LAB University of Applied Sciences

3D scanning benefits in reverse engineering

Reverse engineering and 3D scanning for product development

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Bachelor of Engineering, Mechanical Engineering and Production Technology
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Abstract

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Abstract

With rapid development of technologies in the world, the role of the reverse engineering is increasing day by day. A growing industry is replenished with new processes every year. Still, one of the key roles is given to the 3D scanning technology.

The thesis work builds up a product development approach using the modern technologies, including 3D scanning, to develop a product that is ready to be manufactured. Understanding the customer needs is an important part of product development that defines what should be done. Completing the process of analysing and understanding the behaviour of product components.

The final model provides full information on each part, making them ready to be produced. Representing possible product of the reverse engineering process alongside design challenges to be solved according to the customer.

Keywords

3D scanning, Production, 3D modelling, Artec.

Contents

LIST OF SYMBOLS AND ABBREVIATIONS

3D – 3 Dimensional

CAD – Computer - Aided – Design

UAS - (University of Applied Sciences)

STL – Stereolithography

VW – Volkswagen

OEM – Original Equipment Manufacturer

CT – Computer Tomography

STEP – Standard for the Exchange of Product Data

IGES – Initial Graphics Exchange Specification

DXF – Drawing Exchange Format

1 Introduction

Reverse engineering is a fascinating field that involves the process of deconstructing and analysing a product to understand how it works, with the ultimate goal of replicating or improving upon it. This practice is often used in the technology and engineering industries to gain insight into the design functionality of products. By completing this process, reverse engineering can help to identify potential weaknesses or opportunities for improvement.

The thesis's main goal is to develop the power of 3D scanning technology in the reverse engineering process. The process of reverse engineering has become increasingly vital in modern manufacturing and design processes. The ability to replicate or improve existing designs with greater accuracy and efficiency using the possibilities of 3D scanning technology.

The second important aspect of the work is to apply this technology to create a product according to the customer's demand. The object is planned to be carried through the process of reverse engineering. Desired design and production capacity are the challenges. To overcome these challenges and provide a solution that will satisfy the customer, 3D CAD software should be used and scanning techniques applied.

1.1 Origins of the topic

In the summer months, the author had to get to know 3D scanning technology closer. The main task was to study previous guidance on how to use the scanner and software, get familiar with this technology, and update it, so any student can complete the basic processes without external knowledge.

After completing this project, interest in looking for news and information related to the 3D scanning technology did not disappear, then at the certain point of time, there was an offer from the lecturer Eero Scherman to complete the project with the Fine Art department of LAB University of Applied Sciences. The goal of the project was to scan the clay-made sculptures, create their models, and create files in the 3D printing suitable formats, then create a block text for the LAB UAS website.

At the same time, a customer with a project on the related topic of reverse engineering submitted an offer for the thesis. The main point of the project was the completion of scanning on the certain product, given by the customer and fulfilling the reverse engineering process. After meeting with the customer and discussing on requirements of the task, there was a decision to complete this project.

1.2 Problem description

The customer has requested the completion of a reverse engineering project for a product. The customer had several reasons for this request, including the need to improve the existing design. The reverse engineering process will involve disassembling the product, analysing its components, and reconstructing its design specifications.

To complete this project author will need to use a variety of engineering tools and techniques to accurately measure and document the product's components and specifications. This project will request attention to detail to ensure that the reverse-engineered product meets the customer's expectations and requirements.

2 Theoretical information

2.1 3D scanning technology history

The first mentions of similar technology appeared when ancient Egyptians made 3D plaster replicas of mummy heads. This required materials such as linen and gypsum, which were incredibly valuable in ancient societies. At the time, it was possible for them to capture objects in three dimensions, but it was very time-consuming.

In 1953, in the United States of America, the military began experimenting with an optical measuring system, which used light and high-speed shutters. Later, when technology came from government to the civilian usage, laser-measuring systems became popular very fast. This point in history is assumed to be called the start of scanning technology. (The evolution of 3D laser scanning 2020.)

Within several years with the fast development of technology around the world, the 3-axis Coordinate Measuring Machine was integrated with remote computer control, creating faster and more precise possibilities to scan the objects for industrial use. The first application of this kind of technology is the scanning of the VW Beetle in 1972 (Figure 1), where a car was mapped with polygons and measured using the scanner. The resulting dataset was used for a computer program and resulted in the first wireframe model of a car. (Jalopnik, 2013)

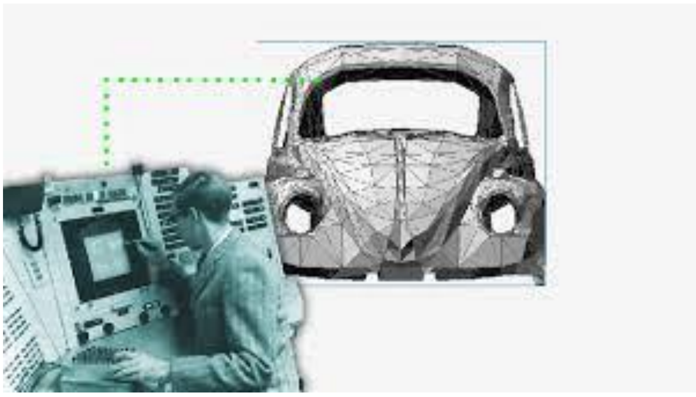

Figure 1. VW Beetle model (Jalopnik 2013)

In the 1980s, 3D scanning technology advanced rapidly with the development of structured light systems. These systems projected a pattern of light onto the surface of an object and used cameras to capture the deformation of the pattern caused by the surface. The data was then processed to create a 3D model of the object. David Marr and Tomaso Poggio, two researchers from the Massachusetts Institute of Technology, were pioneers in this technology. (Kent A. Stevens, 2012)

In the 1990s there was the development of 3D laser scanning systems that used multiple lasers to scan an object from different angles simultaneously. These systems were faster and more accurate than previous technologies and could scan larger objects such as buildings and landscapes. One of the most significant achievements during this period was the development of time-of-flight technology. This technology measured the time taken for a laser pulse to travel from the scanner to the object and back, enabling the creation of highly accurate 3D models.

One notable scanner among many others is the Cyrax, developed by Cyra Technologies. It was the first laser scanner used by surveyors and engineers, and it was portable with its own battery, making it easy to carry. When paired with a laptop, the weight of the system was around 40kg. The Cyrax had a wide field of view (FOV) of 40° x 40° and could capture up to 1200 points per second. It also had a working distance of nearly 50 meters against a flat surface. This scanner is shown on Figure 2 . (Scantech international LTD,, 2020)

Figure 2. Cyrax scanner with battery and laptop (Scantech international LTD 2020)

In the 2000s, 3D scanning technology became more accessible and affordable, and new applications emerged. One of the most significant applications was in the field of medicine, where 3D scanning technology was used to create digital models of organs for education and surgical purposes. The entertainment industry also took part in the promotion of 3D scanning technology with created lifelike characters and environments for movies and video games. Figure 3 shows the comparison between real objects and their scanned version. (Leica Geosystems, 2020)

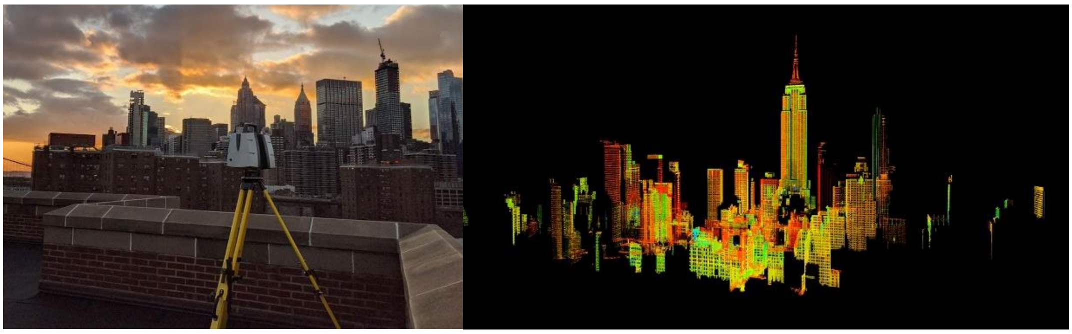

Figure 3. Area to be scanned and results of the process (Leica Geosystems 2020)

Today, 3D scanning technology is ubiquitous and has become an essential tool in many industries, including manufacturing, engineering, and design. The technology has evolved from early systems that used lasers and structured light to modern systems that use photogrammetry and handheld devices. As the technology continues to advance, new applications will likely emerge, further expanding the potential of 3D scanning technology. Figure 4 shows the scanning progress with modern scanner and software. (Creaform3D, 2020)

Figure 4. Modern scanner in use (Metrologynews 2022)

2.2 What is reverse engineering

Reverse engineering is the process of disassembling software, machines, aircraft, structures, and other products to extract design information. Reverse engineering often disassembles individual components of a larger product. A reverse engineering process can be used to determine how a part was designed and created, so that it can be replicated. Companies often use this approach to replace parts that are not available from the original equipment manufacturer (OEM). (Siemens, 2016)

Figure 5 shows the reverse engineering process with the basic steps. However, people often have limited knowledge of the technical methods used to develop products. The challenge is, therefore, to gain a working knowledge of the original design by analysing the product piece by piece or layer by layer.

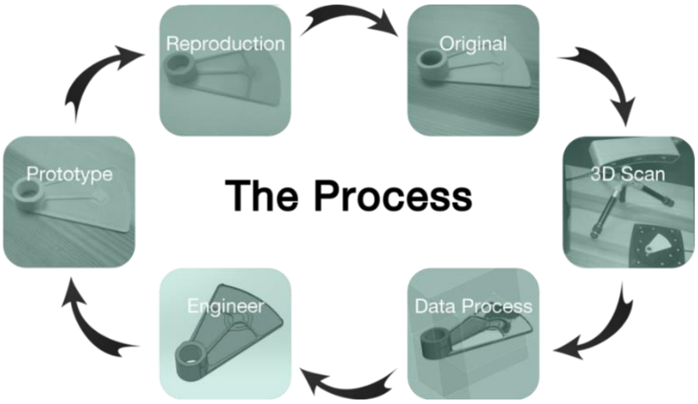

Figure 5. Process of reverse engineering (Siemens 2016)

The process of reverse engineering typically involves several steps. The first step is to analyse the product or system being reverse-engineered in order to gain an understanding of its overall functionality and design. This analysis may involve conducting physical tests and measurements, examining the product or system's components and subsystems, and reviewing any available documentation or schematics. (Siemens, 2016)

Once the analysis is complete, the next step is to create a detailed model or representation of the product that is being reverse-engineered. This model may take the form of a 3D CAD drawing or a computer program depending on the nature of the product. This model is then used to identify the relationships between the product's various components and subsystems and to determine how they work together to achieve the product’s overall functionality. A comparison of the real object to its model version is displayed below on Figure 6.

Figure 6. Real and Scanned object (Johanthan Mun 2015)

In many cases, reverse engineering is conducted using specialized tools and techniques. For example, in the field of computer science, reverse engineering may involve using disassemblers and decompilers to examine the source code of a software program in order to identify how it functions. Likewise, in the field of mechanical engineering, reverse engineering may involve using X-ray and CT (Computer tomography) scanning technologies to examine the internal structure of a product to determine its design. (Techtarget, 2021)

Companies sometimes use reverse engineering to obtain design data for their products that are long out of production. A small company that has been in business for over 40 years may have manufactured many products before the advent of computer-aided design and digital data storage. So, these old products may be based on long-lost paper plans. Reverse engineering allows companies to recover lost designs and create product inventory archives. Modern scanner during scanning is shown on Figure 7. (Market Prospects, 2022)

Figure 7. Scanning of the old automobile with Artec Leo (Artec 3D 2022)

Overall, reverse engineering is a valuable tool that can be used to gain insight into the design and functionality of existing products and systems. Whether used for academic research, product development, or security analysis, reverse engineering plays an important role in many fields of study and industry. (Wevolver, 2021)

2.3 How the 3D scanning works in reverse engineering

3D scanning is an important technique used in reverse engineering to create a digital model of a physical object. This technology involves using specialized equipment that captures the surface information of an object in three dimensions. Received data can then be processed and used to create a digital representation of the object. The process of the scanning is shown on Figure 8.

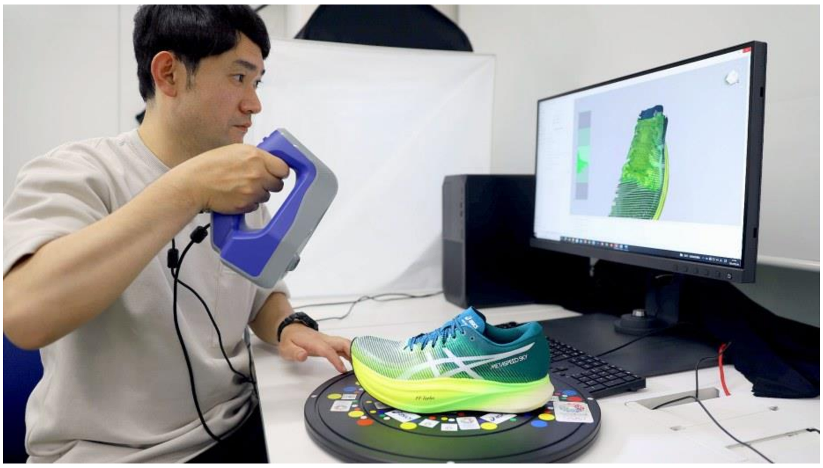

Figure 8. Scanning process with a shoe (Artec3D 2023)

This process involves several steps, including point cloud generation, surface reconstruction, and mesh generation. In point cloud generation data points are processed to remove any noise and create a clean point cloud. In surface reconstruction, algorithms are used to create a continuous surface from the point cloud data. Finally, in mesh generation, a digital mesh is created from the continuous surface, which can be used to create a 3D model. An example of the mesh data from the scanned object is presented on Figure 9. (Artec3D, 2023)

Figure 9. 3D scan of a car body (Artec3D, 2022)

The digital model created through 3D scanning can be used for a variety of applications. Reverse engineering involves usage of the digital model to analyse and understand the design of the original object. This technique is useful for many industries, including manufacturing, where a physical object may need to be recreated or improved upon. The digital model can also be used for quality control and inspection purposes, where the model can be compared to the original object to identify any differences. (Artec3D, 2022)

2.4 Translation

To complete the reverse engineering processes, it is necessary to use computer-aided design (CAD) software suitable format while scanning software outcome files usually in stereolithography (STL) format. The STL file format is utilized in 3D printing and rapid prototyping to depict the surface geometry of a 3D object, this kind of data allows to create the part that possesses a visual appearance of the object and not its full properties. Consequently, it becomes crucial to convert the STL file to a CAD file for further design and engineering adjustments. However, not all 3D CAD software can directly use the STL format. To overcome such a problem a number of solutions can be used.

2.4.1 Usage of the translation websites

To complete the translation process fast and get working file such as STEP. file different online conversion tools can be used, on the Figure 10 is the example of uploading on one of them. Online conversion tools typically use algorithms to analyse the geometric data contained within the STL file and generate a corresponding CAD file.

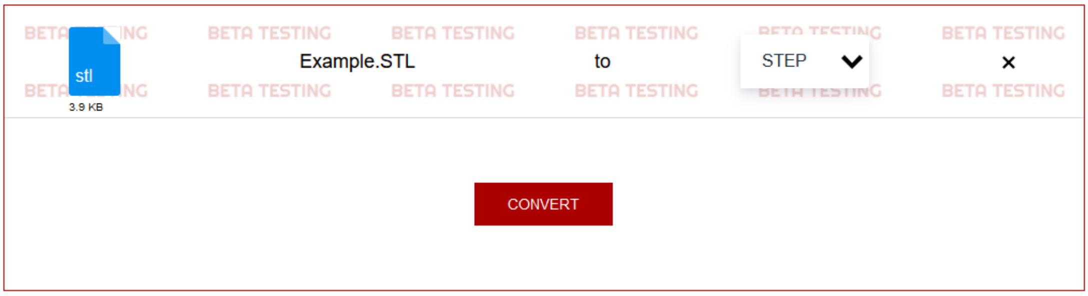

Figure 10. Dropbox for file (AnyConv)

After uploading it is important to note that the accuracy and quality of the converted CAD file may vary depending on several factors, including the complexity of the original STL file, the conversion algorithm used, and the specific CAD format selected. As soon as the translation is done, the user can download the created file in the required format.

2.4.2 GeomagicX software

GeomagicX is a useful tool for reverse engineering processes due to its capability to work with scanning format files and the ability to turn them into 3D models. This software provides a variety of tools for designing and modifying models, including parametric modeling, direct modeling, and freeform modeling. This software is widely utilized in various industries, such as automotive, aerospace, and consumer goods, due to its versatility and powerful functionalities. (Oqton, 2022)

Below are the basic steps on how to use the addon:

1. Create a model in Artec software.
2. Go to the “File” tab at the top of the window.
3. Move to “Export” and click “Meshes”.
4. Open the model in Geomagic.
5. Get to the “Meshes” tab.
6. Complete recognizing via available features.

As soon as the steps are done, the user can work with the ready model. This method allows to get the most accurate model from the scan, due to direct recognition of the created model in ArtecStudio software. How it is seen in the software is shown on Figure 11. (Artec 3D, 2022)

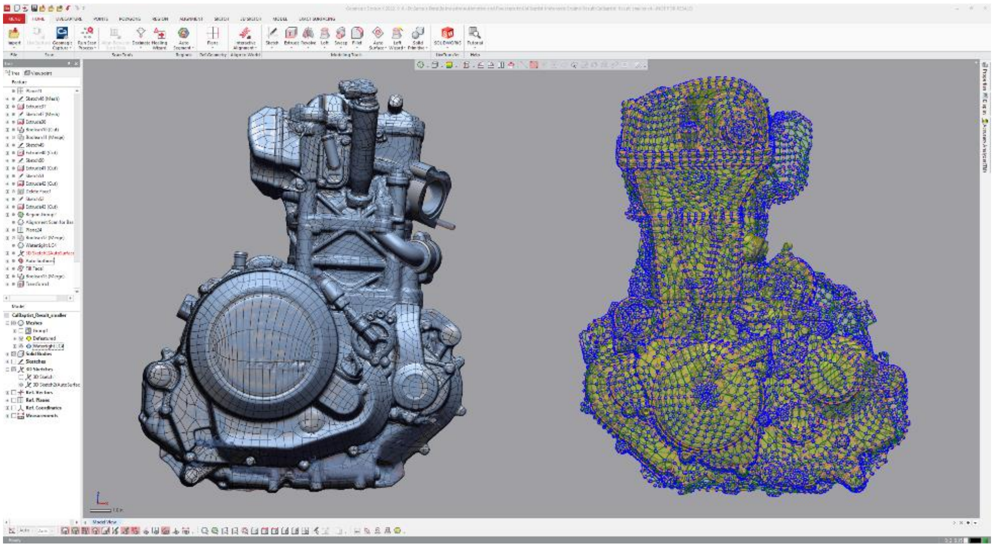

Figure 11. Example of the file in GeoMagic (Artec3D 2022)

2.4.3 Usage of FreeCad software

FreeCAD is an open-source 3D modeling software, that offers a convenient solution to this problem. To accomplish the conversion, the user should first import the STL file into FreeCAD by selecting "File" > "Import" > "STL". Next, the user should select "Part" > "Create shape from mesh" to convert the imported mesh into a solid shape. After that, the user can export the solid shape as a CAD format by selecting "File" > "Export" and choose a suitable CAD format such as STEP, IGES, or DXF. FreeCAD provides an efficient and straightforward method to convert STL files to CAD formats, allowing designers and engineers to use a wider range of tools and software to further refine their designs. Below are Figure 12 and Figure 13 which present the STL version and created model from it. (MakeUseOf, 2022)

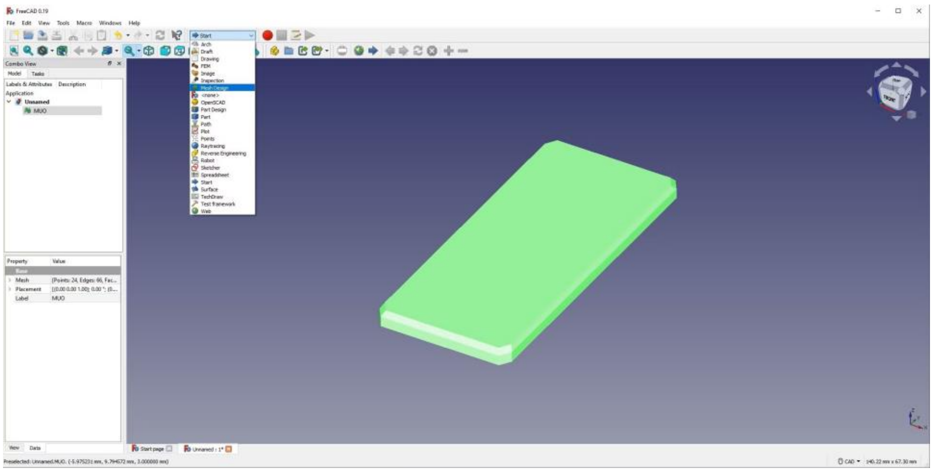

Figure 12. STL model in FreeCAD (MakeUseOf 2022)

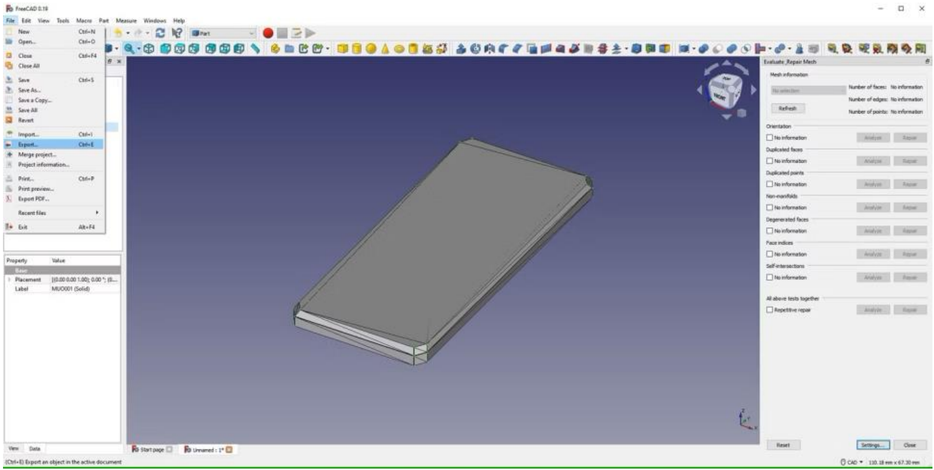

Figure 13. Model created from the STI file (MakeUseOf 2022)

2.5 Additive manufacturing

Additive manufacturing, also known as layer-by-layer manufacturing, is a rapidly emerging technology that enables the creation of 3D objects by building up material following its model created with different software. This technology has received significant attention in recent years due to its potential to revolutionize traditional manufacturing processes by offering numerous advantages such as reduced material waste, increased design flexibility, and faster product development cycles. (TWI, 2019)

Additive manufacturing has been widely adopted across various industries, including aerospace, automotive, medical, and consumer goods. In academic circles, researchers have focused on advancing the technology by developing new materials, improving printing techniques, and exploring its potential applications. (LuxCreo, 2021)

Overall, additive manufacturing has the potential to significantly disrupt traditional manufacturing processes and revolutionize the way products are designed and developed. Implementation of this technique across a wide range of industries, ongoing research, and development efforts, and increasing technical capabilities suggest that additive manufacturing will continue to play an increasingly important role in the manufacturing landscape. Figure 14 shows the creation of part with additive manufacturing.

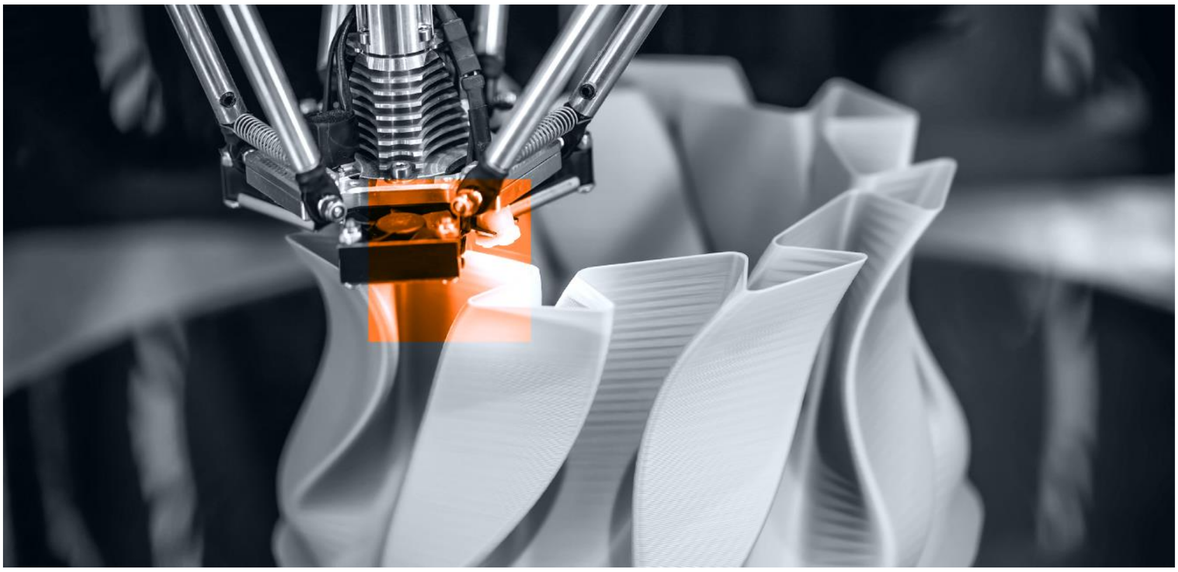

Figure 14. 3D Printing process (Truventor 2021)

3 Completion of the work

3.1 Preparations for scanning

Before conducting any scanning, it is important to work with the surroundings, parts, and equipment preparations. This may include different procedures and interactions with them to obtain better received data and relief of the future modelling processes.

To achieve the optimal scan quality, additional measures were taken. Product parts were cleaned, so there are no dust or other contaminants that may affect the accuracy of the scan. Also, the positioning of the object for each scan was thought out, wooden plates were used to adjust the height and reduce the amount of surface captured by the scanner, while a water-based 3D spray was applied to create a similar and non-reflective surface.

Another necessary thing that should be mentioned is lightning, scanning area should not be dark or overwhelming in the light. Ideally, the object should be placed in a well-lit area with uniform illumination.

Several reference points were marked on the object to help software for future alignment processes. The laptop with the necessary software and power cables was positioned to the side to prevent them from being captured during scanning.

Before scanning, the software and equipment proceeded through the calibration tries for better performance. Figure 15 shows the working area with equipment.

Figure 15. Scanning area

3.2 Scanning process for parts

3.2.1 Handle

Once the necessary preparations for the scanning process were completed, the decision was made to begin with the handle. To ensure consistency and preserve the graphical information, the part was positioned vertically and kept in the same orientation throughout the scanning process the result is shown on Figure 16. To further improve the quality of the data collected, walls were installed behind the handle to eliminate any interference and obtain more accurate information on the shape of the object. This allowed to receive the scan with satisfying quality for further modeling.

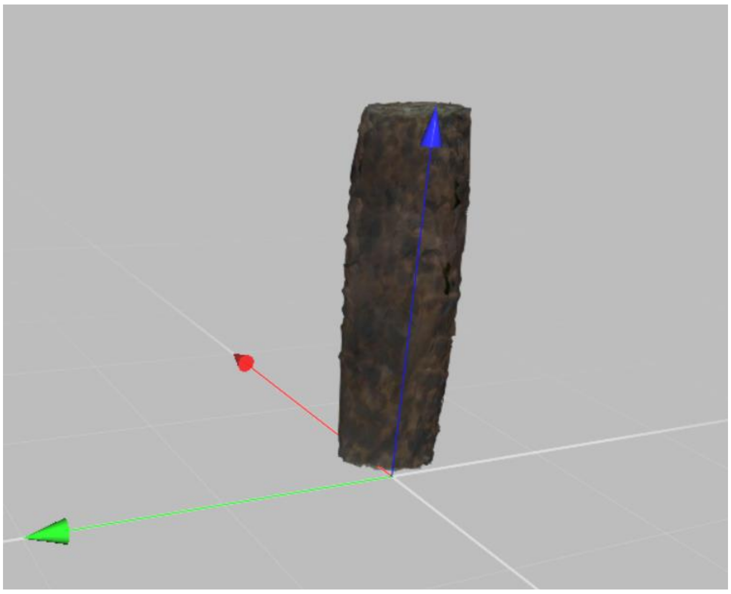

Figure 16. Raw scan of the handle viewed at the the ArtecStudio 16

3.2.2 Scanning of blade

To accomplish the proper scanning of the blade, it was decided to use a water-based spray on its surface. This created a uniform layer of the material which is not reflective and can be scanned easily. Also, the blade was placed vertically, making the tip invisible for the scanner and extra scan to complete future model correctly. During the scanning, it was mentioned that usage of the background with uniform colour helps the software to process data faster with better quality.

Satisfying scans were received after a number of tries and can be found on Figure 17, represented object possess high accuracy in the geometrical and graphical way. It can be seen that scans possess a big number of noises that should be removed during further processes.

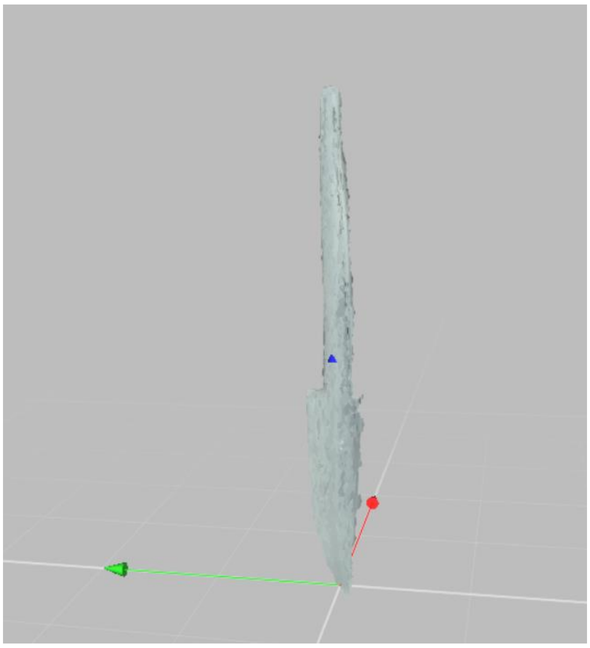

Figure 17.Raw scan of the blade

3.3 Creating and editing models for STL file formats

After the scans have been obtained, the following action is to align and merge them together. This is accomplished by using an automatic or manual alignment tool within the ArtecStudio software, which matches up shared characteristics in the scans and makes necessary adjustments to ensure proper alignment. Once merged, the scans need to be cleaned up to eliminate any unwanted artifacts or noise, which can be done using various tools available in ArtecStudio. Finally, once the scans have been cleaned up, the user needs to create a functional model from them. Side views on the raw scan are shown on picture Figure 18.

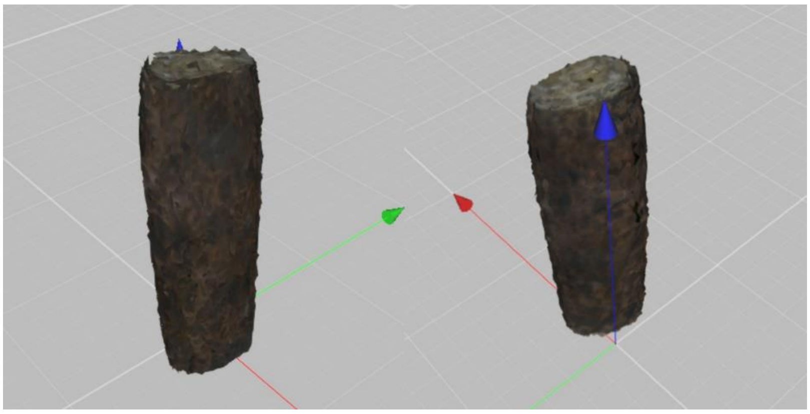

Figure 18. Merged scans of the handle

The "Tools" section in ArtecStudio offers several features for creating a model. To ensure the software works correctly, it is advised to use some form of "Registration" before proceeding to the "Fusion" function. This will enable ArtecStudio to compare the positions of each data point and align them to obtain a clear image of the object. The next step involves selecting a fusion type and applying it, which may take some time for the algorithms to construct a model, the example of the model is on Figure 19. However, it is important to note that the algorithms used in the software can sometimes generate undesired parts or noises.

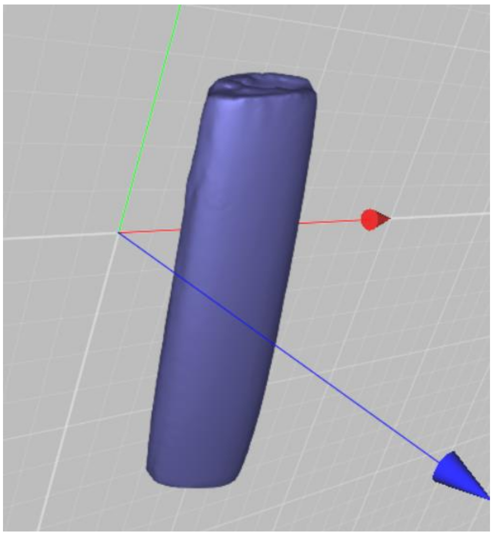

Figure 19. First fused model of handle

The last step in finishing the model involves addressing any issues present. This could involve modifying the shape or texture of the model to suit the user's preferences, incorporating color or other visual details, or using the various functions in ArtecStudio to smooth out any rough areas. These tools are useful for enhancing the model's overall appearance or removing any elements that might detract from its realism and visual appeal, example of the process is shown on Figure 20.

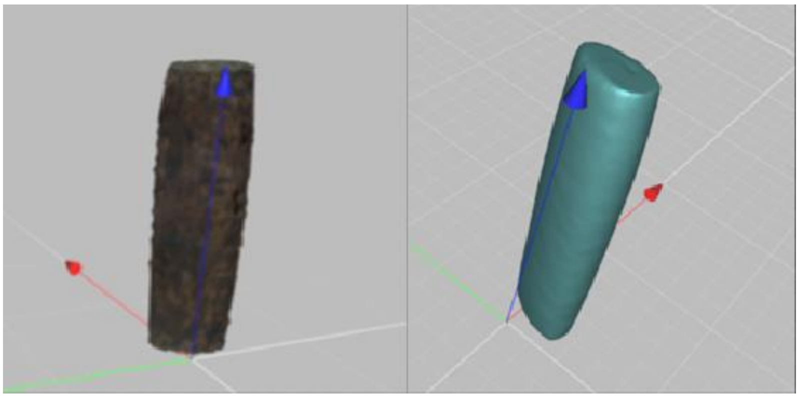

Figure 20. Merged scans to cleaned model

3.4 Usage of SolidWorks to work with STL. format file and further modeling

During the completion of the work, SolidWorks 3D CAD software was the main tool for the convertion of the STL files to the functioning model. The SolidWorks software allows user to work with STL format files and transform them into solid bodies without any additional steps. To complete the translation, the user must select the "Open" tab, choose the desired file, click on the "Options" tab, and select "Import as" followed by "Solid Body." After clicking "OK" and opening the file, the user can begin working with the meshes immediately. How it can be seen in software is presented on Figure 21.

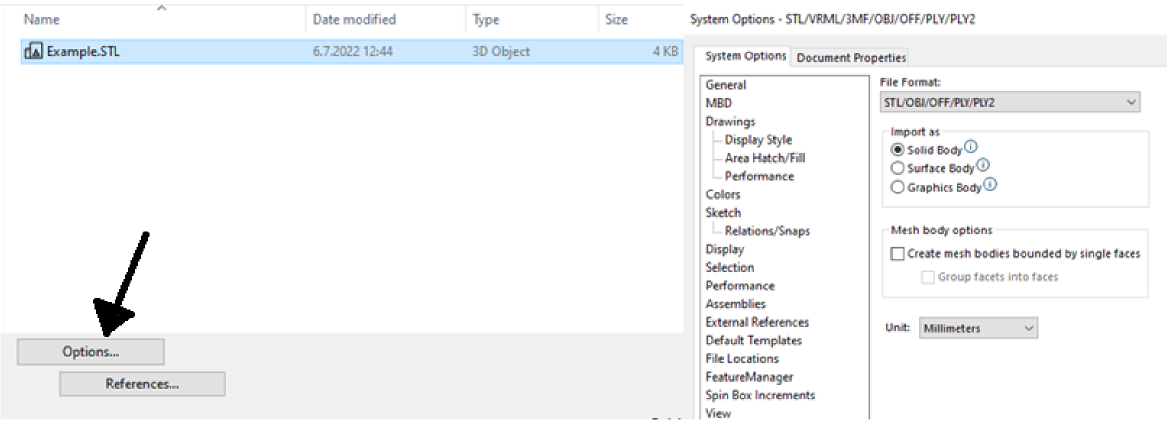

Figure 21. Opening tabs in software (SolidWorks)

The handle of the product was recreated first, being the most important part. After the successful transfer of the STL. file, the author received a visual object with the ability to interact with its geometry. An example of the file is shown on Figure 22.

Figure 22. Opened STL file

The process of translating a file from one software to another can be successful in terms of preserving the overall geometry information of the model. Translated file from Artec software was correctly opened in Solidworks, indicating that the translation of the handle model was carried out effectively. Consequently, the file can be utilized for further 3D modeling, as the geometry information was not lost or spoiled during the translation process. Following the steps of the handle translation, the blade of the knife was the next part of the work. After a successful process of translation of the files that contain information on these parts with the highest accuracy and lowest losses, the work was done at this step. Two models are displayed in Figure 23.

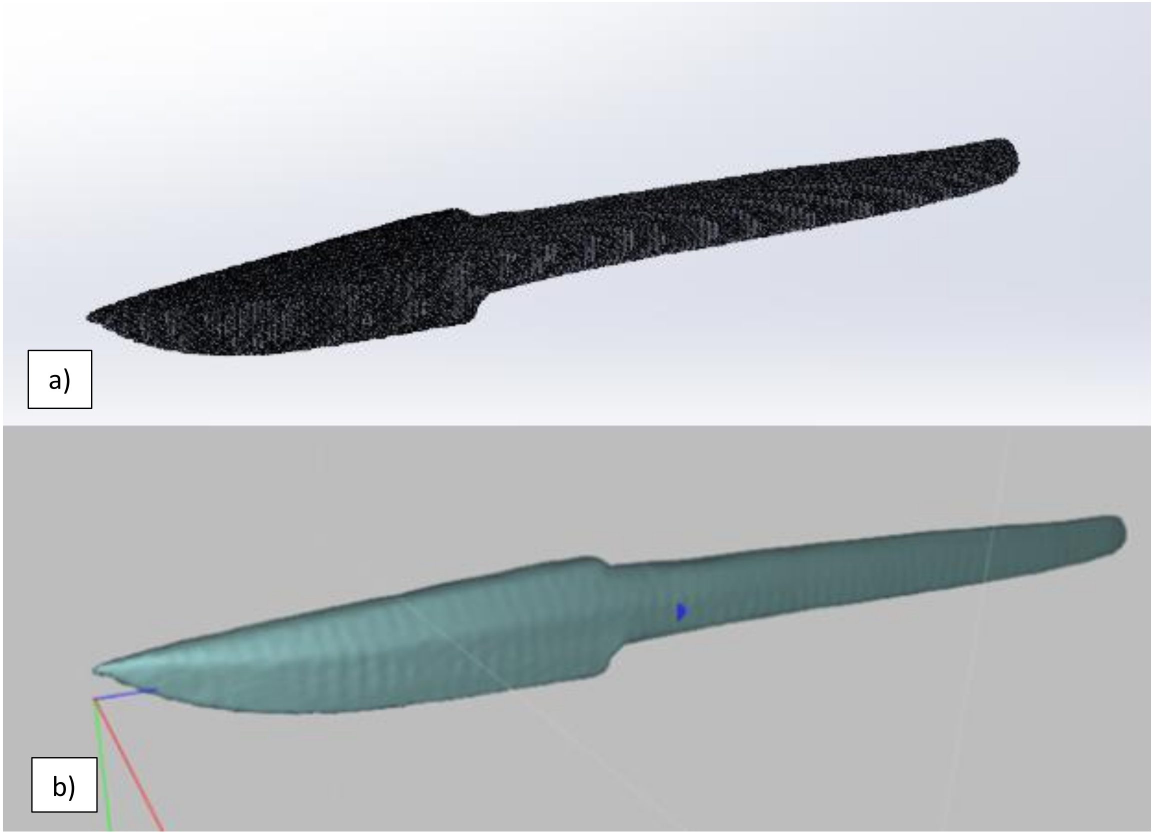

Figure 23. Compared models from softwares (a. SolidWorks, b. ArtecStudio)

With the result of the processes, files from software can be compared. A comparison between a translated file from Artec software and Solidworks necessitates considering several factors. Artec software is principally designed for 3D scanning and capturing physical objects, while Solidworks is primarily utilized for developing digital designs from scratch. Therefore, a translated file from Artec software may not be as accurate or precise as a model created directly in Solidworks.

Furthermore, the quality of the model in Solidworks may be influenced by the format of the translated file. Anyway, using Artec software to capture physical objects can serve as a valuable foundation for constructing 3D models in Solidworks. This approach allows for the recreation of intricate shapes and structures that may be difficult to create from the scratch. The efficiency of using a translated file from Artec software in Solidworks is depending on the specific requirements of the project and the precision necessary for the final product.

During one of the technical meetings with the supervisor, it was decided to accomplish the translation only of 2 main parts, where the second is the blade of the product. After the successful process of translation of the file that contains information on this part with the highest accuracy and lowest losses, the work was done at this step.

3.5 3D modelling of the product

In order to achieve the desired shape, a number of sketches were created to replicate the geometry of the scanned object. The sketches included the ends of the handle to determine the length of the part, as well as sketches from four sides to establish the facets. It was important to ensure that all the sketches were interconnected so that the "Lofted boss" feature could be executed accurately. With the model now created in SolidWorks, it can be easily modified in the future. Figure 24 shows the side view of the model.

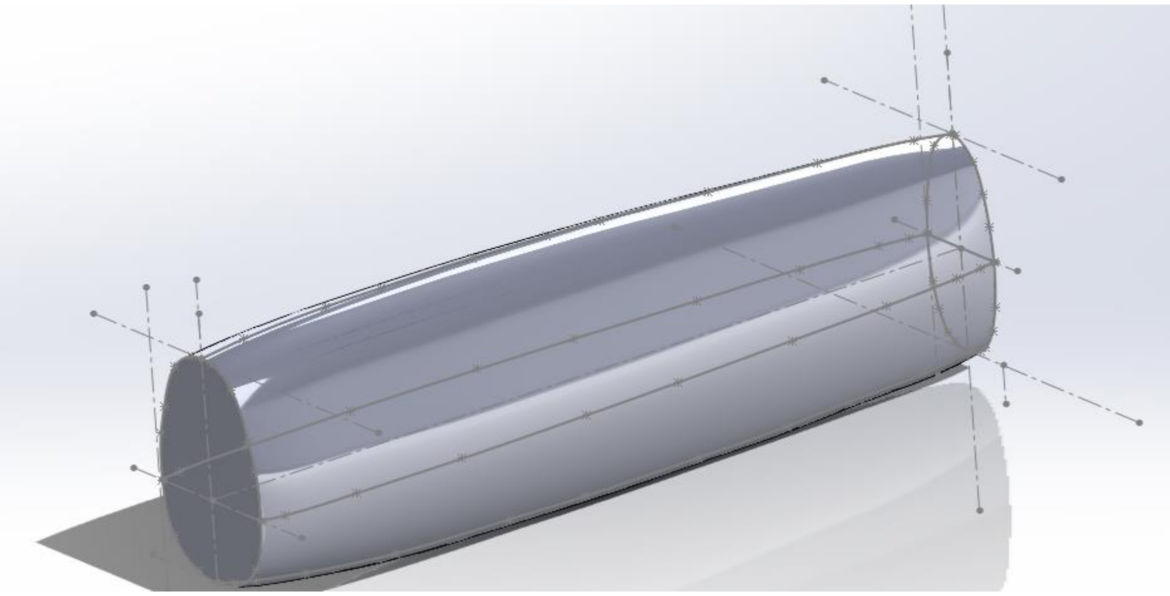

Figure 24. Handle created with sketches

The blade of the product is created following the appearance pattern, which means it is having two facets on each side that are angled to each other and a cutting-edge pattern. With the usage of received dimensions including thickness and length, tang and connections were modeled. Also, during creation it was necessary to remember, that blade of the knife will be created using the machines, which means avoidance of profiles that is hard to produce with machinery. The curvature of the blade appeared as a solid problem during modeling due to its strict dimension requirements and visual appearance. After going through the problems, the model that represented scans was created, it can be found on Figure 25.

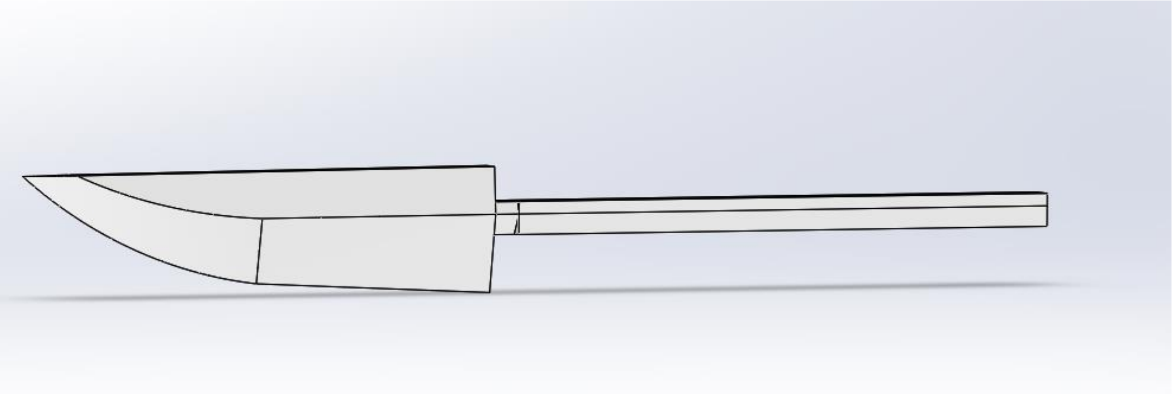

Figure 25. Created blade

The creation of the main parts created a need for modeling the bolster and back plate parts to create a future object with all the components. Both of these parts were meant to be custom, which means their creation was based on blade and handle geometry. Bolster (the part between the blade and handle) had to follow the shape of the handle on its end and fit the end of the blade on its surface. While the back plate had only to follow the right end of the handle. These geometrical patterns are presented on Figure 26.

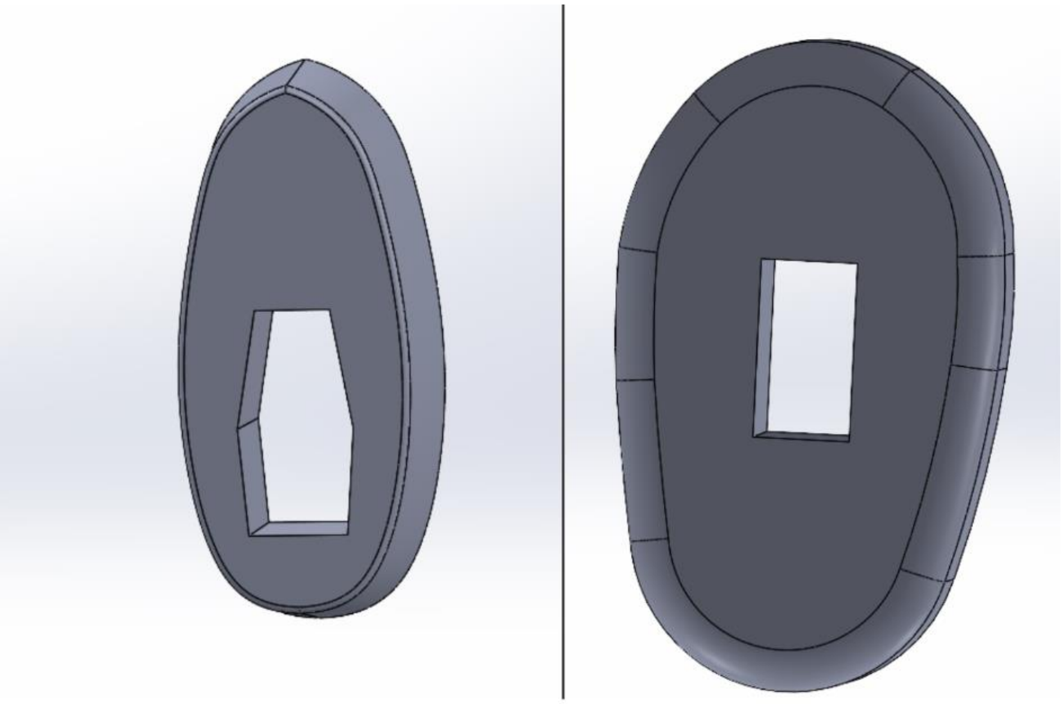

Figure 26. Bolster and back plate features

With scanned parts and created models, first assembly was created. Also, the accuracy of the scanning was checked, according to the dimensions of the original part, models possess most of the important geometry with high precision. 4 parts, including: the blade, handle, and fixers were connected in the same way as in the project's product. Figure 27 gives the view from the side on the model.

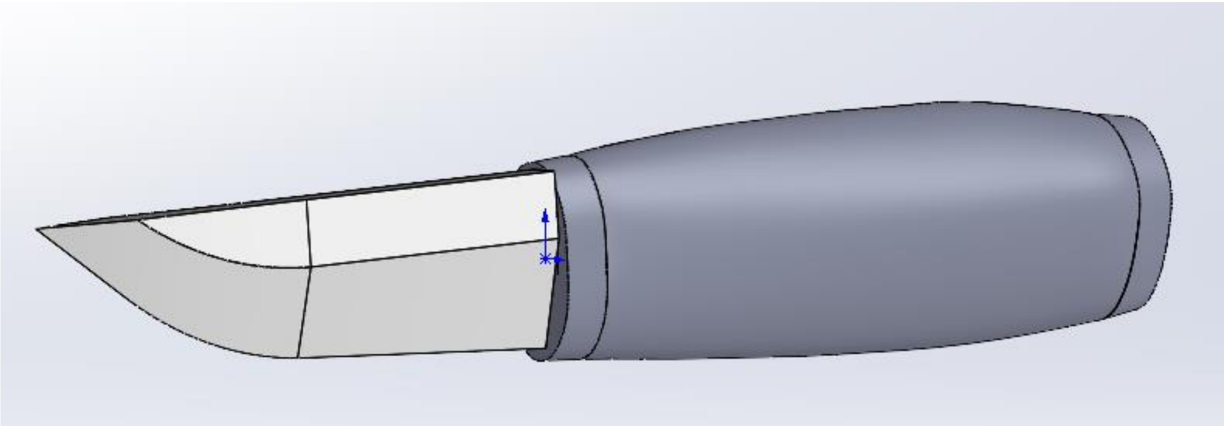

Figure 27. Model with initial parts

As at it can be seen from the picture above, losses on the handle and bolster during modeling caused the blade to get over the edge. This caused a problem to be fixed in the further modeling on both parts, on the other hand, the back plate and end of the handle on its side were said to be more accurate to the original fitment and dimensions.

3.6 Modernisation of the parts and creating adjustments

Updating and adjusting parts is an essential responsibility in manufacturing that can enhance product quality, boost efficiency, and lower expenses. The assigned task involved modernisation and creating new parts to meet the needs of customers. During the design stage, it is important to consider manufacturing processes to ensure that the parts can be produced using machines. This includes modeling and testing the parts to ensure they are suitable for efficient production. To ensure that all the changes were correctly understood and done, meetings with the customer were arranged frequently.

After showing the first completed model of the product, the customer requested a more secure method of fastening the knife to improve reliability during use. To achieve this, the tang geometry was changed to a square shape, and M4 thread was added. To implement the idea, a custom screw was developed to cover the thread and the back plate, securely fixing the construction in place. This modification will ensure that the knife is firmly attached, providing stability and safety during use, overview of the changes can be found on Figure 28.

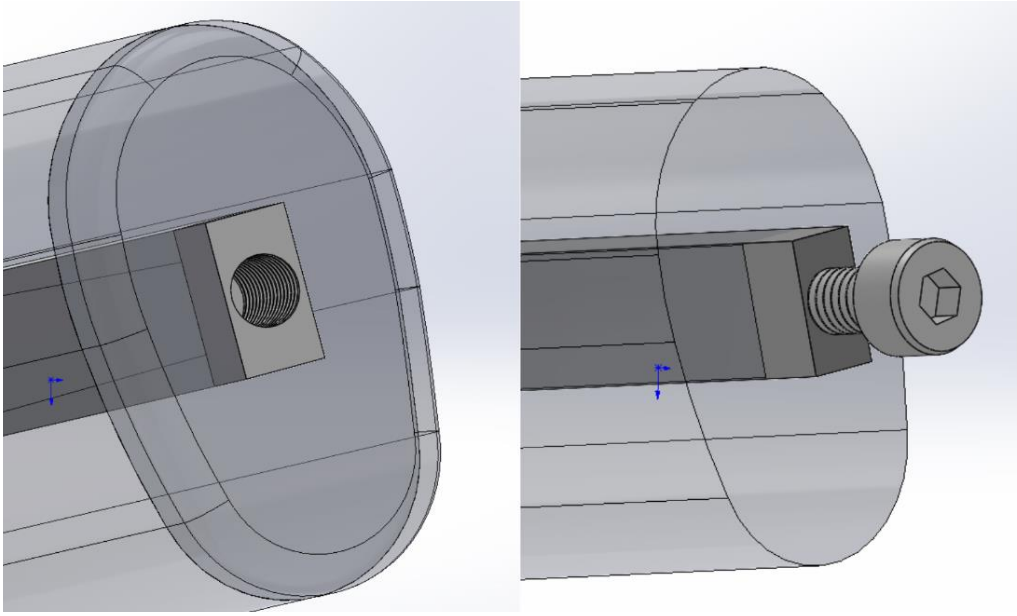

Figure 28. Tang changes and created nut

After consulting with future manufacturers, it was determined that changes needed to be made to the design of a fixing feature. First, the custom fixer was redesigned, which will be screwed onto the thread on the tang, rather than inside of it. A special thread for screwdriver was created to make it possible to use. Created part is shown on Figure 29.

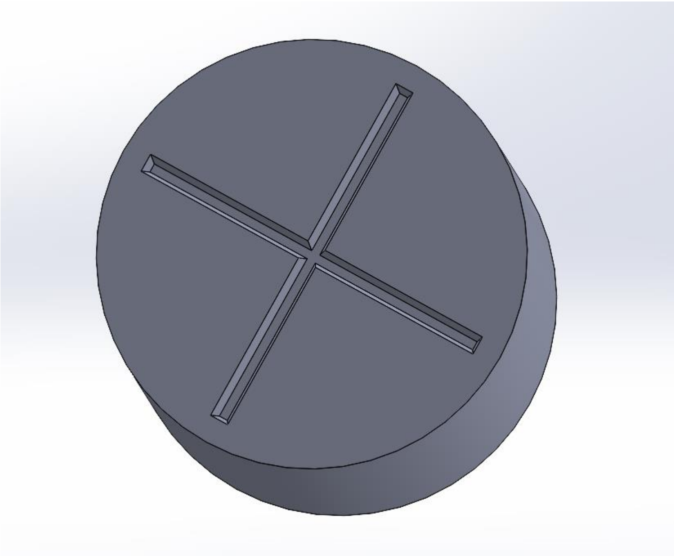

Figure 29. Custom screwable pin

Additionally, changes were made to the handle, including the addition of several millimeters on the sides with the same shape, as well as cutting the same shape into the bolster and back plate. This will provide added stability to the construction by fixing the handle on both sides at the tips. Finally, an extra cavity with the shape of the blade was added to the bolster to enhance reliability during use. Figure 30 shows the changes in the handle.

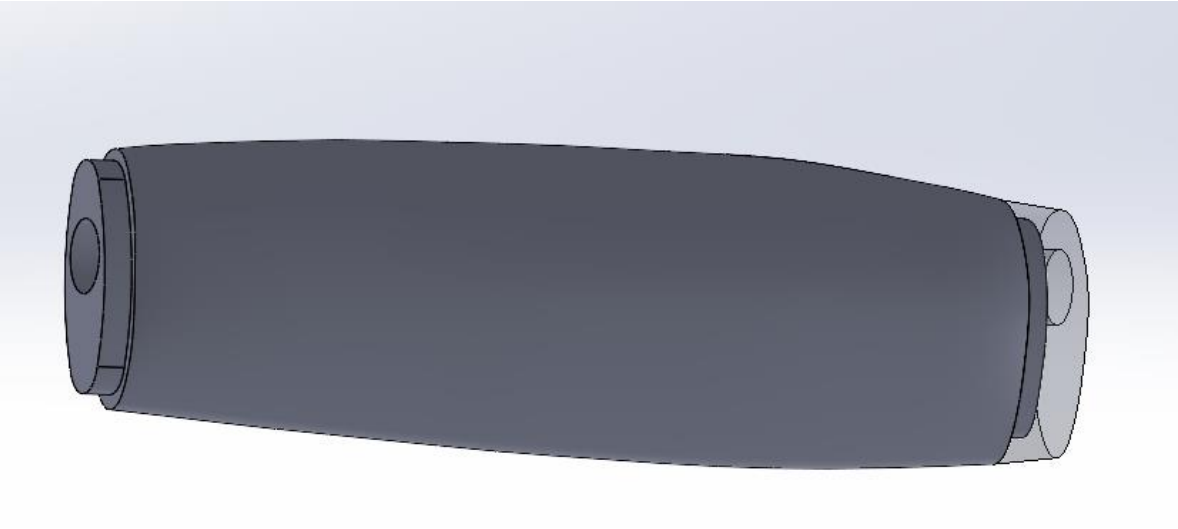

Figure 30. Handles extra millimetres.

Finally, an extra cavity with the shape of the blade was added to the bolster to enhance reliability during use. Changes in the bolster are displayed on Figure 31.

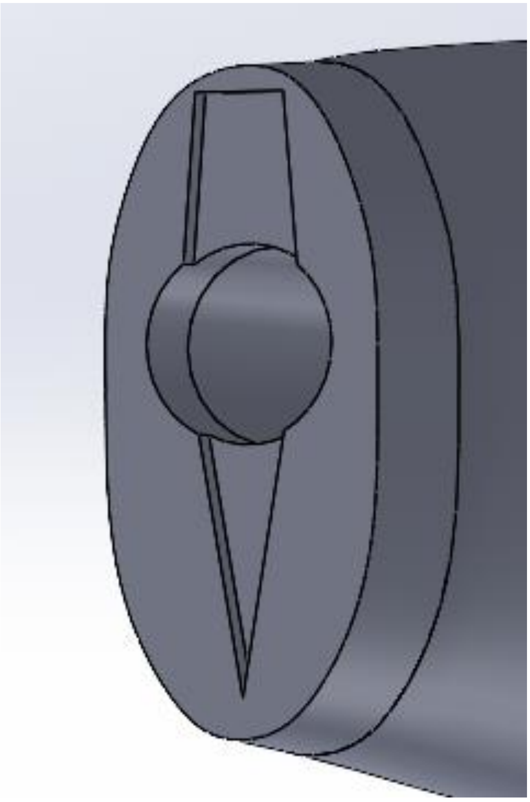

Figure 31. Cavity on the bolster part.

Another discussion with the customer identified a small cosmetic issue with the circular pattern on the tang. This resulted in a problem where the cavity on the bolster was exposing the helve, which was not acceptable. To address this issue, it was decided to divide the tang into two separate parts. Figure 32 describes the solution of the problem.

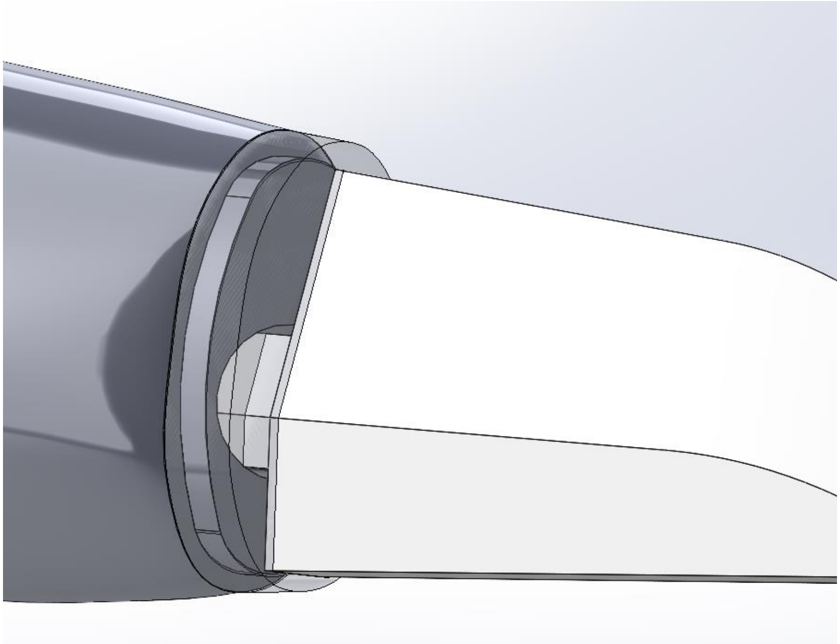

Figure 32. Fixed bolster feature

To join both parts of the tang, a hook was created on one half and a fastening on the other. One part is connected to the blade and replicates its geometric pattern, while the other maintains a circular appearance with a threaded end that is M5 dimension. This type of connection allowed to keep the physical properties of the product as much as its appearance. Figure 33 shows an example of the created scheme.

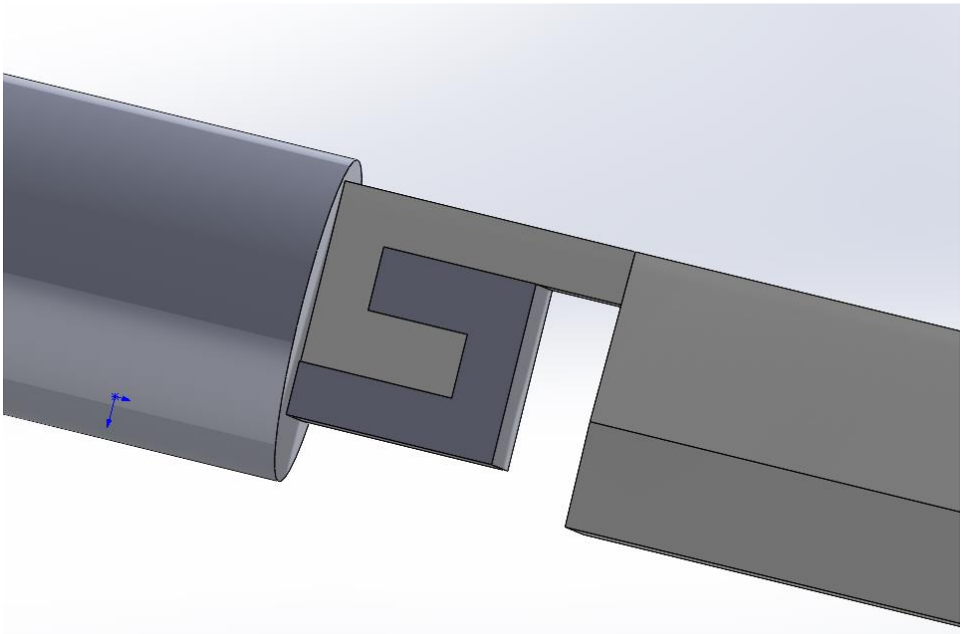

Figure 33. Connected hooks

Later, after the presentation of the hook connection to the customer, it was mentioned that this kind of system lacks stability due to a large amount of free space on the sides, also due to manufacturing reasons it was decided to change the type of hooks to less angled and easier to produce. In addition, the amount of material to be removed from both tangs is reduced leading to less manufacturing time and extra reliability to connections.

Another important thing that was mentioned during the meeting is the material properties of the knife. It was important to assign materials to get the approximate values of the weight of the product and its center mass. Both parameters are valuable for final customer usage. For different parts, different materials were requested (Table 1).

Part	Material
Handle	Oak wood
Blade	Stainless steel
Circular tang	Stainless steel
Bolster	Brass
Back plate	Brass
Custom pin	Brass

Table 1. Parts materials

3.7 Prototyping

Receiving the final version of the product made the author to create the part using additive manufacturing technology. All the models were translated into printing type files, suitable for PrusaSlicer software. By completing this stage, the author accomplishes the possible manufacturing to identify potential problems. PrusaSlicer software with Prusa 3D printer was used to produce the parts, PLA plastic with 0.3 mm width wire is the main material. The scale of the object is 1:1 to input the possibility to compare it to the original product later. The length of the printing and displacement are shown on Figure 34. Prusa software interface.

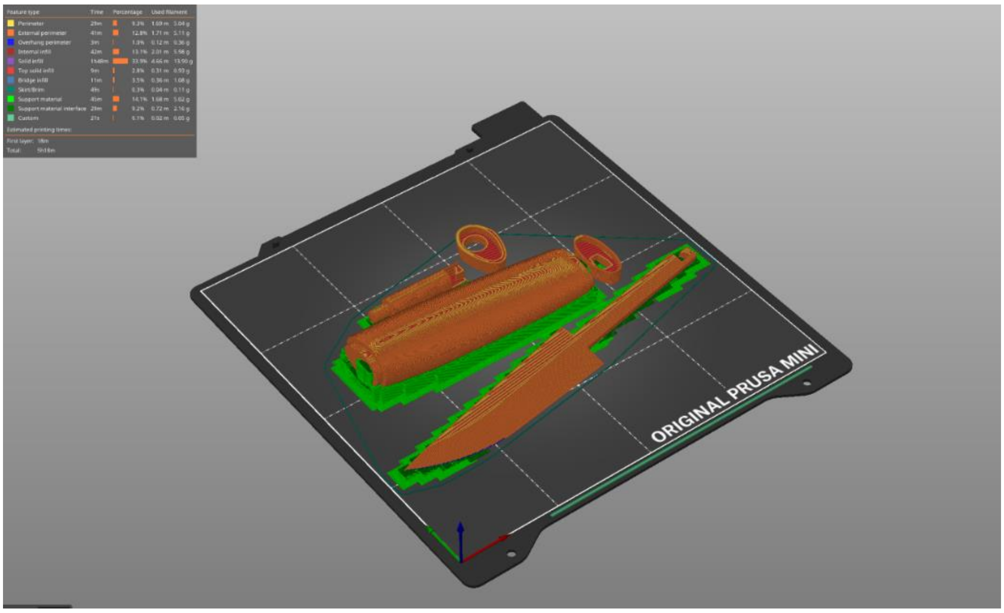

Figure 34. Prusa software interface

Created parts were assembled to check the durability of the parts under loads. With the usage of plastics, the product is shown to withstand basic loads like cutting and chopping. From this author assumes that with the usage of metals, the knife will suit as a durable and reliable product. Its visual appearance is displayed on **Error! Reference source not found.**.

Figure 35. Assembled prototype

4 Review of completed work

Reverse engineering is a time-consuming and challenging process of extracting and analysing the design of an existing product. While it has several advantages, such as reducing time-to-market, improving product design, and enhancing competitiveness, it is not without its struggles. Along the completion of the project, several problems occurred during different stages.

The scanning process of the object was a problem due to the dimensions of the parts and equipment limitations. To complete the scanning of the blade, it required the usage of extra surrounding parts to create a background or usage of the water-based paint on them, so the scanner can collect the data. Calibration of the scanning device took several tries of working to be able to collect the data properly with the highest accuracy.

A minor issue arose during the translation process where a large number of polygons were present in the created model after scanning, resulting in a time-consuming process. Despite this setback, it was decided to maintain the number of triangles to preserve the dimensions of the scanned object with the highest possible accuracy. However, this decision led to prolonged processing times, slowing down the overall project completion.

During modeling, a number of problems appeared. Most of them were related to the correct usage of dimensions that were captured by the scanner. Due to the cleaning of the handle model in the scanning software, the ends of the object were angled and were not representing the real object.

In the above-mentioned problems, the solutions were evident and easy to solve. However, the biggest issues occur from the connection of the models. The reason this was the most problematic and cumbersome issue stems from the fact that it is caused by an unknown reason. As a result, a significant amount of time was spent on solving the problem on time. Once this complicated task was completed, the following steps were completed in the more efficient way.

Notes for future projects

Before the next scanning project starts, it is important to make small research on the object and potential problems for the scanner and software. This will allow to decrease time consumption of the process and keep the data as accurate as possible. Among the possible solutions after research, the author would like to mention proper lighting for objects, as it is a key of the scanning, and the usage of markers on objects or scanned area to make further post-processing operations more precise.

Another important practice to mention is maintaining proper orientation during the scanning. It is crucial to follow the software readings and leads directly to work with 3D modeling software. With only these steps among all the other possible preparations, the end result will be enhanced a lot.

Working with files that have high polygons count in 3D modeling can be a challenging task. However, there are several ways to overcome the problem. One effective solution that the author would use to fulfil the problem is decimation tools that simplify the model by reducing the number of polygons while keeping the shape intact. In the case of using only the scanning software, the solution is to use mesh optimization tools that can analyse and optimize the geometry of a model to reduce the number of polygons without changing the appearance overall but losing some of the details.

This is a part of the work, for which it is required to decide what are priorities at the point of time, whether it is details of the object or smoothness during the following modeling. Additionally, it is worth mentioning the possibility of using other add-ins for SolidWorks software. One of them is not brought up but could be used in the future as a “ScanTo3D” tool. This feature helps the user with the import of the meshes and their further processing with algorithms that recognizes the meshes and creates the surfaces from them.

Speaking of SolidWorks usage, it is essential to keep the proper orientation during the modeling process to ensure alignment with the STL files for comparison with emerging model. When working with the assembly design will be created by utilizing knowledge of mate problems due to design optimization. Correct creation of mating surfaces or parts with simpler geometry will set all the further work to be completed faster due to the availability of fast rebuilds. Also, it is crucial to remember of “Mate” and “Smart Mates” features working algorithm, usually it applies the fastest mating type, while the user can think about certain among all of them. Another useful feature that can be applied in the future is “Mate Reference”, this tool allows to create a specific reference point on the part that can be used for mating later. These few things will accelerate the author's future modeling projects.

5 Summary

The objective of this thesis was to investigate the potential use of modern technologies such as 3D scanning in the reverse engineering process. Proper utilization of suitable techniques and product development practices was expected to facilitate the attainment of the desired outcome. However, certain challenges were encountered in the process.

The study examined the use of 3D scanning for reverse engineering of a knife, with the primary aim of investigating the feasibility of this tool in accurately capturing a product's geometry and creating a 3D model for reverse engineering. During the study author used a structured approach that involves Artec equipment and software utilization, working with the scanned object, processing the data to SolidWorks software, and completing the models according to the customer demand.

Moreover, the thesis delved into the specific challenges and considerations encountered in reverse engineering of the knives, such as the complex curvature and intricate features of knife blades, handles, and other components. It presented various techniques for overcoming these challenges, such as selecting appropriate scanning parameters, aligning, and registering multiple scans correctly, and employing data processing techniques for obtaining accurate and complete knife models.

Finally, the author created 3D model that demonstrates the ideas of reverse engineering and customer needs. Properly used 3D scanning software that allowed to extract necessary information from the initial object to reconstruct its parts for future modeling. Properties such as materials, centre mass and weight of the item are considered to match requirements of similar products on the market. Detailed version of the product was designed with required drawings to achieve a possibility for future manufacturing.

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