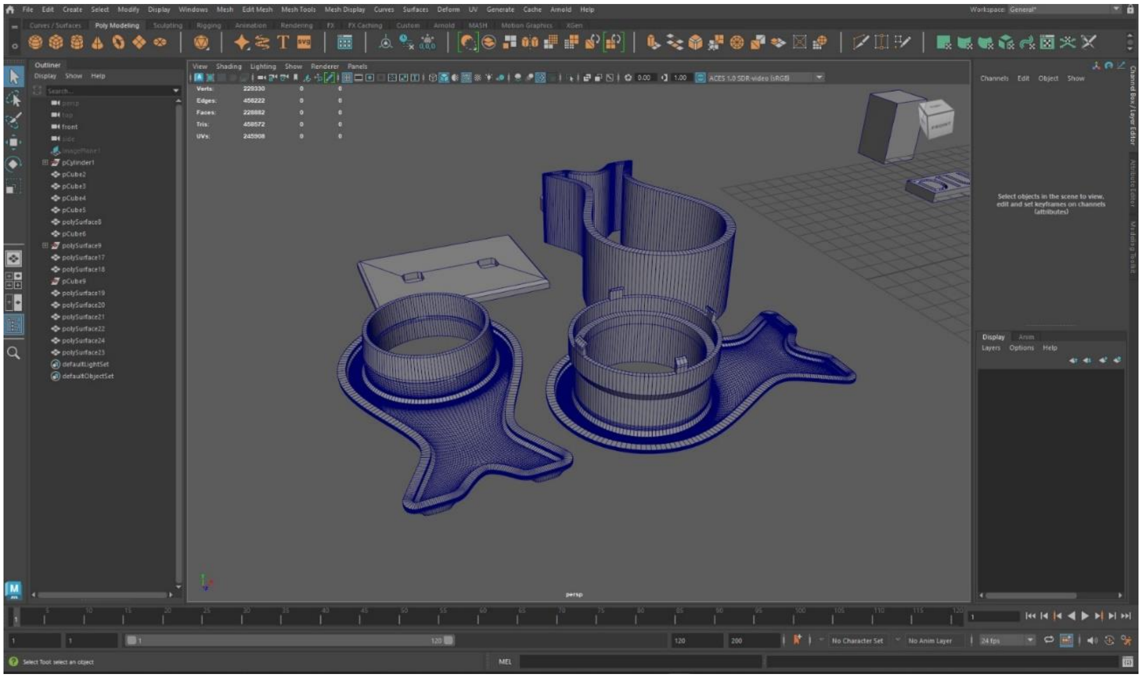


Figure 3.3: Maya modelling interface where we modeled our models for print

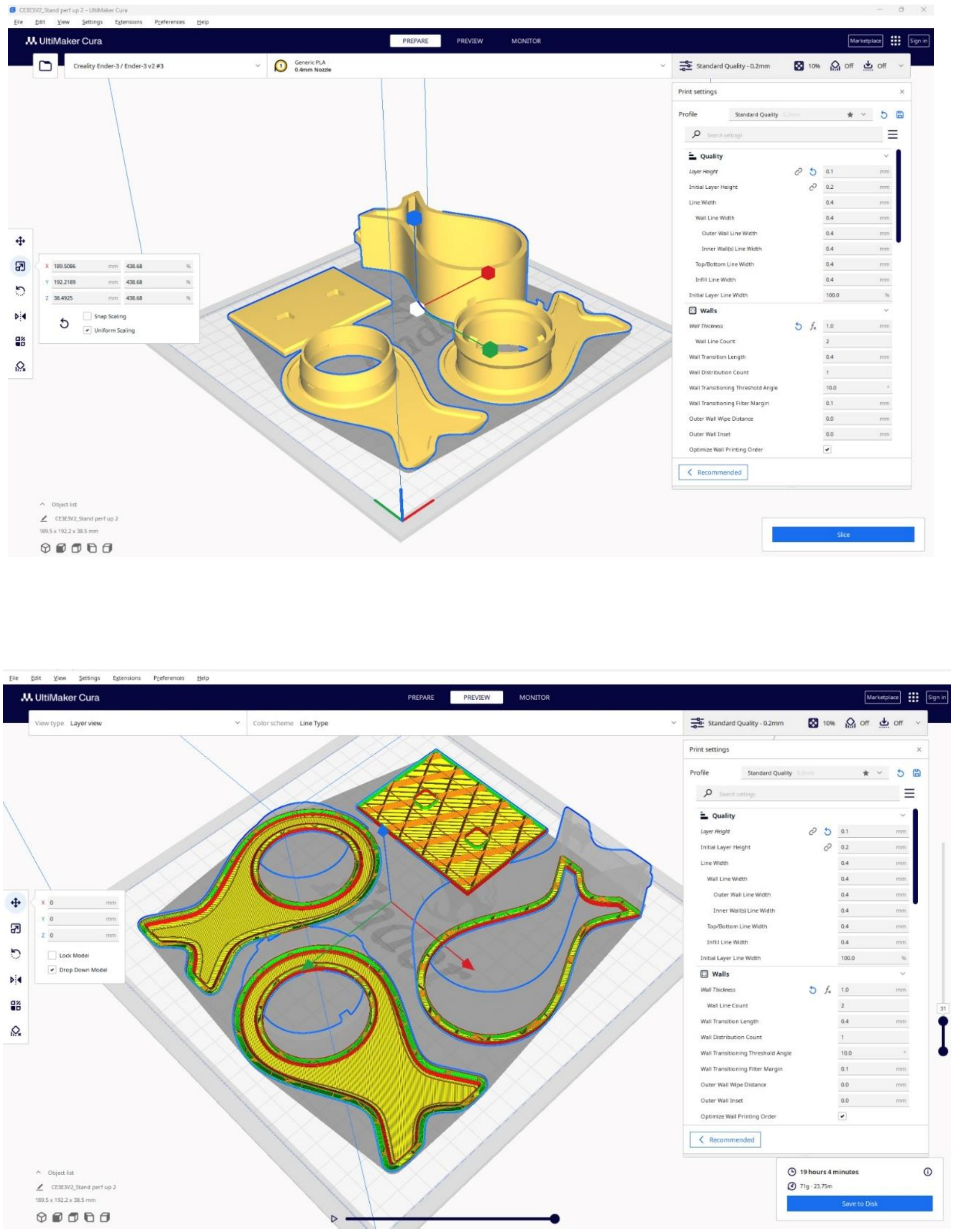


Figure 3.4: Cura slicer interface where we sliced our every model for print

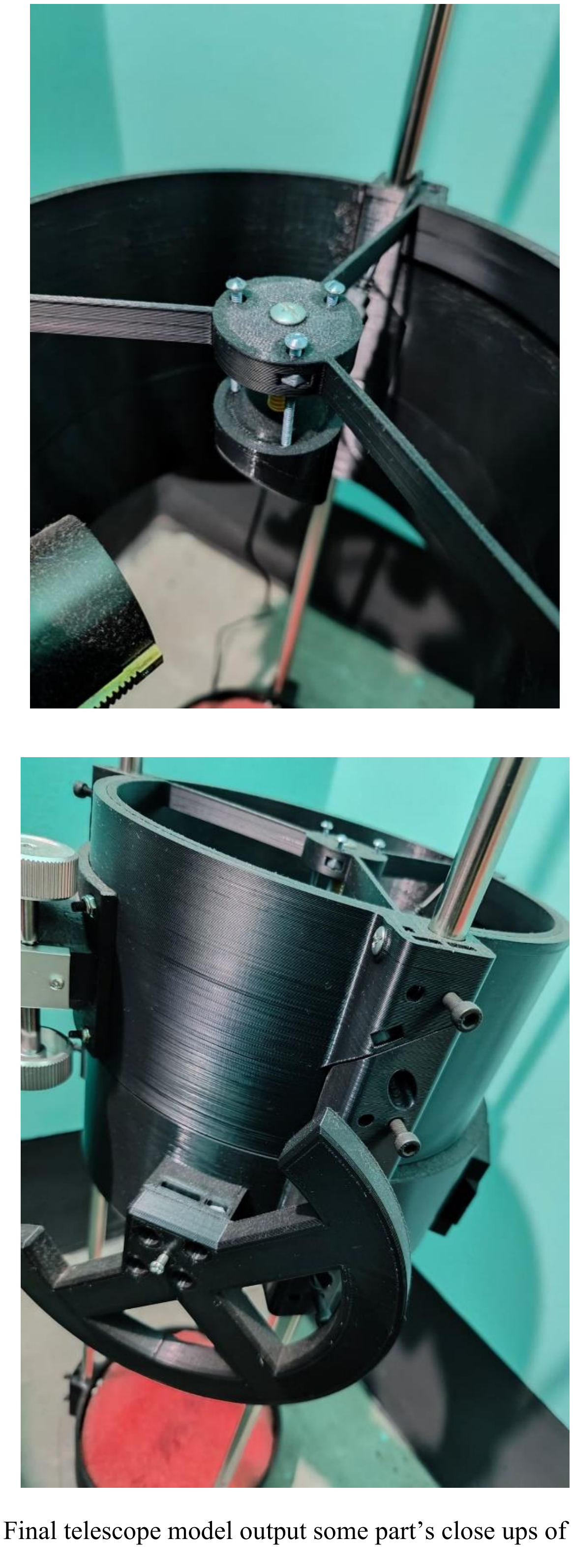


Figure 3.5: Final telescope model output some part’s close ups of the telescope

CHAPTER: 4

EXPERIMENTAL RESULTS AND DISCUSSION

Introduction

The experimentation phase delved into essential sides of 3D printing optimization. Manipulating component angles underneath 90 degree eliminated the need for extra supports, streamlining the printing process. Larger layer heights had been hired for time efficiency, even as expanded wall remember and width more desirable structural integrity. Precision changed into carried out via using smaller nozzle sizes for finer details. Various infill patterns, inclusive of triangle, lightning, and cubic subdivision, were strategically selected to stability electricity and material conservation. Temperature manipulation, adjusting bed and nozzle temperatures, emerged as a key aspect influencing adhesion, detail, and material characteristics. Print speed adjustments have been explored, highlighting the alternate-off among time performance and print best. Nozzle length concerns performed a critical role, with larger nozzles prioritizing pace and smaller ones emphasizing complicated details. The incorporation of locking mechanisms required specific layer heights for top-quality effects. Precision in measurements, facilitated by way of slide calipers, became imperative for tricky model components. Addressing strength issues, the non-stop use of an inverter for the duration of printing become identified as a way to mitigate seam lines and fragility inside the final model. These meticulous experiments shape the idea for nuanced discussions on the interaction of variables within the 3D printing process.

Experimental Methodology

The research methodology encompasses three distinct phases: modeling, slicing, and printing. The slicing process employs Cura Slicer, utilizing the STL file from Meshmixer. Customized printing settings, including layer height, wall count, width, and nozzle size, are adjusted based on the model's purpose. Different infill structures, such as triangle, lightning, and cubic subdivision, are selected to balance strength and material conservation. The finalized GCODE file is exported for the printing phase.

The printing phase involves calibrating the printer's bed level and extruder, addressing nozzle and bed distance issues, and adjusting settings like z-axis offset, bed temperature, nozzle temperature, printing speed, and nozzle size. Considerations for achieving specific outcomes, such as time efficiency or detailed prints, guide temperature and speed adjustments. The inclusion of locking mechanisms order a 0.2 layer height. Precise measurements, facilitated by slide calipers, ensure accurate locking components. To reduce electricity-related problem, continuous printing is maintained through the use of an inverter. This comprehensive methodology forms the basis for the systematic exploration of 3D printing variables and their flexibility.

Figure 4.1: Softwares that we used in our full workflow as like maya, 3ds max, mesh mixer and Cura

Analysis, Results and Findings

The experimental exploration discovered critical insights into optimizing 3-D printing parameters strategically balancing print pace and nozzle length became pivotal, with large nozzles imparting time efficiency but reduced detail, at the same time as smaller sizes ensured advanced detail however demanded more time. The incorporation of locking mechanisms in 0.2 layer height prints showcased meticulous interest to design intricacies. A key locating highlighted the need for precise measurements the use of slide calipers, especially for locking mechanisms.

Headphone Stand

	SPEED	NOZZLE	TEMP(c)	STRUCTURE	SLICE	LOCK
01	50%	0.4	200	CUBIC 20%	WALL Thickness 1.2 LAYER Height 0.4 Wall Count 3	N/A
02	400%	0.4	200	CUBIC 20%	WALL Thickness 1.2 LAYER Height 0.4 Wall Count 3	N/A
03	100%	0.8	200	CUBIC 20%	WALL Thickness 1.2 LAYER Height 0.4 Wall Count 3	N/A
04	100%	0.4	250	CUBIC 20%	WALL Thickness 1.2 LAYER Height 0.4 Wall Count 3	N/A
05	100%	0.4	200	LIGHTINING 20%	WALL Thickness 1 LAYER Height 0.6 Wall Count 2	N/A
06	100%	0.4	200	TRIANGLE 40%	WALL Thickness 2 LAYER Height 0.2 Wall Count 4	N/A
07	100%	0.4	200	CUBIC SUBDIVISION 10%	WALL Thickness 1 LAYER Height 0.3 Wall Count 2	YES

Table 1: Comparison chart for all the experiments

Moreover, addressing strength-related demanding situations via continuous printing using an inverter proved essential in minimizing seam line fragility. This complete analysis presents a roadmap for effective 3-d printing optimization, balancing various parameters to attain preferred consequences.

Figure 4.2: Strength comparison side by side 1st one is fragile and 2nd one is hard

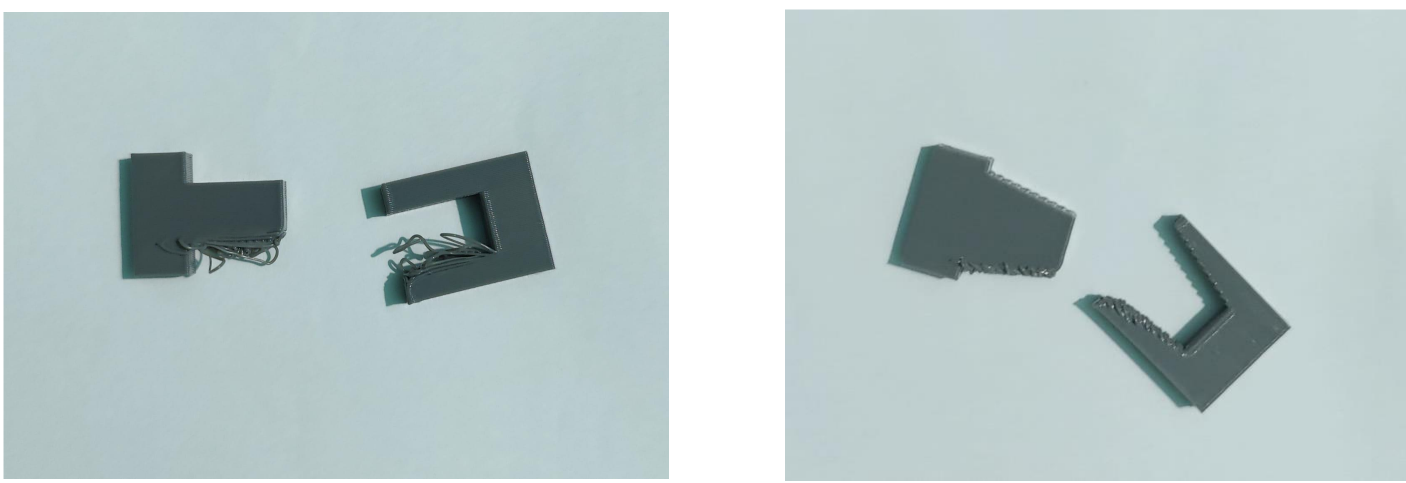


Figure 4.3: 90 Degree angle issue comparison side by side

Figure 4.4: Bevel issue comparison side by side 1st one has stringing and 2nd one is clean

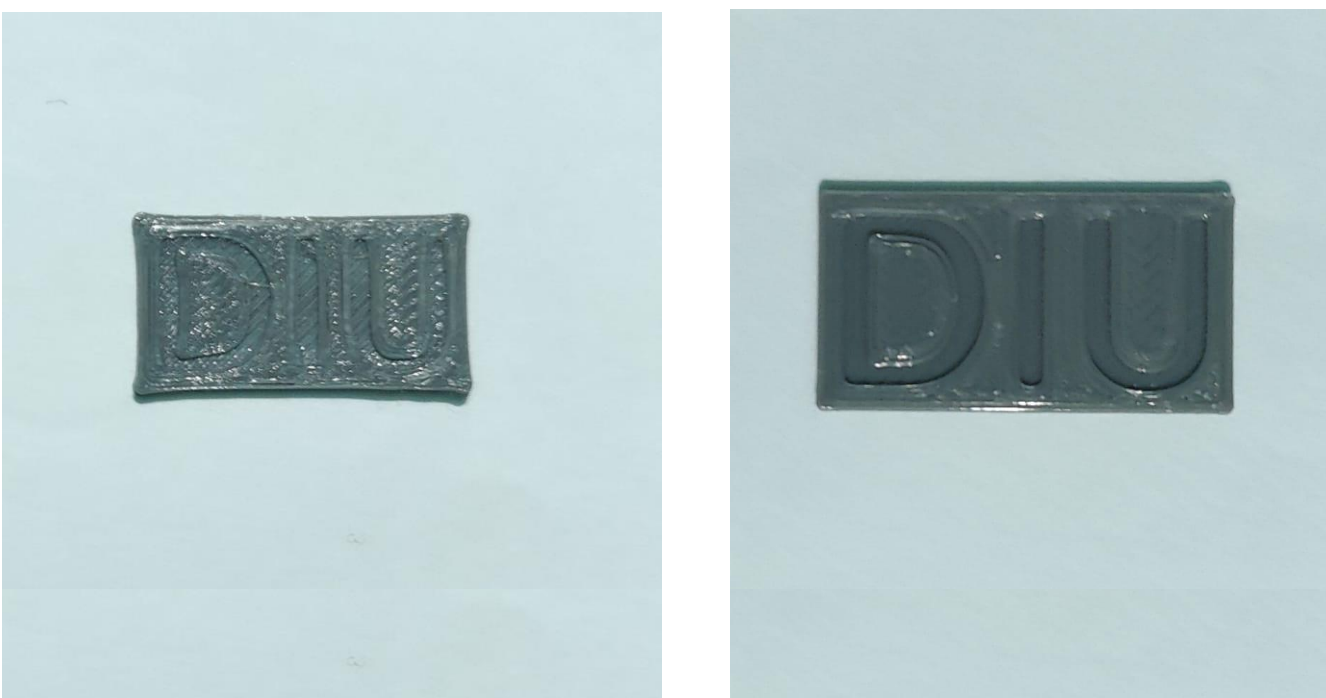


Figure 4.5: Text cliarity issue comparison side by side 1st one is less detailed and 2nd one is clearer

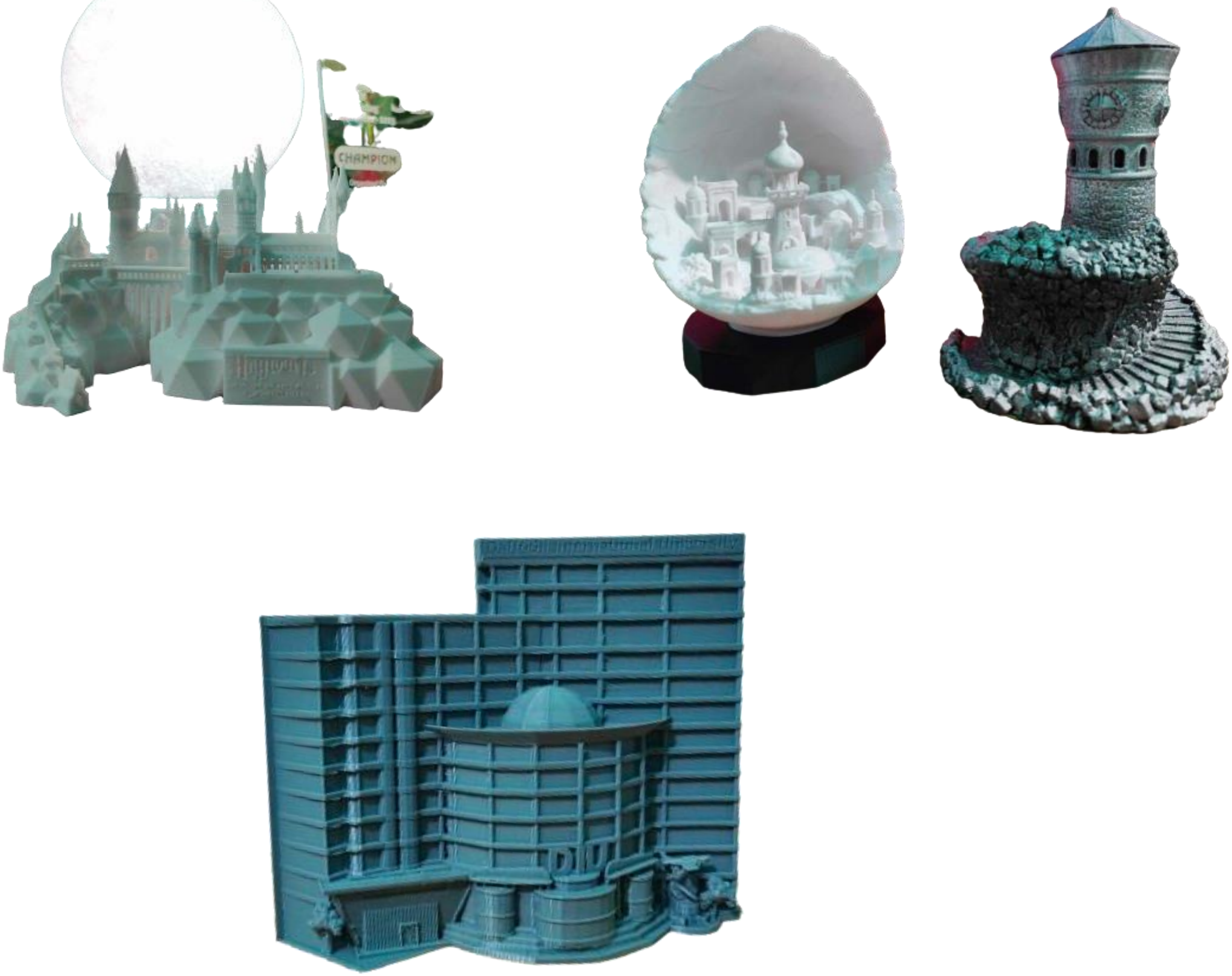


Figure 4.6: Some 3d printed outcomes from our research like showpieces and fridge magnet

Figure 4.7: Some 3d printed outcomes from our research 1st one is telescope and 2nd one is headphone stand

CHAPTER: 5

CONCLUSION, AND FUTURE SCOPE OF WORK

Conclusions

The Conclusions section encapsulates the important thing insights drawn from the experimental consequences and discussions, providing a complete knowledge of the optimization of 3-D printing procedures for prototyping and alternative part production. The effectiveness of software integration, hardware choice, material issues, and workflow optimization techniques is underscored, providing practical implications for practitioners. Real-international programs and challenges, which include power dependency at some stage in printing, in addition contribute to the depth of knowledge. The phase concludes with a forward-searching perspective at the Future Scope of Work, highlighting potential areas for endured exploration and improvement inside the dynamic landscape of 3D printing technology. Overall, the Conclusions phase serves as a fruit of the research, consolidating actionable insights and guiding future endeavors in advancing three-D printing procedures for numerous applications.

Future Scope of Work

The Future Scope of Work envisions a trajectory for ongoing exploration and advancement in the realm of 3D printing optimization for prototyping and substitute component production. Building at the insights gained from the current observe, capacity areas for future research encompass in addition refinement of software integration strategies, exploration of extra hardware options, and the continuous assessment of rising materials for better 3-d printing capabilities. The integration of synthetic intelligence and gadget gaining knowledge of algorithms into the optimization technique provides an intriguing road for growing performance and precision. Additionally, addressing environmental sustainability concerns via the development of eco-friendly materials and examining the ability for 3D printing in novel programs remains a pertinent location for destiny research. The Future Scope of Work aims to foster endured innovation and evolution in 3-d printing technology, pushing the bounds of its practical programs and contributing to the ongoing discourse within the subject.

References

[1] https://3dprinting.com/what-is-3d-printing/, last accessed on 21-06-2023 at 12:00pm.

[2] https://www.cnet.com/tech/computing/best-3d-printer/, last accessed on 09-07-2023 at 08:00pm.

[3] https://all3dp.com/1/3d-printing-prototyping-starter-guide/, last accessed on 10-07-2023 at 11:00am.

[4] https://nexa3d.com/blog/3d-printing-prototypes/, last accessed on 25-08-2023 at 03:00pm.

[5] https://ultimaker.com/learn/rapid-prototyping-how-to-use-3d-printing-for-your-rapid-prototyping-needs/, last accessed on 22-08-2023 at 02:00pm.

[6] https://www.cnet.com/tech/computing/best-3d-printing-filament/, last accessed on 12-08-2023 at 07:00pm.

[7] https://www.matterhackers.com/3d-printer-filament-compare, last accessed on 26-08-2023 at 05:00pm.

[8] https://all3dp.com/1/3d-printer-filament-types-3d-printing-3d-filament/, last accessed on 13-08-2023 at 04:30pm.

[9]https://www.reddit.com/r/BambuLab/comments/11fovyb/need_good_filament_brands/ , last accessed on 06-07-2023 at 09:00pm.

[10] https://www.sciencedirect.com/science/article/pii/S2351978919308169, last accessed on 02-07-2023 at 05:30pm.

[11] https://www.mdpi.com/2073-4360/15/11/2519, last accessed on 14-06-2023 at 03:30pm.

[12] https://www.sciencedirect.com/science/article/pii/S2666412721000441, last accessed on 16-08-2023 at 10:30pm.

[13]https://www.researchgate.net/publication/350374850_A_Review_paper_on_3D-Printing_Aspects_and_Various_Processes_Used_in_the_3D-Printing, last accessed on 14-07-2023 at 12:30pm.

[14] https://www.matterhackers.com/3d-printer-filament-compare, last accessed on 26-08-2023 at 05:00pm.

[15] https://www.mdpi.com/2073-4360/15/11/2519 , last accessed on 14-06-2023 at 03:30pm.

[16] https://ultimaker.com/learn/rapid-prototyping-how-to-use-3d-printing-for-your-rapid-prototyping-needs/ , last accessed on 22-08-2023 at 02:00pm.

[17] https://hbr.org/2015/05/the-3-d-printing-revolution, last accessed on 06-07-2023 at 09:00pm.

[18]https://www.nytimes.com/2022/07/03/business/3d-printing-vulcanforms.html, last accessed on 06-07-2023 at 09:03pm.

[19] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10255598/, last accessed on 06-07-2023 at 09:08pm.

[20] https://www.xometry.com/resources/3d-printing/3d-printing-guide/, last accessed on 06-07-2023 at 09:20pm.