DESIGN AND PRODUCTION OF A CHARGE COUPLE DEVICE (CCD) CAMERA HOLDER FOR A TRAVERSE SYSTEM USING ADDITIVE MANUFACTURING METHOD

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (AUTOMOTIVE TECHNOLOGY) WITH HONOURS

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Faculty of Mechanical and Manufacturing Engineering Technology

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**A thesis submitted
in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this thesis entitled “Design, Production Of A Charge Couple Device (CCD) Camera Holder For A Traverse System Using Additive Manufacturing Method” is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Muhammad Syamil Bin Che Sukri

Date : 27-1-2022

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours.

Signature	:	
Supervisor Name	:	Puan Fadhilah Binti Shikh Anuar
Date	:	27-1-2022

DEDICATION

To my beloved parents,

Che Sukri Bin Che Leh and Noraini Binti Nordin

Thank you for all the support, encouragement, enthusiasm, patient and willingness.

To my honoured supervisor,

Puan Fadhilah Binti Shikh Anuar and all UTeM lecturers and staffs.

To my dearest friends

Thank you for always giving me a guidance and persistent help to complete this project thesis.

ABSTRACT

A Charge Couple Device (CCD) camera is the most often utilised application in particle image velocimetry (PIV) systems since it is used for measuring. Errors are caused by both computational and environmental causes. Without a suitable camera holder, the camera can easily be tilted, resulting in incorrect flow speeds. When using a camera tripod manually, it's difficult to calibrate the camera position accurately and precisely. As a result, using the manufacturing additives approach to prototype the camera holder is necessary to ensure that the CCD camera can be held appropriately. Additionally, Auto Cad software was utilised to create the design for the camera holder. It is an excellent approach to locate the correct design concept to use the pugh technique as a procedure to perform the design selection process. As a result, the camera holder is expected to be able to firmly hold the camera while also being placed on an aluminium profile to allow for camera movement. Finally, the camera holder's specifications must match the true dimensions of the 76mm (W) x 76mm (H) x 54.6mm (L) ccd camera in order to hold it properly.

ABSTRAK

Kamera Charge Couple Device (CCD) adalah aplikasi yang paling sering digunakan dalam sistem velocimetry image particle (PIV) kerana digunakan untuk mengukur. Kesalahan disebabkan oleh sebab komputasi dan persekitaran. Tanpa pemegang kamera yang sesuai, kamera dapat dimiringkan dengan mudah, menghasilkan kelajuan aliran yang salah. Apabila menggunakan tripod kamera secara manual, sukar untuk menentukur kedudukan kamera dengan tepat dan tepat. Akibatnya, dengan menggunakan pendekatan aditif pembuatan untuk membuat prototaip pemegang kamera diperlukan untuk memastikan pemegang camera yang betul dihasilkan. Selain itu, perisian Auto Cad digunakan untuk membuat reka bentuk pemegang kamera. Ini adalah kaedah terbaik untuk mencari konsep reka bentuk yang betul dengan menggunakan teknik pugh sebagai prosedur untuk melakukan proses pemilihan reka bentuk. Hasilnya, pemegang kamera diharapkan dapat memegang kamera dengan kuat sementara juga diletakkan pada profil aluminium untuk memungkinkan pergerakan kamera. Akhirnya, spesifikasi pemegang kamera mesti sepadan dengan dimensi sebenar kamera 76mm (W) x 76mm (H) x 54.6mm (L) ccd agar dapat menahannya dengan betul.

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In the Name of Allah, the Most Merciful,

The Most Gracious First and first, I would want to express my gratitude and appreciation to Allah the Almighty, my Creator and Sustainer, for all I have received from the beginning of my existence. I would like to express my gratitude to Universiti Teknikal Malaysia Melaka (UTeM) for facilitating this research.

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LIST OF SYMBOLS AND ABBREVIATIONS

2D	-	2-Dimension
3D	-	3-Dimension
AM	-	Additive Manufacturing
CAD	-	Computer-Aided-Design
CCD	-	Charge Couple Device
PA66	-	Polyamide 66
mm	-	Length
PIV	-	Particle Image Velocity
m/s	-	Velocity
CTE	-	Charge Transfer Efficiency
QE	-	Quantum Efficiency
CCE	-	Charge Accumulation Efficiency
Hz	-	Frequency
SLA	-	Stereolithography
SLS	-	Selective Laser Sintering
FDM	-	Fused Deposition Modelling
ASTM	-	American Society for Testing and Materials
NPD	-	New Product Development
RP	-	Rapid Prototyping
SFF	-	Solid free Form Fabrication
LM	-	Layered fabrication
DCM	-	Digitalizing the Construction Monitoring

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

This chapter describes the objective of the research project, the importance of this study and its problems, including the limitation of this research project. It also describes the subject matter, goal, and criteria for the analysis, which serves as an introduction to the project.

1.2 Project Overview

In the present age of IR 4.0, the fact that a digital camera is incorporated into a smartphone makes it easy to use a digital camera or to capture moments more easily. Cameras, on the other hand, are available in a range of configurations, depending on their intended function, including DSLR cameras, mirrorless cameras, small digital cameras, and action cameras. When it comes to modern optical microscopes, one of the most important components to consider is the Coupled Charging Device (CCD), which is often integrated into the camera and is used to increase the brightness of each probe light source while also forcing them to move in synchronization with one another. Electronically scanned film images are converted into visual images using charge coupled devices (CCD) sensors, light and laser densitometers, and flat scanners. These technologies allow the conversion of qualitative film images into visual images based on the optical density of the film. (Jurik, 2007).

The Particle image velocimetry (PIV) system is one of the applications that makes use of the CCD camera technology. Particle image velocimetry (PIV) is a non-intrusive, quantitative, and qualitative optical measurement device that is based on lasers. Flow visualization and measurement are accomplished via the use of the instantaneous velocity field, the average flow field, and the average flow visualization(Hu *et al.*, 2001). A new kind of camera holder will be developed as part of this project, which will be more convenient and simpler to use in conjunction with a PIV system, in order to achieve this goal.

It was with the help of this design, which was made using the most current manufacturing technologies, including CATIA V5R21 and Ansys Workbench software, that a new ergonomic camera holder was developed and manufactured using 3D printing. Also included is the use of a lightweight FS3200PA Nylon powder material and the use of an Additive Technology known as Selective Laser Sintering to create the product itself (SLS).

1.3 Problem Statement

Having the CCD camera in the incorrect position may result in many problems, including the amount of mistakes produced by computation and environmental conditions, among others (Stolzenburg *et al.*, 2011). In the lack of an appropriate camera holder, it is possible that the flow velocity measurement will be inaccurate as a consequence of the camera tilting easily. It is more difficult to calibrate the camera position, laser shot, and picture alignment when using a camera tripod that is operated manually. The calibration of the PIV system will take substantially longer and will need the participation of at least two individuals.

An automated traverse system may be utilized instead of a tripod as a consequence of this development. A proper CCD camera holder, on the other hand, will be necessary in order to guarantee that the camera holder is suitably supported and moveable on the traverse system. Unfortunately, there is no particular holder for a CCD camera available on the market (Model no: 630090). Additionally, a camera holder that was designed to fit a certain aluminum profile with dimensions of 40 mm x 40 mm was examined for use with an in-house built traverse system. Therefore, various important design elements of the holder must be taken into consideration in order to support both the camera size and the aluminum profile at the same time.

1.4 Research Objective

The aim of the research is to ensure that the camera holder can tightly hold the camera and place it on the aluminum profile. Specifically, the objective is:

a) To design a camera holder to match a Couple Charge Device (CCD) camera of a Particle Image Velocity (PIV) system.

b) To analyze the camera holder design using finite element analysis (FEA) and produce a prototype using AM method.

1.5 Scope of Research

In particular, the focus of this study is the design of a camera holder utilizing additive printing techniques, as well as the testing of a certain aluminum profile size that will be utilized in combination with the camera holder. The camera holder is being developed particularly for a CCD camera with dimensions of 76mm(W)x76mm(H)x56.4mm(L), made by the TSI company. The camera holder should allow for at least one direction of movement on the aluminum profile, either forward or backward.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

To guarantee that a project works successfully, various elements should be fully analyzed and examined before to start. The project will be changed in view of the collected data in order to continue working effectively and achieving the project's objective. To get the best outcome feasible, researchers evaluated all data or information acquired from a variety of sources during the course of their study. This is done to confirm that the CCD camera holder meets with all standard specifications and operates as designed.

2.2 Type of Camera Holder

When photographing or filming, it is critical to keep the camera steady. It also has a more realistic movement thanks to the compact camera. While the camera is naturally stable, it is possible that further stabilization is necessary. A mobile phone camera that is not equipped with an ultrasonic lens must be used with image stabilization. An absence of this characteristic may cause the picture to seem unsteady. On the market are tripods for cameras such as the Kirk Low-Profile Tripod and Handle Pod, as well as the Magnus Bendable Tabletops with Smartphone Mount and the Table Top Tripod (Todd Vorenkamp, 2015).

Figure 2.1 Shows Kirk Low Pod Camera holder

It acts as a support for the camera and allows it to snap pictures from low angles or in close proximity to the subject. There is just one-color option: black. Using a carrier handle that has been included into the frame, the camera support may be lifted up and moved about the room. Aside from that, the mount's four rubber feet keep it from rolling around over rocks and other rough terrain. - Because of the powder coating applied to the metal frame, it will last for years.

Figure 2.2 Shows HandlePod Camera holder

Handle Pod Camera Holder is a one-of-a-kind, easy-to-use support for point-and-shoot cameras and ultra-compact camcorders. The foldable portable mount is secured to any camera using a 1/4"-20 screw, which is industry standard. The strong grooved handle of the Handle Pod adds extra stability while shooting handheld video in portrait or landscape orientation. When the Handle Pod is folded down, it transforms into a quadpod for use on a table, and its four rubber feet provide stable video and still capture from any flat surface when used in conjunction with a tripod.

Figure 2.3 Shows Table Top Tripod

The Table Top Tripod is ideal for photographing from a table top or other high surface. Alternatively, you may set the TT-100 on the ground or floor to get more stable low-angle images. The TT-100 is constructed entirely of aluminum for robustness and lightweight, making it an ideal tool for macro or product photography. The overall load capacity of the system is 6 lb. The tripod has a little ball head that connects to the 1/4"-20 screw on the tripod and fits almost any camera. The ball may be loosened with a single lever, enabling the camera to tilt or pan. The ball pivots and pans 360 degrees, and a groove on one side allows for a 90-degree tilt in one direction.

Figure 2.4 Shows Bendable Tabletop Tripod with Smartphone Mount

These straps may be looped around a fence, a tree limb, a chair leg, or anything else that is both sturdy and compact enough to keep the tripod's legs in place. In addition, the smartphone mount is compatible with the vast majority of protective covers on the market. As a result, you'll always have it with you. It only weights approximately 6 oz, so you can carry it with you everywhere you go. A fence, tree limb, or chair leg that is sturdy enough to support the weight of a small camera yet small enough to wrap the legs around is what you need for this gadget. A tiny camera may be held in place by its legs, which can be bent around any object that is powerful enough to hold the camera yet small enough to fit around the legs.

In addition, it includes a flat head that can accommodate a point and shoot camera or a tiny video camera weighing up to two pounds. When utilized in this manner, the flexible legs are coated in foam, and the rubber feet help to keep them steady on a flat surface. Here, the ball head is mounted to the camera using a conventional 1/4" thread "-20 screw to keep the camera stable. It is equipped with a rapid release mechanism.

2.2.1 Passive Holder

A passive camera holder is constructed from a series of bars that are connected through joints. Its base may be connected to the operating table rail, and its tip has a clip for securing an endoscope or other piece of medical equipment. The surgeon may reposition the holder by grasping it in his or her hands and moving it to the appropriate area. The holder is kept from moving once it is released by friction in the joints or a brake mechanism, which guarantees that the endoscope stays in the proper position after it is released.

2.2.2 Active Holder

In the world of camera holders, an active camera holder is one that is motorized and equipped with electric motor-driven joints. These electromechanical arms may be controlled through a variety of various user interfaces. They may be moved using a hand controller or by holding and manipulating them in the same manner that a passive camera holder is moved. In each of these scenarios, one hand is necessary to manipulate the endoscope, and the surgeon must release a tool to move it. Avoiding instrument release is accomplished by employing a hand controller installed on the instrument, a foot controller, voice control, or by directing the robot with the surgeon's head motions. Instrument tracking, in which the robot maintains the dissecting instrument's tip in the center of the display automatically, is another method of avoiding release.

The active grips are constructed and interfaced differently, enabling the surgeon to individually adjust positioning and positioning precision. Due to the fact that the active camera holders are powered by electric motors, they are not totally autoclavable. They, with the exception of the autoclavable scope, should consequently be draped in sterile curtains (Jaspers *et al.*, 2004).

2.2.3 Benefits

In terms of holding the camera, assistants are frequently instructed to use their other hand to inhale or withdraw the camera lens, depending on the situation. The option of having two assistants is accessible; however, due to a shortage of available workers, this is not always practicable.

The camera holder has been created to aid in the preservation of the camera's structural integrity and stability. It is not difficult to move around with this gadget, which is not heavy and allows for several points of view to be observed. There have been instances in the past where robotic camera holders have been employed, but they are both expensive and time-consuming to implement.

2.3 Charge-Coupled Device (CCD) camera

Digital camera systems use a variety of charge-coupled device (CCD) detector types to acquire images in contemporary optical microscopy. Until recently, the majority of images seen under a microscope were taken using specialized ordinary film cameras. This old technology, which is based on the photon sensitivity of silver-based photographic film, involves the temporary retention of a latent image in the exposed film in the form of photochemical reaction sites that become visible in the film emulsion layers after chemical processing (development).

Digital cameras do away with the need for a sensitized film in favor of a CCD photon detector, a thin silicon wafer divided into thousands or millions of light-sensitive regions that capture and store image data in the form of localized electrical charge that varies in response to incident light intensity. The changing electrical signal associated with each picture element (pixel) of the detector is rapidly read out as an intensity value for the corresponding image point, and the image may be reconstructed and shown on a computer monitor almost quickly following digitization of the data.(System, 2015).

2.3.1 Characteristics

CCD were a sort of image intensification device capable of detecting very low light output across a broad range and distinguishing objects from starlight [6]. Due to the CCD cameras' high resolution, sensitivity, and fast sample rates, they are capable of capturing scene characteristics in real time.(Thorn *et al.*, no date). An image intensification device that could detect very low light emission over a broad range and distinguish objects from starlight was known as a CCD [6].

They are able to collect scene information in real time because of the CCD cameras' high resolution, high sensitivity, and fast sample rates (Camera, 1987). An extremely tiny

CMOS color CCD camera system has been constructed, incorporating a CCD image sensor. A camera system that used the CCD image sensor can be seen in Figure 2.5.

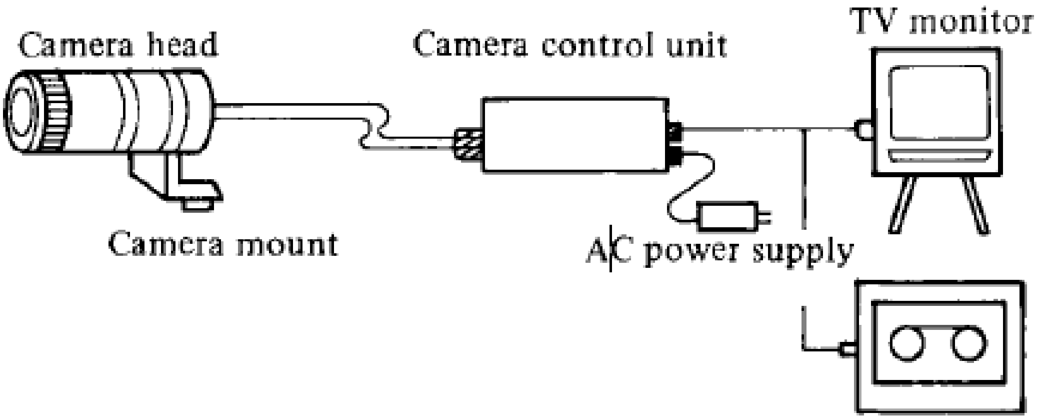


Figure 2.5 A video colour system (Camera, 1987)

2.3.2 Type of CCD camera

In general, there are two kinds of CCD sensors available on the market: area CCD sensors and linear CCD sensors. Area CCD sensors are more frequent than linear CCD sensors, and therefore have a higher sensitivity. Each of the optical sensors on the CCD Linear Sensor is oriented in a single straight line for the purpose of this particular sensor. The optical sensors that are included inside the CCD are referred to by a number of distinct designations. Various terminology, including as cells, photo sites, image elements, and photo elements, are used to characterize these sensors.

When converting an electrical signal into a digital signal, it is common to employ a light strike signal (also known as an analogue signal). For example, the essential function of the CCD sensor, which is the conversion of an optical analogue signal into an electrical signal, may be compared to the operation of collecting rainwater in a bucket (see Figure 1). As an example, a photon falling on the surface of a charge coupled device may be used to mimic a droplet of rain (CCD). Each cell will be represented by a bucket, which will be used to collect any rainfall that occurs on it.

Depending on how much light is received, the cell fills to a specified level and then stops filling. It takes a succession of processes until the energy that has been stored in the cell is locked and timed out. The bucket or cell will either empty the water out or transfer the photons to the next bucket or cell when it is entirely filled with water (or, in real life, when the cell is totally charged with photons). After then, the process will repeat itself until it reaches the last cell in the chain. The output signal from this last cell will be delivered to the computer, where it will be processed further.

2.3.3 Design and Production of CCD camera holder prototypes application of 3D printing

Figure 2.6 Shows a drawing of camera mount as designed (Davis and Wheeler, 2020).

Figure 2-6 depicts a conceptual diagram of the camera holder as it was originally intended. An attachment hole for a ring stand is located on the right side of the mount. A rectangular slot on the left side of the mount is used to secure a camera with screws. The printer utilized a fused deposition modelling (FDM) technology and filament composed of polylactic acid for the printing process (PLA). When it came to printing these mounts, a variety of polymers might have been used, but PLA was the most suitable because to its strength and ease of printing, as well as its affordability and biodegradability as waste.

The temperature of the nozzle was maintained at 215 degrees Celsius, while the temperature of the heated print bed (glass) was maintained at 60 degrees Celsius. Prints were created at 20 percent infill (triangular) at a print speed of 90 mm/s, with 1 mm outer walls and 1 mm top and bottom layers at a print speed of 90 mm/s. Each mount took around 3 hours to print and 55 g of plastic, with no visible warping in the final product.

Figure 2.7 Shows the design of smartphone holder(Dewi *et al.*, 2020)

The three-dimensional printing (3D printing) production method for camera holders is divided into four steps. Printing is a part of the design process, which also involves digital simulation, the shift from computer-aided design (CAD) to computer-aided manufacturing (CAM), and the transfer from CAD to CAM. When considering the design process through to the production printing stage, it is clear to see that the quality of the 3D printer output is dependent on the material being used and the 3D printer being utilized for the production printing.

It is necessary to use the digital simulation approach in order to reduce the possibility of mistakes in the printed output. In order to develop three-dimensional drawings, CAD software is used; in addition, CAM software is required in order to interact with the machine. It is necessary to support the geometry of the 3D model in order for it to maintain its integrity while it is heated up. A limit to the possibilities of 3D printing has been established. A limitation on the amount of items that may be made using 3D printing, on the other hand, has been placed on the technology (Dewi *et al.*, 2020).

2.3.4 Size and Dimension

The TSI CCD camera series is used for the Challenging application for Particle Image Velocimetry (PIV), and it comes in a different variety of sizes and dimensions. The TSI company provides five different versions of CCD cameras, each with its own set of features and functions. CCD cameras Model 630090 4MP-LS, Model 630091 4MP-HS, Model 630092 8MP, Model 630093, and Model 630094 29MP 16MP are among them. Although all CCD camera designs are similar, there are differences in width, height, and length. Figure 2.2 displays the design of the CCD camera from TSI company. The camera dimensions for this model are 76mm (W) x 76mm (H) x 54.6mm (L).

Figure 2.8 CCD camera model 630090 (Velocimetry, Laser and Fluorescence, no date)

2.3.5 PIV system

Researchers in the field of fluid flow have taken use of recent advancements in PIV methods to expand their investigations during the past decade. It is critical to verify that the camera is in excellent working order and is not moving while employing the PIV technique in order to generate high picture quality when employing the technique (Baik *et al.*, 2009). Because of the excellent resolution that can be reached with CCD cameras, they have been utilized to collect PIV pictures for a long time in this application (Lai *et al.*, 1998). The PIV system in Figure 2.9 has been used in fluid dynamic studies to calculate velocity distributions in planar cross sections of fluid flow. Besides the CCD camera, the PIV system also consists of a Dual Pulsed Laser (Nd-YAG) light sheet optics, and a synchronizer, as seen in Figure 2.9

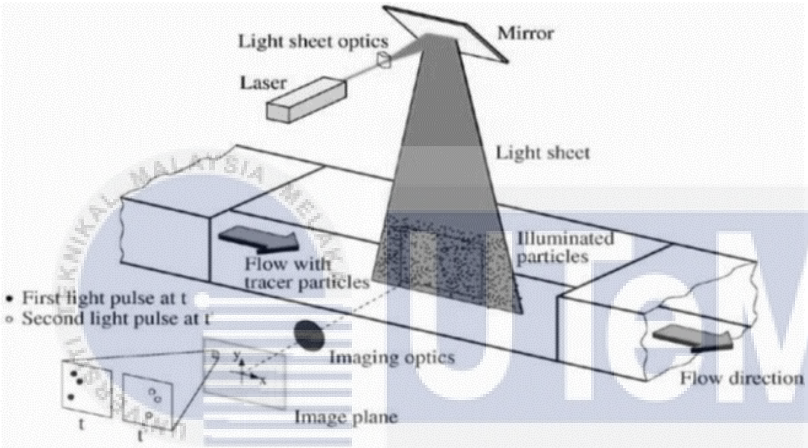


Figure 2.9 Particle Image Velocimetry system(Boopathi *et al.*, 2015)

When tracer particles in the flow are lighted, the CCD camera is utilized to catch the illuminating light. This allows the movement of the tracer particles, which represents the flow velocity, to be caught on pictures. The flow velocity may be estimated using the Stokes equation by knowing the distance between particle movements and the time necessary to go that distance.

The velocity v(x) =1/Vt(x) is the fluid pressure, and p(x) is the distance between the particle motions. In order to calculate the velocity vector of this area in the flow field, use the following formula: The speed of light is defined as V = 4 k(s/t) (Kini *et al.*, 2001)(Puyguiraud, Gouze and Dentz, 2019). Particle image velocimetry (PIV) was the first approach to give high-resolution velocity measurements with conventional camera spatial resolutions, and it is still the most frequently used technique today. Furthermore, when it comes to providing precise PIV findings, determining whether a high-speed system is capable of doing so becomes increasingly important. The fact that high-speed PIV is utilized in a variety of flow domains, spanning from biomechanics to machine mechanics, demonstrates the significance of this technique. As a result, the extensive application of high-technology in the production of digitalization circuits has resulted in the widespread usage of CMOS sensors on CCD cameras today. (Lima *et al.*, 2008; Falchi and Romano, 2009; Khatibi, Time and Rabenjafimanantsoa, 2016).

2.3.6 Features and functions CCD camera used for PIV system

Noise, charge transfer efficiency, quantum efficiency, and charge accumulation efficiency are the most critical CCD characteristics [16]. Each model is equipped with the same sensor, a progressive CCD Interline Scan with Micro lens. CCD cameras are available in a wide range of setups [10].

For instance, the 630090 4MP-LS, the first TSI model, offered a high frame rate that enabled it to take PIV images at a fast pace while preserving the same pixel quality (2360 x 946, 2.2 MP). The frame rate is increased to 30 frames per second from 24. It has a high energy lot of 15 Hz and can monitor PIV flow at a rate of 32 frames per second.

2.4 The use of Finite Element Method in product development

It is commonly referred to as the Finite Element Method (FEM), and it is a software programmed that was developed to evaluate a design as a confirmation before proceeding to produce the design. This is accomplished through the use of numerical methods for addressing engineering and mathematical physical problems. When analyzing a design prototype, this application was also created with the purpose of giving the user with real-world experiences regarding the current state of the design prototype, which was the goal of the original design.

A prototype may be predicted by using this programmed since it will calculate the possibility based on the force that is given to it, as well as the type of material that is used, the form of the design, and all other factors that are taken into consideration throughout the prototype design process. When applying the finite element approach to a specific circumstance, FEA may distinguish between structural difficulties and non-structural problems.

For the structural problem, the outcomes will include stress analysis, buckling analysis, vibrational analysis, and impact analysis; for the non-structural problem, the outcomes will include heat transfer, fluid mechanics, and electric or magnetic potential. Because this project will only be concerned with the structural concerns that occur while analysing the CCD camera holder with Ansys' finite element approach, it will be limited in scope (‘Introduction to Finite Element Methods’, no date; ‘Introduction to Finite Element Analysis (FEA) or Finite Element Method (FEM) Finite Element Analysis (FEA) or Finite Element Method (FEM)’, no date).

2.4.1 Applications in Engineering

With the help of the FEM, it is possible to solve mathematical models for a wide range of engineering problems, including stress analysis of truss and frame structures and complex machineries, as well as dynamic reactions of automobiles, trains, and aircraft that are subjected to a variety of mechanical, thermal, and electromagnetic loads. Finite element applications can be found in a wide range of industries, including automotive, aerospace, and military, consumer goods and industrial equipment, as well as energy, transportation, and construction, as shown in Figure 2.10. Finite element applications are also found in a wide range of industries, including automotive. Materials science, biomedical engineering, geophysics, and a number of other new domains have been added to the list of FEA applications in recent years(کریستینا، رود. 1375, کوکورس).

Figure 2.10 Objects built with small pieces and lego(1375, کوکورس. رود ،کریستینا)

2.4.2 ANSYS Workbench software

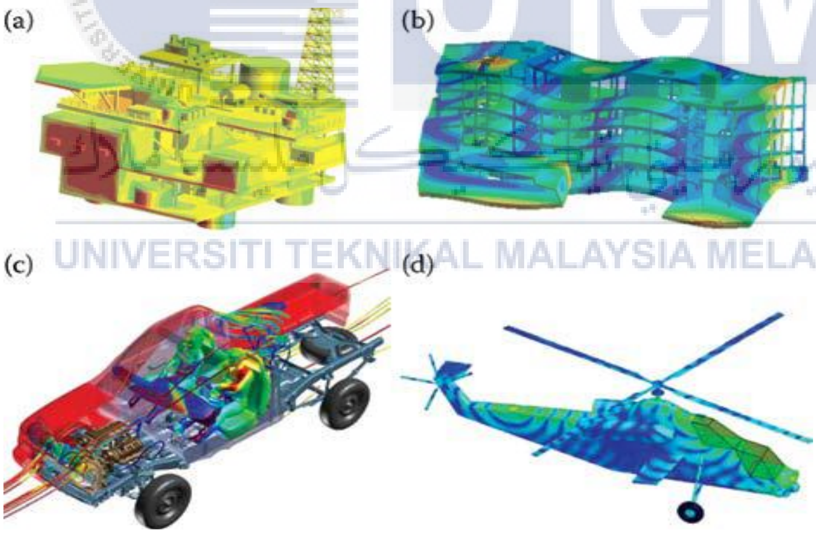


Figure 2.11 Examples of finite element analysis (FEA) using ANSYS Workbench(1375, کوکورس. رود ،کریستینا)

There have been several commercial programmed available for conducting the FEA during the course of the last few decades. ANSYS® Workbench is a user-friendly platform that seamlessly combines the advanced engineering simulation technologies offered by ANSYS, Inc.'s range of products. It communicates with all major CAD systems in both directions. The Workbench environment is intended to boost the efficiency of the engineering team while also making it easier to use. A growing number of firms have adopted it as a vital tool for product development, and it has found uses in a diverse range of technical sectors (Figure 2.11).

2.4.3 The fundamental step in doing FEA in Ansys

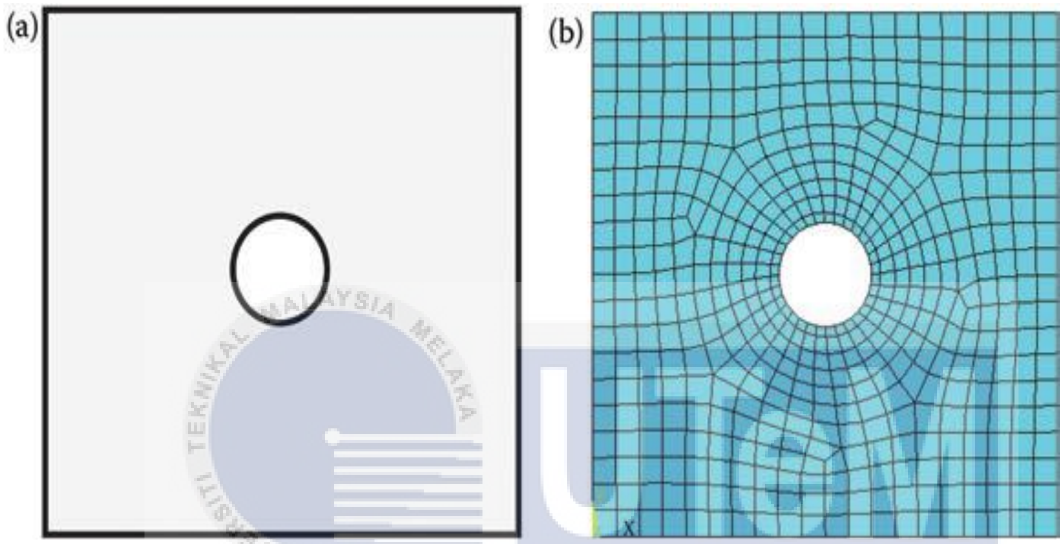


Figure 2.12 (a) A CAD plate with a hole; (b) A FEM discretization (mesh).

The first step is to learn the fundamentals of conducting a FEA. Disassemble and patch together the CAD/geometric model in order to create a "mesh" (a collection of components connected by nodes) as shown in Figure 2.12. Write a thorough explanation of the operation of the physical quantities on each constituent in the system. The components at the nodes are connected (assembled) in order to construct an approximation system of equations for the whole model by linking (assembling) the elements at the nodes. It is necessary to apply loads and boundary conditions (e.g., to prevent the model from moving). Attempt to discover a solution to a system of equations that contains unknown quantities at each of the nodes of the system (e.g., the displacements). Calculations must be performed at elements or nodes in order to get the required numbers (e.g., strains and stresses). When working with commercial finite element analysis tools, this method is often broken down into the following parts. Preparation of the materials (creation of FEM models, definition of element attributes, application of loads and restrictions, etc.) Formulation and solution of finite element problems (build and solve the finite element system of equations, compute element results). The last phase is called post-processing (sort and display the results)(1375, كوكورس. رود ،كريستينا).

2.5 Additive Manufacturing (AM)

In recent years, the additive manufacturing (AM) technology, also known as three-dimensional (3D) printing, has garnered a considerable deal of interest from both students and academics. (Fu *et al.*, 2017). In the industry, the phrase Additive Manufacturing refers to a group of diverse manufacturing methods that may be used to treat a number of materials such as plastic, metal, and ceramic materials. There are several different additives manufacturing methods, including processes such as stereolithography (SLA), selective laser sintering (SLS), and fused deposition modelling (FDM) (FDM). In sectors that benefit from weight reduction and have complicated products created in small numbers, such as aviation, aerospace, and automotive, additive manufacturing (AM) is largely employed to manufacture parts (Galjaard, Hofman and Ren, 2015).

Because of its great precision, cheap cost, and ease of application, additive manufacturing (AM) technology is also commonly employed in medical and dentistry. 3D printing methods are used in a range of medical applications, including the following: vascular surgery To name a few of the disciplines now being investigated, tumour detection and treatment, surgical optimization, biocompatible organ and tissue printing, tumour detection and treatment, face reconstruction, orthodontics, exoskeletons, and prosthetics are all examples (Blaya *et al.*, 2018). The material characteristics of the structure and the manufacturing technologies used have an influence on the technique's design and construction. General technology includes a variety of processes such as stereolithography, selective laser sintering (SLS), modelling of fuse deposit patterns, ink jet printing, color jet printing, direct metal laser sintering, 3D printing, and laminated products, among others (Galjaard, Hofman and Ren, 2015; Manzhirov, 2015).

A considerable possibility exists to reduce product development costs and cycle time by a large margin via the use of additive manufacturing technology (AM) for the purpose of modifying the concepts of different equipment for new product innovations. During the printing process, three important aspects impact the precision and accuracy of printed pictures. These factors are the material quality utilized, the printing settings used during the printing process, and the post-processing phases. Concept manufacturing time and costs may be reduced by integrating numerous versions into a single unit, with the final configuration being optimized for mass reduction after the unit has been assembled (Technology, 2019), (Yancey and Mouriaux, 2016).

In addition to being an attractive manufacturing alternative, 3D printing (also known as additive manufacturing) has the potential to bring about a paradigm change in the aerospace industry by allowing the rapid and low-cost production of spacecraft components. While at Utah State University in 2005, the group developed a prototype on the size of a micro-satellite using a high-definition polymer model to aid in the validation of the idea. Additive manufacturing (also known as additive manufacturing) has been selected as a demonstration and test case for the holistic process approach presented in Figure 2.4, proving that additive manufacturing is a major facilitator of the current paradigm shift in engineering and aerospace (Yancey and Mouriaux, 2016).

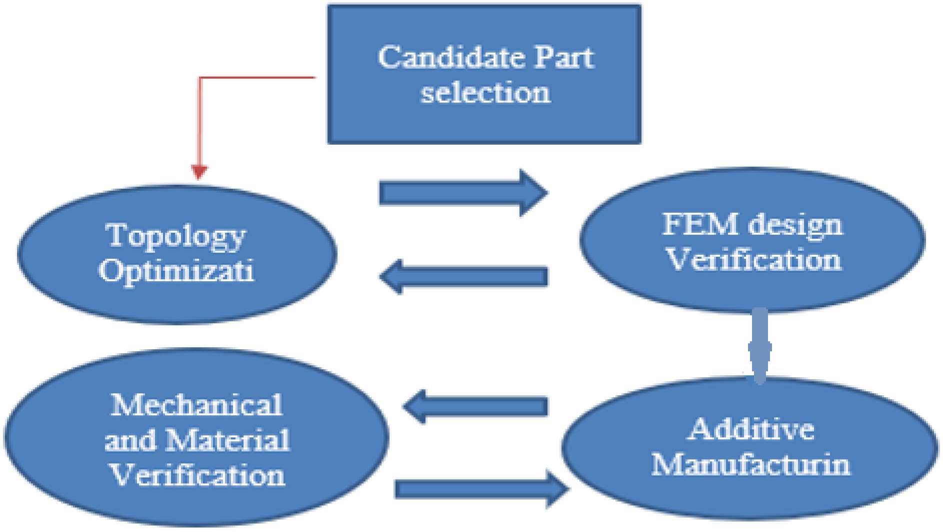


Figure 2.13 A flow chart depicting the overall process flow of component fabrication

2.5.1 Advantages and Disadvantages

Several advantages and disadvantages of additive manufacturing technology for the production of high-quality products are discussed in detail below. These include (Technology, 2019):

Table 2.1 Advantages and Disadvantages of additive manufacturing technology in high quality product

Parameter	**Fused Deposition Modelling**	**Stereolithography**	**Selective Laser Sintering**	**Selective Laser Melting**
Operation principle	FDM	SLA	SLS	SLM
Advantages	- Low cost - Fast printing time	- High print resolution - High automatization	-No support structures -High quality	- High durability - High Quality
Disadvantages	- Support structures -Low quality	- Narrow material - High maintenance costs	- Long printing time	- High cost

2.5.2 Types of 3D printing

There have been several different 3D printing technologies produced, each of which has its unique set of properties. Three-dimensional printing technologies are classified into seven categories by the American Society for Testing and Materials (ASTM), which include binding jetting, directed energy deposition, material extrusion, material jetting, powder bed fusion, sheet lamination, and vat photopolymerization.

Three-dimensional printing technologies are classified into seven categories by the ASTM. According to the American Society for Testing and Materials, binding jetting is the most extensively used 3D printing process. The phrase "3D printing" refers to a range of manufacturing processes that build objects layer by layer, as opposed to traditional production methods.

The methods used to produce plastic and metal parts, as well as the materials used, surface polishing techniques used, durability of the components, production speed, and cost, are all different. Stereolithography (SLA), Selective Laser Sintering (SLS), Fused Deposition Modeling (FDM), Digital Light Process (DLP), Multi Jet Fusion (MJF), PolyJet, Direct Metal Laser Sintering (DMLS), and Electron Beam Melting are some of the several techniques of 3D printing (EBM) (Shahrubudin, Lee and Ramlan, 2019).

2.5.3 3D Printing technique

On-demand medication and continuous jet printing are used to spray various medications and excipients (ink) precisely in tiny droplets of varying sizes on powder-free surfaces. Next, 3D powder printing utilizes powder to spray ink, which hardens to form a shape. The process of liquefaction and extrusion of a polymer is called Infusion deposition modelling.

Upon solidification, the polymer is removed layer by layer in an x-y-z pattern, producing a design chosen by computer.

Stereolithographic printing is based on the photopolymerization process and uses ultraviolet light to replicate the model. Fusion deposition modelling requires a fluid held in a roll and pushed through an extruder nozzle at a temperature above the melting point of the treated material. This process results in tiny filaments, which rapidly compress once created. The pressure-assisted micro syringe method utilises a device that sprays viscous and semi-liquid material. Nonetheless, inkjet-based printing systems are still widely utilised, although laser and nozzle-based systems are starting to grow in popularity.

2.5.4 Materials used in the production of 3D-printed

To continuously generate high-quality goods in 3D printing, it is necessary to use materials of consistently high quality. For the material controls, this is achieved through the development of processes, requirements, and agreement documents. While it may not be possible to fabricate entire working components out of ceramics, metallics, polymers, and their mixtures in the form of hybrids, composites, or functionally graded materials, it is certainly possible to fabricate functional pieces using 3D printing(Shahrubudin, Lee and Ramlan, 2019)

2.5.4.1 Metals

Metal materials have outstanding physical characteristics, and this material may be utilized in a variety of complicated manufacturing processes, ranging from the printing of human organs to the production of aircraft components. Aluminum alloys, cobalt-based alloys, nickel-based alloys, stainless steels, and titanium alloys are just a few examples of the materials that fall under this category(Murr, 2016; DebRoy *et al.*, 2018; Hitzler *et al.*, 2018).

A cobalt-based alloy is appropriate for use in dental applications that are 3D printed. The reason for this is because it has high specific stiffness, resilience, high recovery capacity, elongation, and it is heat-treated under controlled circumstances. Furthermore, 3D printing technology has the potential of producing aircraft components out of nickel base alloys, which are used in the aerospace industry.

2.5.4.2 Polymers

Three-dimensional printing polymer materials in a liquid state or with a low melting point are particularly popular in the 3D printing industry because of their cheap cost, light weight, and processing flexibility. Polymers played a significant role in the development of biomaterials and medical device products, often as inert materials, by contributing to the successful functioning of the devices and by providing mechanical support in numerous orthopedic implant applications, among other things (Caminero *et al.*, 2018). In addition to being biodegradable, PLA is made from sugar cane and maize starch. Product comes in two distinct textures, soft and firm, to suit your preferences. Polylactic acid, which is used in a range of industries, is used in the production of plastic. In order to make superior items, hard polylactic acid is employed in their manufacture.

2.5.4.3 Composites

Carbon fibre reinforced polymer composites and glass fibre reinforced polymer composites are two types of composite materials that may be used. In the aerospace sector, carbon fibre reinforced plastics composite structures are widely used owing to their high specific stiffness and strength, as well as their corrosion resistance and outstanding fatigue performance, among other characteristics.(Hao *et al.*, 2018).

2.5.4.4 Ceramics

Ceramic is a long-lasting, fire-resistant, and ecologically acceptable construction material. Due to the fluid condition in which ceramics are in before to setting, they may be molded and formed into almost any geometry or shape, making them particularly well-suited for use in the building of future structures and infrastructure. Ceramic materials have use in a variety of fields, including dentistry and aircraft building. Examples of this kind of material include alumina, bioactive glasses, and silica.(Gmeiner *et al.*, 2015; Zocca, Lima and Günster, 2017). 3D Printing technology has the potential to be utilized in the processing of alumina powder. It is a wonderful ceramic oxide with a wide range of applications in a variety of disciplines, including catalysts, adsorbents, microelectronics, chemical processing, aerospace, and other high-tech sectors.

2.5.4.5 Smart materials

According to the definition, a smart material is one that has the potential to modify the geometry and shape of an object when subjected to external influences such as heat and moisture. Three-dimensionally printed goods made of smart materials include a self-evolving smart material-based device and a soft robotics system, which are both examples of 3D printed items made of smart materials. A smart material is frequently referred to as 4D printing material in certain areas due to its ability to print in three dimensions when used in 3D printing applications. Among the smart materials that fall into this category are form memory alloys and shape memory polymers, to name a few of instances of which.

2.5.4.6 Powders

Powdered materials are used in 3D printers to create things and goods. Using a printer, this powder is heated and then disseminated in layers to obtain the required thickness and design. Printers make use of a wide variety of powders. However, the most often used are:

- Polyamide (Nylon)

The strength and flexibility of nylon are exceptional, as is its durability. As a result, it is employed in the construction of 3D models

- Alumide

Industrial prototypes and models made from this powder are the strongest available.

2.5.5 The Applications of 3D Printing

The 3D printing technology offers unparalleled versatility in components and production. 3D printing technology may make components lighter, more precise, and more complex, reducing energy and resource needs in the aircraft industry(Joshi and Sheikh, 2015). Because they are tensile, oxidation/corrosion resistant, and damage tolerant, nickel-based alloys are preferred in the aircraft industry. 3D printing techniques in the automotive industry have created a new aesthetic phenomenon that allows for the production of lighter and more complex structures in a short amount of time. This enables businesses to test a variety of options while properly focusing on the stage of advancement with the implementation of 3D printing technology in the automotive industry(Shahrubudin, Lee and Ramlan, 2019).

3D printing technology can nearly simultaneously reduce waste and material usage. Furthermore, 3D printing technology may save costs and time while allowing new ideas to be tried rapidly. Food coating is also known as 3D food printers, which are made directly from computer-aided design data by deposition of the next layer after layer(Dankar *et al.*, 2018). 3D printing technology is a very energy-efficient method for producing ecologically friendly and cost-effective food. 3D food printing may be as healthful and beneficial to people as it is to animals since it provides new mechanisms for food adaptation and can adapt to individual needs and tastes.

2.6 Stereolithography (SLA)

a stereolithography-based digital light processing 3D printer for exposure curing the procedure started once the STL file was imported into the 3D slicing programmed. The printer was divided into layers, and the output was exported in the reserved TDL format. Unlike other rapid prototyping methods, SLA prioritizes quality over speed. It can manufacture things in a couple of hours using 3D CAD data. By stacking liquid photopolymers (a kind of plastic) together, it is feasible to produce fully 3D things with this technique of 3D printing. This process converts liquid photopolymers (a kind of plastic) into three-dimensional objects. When the plastic comes into touch with another object, it briefly becomes semi-fluid before solidifying.

Each layer on the printer's print bed was constructed using the solid laser and direction filtering mirrors on the X and Y axes. Following that, a razor-sharp recoated edge is used to traverse the product's surface, ensuring that each thin cup of rubber is equally distributed before to the subsequent step. This results in the printing cycle, which generates 3D things from the ground up. Following completion of the 3D portion, a synthetic shower is often placed to avoid overflow. Bake until the dish is browned on both sides in a well-lit broiler oven. This boosts the product's stability and grounding. Figure 2.11 illustrates the stereolithography (SLA) technology(Ding *et al.*, no date).

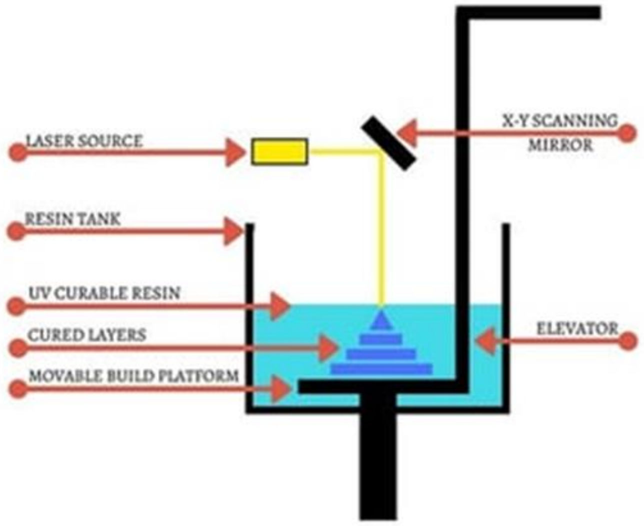


Figure 2.14 Schematic of Stereolithography (SLA) system

2.7 Selective Laser Sintering (SLS)

SLS (figure 2.12) is a fast-prototyping method that may be used to create high-quality complicated geometries straight from digital models. It is also incredibly adaptable (RP). SLS is a technique that employs a laser to sinter powdered materials layer by layer, using 2D data from CT or MRI imaging as a starting point. An in-depth assessment of the literature on selective laser sintering (SLS) in biological and clinical applications is offered in this paper. Following a brief introduction to SLS technology, the best material processing parameters as well as the most recent breakthroughs in material production are presented.

There are many case studies that address a wide range of subjects in depth, including patient-specific guides and prostheses, preoperative planning, and bone scaffolds for tissue engineering. Despite the restricted availability of acceptable polymers, SLS has been extensively employed as an additive manufacturing technique rather than a rapid prototyping method. This is despite the limited availability of relevant polymers. Increasing evidence shows that SLS may enhance clinical and biological results while simultaneously cutting expenses and saving time (Saffarzadeh, Gillispie and Brown, 2016).

Figure 2.15 Selective Laser Sintering machine diagram

2.8 Topology Optimization

A common design strategy in recent years has been topology optimization, which has gained popularity as a consequence of the fast rise of computer-aided design technology in the manufacturing sector. However, despite its relative young, topology optimization is a fast emerging topic of study that has fascinating theoretical implications for a variety of subjects, such as mathematical modelling, physics, computer simulation, and computer science, among others. This chemical is also used in a variety of practical applications in the industrial business, as previously stated (particularly in the automobile and aerospace industries)(Rozvany, 2009). Topology optimization, which is a technique used to optimise the material arrangement of load-bearing structures as they are being produced, is a procedure that may be used to do this. Specifically, while attempting to solve the classic Michell truss issue (1904), the aim is to discover the planar truss that will support the least amount of weight for a given load and set of limitations while retaining structural integrity in the process. In the early 1960s, as a consequence of the merger of mathematical programming and sensitivity analysis, a new optimization theory was developed, which is still in use today: heuristic optimization. a constraint-based approach to optimization (Galjaard, Hofman and Ren, 2015)

2.8.1 Sizing, Shape, and Topology Optimization

A design variable is a size parameter that is associated with a finite-element simulation, such as the cross-sectional area of truss members, that is used to discover the ideal design solution when dealing with high-quality design difficulties. In this situation, the cross-sectional areas of truss members are employed as design variables for the truss members. In this example, it is believed that cross-sectional areas may be accessed as either continuous or discrete values, depending on the context in which they are used. It is nearly always the case that allowing for structural form change results in a more favorable design outcome.

When dealing with shape optimal design problems, in general the shape of the structure can be varied either directly through the use of design variables that describe the shape of the boundary, such as the nodal coordinates of key nodes taken as design variables (the geometric approach), or indirectly through the use of fictitious loads or displacements acting on an auxiliary structure taken as design variables (the fictitious loads and displacements approach) (the natural approach). Scholars have long been intrigued by the difficulty of developing the optimal plan or topology for a structure from the ground up. In this article, we will discuss the subject in more detail (Formulation, 1995).

2.9 Process selection

A range of criteria must be examined in order to choose the most appropriate technique, including cost, component quality, component attributes, design envelope, time (speed), and other considerations relevant to the situation. This problem has been the focus of a number of research, the bulk of which have included the creation of decision support systems to assist AM users in selecting the AM technique that is most appropriate for their unique circumstances. A computer-based selector programme, as well as the selection of other production methods, have been the subject of recent research and development initiatives (West, Sambu and Rosen, 2001; Taylor, Pande and Kumar, 2008; Ren *et al.*, 2009).

2.10 Overview Concept and Design

There have been so many studies on diffusion phenomena, particularly in the late twentieth and early twenty-first centuries, that it is critical that the development of design principles is regarded as a component of mechanical engineering and is carried out while developing or redesigning systems with complex characteristics. Different forms and designs of retail sector services for all customers have a distinct value as essential to provide an attractive user experience, but all merchants will benefit from the competitive advantage that will be produced by different forms and designs (Kotsopoulos, 2007).

According to Kotsiopoulos, Nadal, and Lopez, (Nadal-serrano, Nadal-serrano and Lopez-vallejo, 2017). (‘From Design Concepts to’, 1916; Kotsopoulos, 2007) open-ended philosophical frames are used rather than established building morphologies and typologies in research. A theory is more than simply a verbal concept; it offers the "manifold link" between the location, geometry, programmer, situation and material factors, among other variables. Principles for visual development are used to provide concept descriptions expressed according to the technique utilizing formal grammar formalism.

Broad strokes are used to analyses the design approach and show which factors an architect needs to consider at each level and how the interactions between various design components may be arranged and how a well-balanced design can be constructed (Tupper, 2013). The ability to diagnose problems and devise productive hypotheses is critical for many architects and designers in the production of creative architecture (Kotsopoulos, 2007). The design phase is divided into three stages:

- Concept (preliminary or feasibility) design
- Contract (full) design
- Detail (build) design.

Further analysis and critical facts to decisions may be made by algorithm, in greater detail, inquiries are made on a more comprehensive and precise basis (Tupper, 2013). A market analysis shows that 70% to be correct. and between 80% and 85% of the world's biggest organization's use a prescriptive step-by-step New Product Development (NPD) approach (Hart, 2012).

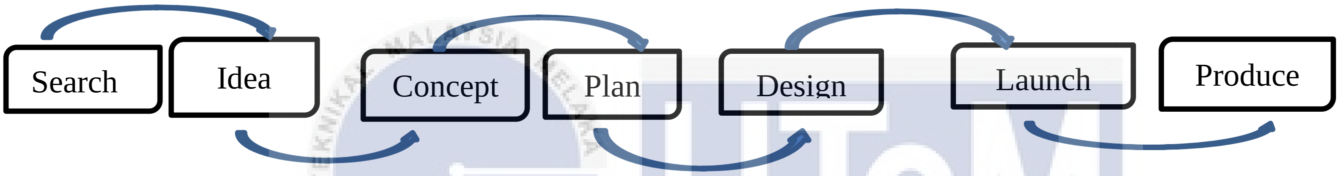


Figure 2.16 Represents an example NPD

The techniques for creating ideas as part of a continuous process. Potential creators and innovators must be motivated and educated in order for them to succeed. stages in the ideation process, Idea description, examination of intellectual property databases, and Internal concept examination, timeline development, competition assessment, and supply chain enhancement are some of the tasks that will be performed.

2.11 Rapid Prototyping (RP)

Rapid prototyping (RP) is a term used in the manufacturing sector to describe a variety of technologies that enable physical product prototypes to be created in the early phases of development in a short amount of time and with high accuracy and speed. In the early days of 3D printing, machines such as stereolithography (3D systems), powder sintering (such as selective laser sintering (SLS) from DTM), filament extrusion (such as fusion deposition modeling (FDM) from Stratasys), and sheet lamination were among the first technologies to be developed(Campbell *et al.*, 2014).

Numerous rapid prototyping machines produce physical images based on their sliced results, and direct slicing is a hot topic in the field of rapid prototyping technology. 3D systems are created and published in 1987 as the STL format, which allows 3D CAD models to be converted for usage in Stereolithography Apparatus (SLA).

It is generally recognized by all RP systems and has emerged as the de facto standard because to its two primary strengths, namely its simplicity and its independence from the constraints of particular CAD modelling methodologies (Cad *et al.*, 1997). When manufacturing components using the RP technology, a 3D CAD model is produced, followed by Geometry information processing and then the RP process, and finally the finished product (Cao and Miyamoto, 2003).

2.12 CATIA Software

CATIA is a computer-aided design (CAD) tool for mechanical design. It is a feature-based, parametric solid modelling design tool that makes use of the user-friendly Windows graphical user interface to make design decisions. When designing 3D solid models, you may utilise automated or user-defined relations to represent the design purpose. You can develop completely associative 3D solid models with or without restrictions.

2.12.1 Introduction of CATIA V5 software

Figure 2.17 CATIA Software

CATIA V5 covers a substantial part of today's most commonly utilised sectors, including the product life cycle. It is capable of performing a wide range of analyses, simulations, and optimizations, as well as producing drawings and NC programmes for use in the manufacturing process. CATIA V5 is available for Microsoft Windows and Apple Macintosh computers. It may be adopted and used in a range of industries, including the car and aerospace industries, consumer product production, machine tool manufacture, and capital equipment manufacturing for heavy engineering.

However, data created on one platform may be used in another platform's product development. CATIA V5 is modular in design, with several portions from which clients may choose based on their specific needs. Mechanical design, shape and styling design, product synthesis, equipment and system engineering, analysis, machining, and infrastructure are just a few of the specialisations accessible in this discipline. CATIA is a three-dimensional interactive computer-aided design tool that has been used in a wide variety of industries, most notably the automotive industry(Redondo and LeSar, 2004).

2.13 AutoCAD Software

Auto Cad software has the possibility of showing a realistic depiction of the job in three-dimensional computer graphics and of modelling deviations from the original project timetable in order to improve productivity. It is possible to generate and edit sketches with AutoCAD software. These sketches may then be viewed, monitored, disseminated and stored. It is possible to utilize computer-aided drawings and 3D models to depict the current status of a building project when they are observed in real time. Because 3D CAD is used at every level of the design process, it results in more effective project development, design, and construction than traditional methods. (Memon, Muhd and Mustaffar, 2005).

Designers may utilize Auto Cad as a single assessment tool for analyzing distances and reaches, graphical requirements, and positional comfort in the early phases of the design process(Feyen *et al.*, 2000). Aside from that, AutoCAD is a widely used 2- and 3-dimensional modelling and drafting tool, with millions of users across the world producing, presenting, and conserving precise and information-rich drawings, in addition to developing, uploading, and reusing such designs. In addition, Despite the fact that there are many different ways to manufacture popular physical components, data snippets from 3D CAD models serve as the foundation for many additive manufacturing processes, regardless of how popular the techniques are.

Rapid prototyping (RP), also known as solid free form fabrication (SFF) or layered fabrication (LM), is a process for creating material parts by layering them directly from a computer-powered 3D model, which is known as solid free form fabrication (SFF). Additionally, a specific slicing system may generate distinct slicing data from the same model (Cao and Miyamoto, 2003). AutoCAD It is commonly acknowledged that the building industry is an information-intensive and diverse one(Memon, Muhd and Mustaffar, 2005).

The Digitalizing the Construction Monitoring (DCM) model is part of an overall research project in Malaysia to build Tele-construction, which automates a variety of construction processes and maps the real progress bar map by combining digital photographs and AutoCAD drawings. (Memon, Muhd and Mustaffar, 2005). Computer-Based Design and Manufacturing is useful for modelling and engineering problems where computing power and high-end memory are essential (Finite Element Analysis, computational fluid dynamics, optimization, CGI animation, and photorealistic rendering are all examples)(Wu, Terpenny and Schaefer, 2017)

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, the methodology used in this research project is explained in detail. A methodology chart is presented to outline the whole designing process a CCD camera holder from beginning until a prototype is produced. Data collection, test findings, and prototype development are required to completed this research project. Detailed information on each process is provided in each subsection.

3.2 Overall Process

The project proposal's purpose, problem description, and scope of work are all covered. The process begins with data and information collection. The data is compiled from reputable sources, including reference books, journals, and the Internet. Each piece of information is crucial in the research process. This section will discuss the approach and procedures that will be utilized to complete this project. Include the design of the prototype, which will be tested in a real-world environment. A sequence of tests is necessary to identify the best possible outcome.

3.3 Project Planning Schedule (Gantt chart)

Table 3.1 Process of project planning in Gantt Chart

Task	W 1	W 2	W 3	W 4	W 5	W 6	W 7	W 8	W 9	W 10	W 11	W 12	W 13	W 14

Preparation														
Problem identification														
Detail design planning														
Development and testing														
Documentation														

3.4 Process flowchart

Diagrams and charts were required throughout the course of this project. It needs a flow chart to demonstrate how the flowchart should be planned. The various behaviors shown in the flow diagram correspond to each step of the flow diagram. The rows and arrows depict the steps' sequences and connections. The flow chart is shown in Figure 3-1:

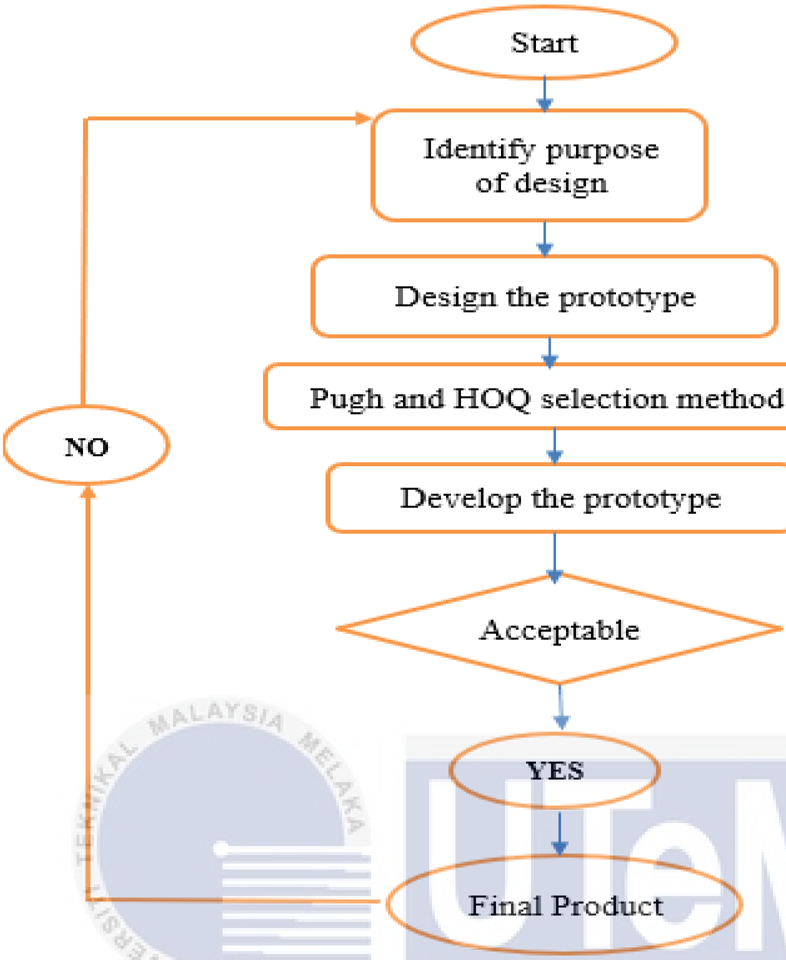


Figure 3.1 Flow chart for prototype production

3.5 Dimensions

In the process of producing a design, dimension is critical because it can help to build a good vision or idea of what the design should look like.

3.5.1 TSI Camera Model 630090

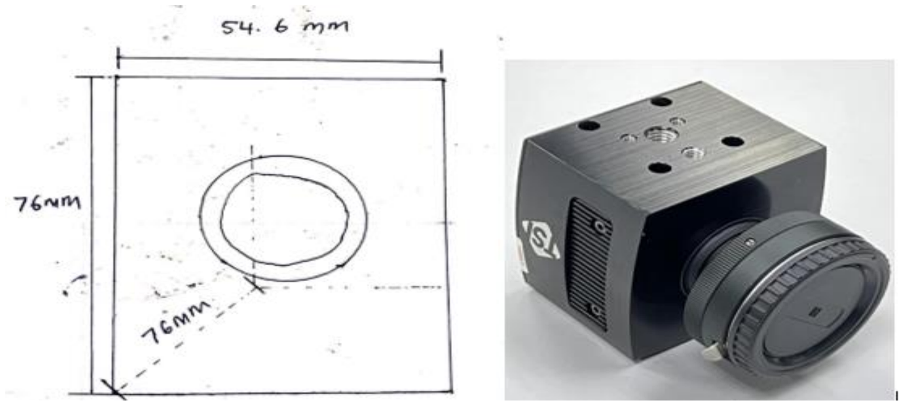


Figure 3.2 The camera's dimensions are 76mm(H) x 76mm(L) x 56.4mm(W)

When it comes to the dimensions of the TSI camera model 630090, the length and width of the camera holder are the first things that should be considered. The camera holder dimension range must not exceed 76mm x 54.6mm in order for the holder to be able to hold the camera securely and safely.

3.5.2 Aluminum Profile 40 X 40 MM

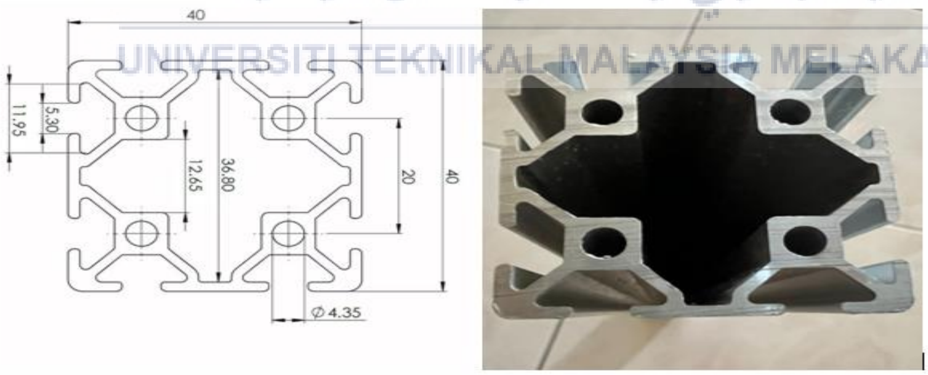


Figure 3.3 Aluminum profile

In the aluminum profile, the dimension of the T slot is critical because the T slot serves as a rail for the holder to move and lock the movement. Catia software is used to produce aluminum profiles, which are necessary in order to make it easier to create an accurate design holder with accurate dimensions, and the holder can slide smoothly on the aluminum profile.

3.6 General Sketching of the camera holder

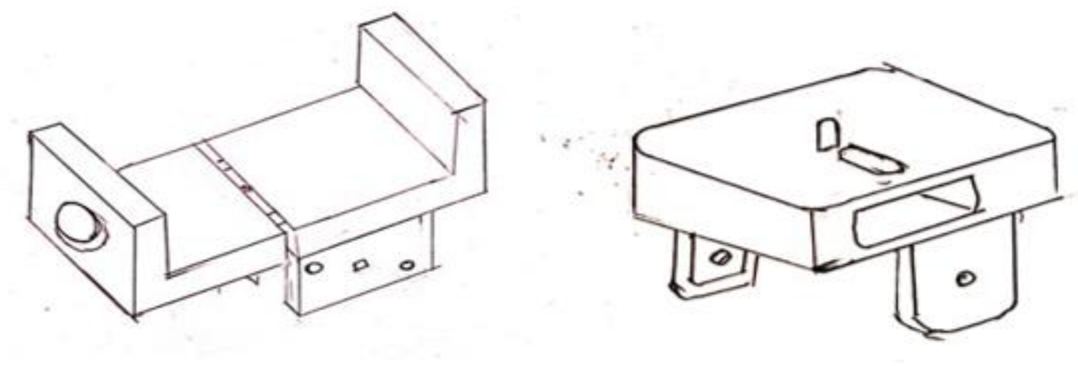


Figure 3.4 The sketching design of the holder in different concepts

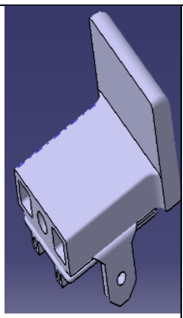
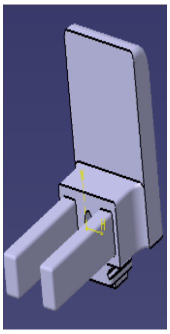
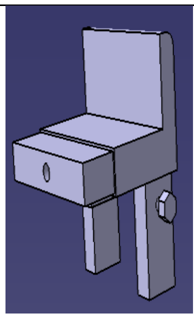
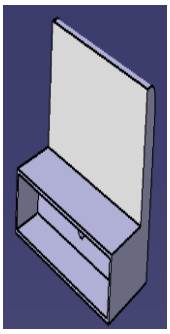
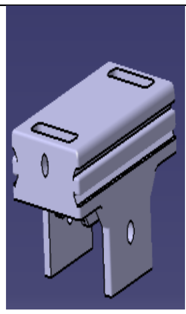
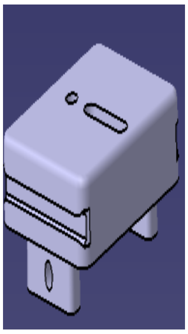
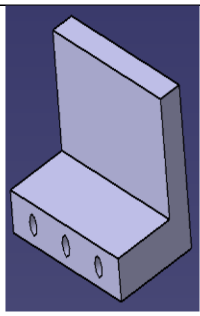
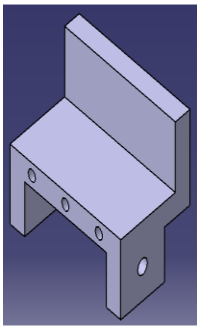
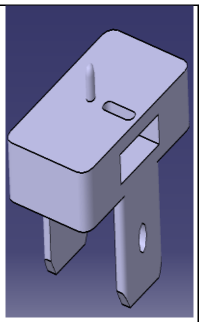
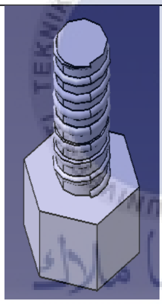
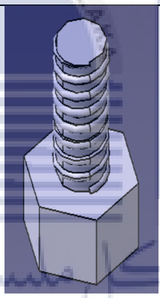
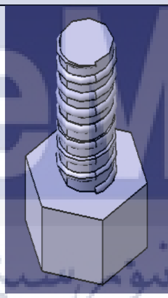
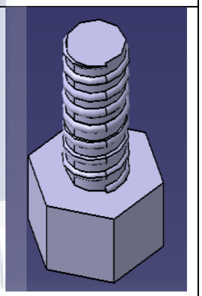
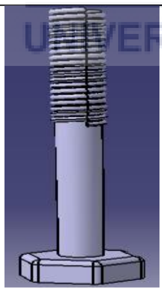
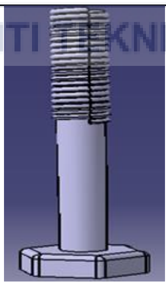
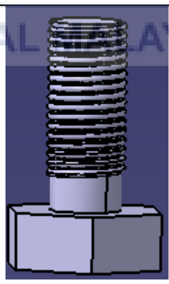
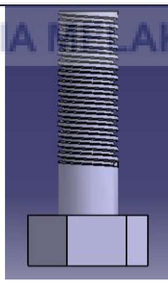
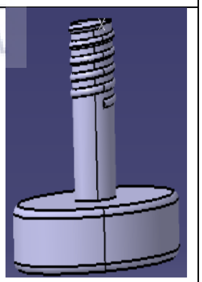
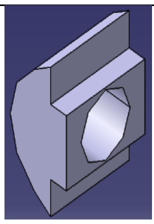
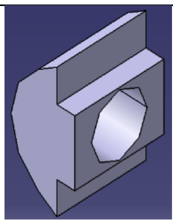
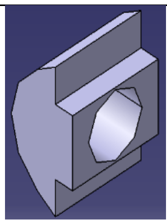
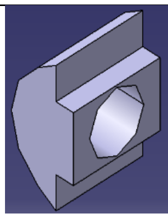
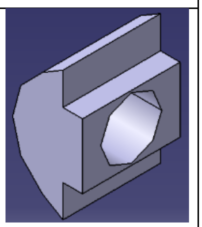
3.6.1 Morphological Chart

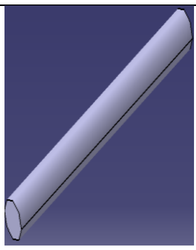
The morphological chart is a technique for analytically and systemically generating concepts. Possible components depending on their roles are shown in a morphological chart. Functions are stated in columns and the methods by which the functions are carried out are given in rows. This results in a matrix of functions and components that fulfil this purpose. By carefully selecting a number of components and combining them, a concept is created.

A morphological diagram is composed of functions and components (in columns) (listed in the rows). The parameters define the features a product need (characteristics). The parameters are important to the solution. What the product should be. The components are the way to achieve the product's functions (or features). Therefore, the components are the methods to achieve the specifications. These parameters are abstract and show a category (with no reference to material features). Table 3.2 shows the morphology chart for CCD camera holder.

Table 3.2 Differences between Design A, Design B, Design C, Design D and Design E

DESIGN	A	B	C	D	E

Holder	 	 	 	 	
Lock Screw	 M5 x 2	 M5 x 2	 M5 x 2	 M5 x 2	 M5 x 4
Adjuster Screw	 M8 x 1 Length = 55mm	 M8 x 1 Length = 45mm	 M8 x 1 Length = 35mm	 M5 x 1 Length = 10mm	 M5 x 1 Length = 10mm
T- Nut	 T-Nut x 2	 T-Nut x 2	 T-Nut x 2	 T-Nut x 2	 T-Nut x 2

Stainless steel Rod				 Length = 45mm	

3.7 Conceptual design of camera holder

There in conceptual design, a solution to a problem is chosen from a large number of alternatives that must be examined. The definition of a good project is the presentation of outstanding solutions that make it clear how the problem's various design conditions are met, including functional requirements related to the structure's purpose, structural needs aimed at safely meeting the various external actions (gravity loads, climatic loads, etc.), and environmental requirements.

Additionally, in addition to the previously mentioned technical and financial considerations, there must also be considerations for the designer's personal aesthetic preferences, which he or she will have developed and refined over the course of his or her career, as well as societal considerations, which must be taken into account in order to make the project work in the context in which it is intended. Five different ideas have been sketched down on paper. For each concept, there are numerous versions based on the structure, Adjuster and Function that are incorporated in morphological charts.

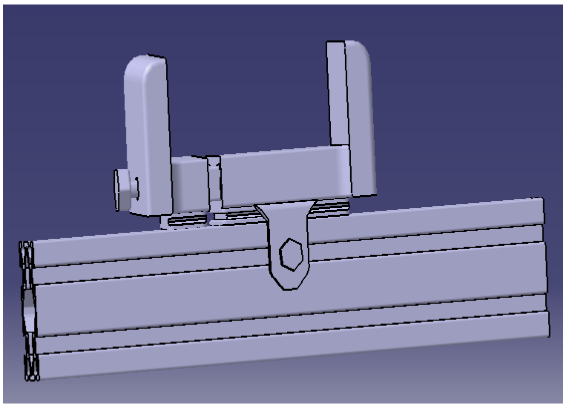


Figure 3.5 Design A

The design shown above is the first concept developed as a consequence of a reference based on camera holder designs that are now available and have already evolved with the introduction of new camera holder designs. An adjustable screw adjuster is located in the middle of this camera holder, which helps to ensure that the camera is locked nice and tight. The base of this design features a 5mm height, which serves to facilitate the rotation of the adjuster screw without clashing with the aluminum profile.

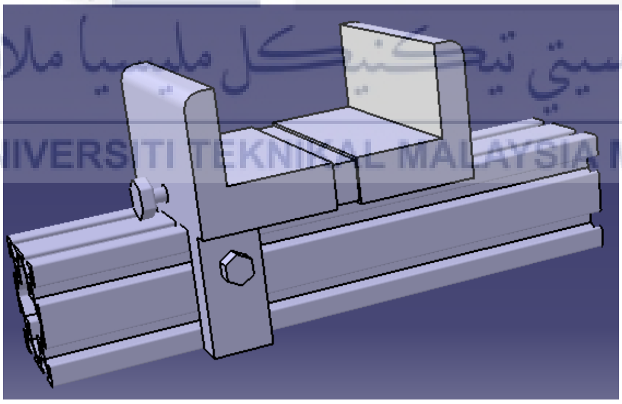


Figure 3.6 Design B

This design is conceptually similar to design A, but it without a base and each part holder is designed differently.

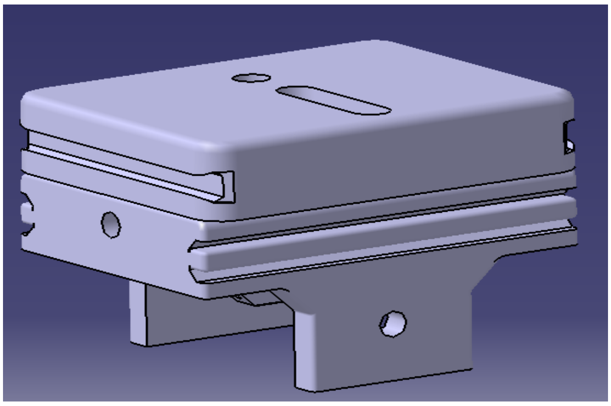


Figure 3.7 Design C

This design has a quick release plate mounted on a base that protects the plate while performing left and right movements over through the aluminum profile.

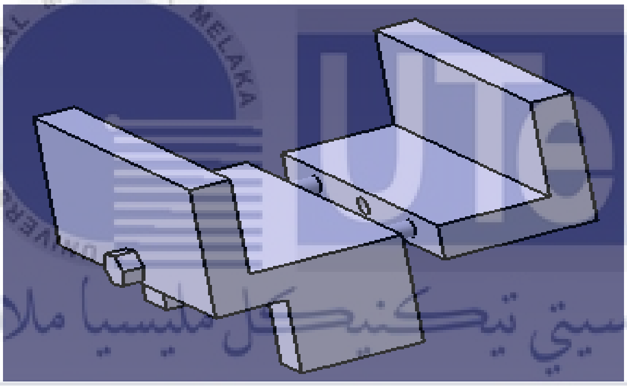


Figure 3.8 Design D

This design has the same concept as designs A and B, but it has two stainless steel rods in the middle of the holder that serve as rails or supports for the camera holder.

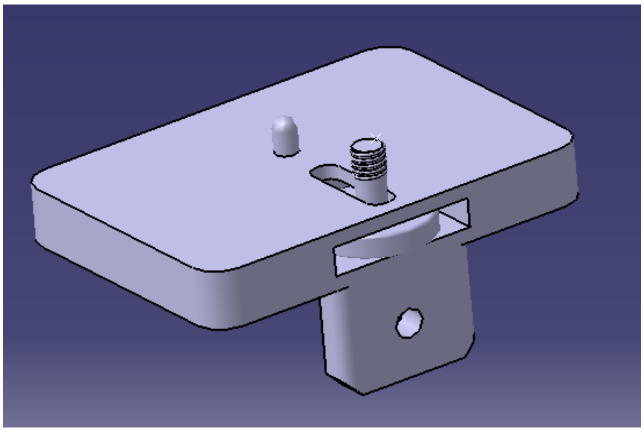


Figure 3.9 Design E

Similar in appearance to design C, design E does not include a base that is attached to the release plate, and it only has one camera lock on top, as well as one screw to fasten the camera to the release plates for the conceptual designs are derived from internet-based investigation. Function, structure, and ergonomics are all well specified inside each concept. Several criteria must be considered in order to develop all of the ideas in order to get the best design.

3.8 Create designs with CATIA V5R21

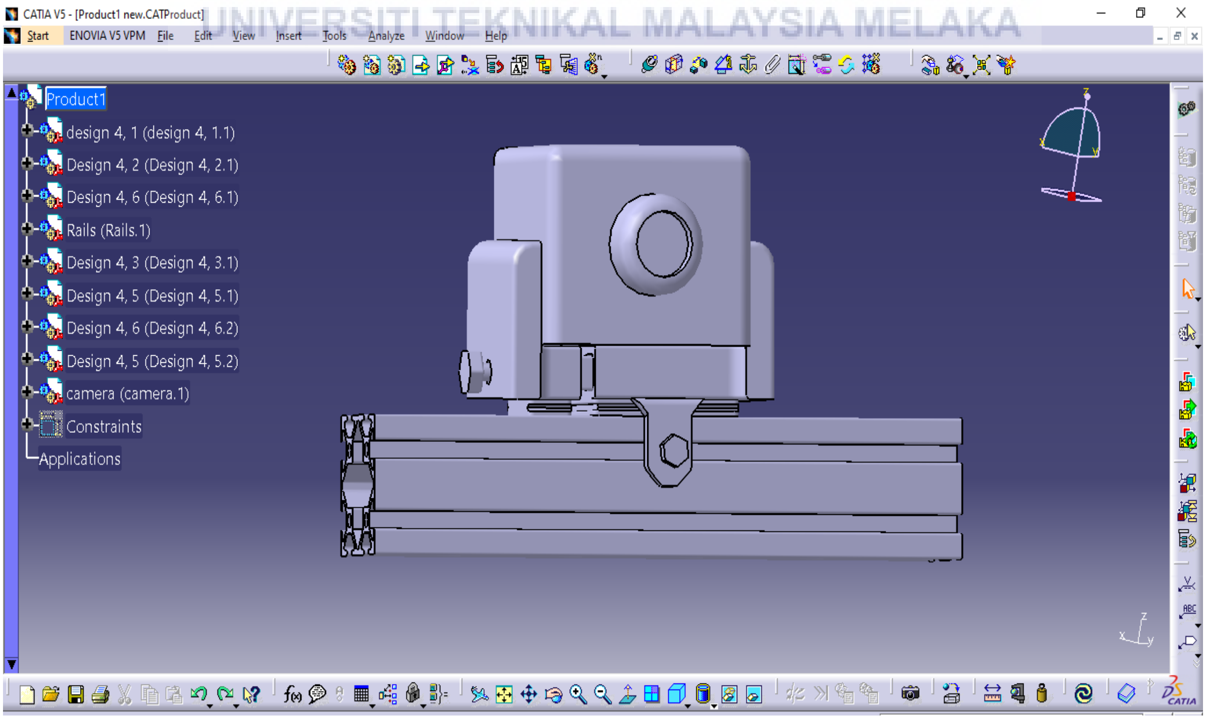


Figure 3.10 Finished design after assembling all parts.

The camera holder was designed using CATIA software and was based on an existing design available on the market. So, once the design process is finished, all data is gathered and processed. This project study's goal is to automate appliance modelling by merging knowledge-based engineering approaches into basic design processes. Included is the use of practical engineering-based information to gain a more accurate view of the entire production process and the final product's cost. Any structural issues may result in massive losses. To reduce equipment development costs, it may be beneficial to concentrate efforts on the design phase.

3.8.1 Analyze the clash of the components

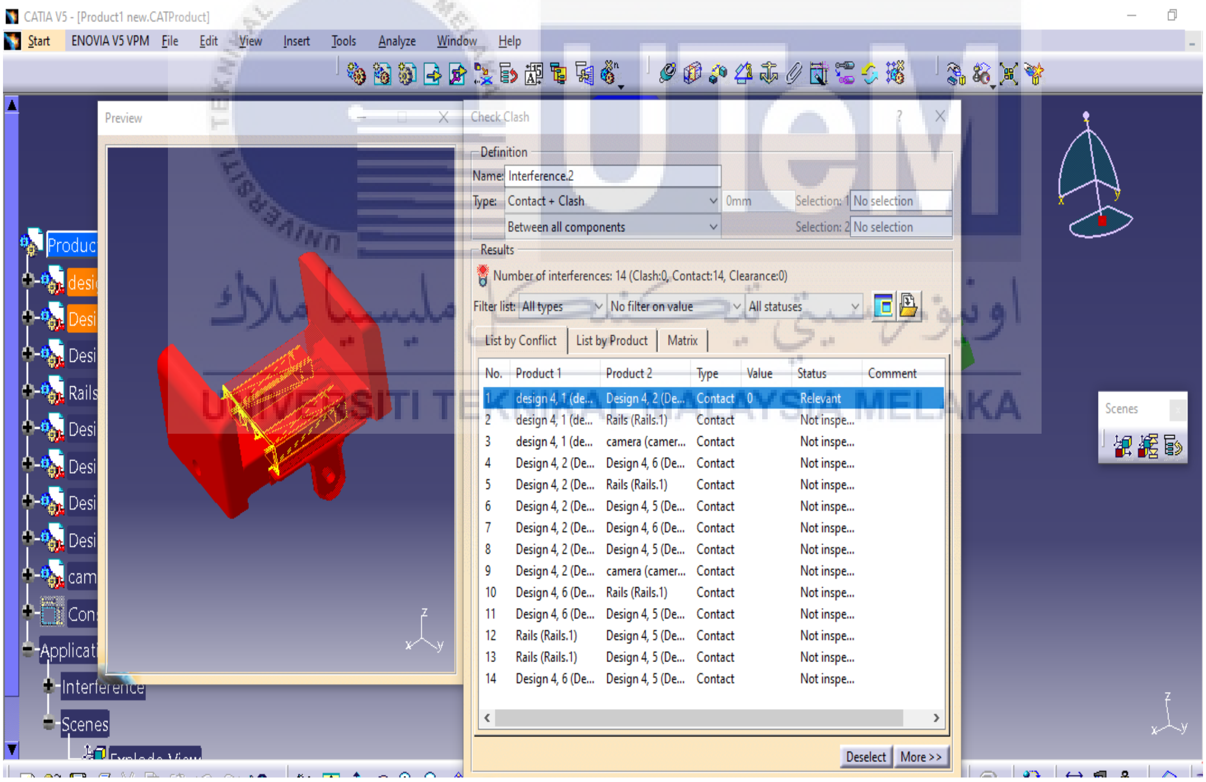


Figure 3.11 Shows the result clash between component

In CATIA, doing static collisions is a strong technique for detecting areas of interference, contact violations, and minimum emission violations, among other things. In this part, need to learn how to prepare your collision analysis, read your collision analysis, and alter the internal collision parameters in CATIA V5.

3.9 Calculation for camera weight

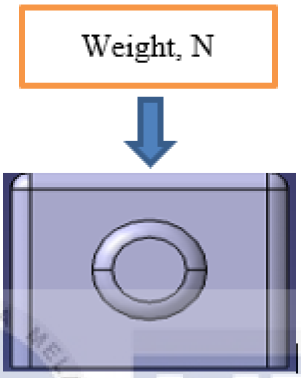


Figure 3.12 TSI CCD camera

$$\boldsymbol{Force, F = mass\ (kg)\ \times acceleration\ (ms^{-1}\ )}$$

$$\boldsymbol{F = m\ \times a}$$

a = gravitational force
= 9.81 ms^{-1}
m = camera weight, Kg

For the purposes of basic physics textbooks, weight is frequently defined as the gravitational force exerted on a stationary object. W = mg, where W is the weight of the item, m represents its mass, and g represents the gravitational acceleration of the object. Newton's Second Law states that when a constant force acts on a static body, the object will accelerate as a result of the constant force acting on it. In this case, the constant force of gravitational acceleration will cause the static body to accelerate at the rate of F = mg.

3.10 Analyze design with Ansys Software

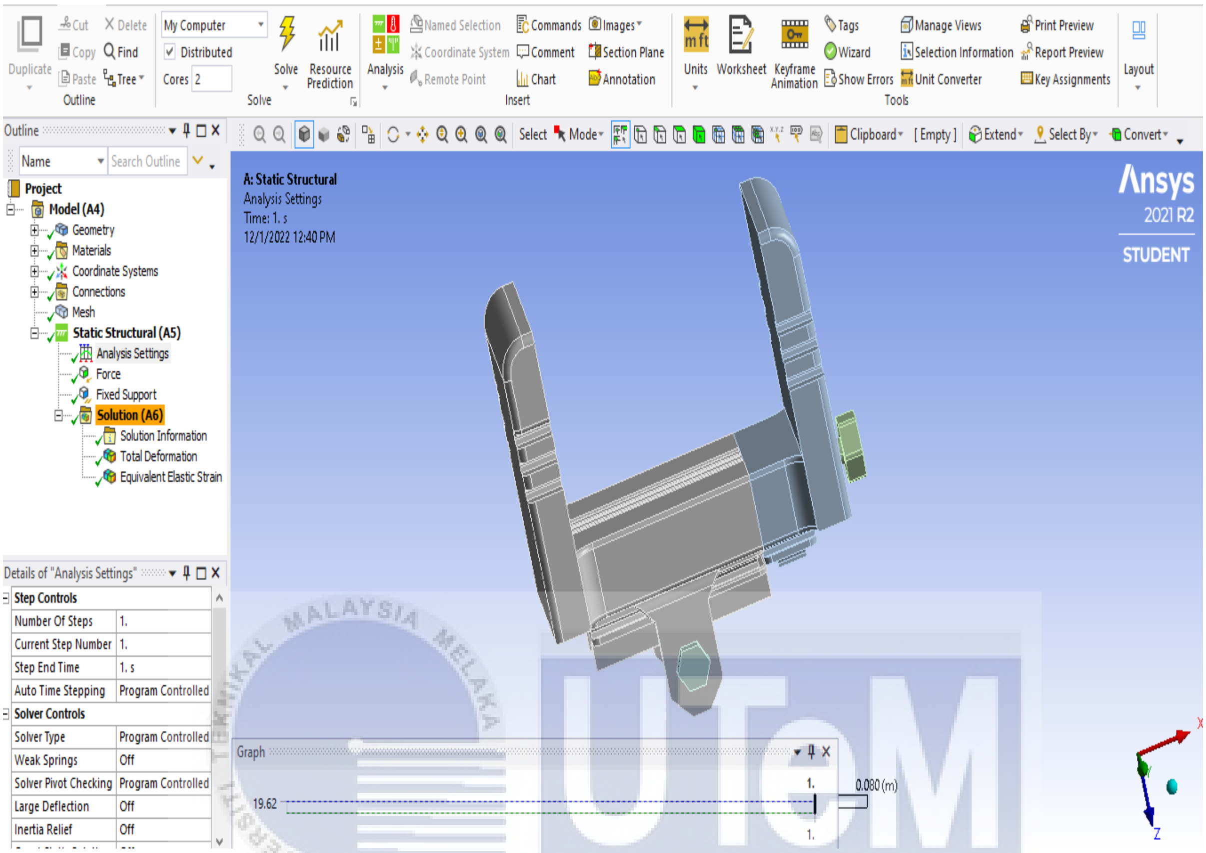


Figure 3.13 Workbench 2021 R2 student version

Ansys provides structural analysis software tools that allow structural engineers of all levels and backgrounds to tackle difficult structural engineering issues more quickly and effectively than they would otherwise be able to. This software is capable of doing finite element analyses (FEA), customizing and automating solutions for structural mechanics difficulties, and analyzing a variety of different design situations.

Ansys software requires that the design files from Catia be converted to the Stp file format before they can be loaded into the software. After the file has been opened in the Ansys software, all of the components must be identified by the type of material used in each part before the analysis can be performed out on it.

3.10.1 Materials Selection

Technology is more closely related with design and development processes than it is with the way of selecting materials that have been selected. Nylon, stainless steel, and aluminum are the types of materials that were employed in the development of a prototypes. When it comes to material selection, one of the most crucial considerations to keep in mind is identifying product design criteria as well as the availability of appropriate materials.

As a result, it appears vital that the risk of failure be reduced while yet ensuring the holder's capacity to perform. In order to test the model, it must be built using SLS 3D printing and based on the original design and drawings. Standard characters are distinguished by a few characteristics that must be present in order to be recognized as such. Through the application of geometric relationships, Ansys is capable of measuring or determining these elements. It makes it possible to conduct more in-depth research into the design appropriateness of material selection and load situations.

3.10.2 FEA Parameter

Table 3.3 FEA parameter for nylon (PA 66)

Property	Value	Unit
Density	1140	kg m^-3
Derive from:	Young modulus and Poisson's ratio	
Young modulus	2.700 e^+9	Pa
Poisson's ratio	0.39	
Bulk modulus	4.0909 e^+9	Pa
Shear modulus	9.7122 e^+9	Pa
Bilinear isotropic hardening		
Yield strength	5 e^+7	Pa
Tangent modulus	0	Pa

Table 3.4 FEA parameter for hardware components (Stainless steel)

Property	Value	Unit

Density	7750	kg m^-3
Coefficient of thermal expansion	0.1	c^-1
Derive from:	Young modulus and Poisson’s ratio	
Young modulus	1.93 e^+11	Pa
Poisson’s ratio	0.31	
Bulk modulus	1.693 e^+11	Pa
Shear modulus	7.3664 e^+11	Pa
Tensile yield strength	2.07 e^+8	Pa
Compressive yield strength	2.07 e^+8	Pa
Tensile ultimate strength	5.86 e^+8	Pa
Compressive ultimate strength	0	Pa

Table 3.5 FEA parameter for hardware components (Aluminum Alloy)

Property	**Value**	**Unit**
Density	2770	kg m^-3
Derive from:	Young modulus and Poisson’s ratio	
Young modulus	7.1 e^+10	Pa
Poisson’s ratio	0.33	
Bulk modulus	6.9608 e^+10	Pa
Shear modulus	2.6692 e^+10	Pa
Tensile yield strength	2.8 e^+8	Pa
Compressive yield strength	2.8 e^+8	Pa
Tensile ultimate strength	3.1 e^+8	Pa
Compressive ultimate strength	0	Pa

3.11 Concept Selection

3.11.1 Pugh Selection Method

Table 3.6 Criteria selection between five design using Pugh selection method

Selection Criteria	A	B	C	D	E
Size	0	+	0	0	+
Stability	+	+	0	+	0
Cost	0	0	0	-	+

Easy to use	+	0	-	0	-
Lightweight	-	+	0	-	0
Durability	+	-	+	+	-
Comfortability	+	0	+	0	0
Sum +	4	3	2	2	2
Sum 0	2	3	4	3	3
Sum -	1	1	1	2	2
Net score	3	2	1	0	0
Rank	1	2	3	4	5

The Pugh Concept Selection Method is a quantitative approach that is used to rank the multidimensional alternatives in a choice set in order of priority. This technique is widely used in engineering to make design decisions; but it may also be used to rank investment alternatives, vendor alternatives, product alternatives, or any other collection of multidimensional entities. In its most basic form, a decision matrix involves developing a set of criteria based on which the prospective alternatives may be dissected, scored, and summed to provide a total score that can then be ordered in order of preference. It is important to note that the criteria are not weighted in order to facilitate a speedy choosing process.

3.11.2 House of Quality, HOQ

Student:	MUHAMMAD SYAMIL BIN CHE SUKRI
Date:	20/6/2021

Correlation:	+	.	-
	Positive	No correlation	Negative

Relationships:	5	3	1		REJECTED
	Strong	Moderate	Weak		ACCEPTED

	1: low, 5: high Customer importance rating	Desired direction of improvement (↑,0,↓) Functional Requirements (How) → Customer Requirements - (What) ↓	WEIGHT	SAFETY	EASY OF OPERATION	HIGHLY RELIABLE	DIMENSION OF PROJECT	Weighted Score	DESIGN A	DESIGN B	DESIGN C	DESIGN D	DESIGN E
1	5	SIZE	5		3		2	50	4	4	3	4	5
2	5	FLEXIBILITY can move at X axis	3				3	30	5	4	5	3	4
3	3	STABILITY	2	5	3	5	2	51	4	3	4	3	3
4	3	LIGHTWEIGHT		3	3	4		30	3	4	3	3	4
5	3	COST	1		3			12	4	5	3	4	4
6	5	DURABILITY	2	4	3	1	3	65	5	3	4	3	2
7	2	COMFORTABILITY		3		3		12	5	3	4	3	3
8	5	CAN HOLD MULTIPLE CAMERA		2	3	3		40	5	4	3	4	2
9								0	1277	1044	1058	972	937
		Technical importance score	59	60	72	53	46	290					
		Importance %	20%	21%	25%	18%	16%	100%					
		Priorities rank	3	2	1	4	5						
		Difficulty	3	1	3	1	5	easy, 5: very difficult					
		Cost and time	3	3	1	3	3	1: low, 5: high					
		Priority to improve	2	5	3	4	1						

Competitive evaluation (1: low, 5: high)

Figure 3.14 Resulted of HOQ

This study's results show that developing a high-quality house satisfied the customer's requirement for an engineering aspect. The information gathered was then used to develop the technological solution. According to the HOQ survey, 'Ease of operation' is the most important functional criterion. For this reason, technical ease of use comes second in significance only to the "Project Dimension" because it has a much greater impact on the overall success of the project. Nevertheless, the 'Dimension of the project' will be taken into consideration. In addition to "Ease of operation," the "Project Dimension" must be discussed in detail. The 'Material type' chosen by the client was based on their needs. It's then essential to emphasize the 'cost of production' due of budget constraints. As a result, it is essential to perform market research on the current market price for 3D printing with a Sintering Laser System (SLS), nylon filament material, and other hardware components required for this project.

3.11.3 Three Selected Concept

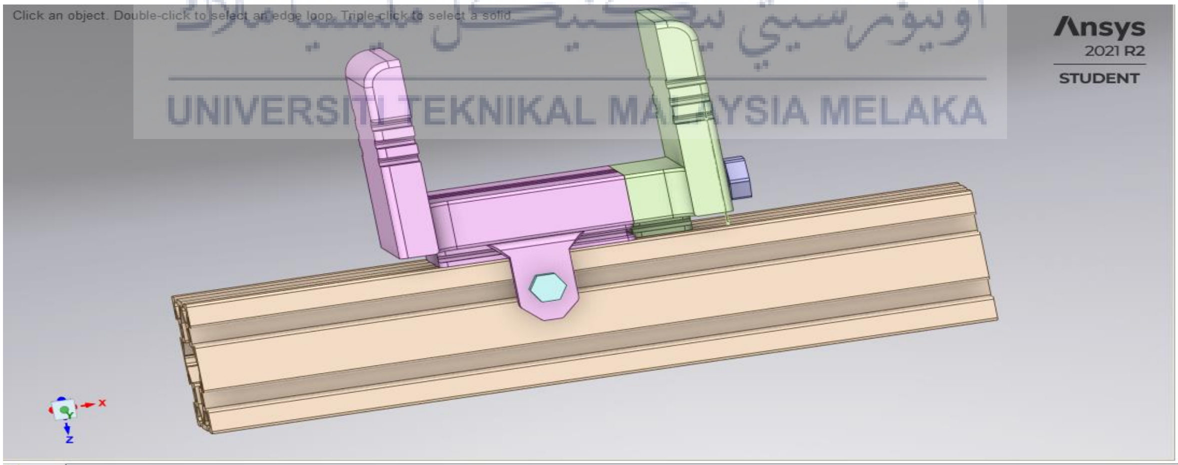


Figure 3.15 Design A

According to Pugh's Selection Method and the House of Quality, this concept design is the first best of five that have been created. Numerous factors, such as stability, resilience, and other factors, are considered during the selection process. The base just below the holder enables the screw adjuster to be rotated freely without colliding with the aluminum profile surface that securely holds the camera. As a result, durability and ease of use are the primary reasons for this design's significance.

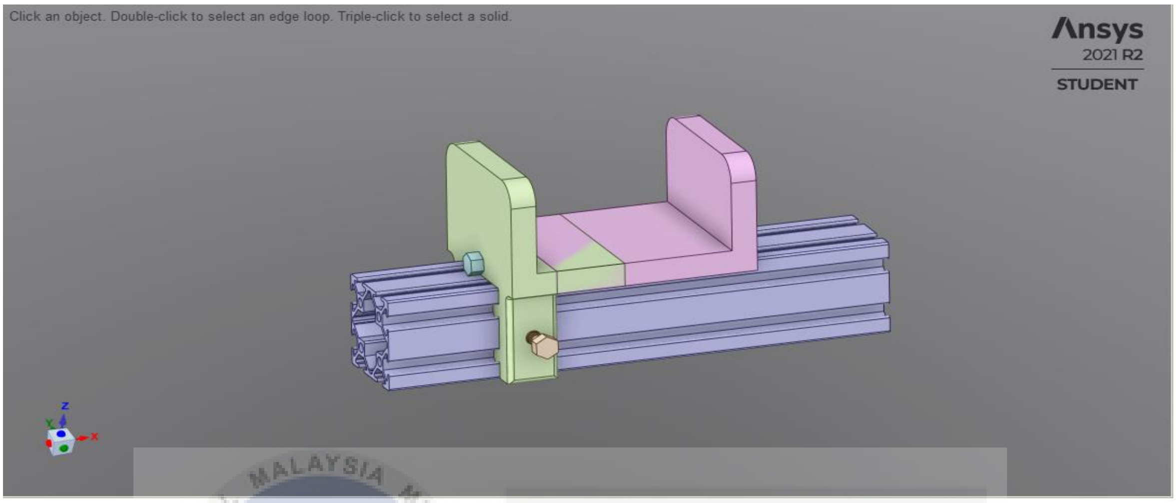


Figure 3.16 Design B

The distance between the holder and the aluminum profile surface best describes this conceptual design. It is stable and has a high durability. however, it is not easy to use because the adjuster screw is located close to the surface of the aluminum profile, making rotation a little difficult.

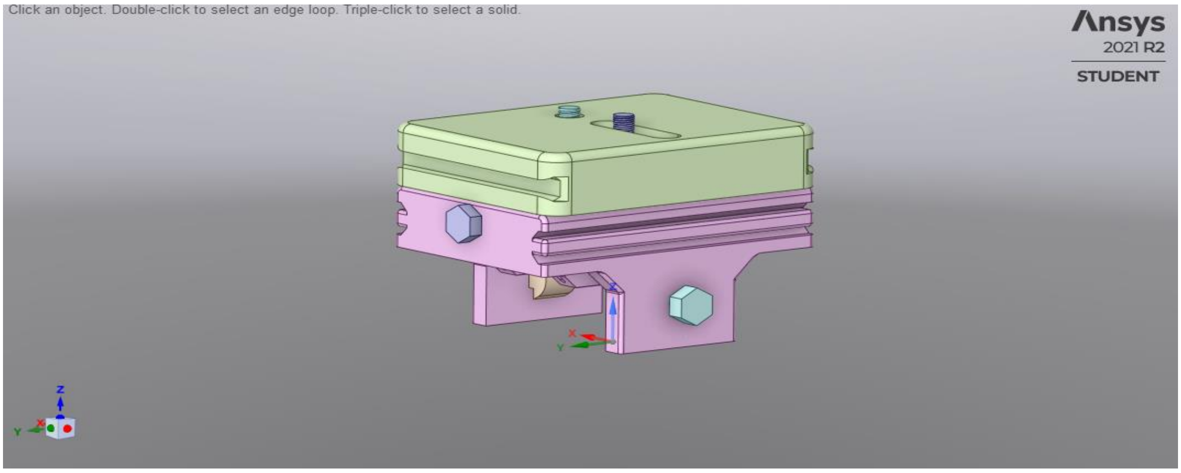


Figure 3.17 Design C

This design is more stable, long-lasting, and comfortable to use. However, this has a limitation in terms of holding various types of cameras with various designs.

3.12 Ultimaker Cura 4.12.1 software

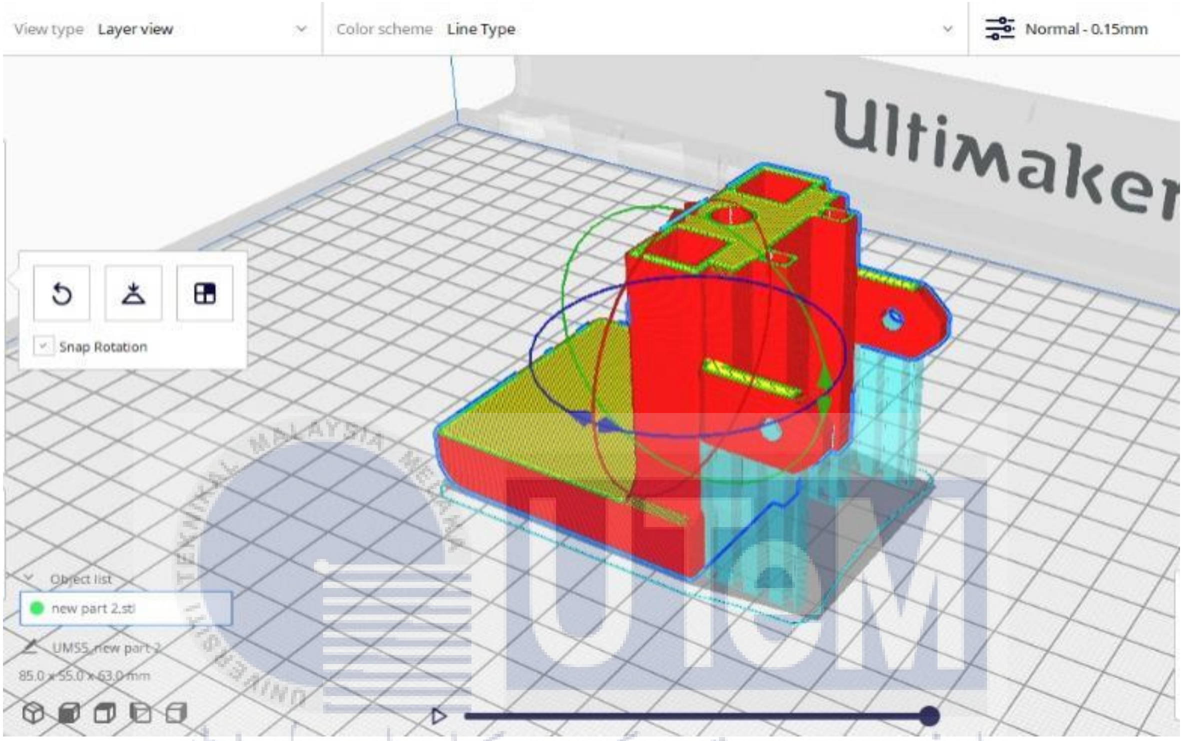


Figure 3.18 Part 2 design A

In order to guarantee that the measurements of each part are right and exact before printing, the Ultimaker Cura software is used. The software can also determine the weight of each part. This programmed can predict the amount of time it will take to complete the printing process.

3.13 3D printing (Sintering Laser Systems, SLS)

Figure 3.19 SLS Farsoon S402P

SLS is a modern method used for quick and low-cost component manufacture. SLS employs a laser to sinter powdered material (usually nylon or polyamide), automatically targeting the laser at places in space specified by a 3D model and binding the material together to produce a solid structure. Similar to selective laser melting, the two instantiations have the same notion but vary in technical detail. SLS is a newer technology, formerly utilized for quick prototyping and low-volume component part manufacture. Production positions expand as marketing of additive manufacturing improves. The printer warms the powder slightly below the raw material's melting point, allowing the laser to trace the shape more easily.

3.13.1 3D printing process

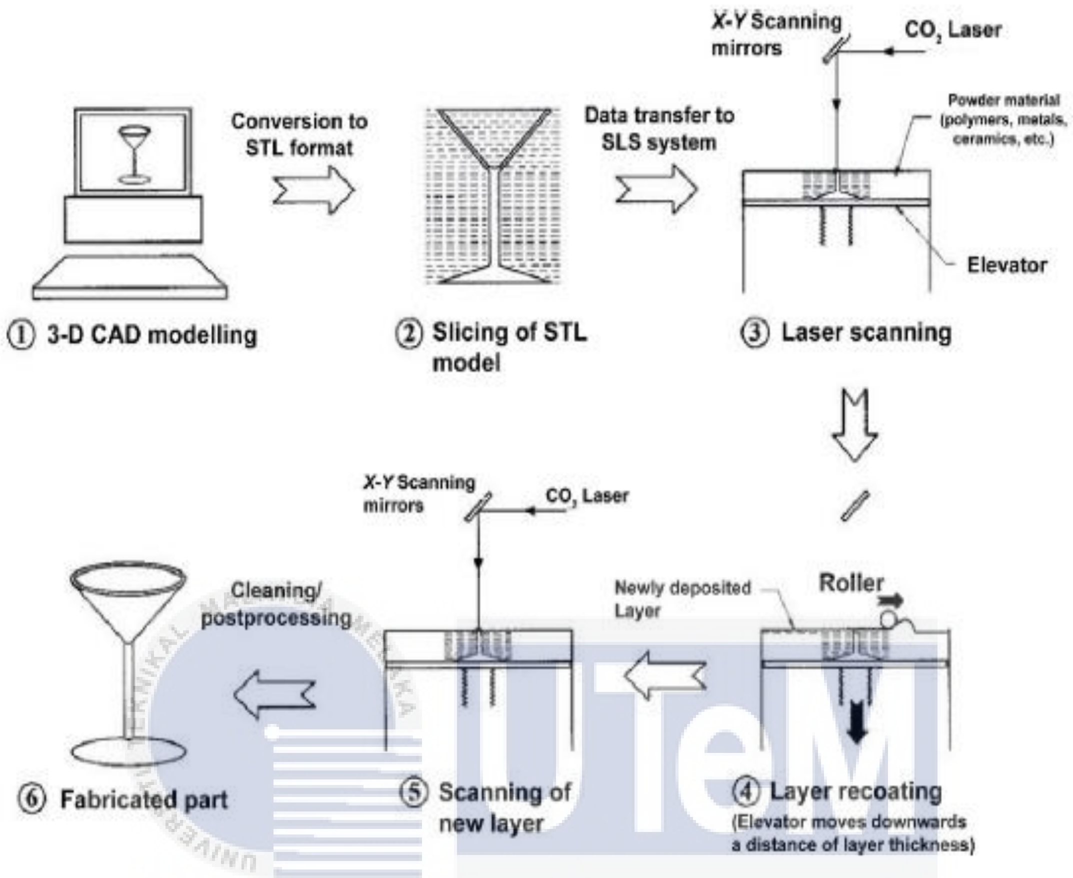


Figure 3.20 SLS process (Zhang, Fisher and Leong, 2015)

It is necessary to create the model in CAD software or 3D scan data, then export it in 3D printable file format (STL or OBJ). For each SLS printer, there's software for configuring print settings, positioning models, forecasting print times, and layering digital models. A print preparation software transmits printer instructions through wireless or cable connection after setup.

After all preprint checks are finished, the machine is ready to print. Depending on the part's size, intricacy, and density, SLS 3D printing might take hours or days. A small coating of powder is put on a platform within the build chamber. The printer warms the powder to just below the raw material's melting point, allowing the laser to target particular areas of the powder bed to solidify parts.

The laser scans a cross-section of the 3D model and melts the powder. This mechanically welds the particles together. No need for separate support structures since the unfused powder functions as a support structure during printing. The platform then falls one tier.

3.14 Aluminum Profile PS 5 Series

Figure 3.21 Aluminum profile 40 X 40 MM

The camera holder is moved the CCD camera along the 4040 aluminum profiles.

3.15 Bill of Material

Table 3.7 Material

No.	Material / Components	Quantity	Price (RM)
1	Bolt M8 - 55 mm	2	2.50

			
3	Butterfly bolt M5 - 10 mm 	2	3.30
5	T Block Square Nut Sliding M5 	2	4.30
6	Half Round Elasticity Elastic Spring M5	2	4.45

			
7	Self-adhesive Cushion Protector 	2	3.50
	TOTAL		**18.05**

3.16 Predicted result

It was expected that the camera holder would hold the camera securely and have the necessary balance to move the CCD camera without swaying or slipping. Particle image velocity (PIV) systems can benefit from the usage of CCD cameras for their measurement capabilities. Additionally, it is necessary to guarantee that the camera holder can be placed on an aluminum profile and that it may move freely. It is also expected that the design of the camera holder will have a solid structure in order for it to last for a longer period of time.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter describes the project's final findings and data analysis, as well as their implications. It will be necessary to simulate the collected data. To get a better result than other methods, use the Ansys workbench software for the most important sections of analysis. Ansys Workbench is a simulation tool for designers, engineers, and analysts that allows them to easily analyses fully featured CAD assembly. This is achieved by eliminating geometry preparation and meshing, two of the most time-consuming and labor-intensive tasks in a normal structural simulation. Chapter 4 focuses into the components of designs A, B, and C. A design view, an orthographic component view with dimensions, and finally an exploded design view. The flow chart below illustrates how activities are performed in sequence.

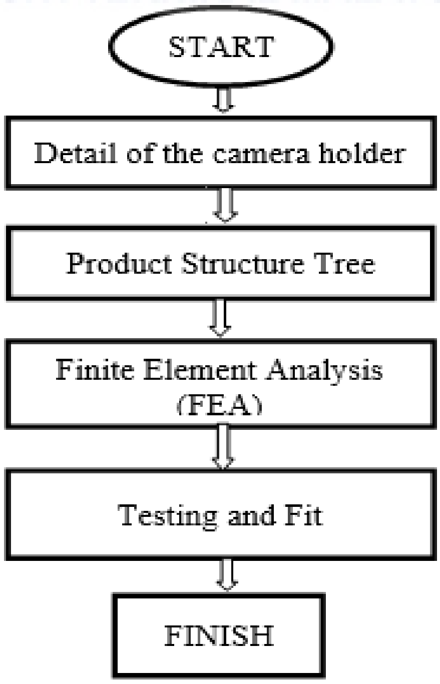
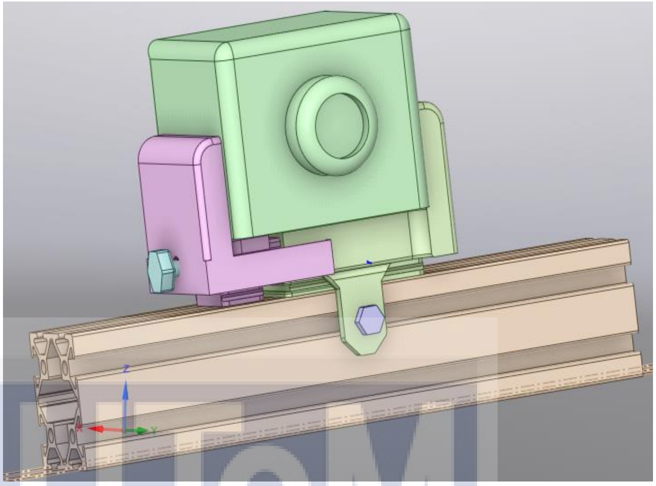


Figure 4.1 Flow chart of working process of chapter 4

4.2 Detail of the camera holder

Table 4.1 Criteria from the best concept design

Criteria	Design A
• Easy to adjust skrew adjuster • Waterproof material • Comfortable • High durability • Securely grip the camera	

There are five criteria of concern that must be considered on the cast in order to achieve the best concept design possible. The 3d - printed camera holder criteria are visualized in the Table 4-1. All of these criteria were developed with the help of the CATIA and ANSYS software applications. This model of camera holder is suited for use with any model of CCD camera manufactured by the TSI company

4.3 Selection Method

4.3.1 Pugh Selection

Table 4.2 Pugh selection method table

Selection Criteria	A	B	C	D	E
Size	0	+	0	0	+
Stability	+	+	0	+	0
Cost	0	0	0	-	+
Easy to use	+	0	-	0	-
Lightweight	-	+	0	-	0
Durability	+	-	+	+	-
Comfortability	+	0	+	0	0
Sum +	4	3	2	2	2
Sum 0	2	3	4	3	3
Sum -	1	1	1	2	2
Net score	3	2	1	0	0
Rank	1	2	3	4	5

The Pugh method resulted in an overall net score gain of three points for design A, placing it in first place overall and in first place overall net score gain. Design B takes second place with two points, followed by designs C, D, and E, which take third, fourth, and last places with one, zero, and zero points, respectively. The fact that one of the most essential attributes of a product is that it is simple to use demonstrates that customers are drawn to items with easy design features. The design's high level of stability offers users with a high level of comfortability because of its simple. In addition, design A is visually appealing, which increases its appeal to potential buyers as a result of this. When comparing design A to designs B, C, and D, design A is the most comfortable.

4.3.2 House of Quality

Table 4.3 Resulted of HOQ

DESIGN A	DESIGN B	DESIGN C	DESIGN D	DESIGN E
4	4	3	4	5
5	4	5	3	4
4	3	4	3	3
3	4	3	3	4
4	5	3	4	4
5	3	4	3	2
5	3	4	3	3
5	4	3	4	2
1277	1044	1058	972	937

According to the outcomes of the analysis carried out using the house of quality technique, there are five designs that have been evaluated, with three of the five designs getting the highest possible scores in the examination. It is required to investigate the relationship between customer requirements and Functional Requirements in order to make these evaluations.

As shown in the Table 4-3, Design A achieved the highest score of 1277, while Design C and B obtained scores of 1058 and 1044 to position them in second and third place, respectively. All three designs (A, B, and C) will be subjected to a final review by the FEA before being made accessible for 3D printing. Finally, the outcomes of the FEA investigation will have a significant impact on the final design.

4.4 Technical drawing

An orthographic perspective displays an object's top, front, and side views. a 45-degree sheet of paper displays the object's 3D geometry. An orthographic view can show the object's dimensions and scale. An exploded view, also known as a technical drawing, shows the interrelationships of an object's parts. It shows the component with a slight space between them to properly create it.

4.4.1 Orthographic View

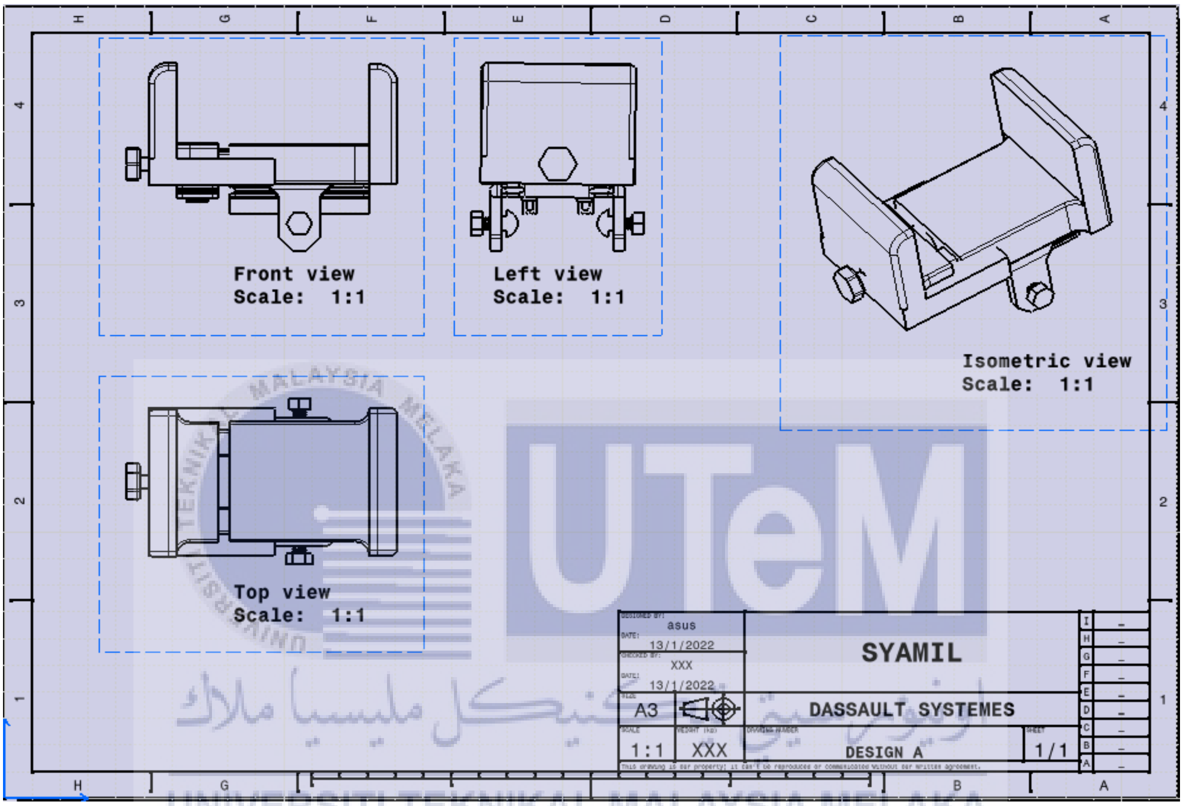


Figure 4.2 2D drawing of design A

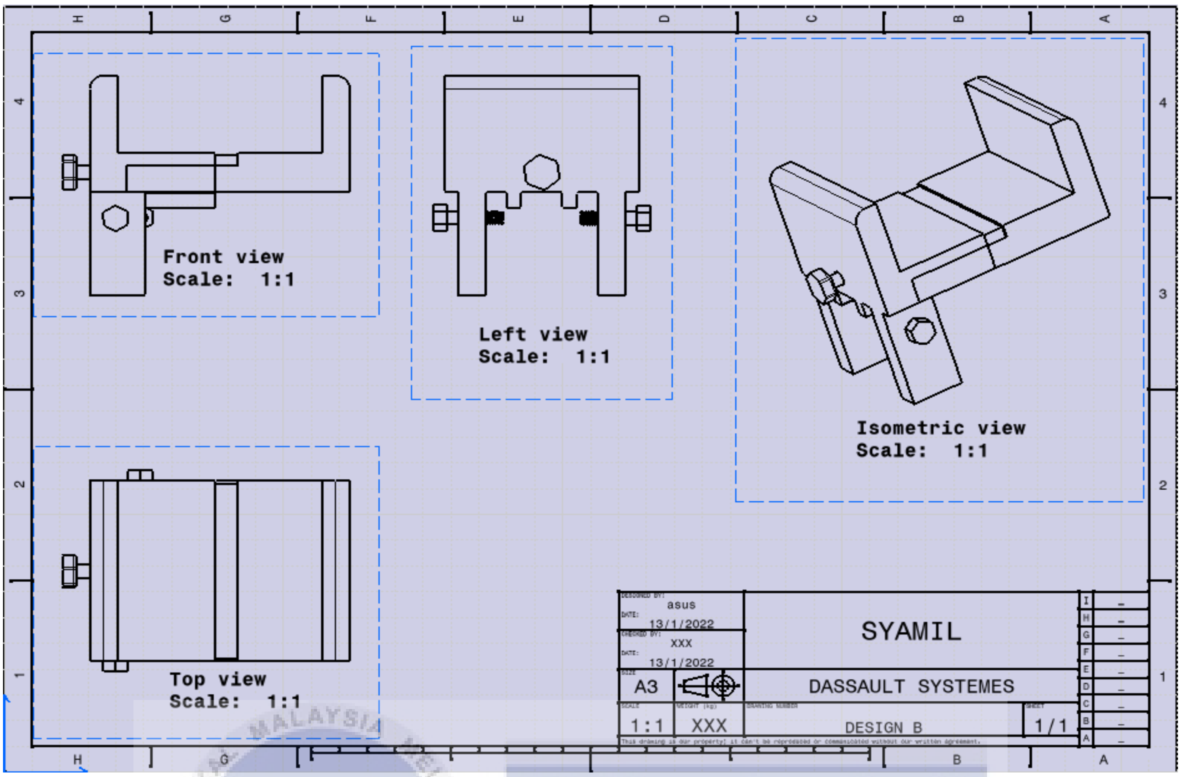


Figure 4.3 2D drawing of design B

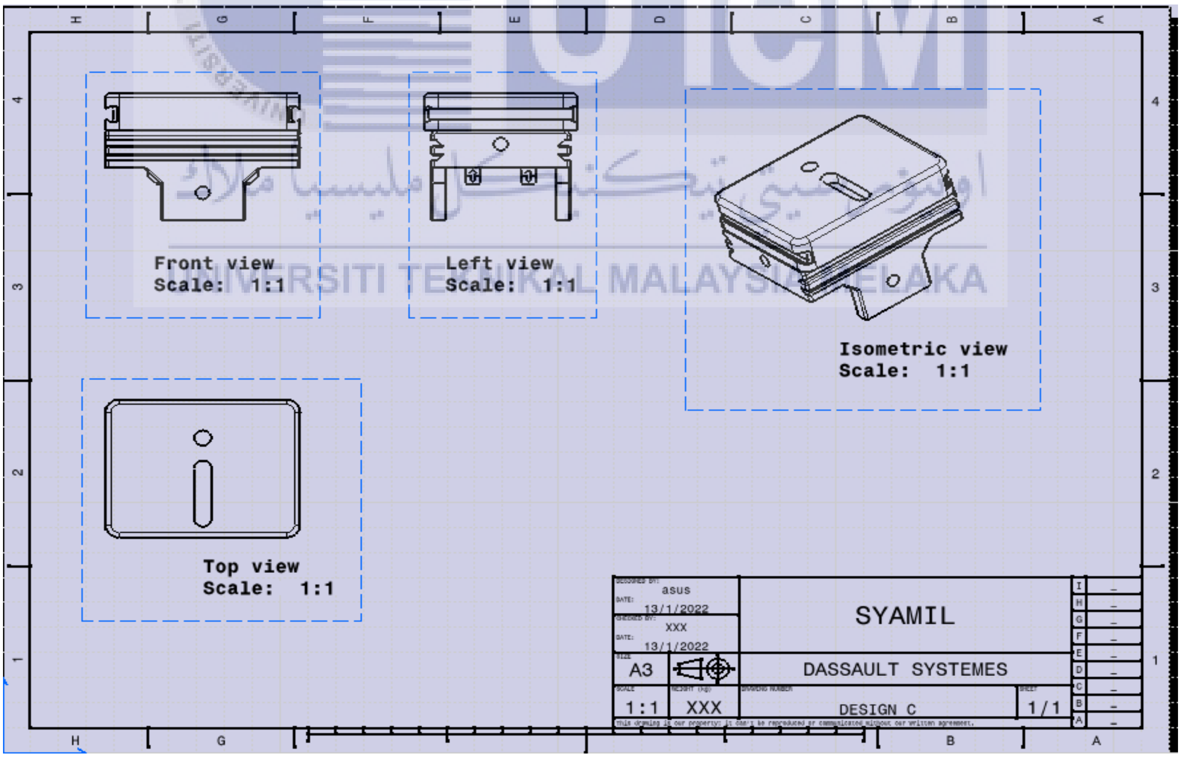


Figure 4.4 2D drawing of design C

As with the design illustrated above, design C is unique from designs A and B in that it is designed to keep the camera utilizing screws attached below the camera, while designs

A and B do not. Additionally, Designs A and B secure the camera by compressing its left and right sides.

Additionally, it is proved that when the load distribution process is used, design A is much heavier than designs B and C. Thus, the procedure of assembling design components A and B is basically similar. As a consequence, in comparison to design C, which includes a plate for mounting the camera and a base for mounting the plate, and is placed on aluminum profile rails, design C includes only a plate for mounting the camera.

4.5 Tree Diagrams of the Structure

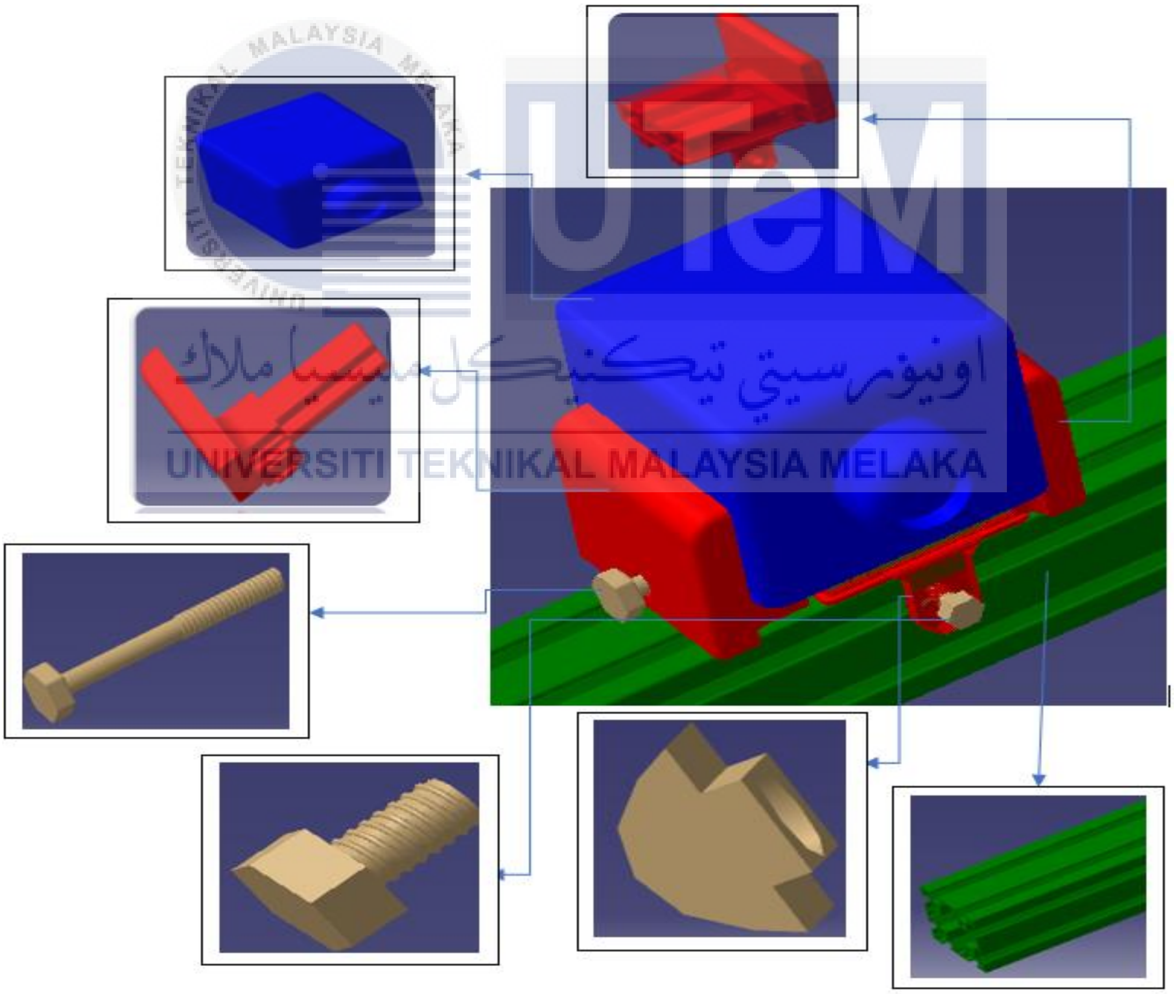


Figure 4.5 Assembly of All Parts

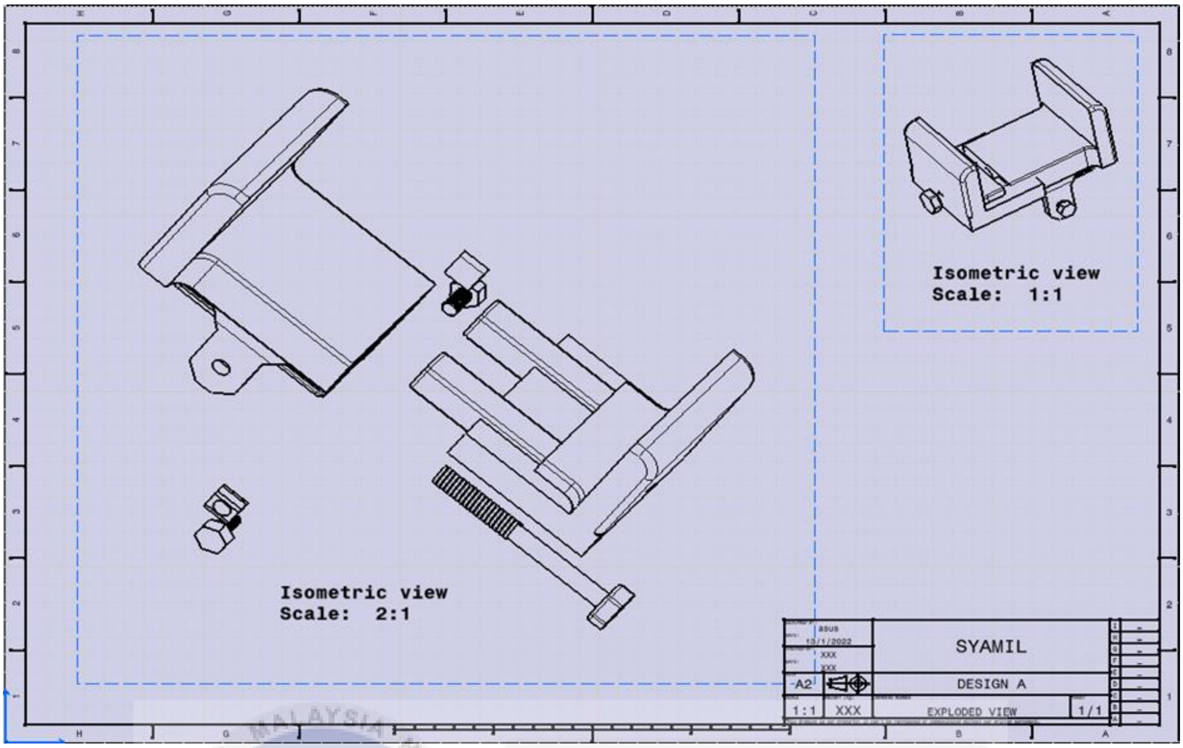
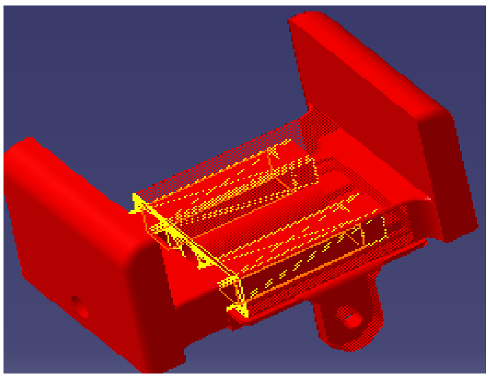


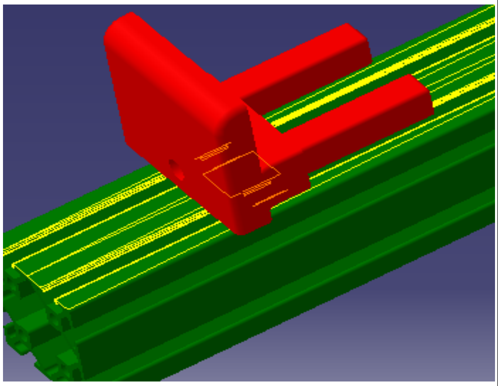
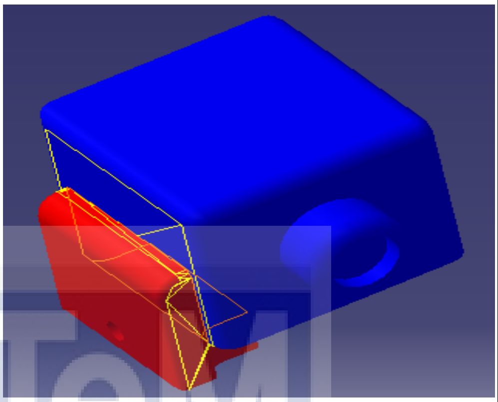
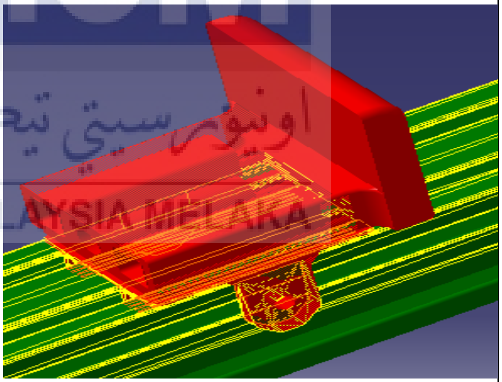
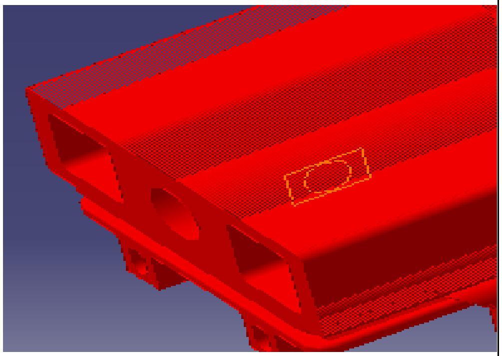
Figure 4.6 Exploded drawing of design A holder

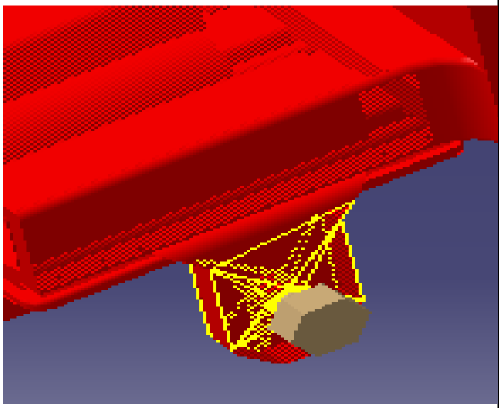
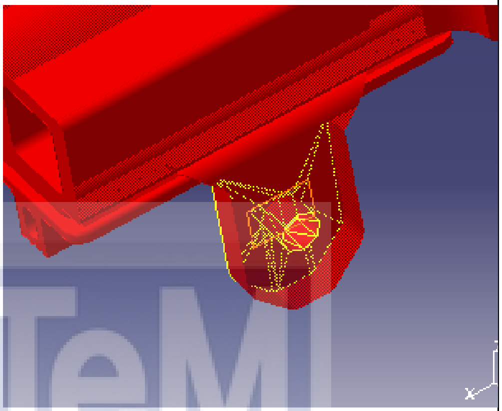
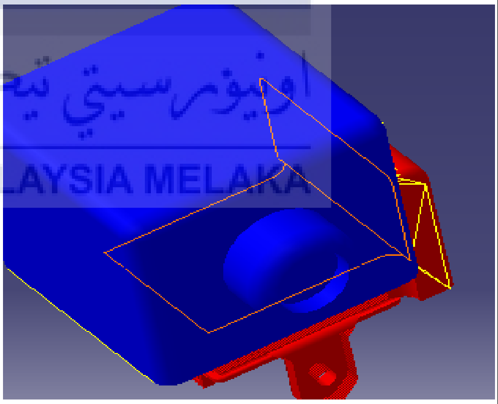
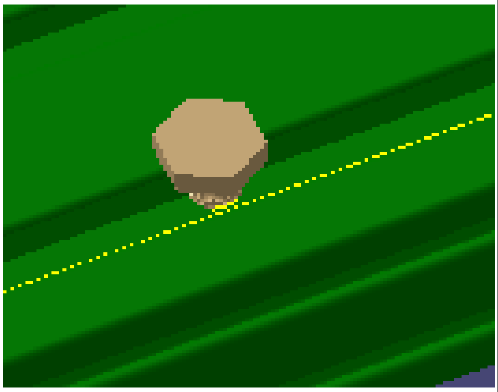
Figure 4-5 and 4-6 shows the part assembly of design A in its completed form. Following the completion of the detail drawing, all of the pieces will be integrated to make the Tree diagram structure and exploded drawing view.

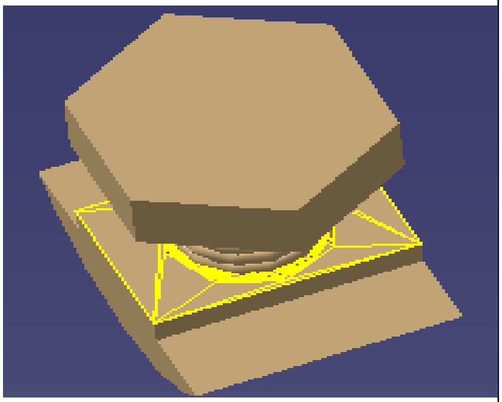
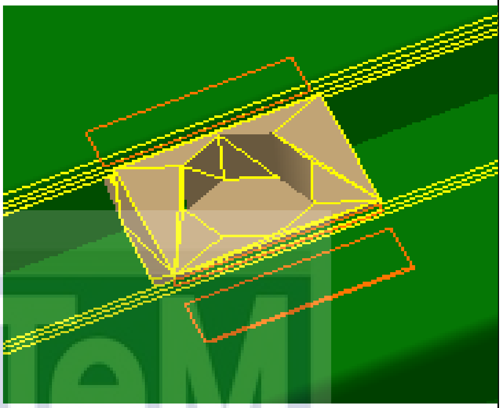
4.6 Analyze the clash between all components

Table 4.4 The result of each component's clashing check

No	Type	Status	Picture
1	Contact	Relevant	

2	Contact	Relevant	
3	Contact	Relevant	
4	Contact	Relevant	
5	Contact	Relevant	

6	Contact	Relevant	
7	Contact	Relevant	
8	Contact	Relevant	
9	Contact	Relevant	

10	Contact	Relevant	
11	Contact	Relevant	

Based on the clash analysis result in Table 4.4, it is critical to do static collisions in CATIA, which is a strong tool that can discover regions of interference, contact, and minimal emission violations. The results in Table 4.4 demonstrate the importance of performing static collisions in CATIA. According to the table results, Design A has the correct dimension value for each component when the analysis results show that there is no contact or clash that causes the connection of parts to be incorrect and collide with each other. It is possible to save the 3D CAD files as STL files, which makes them safe to use in the subsequent process of printing prototypes using 3D printing.

4.7 Load Distribution

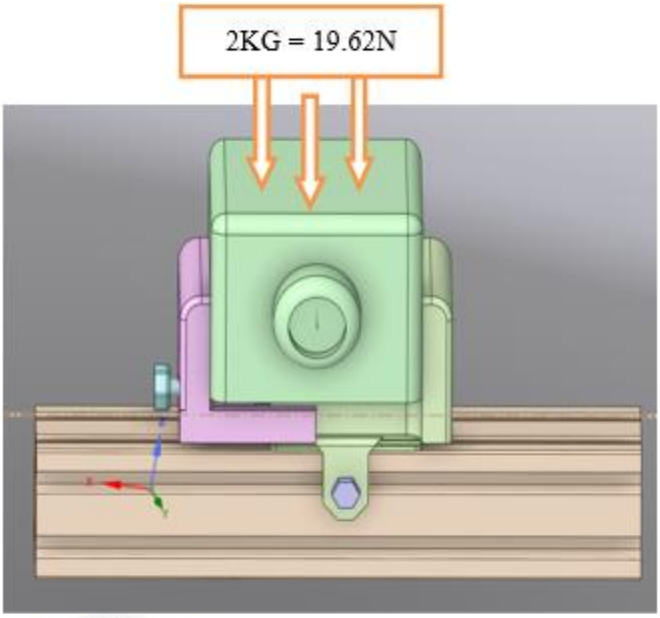


Figure 4.7 Distribution of force at the camera holder

The total amount of weight that may be safely stored by the holder while in a fixed posture is referred to as static weight. It is required to execute a load distribution test on the components of the handle before performing a detailed analysis on each section of the holder design. It is necessary to execute this test in order to obtain a rough analysis of where the force is concentrated while holding the camera. The component can be found at the very top of the camera holder's design. After that, the static structure was stimulated in order to collect the information that was needed. It is as a result of this that the camera weighs 19.62 N.

4.7.1 Load distribution data of design A

Table 4.5 Mass of all component

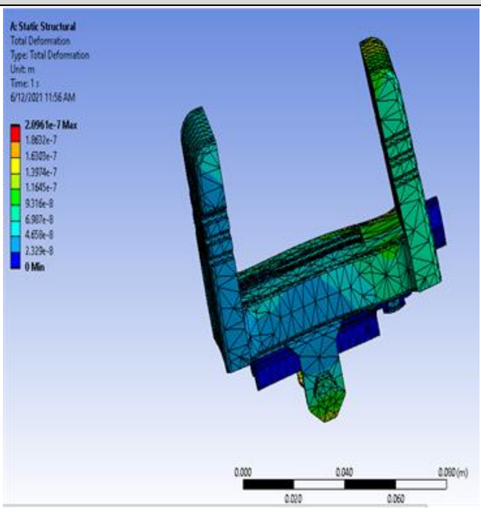
Parts	Quantity	Mass (kg)
Holder	2	0.13
M8 bolt	1	0.04

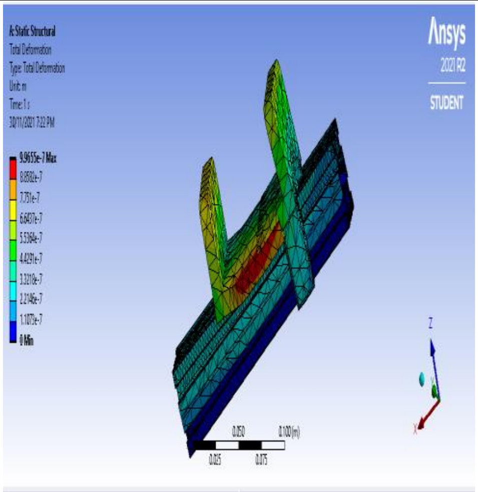
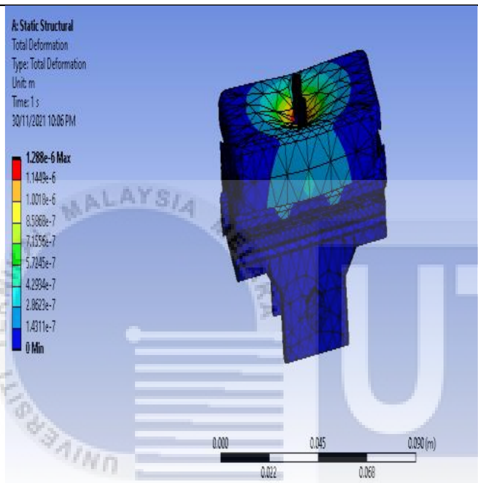
M5 Butterfly bolt	1	0.03
M5 T-nut	2	0.03
Camera	1	2

4.8 FEA Analysis

A total deformation and equivalent stress analysis is the process of analyzing the "Total deformation" and "Equivalent stress" modes of a model by taking into account the "Total deformation" and "Equivalent stress" of all the parts of a selected design, Design A, Design B, and Design C. The results of the FEA analysis of all designs of the selected design from the best idea are shown in Table 4.6 below.

Table 4.6 Resulted of FEA analysis of Total Deformation

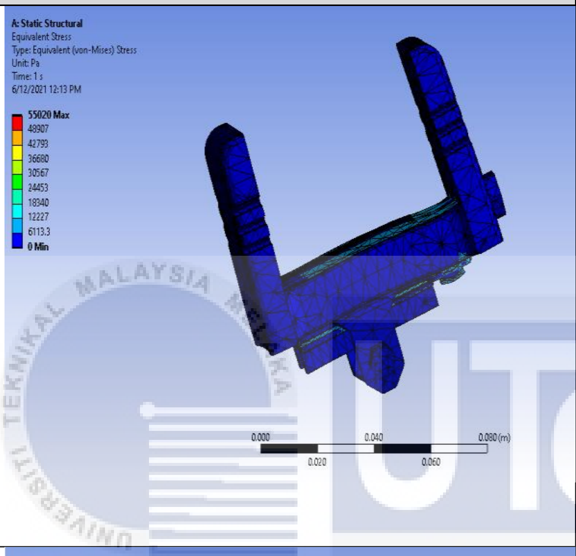
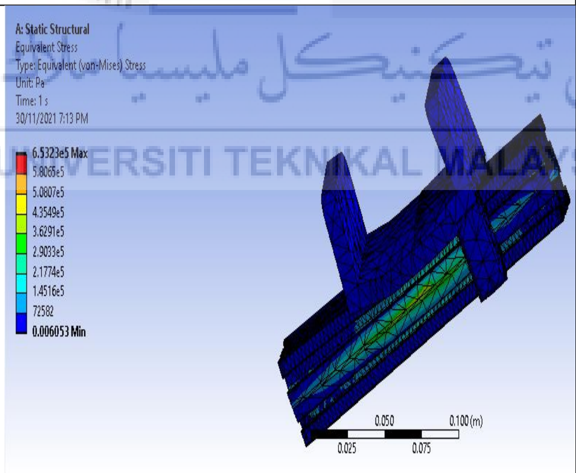
Force: 19.62 N	**Figure result analysis of Total Deformation**	**Maximum, (m)**	**Minimum, (m)**
Design A		2.0961x10^-7	0

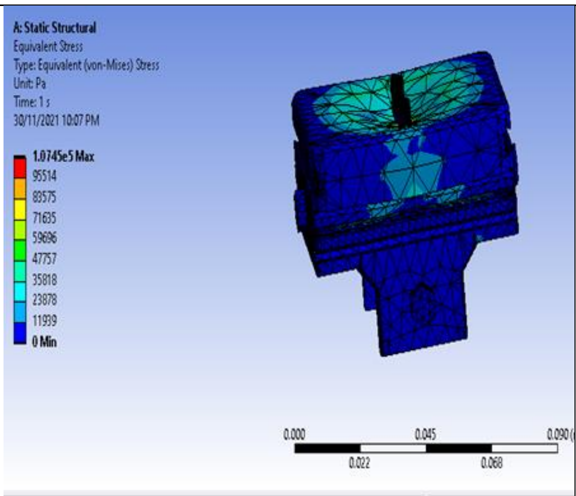
Design B		9.9655x10^-7	0
Design C		1.288x10^-6	0

For the total deformation generated by the solid camera holder design, the results of the finite element analysis (FEA) are shown in Table 4.6. When the color red is used to describe the position of the greatest deformation, green is used to represent the site of medium deformation and blue is used to represent the area of the smallest deformation. The findings of finite element analysis are influenced by factors like as geometry and materials.

According on the geometric patterns used, different deformation results can be obtained. The camera holder from design A displays the smallest amount of deformation when compared to designs B and C, as can be seen in table 4.6, with maximum values of 2.0961x10-7 and 2.329x10-8 together. This results in Design A having the smallest red marks, which indicate the highest pressure, while having a great number of blue markings, which indicate the lowest pressure.

Table 4.7 Resulted of FEA analysis of Von Mises Stress

Force: 19.62 N	**Figure result analysis of Von Mises Stress**	**Maximum stress, (Pa)**	**Minimum stress, (Pa)**
Design A		55020	0
Design B		6.5323x10^5	0.006053

Design C		1.0745x10^5	0

According to Table 4.7, when a force of 19.62 N is applied to the model's stress generator, the model generates the greatest amount of stress. Due to the fact that the model is not sturdy enough to withstand the enormous power that has been put to it, this has occurred. Additionally, the results of this research are reported in Tables 4.7. The number of Von Mises Stress data points at the maximum and minimum levels is presented in the table.

In terms of maximum and minimum values, Design A has the lowest maximum and minimum values when compared to Designs B and C, based on the available data. Following consideration of the model's design and geometry, it is concluded that the results of the evaluation of the maximum and minimum values of stresses in Pa are determined. Based on the FEA results and the explanation above, it is possible to conclude that design A received the best overall outcome in the test. As a result, design A was chosen and will now be put through the 3D printing process.

4.8.1 Factor of safety (FOS)

Safety factor is a straightforward measure that assesses the safety of a design, assisting designers in determining if the design they have produced or manufactured is safe for user usage or not. The straightforward factor is often referred to as the safety factor. The objective of design analysis is to arrive at a safe design. When a design fails, it may result in a danger to human life and a significant financial loss. The safety factor is calculated using the formula shown below.

$$\text{Factor of safety, FOS} = \frac{\text{Ultimate stress}}{\text{Material strength}}$$

Table 4.8 Result of Safety Factor

Force applied: 19.62 N	Material strength (Pa), Nylon	Ultimate stress (Pa)	Factor of Safety
A	4.6e+7	55020	0.012
B	4.6e+7	6.5323x10^5	0.014
C	4.6e+7	1.0745x10^5	0.023

The highest safety factor is achieved by Design C when the applied load is 19.62 N, and the lowest safety factor is achieved by Design A when the applied force is 19.62 N, according to Table 4-8. Because the safety factor is dependent on the loading conditions as well as the risks of failure or unacceptable performance, this Safety Factor selection is reasonable from a logical perspective. The safety factor is not increased because the applied force is lower; rather, it is increased because the ratio of ultimate pressure to working pressure is increased. When it comes to safety factors, the design pattern is really significant. Although design A has the lowest safety factor when compared to designs B and C, this does not mean that designs B and C are completely unsafe to use.

4.9 The hour of 3D printing

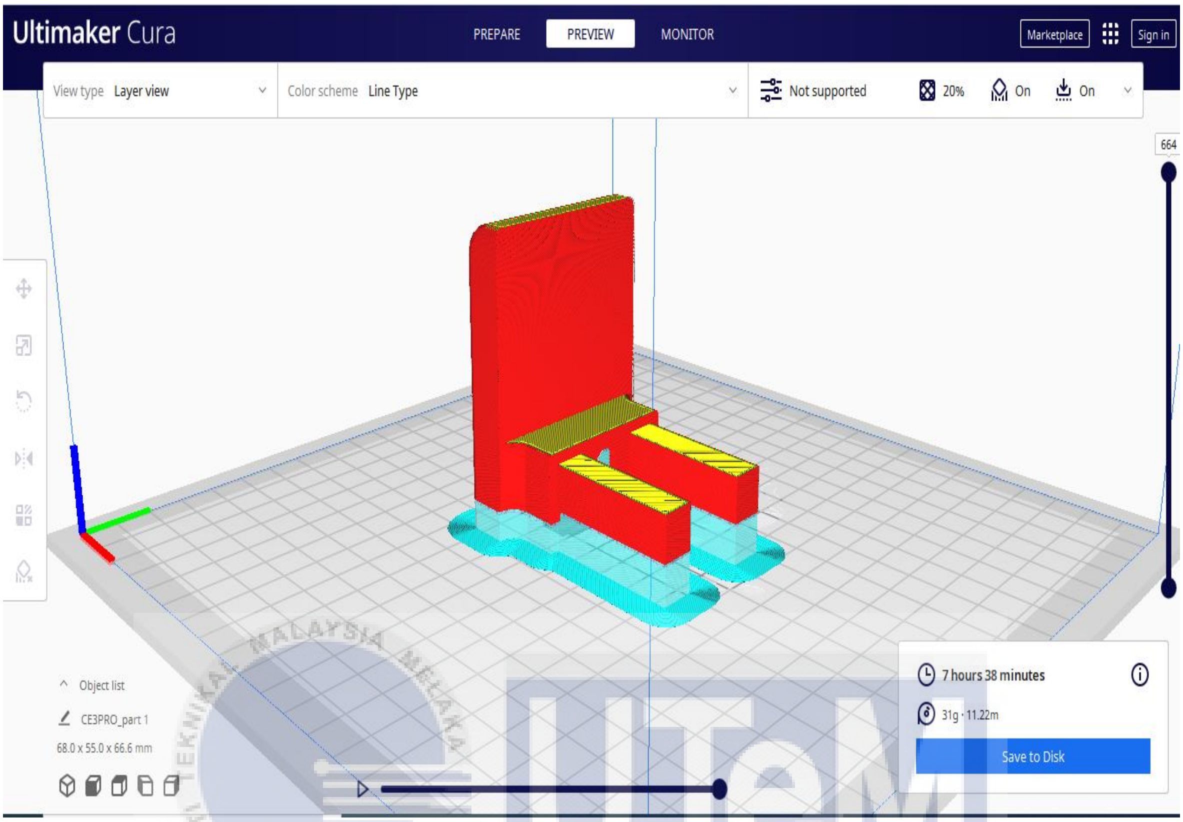


Figure 4.8 Printing hour of holder part 1

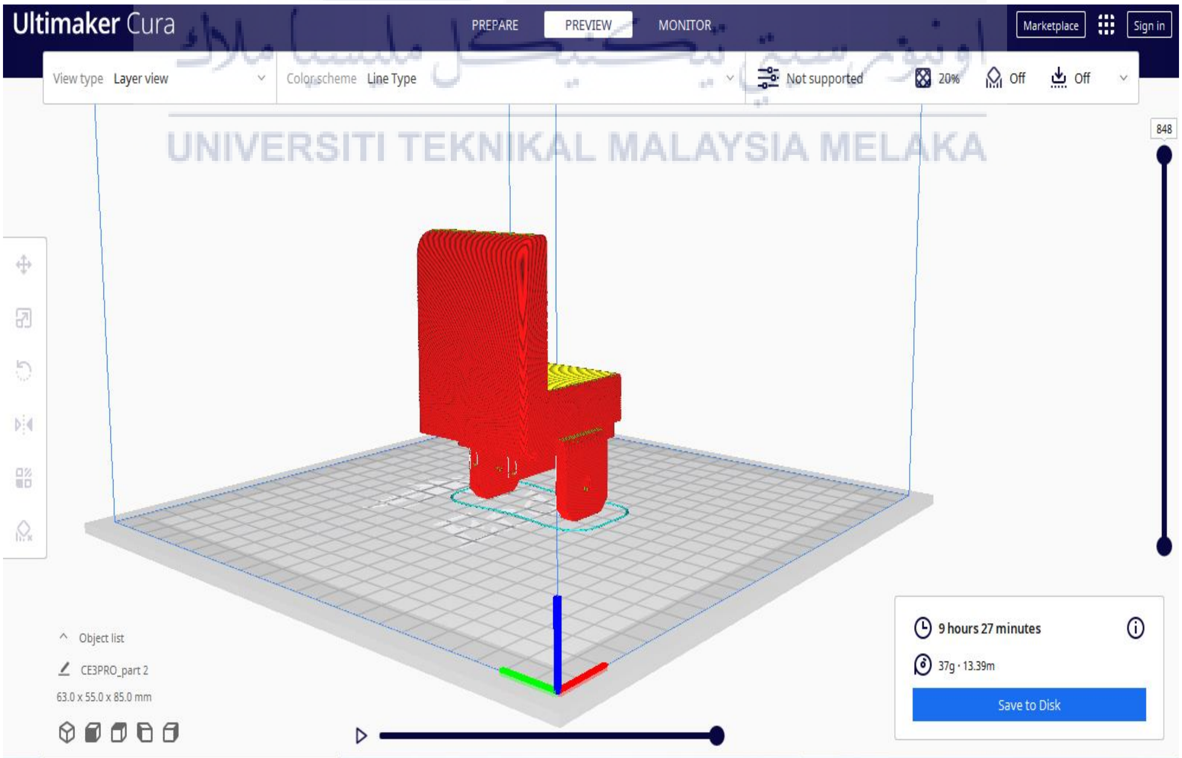


Figure 4.9 Printing hour of holder part 2

Based on the figures 4-9 and 4-9 above, the calculation of the number of hours required to print parts on a Creality Ender CR-6 FDM 3D printer using the Ultimaker Cura software is shown in the given figure. Design of the Holder, Part 2 The number of printing hours required is more than that required for the holder part 1 design. When considered logically, the holder part 2 design is expected to need the greatest number of printing hours due to the fact that the design has a larger geometric size to print when compared to the holder part 1 design. Design holder part 2 requires 9 hours and 27 minutes to completely finish the printing process, but design holder part 1 requires just 7 hours and 38 minutes to complete the printing process.

However, due to a lack of time for other tasks, the printing process used for the parts was changed to the SLS 3d printer, which was more efficient (SS402P). The SS402P SLS 3D printer was selected for this project because of its ability to reduce printing time. The majority of designs, even those with intricate or challenging forms, may be produced in one to two days. In addition, as compared to FDM 3D printing machines, SLS printing machines can produce all of the components at the same time. Because of this, using SLS type 3D printing as the primary additive manufacturing process for component printing is an excellent decision.

4.10 Testing and Fit

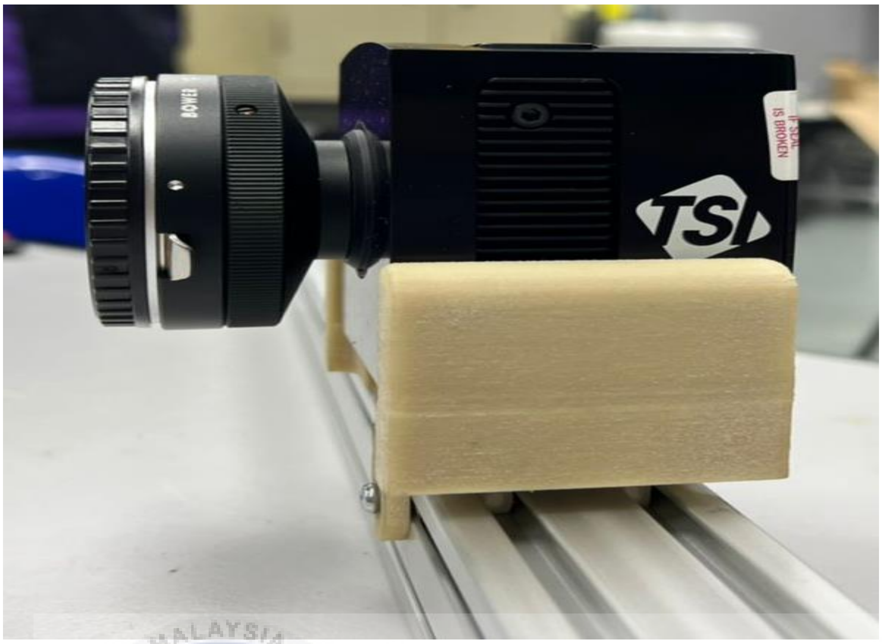


Figure 4.10 The position of the camera condition on the holder

Designing this camera holder begins with the design idea that has been chosen and continues from there. Because of the slider design under the camera holder, which works to move the camera holder on aluminum profile rails, this product has a lot of flexibility in terms of positioning. The pre-installed camera holder is ready to be used with a CCD camera that may be mounted and tested directly on the aluminum profile that was previously installed. Figure 4.10 above illustrates the finished product.

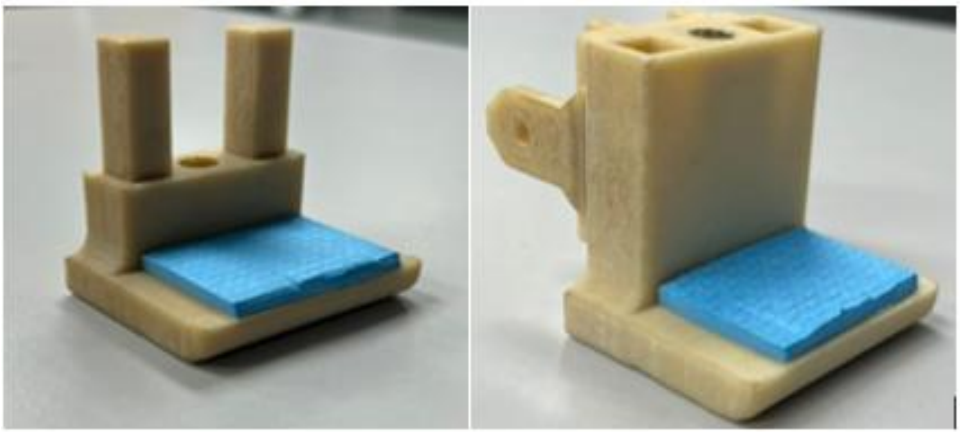


Figure 4.11 Self-adhesive Cushion Protector was used on both the holder

The first issue that appears after attaching the CCD camera to the holder is that the camera does not lock firmly in place after being attached. According to Mrs. Fadhilah's discussion, the Supervisor agreed to insert rubber into each of the left and right holders of the camera in order to ensure that the camera is held firmly and does not cause harm to the CCD camera. The figure above shows the design of the holder after the Self-adhesive Cushion Protector has been applied.

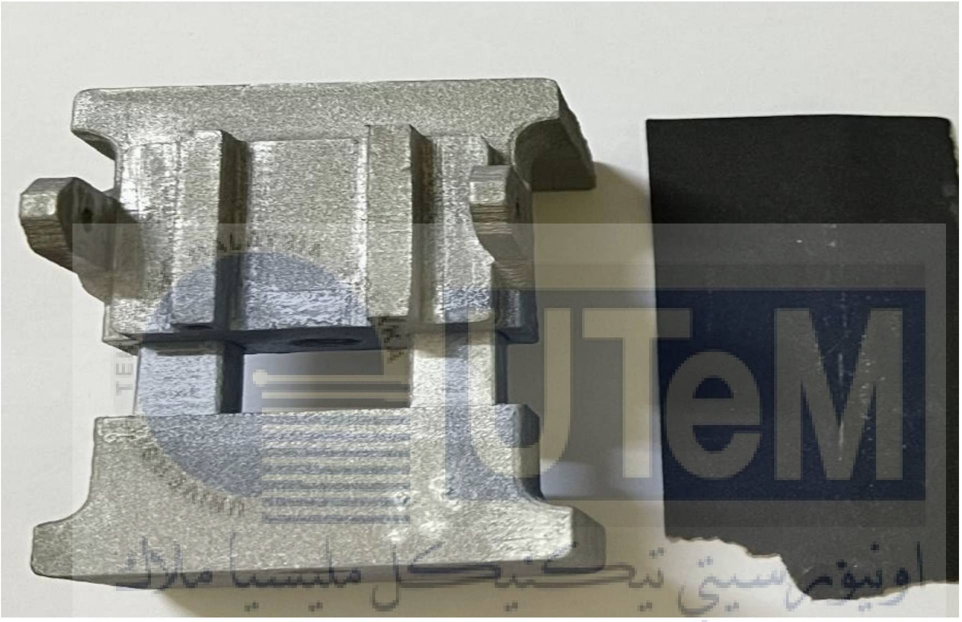


Figure 4.12 The surface of the slider holder with sandpaper

Because of the high friction force between the slider holder and the aluminum profile, the CCD camera's movement is limited as shown in Figure 4.12 above. This is due to the non-slippery or too tight fit of the slider holder's surface with the aluminum profile. The surface of the slider and the bottom side of the lock holder must be smoothed off with sandpaper in order to allow for smooth motion of the camera holder along the aluminum profile.

Figure 4.13 Butterfly head screw M5 used as a lock holder

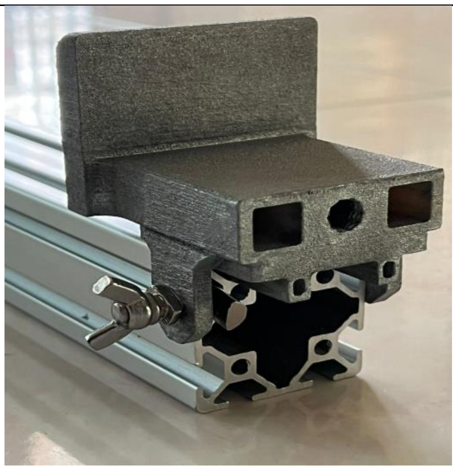
Initially, a standard m5 screw was utilized as a holder movement lock on the aluminum, but this was soon abandoned. In reality, opening and tightening the lock will be a bit tough due to the fact that it will require the use of a screw driver to open and tighten it. Accordingly, as illustrated in figure 4.13, the butterfly head screw is employed to make it easier for the user to tighten and adjust the lock of CCD camera holder.

4.10.1 Procedure to assemble part of the camera holder

The steps in assembling the prototype are depicted in the table 4.9 below, which is illustrated by a photo.

Table 4.9 Assemble procedure of the CCD camera holder

Step	Picture
Step 1: The first step is to attach the part 2 handle to the aluminium profile and check that the slider fits properly within the aluminium rails. After that,	

insert the t-nut into the aluminium rails and secure the holder with butterfly head screws on both the left and right sides.	
Step 2: The second step is to take part 1 holder and insert it into holder part 2 properly, making sure that part 1 holder can come out and enter through the hole in the holder part 2.	
Step 3: The final step is to properly insert the M8 bolt into the holder by using a richet and box 13 to tighten and loosen the holder.	

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The results of the study were reported in this chapter, as well as proposals for further research in the future. In general, a significant amount of research has been done into developing CCD camera holder prototypes using additive manufacturing techniques, both in terms of analysis and manufacture, in order to determine the optimal sample selection for usage in production. The conclusion section contains information such as an overview of the research and a summary of the findings. In the recommendations section of the paper, it is urged that this project be further investigated and developed.

5.2 Conclusion

In this research, the first aim is to build and model a CCD camera holder for use in a Particle image Velocimetry (PIV) system located in an advanced fluid mechanics laboratory, UteM. Overall, this aim was accomplished by the construction and design of a camera holder model in CATIA V5R21an software, which was then filtered and analyzed in Ansys Workbench software to determine the status of the simulated prototype after a force was applied.

Based on Von Mises stress and total deformation, a comparison of the whole analysis was made. For each model, the results of the study may be used to determine the safety of factor values. After printing the prototype using nylon material (FS 3401GB and FS 3300PA) on an SLS 3d printing process, the prototype camera holder is subjected to multiple tests with the CCD camera model 630090 from the TSI company, and it has shown to be capable of performing the task.

A recent study found that holder for CCD cameras has the most potential for growth in the real market. In general, the additive manufacturing technology is appropriate for the production of camera holders, but the kind of material used and the design of the prototype are important considerations in this process. For this reason, it is required for future studies to investigate and explore a variety of handle designs that are more compatible with this project in order to improve its compatibility.

5.3 Recommendation of future development

With all of the data, this project can always be improved; here are some thoughts for how this project may be improved in the future:

- On an aluminium profile, create a camera holder design that can be moved in all directions (forward, backward, left, and right).
- Improve the design of the holder with the use of a roller or ball bearing that can provide smooth movement of the holder on the aluminium profile.
- Instead of utilising screws to tighten the holder, alternative tools such as springs, iron rods, clips, and magnets can be used.
- Consider a new material type for the same manufacturing procedure.

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[58] □□□□□□□□□*)* □□□□□□ □□□ □□□□□□ □□□□□□ (1375) كريستينا، رود. كوكورس □□□□□□□□ □□□□□ □□□□ □□□□□□□ □□□□□□□□ □□□□□□*."(*□□□□□□□ □□□□□□*No Title*.

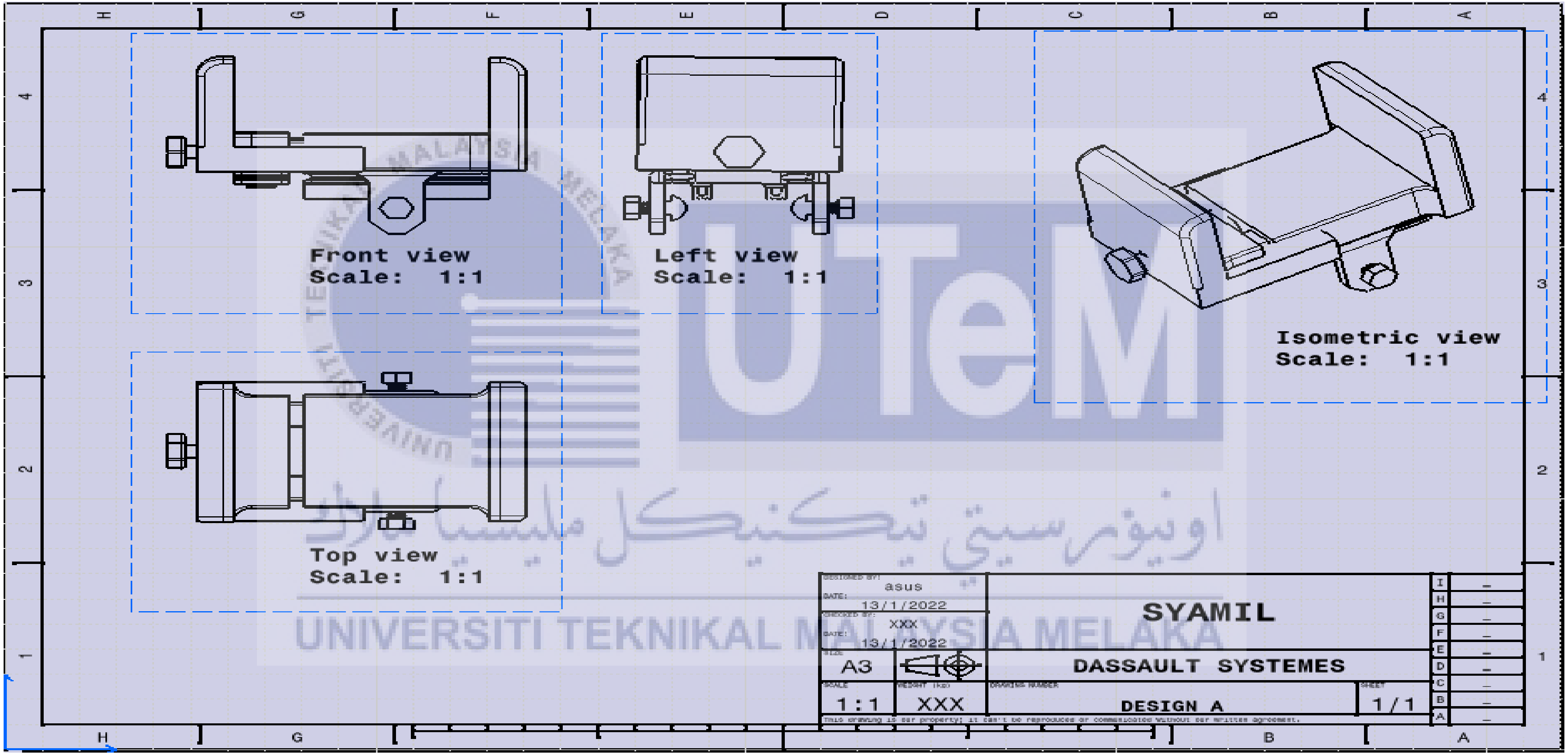
APPENDICES

APPENDIX 1 FEA parameter for nylon (PA 66)

Property	**Value**	**Unit**
Density	1140	kg m^-3
Derive from:	Young modulus and Poisson's ratio	
Young modulus	2.700 e^+9	Pa
Poisson's ratio	0.39	
Bulk modulus	4.0909 e^+9	Pa
Shear modulus	9.7122 e^+9	Pa
Yield strength	5 e^+7	Pa
Tangent modulus	0	Pa

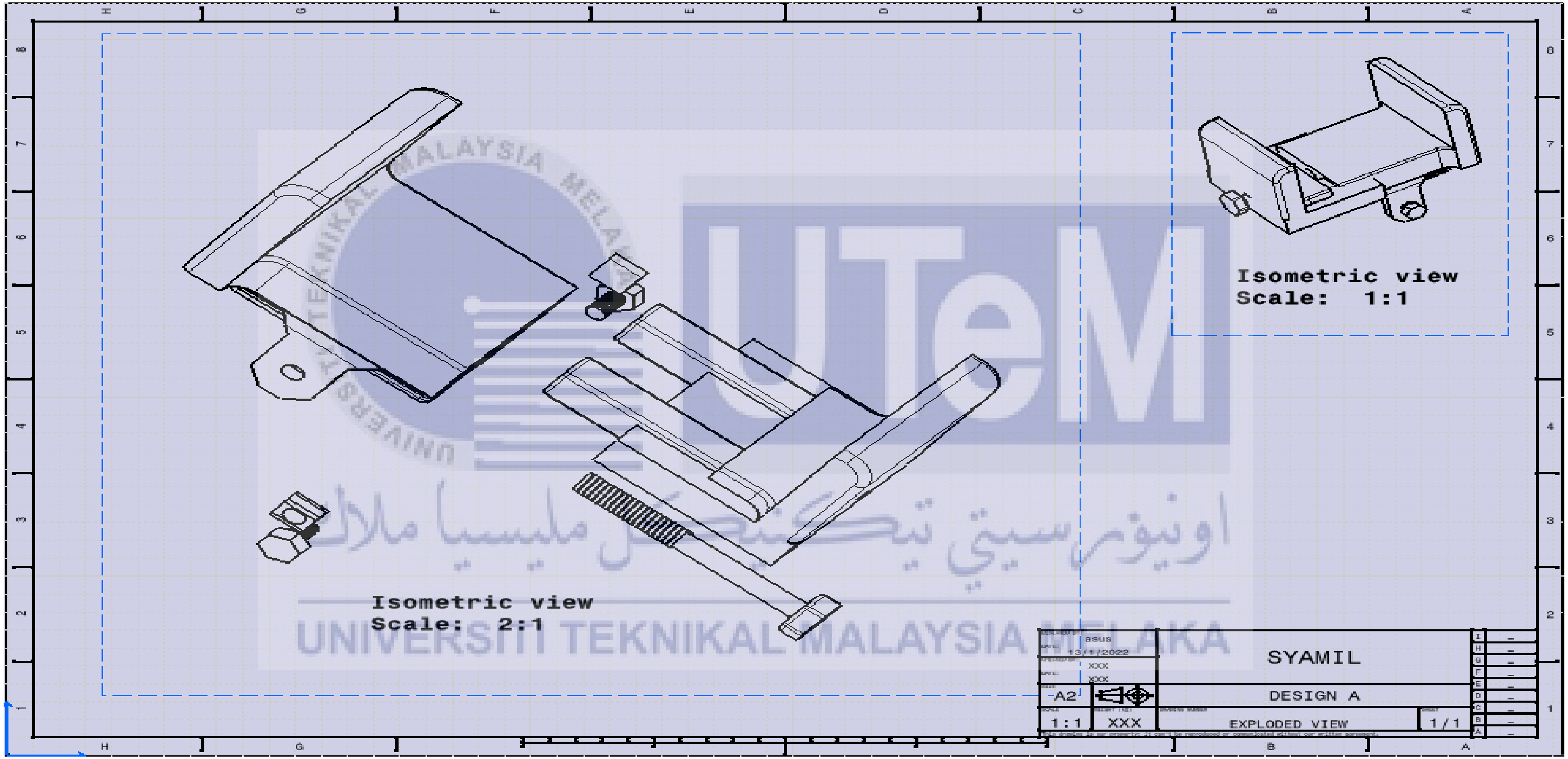
APPENDIX 2

Orthographic view design A



APPENDIX C

Exploded drawing view design A



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	Student Names: Capitalized Each Word, maximum 2 line Times New Roman,12		
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	Faculty: Faculty of Mechanical and Manufacturing Engineering Technology (Capitalized Each Word, Times New Roman,12)		
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