FINAL YEAR PROJECT REPORT

Reverse Engineering of PDC Drill Bit

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Mechanical Engineering

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CERTIFICATION OF APPROVAL

Reverse Engineering of PDC Drill Bit

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Approved

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May 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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(Muhammad Ariff Zaky Bin Mohd Zolkafly)

ABSTRACT

Reverse engineering (RE) is a very important technology especially in geometrically design and manufacture application area where this technique has been widely recognized as an important step in products and systems. This study is focus on the PDC drill bit which is one of the fixed types drilling tool use in oil and gas industry for the drilling of a well. The actual drawing or blueprint of the drill bit is hardly to be retrieved in order for a study of the engineering problem for a learning institution. Drill bit has a short life span of about six to eight month due to wear and tear and to replace a new drill bit will take a high cost in the downtime cost of the well. In this project, a wear and tear PDC drill bit will be choose to be reverse engineered, analyse, rebuild of the like new bit design, design improvement and fabrication of the prototype. This project is mainly focused on the non-contact RE method to scan one type of PDC drill bit which has a severe wear and tear condition. The PDC drill bit will first be scan using a 3D scanner in order to produce the 3D CAD design of the original bit. Then, the 3D CAD design will be redesign so that it would be look like the original part of the PDC drill bit before it happens to wear and tear. Lastly, a Finite Element Analysis (FEA) will be done on the rebuild drill bit design with a few selection of material used and a prototype of the rebuild design is fabricate. It is expected that this project meet its objectives and will be completed in time with a documentation of the analysis will be produce and the prototype of the drill bit that has been modified will be manufactured.

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CHAPTER 1

Introduction

In engineering, there are mainly two types of engineering which are forward engineering and reverse engineering which involve the process of designing, manufacturing, assembling, and maintaining products and systems. Reverse engineering (RE) is a very important brand especially in geometrically design and manufacture application area, and this technique has been widely recognized as an important step in the product development cycle [1]. The model that is created using reverse engineering are for various reasons including to design tool for the production of a copy of an object, to study the concept of an existing design, or to analyze the design for improvement. In contrast to the traditional production sequence, reverse engineering typically starts with measuring an existing object, so that a solid model can be deduced in order to make use of the advantages of CAD/CAM/CAE technologies [2]. The author point of view is that RE is a process to reproduce an existing object in order to analyze the design and to modify the design to improve its function, to change its dimension and design for the aesthetic value, or to reproduce the object that is specially made for a product to be used by others.

1.1 Background of Study

A short lead time in product development is highly demanded to satisfy needs due to the globalization of manufacturing activities and changes in market requirements nowadays. The engineering areas such as aerospace, manufacturing, automotive, shipbuilding, and medicine are strongly benefit from the application of RE to reduce product development cycle significantly [3]. The industry of oil and gas will also benefits from RE technology for its component production.

The applications of RE in the industrial area are defined in the following aspects: [4]

- Design of a new component. The design of new part comes from an existing real part model.

- Reproduction of an existing component. Some parts exist for which no design/manufacturing documentation exists but it can be obtained by RE approach.
- Recovery of a damaged or broken component. If the surface of a part to be measured is damaged or worn away, the reconstructed CAD model may not be precise compared with the true surface of the part.
- Development of model precision. The engineer can finish a product concept design based on the requirements of function and aesthetics and then use some soft material, such as wood or plaster, etc., to fabricate models.
- Observation of a numerical data. Scanning the part and reconstructing a 3D-CAD model by the RE approach, the designer can compare this model with the first model.

RE process has following advantages such as fast availability of CAD models, physical model is used as the starting point, shortened development process, fully developed product at the start of production, reduction in product and production costs [5].

The process of RE can usually be subdivided into five stages; digitization of the part, data capturing, processing of measured data, surface approximation- for solid modelling of the part (CAD modelling), technical documentation and NC part programming and CNC milling machine- for the part manufacturing. Digitalization of a part surface in RE can be achieved by utilizing either contact probing or non-contact sensing method as shown in Figure 1 [6]. The contact method includes point to point sensing with touch trigger probes method and the analogue sensing with scanning probes where data is gathered slowly by moving the probe stylus tip on the object surface. Vice versa, the non-contact method is much faster where there is no contact between RE hardware and object during data gathering. The geometry of the object is captured by scanning the object and the data gathered is calculated. Classification of non contact RE method is made based on data acquisition technique, either reflective or transmissive.

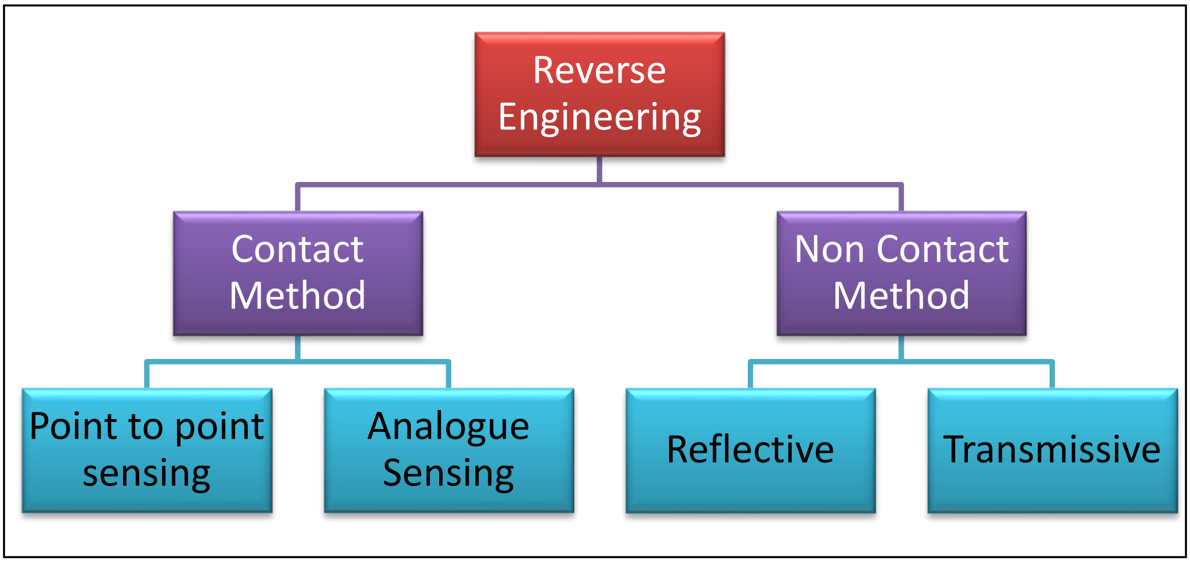

Figure 1: Reverse Engineering Method

1.2 Problem Statement

In the intensely competitive global market, manufacturers are constantly seeking new ways to shorten lead-times to market a new product. Rapid product development (RPD) refers to recently developed technologies and techniques that assist manufacturers and designers in meeting the demands of reduced product development time. This is very important for the manufacturers of the oil and gas component as all the component that they produced has its own lifetime because of the exposure to wear and tear is very high. One of the important parts in oil and gas is the drilling of a well. The drill bit use in drilling often face the problem of a short lifetime where the drill bit will need to be replace because of wear and tear which will affect the downtime cost of the drilling well during the changing of the bit. Some of the drill might have the old design that the company might not have reproduce the product. A solution to this problem is needed in order to accommodate the problem of not having the CAD drawing of the original part as the company has not produce it anymore or the company has vanished together with the original drawing. To reproduce the drawing by starting with a CAD drawing from the basic will take a very long time and if the design is too complicated it might be impossible for the designers to design the parts. Besides, it will also make it impossible for a learning institution to study on the engineering problems of the drill bit as the blueprint cannot be retrieved from the manufacturing company. Thus, a more effective solution will be needed.

1.3 Objective

The main objectives of this study are:

I. To reverse engineered the worn PDC drill bit into a 3D CAD model design.
II. To regenerate CAD model of the worn drill bit into like new model design.
III. To execute Finite Element Analysis (FEA) studies on the rebuilt design.
IV. To fabricate a prototype of the part model.

1.4 Scope of Study

The scopes of study based on the objectives can be simplified as follow:

I. Non- contact method of reverse engineering (3D scanner).
II. One type of worn drill bit with a particular size (PDC drill bit).
III. CAM software programming with Finite Element Analysis (FEA) software.
IV. Fabrication of the prototype.

1.5 Relevancy of the project

Increasing demand of design and production in manufacturing industries nowadays has as well cause growing number in the demand of both hardware and software tools for RE purposes [7]. In the oil and gas industry, reverse engineering is needed to produce the part that can be used for a long time so that it would not affect the downtime cost in changing the parts. The component could also be analyse to increase the efficiency of the product and simplify the production process. Besides, the complex design of a part can be handled by using this method in order to reproduce the part or to improve the design.

1.6 Feasibility of the project

In this project, 3D scanner that will be used is 3D VIUScan scanner which owned by UTP. Thus, it will be available for the student to use the scanner at all time. The knowledge on this scanner functions and skills on scanning skills also will be provided before project work started. Various type of 3D modeling software also available and can be used in the provided laboratories. The drill bit is located in UTP which it will be easy for the study and the mobility of the component to be completed in two semesters.

CHAPTER 2

Literature Review

There are various number of researches and studies that have been carried out which is related to reverse engineering technology. Inclusive is the study material of the oil and gas component which has been selected for this study. The books and journals that have been referred have a different work scopes depending on the objectives. Some related points and topics are discussed below.

2.1 Reverse Engineering versus Forward Engineering.

Reverse engineering is consisting of four stages of process in its development of the technical data to support the efficient use of capital resources and to increase productivity. The stages are conducted after a rigorous pre-screening of potential candidates, consist of data evaluation, data generation, design verification, and design implementation [8]. While the forward engineering is the traditional process of moving from a high level concept and abstractions to the logical, implementation-independent design needed in a physical system, then reverse engineering is the design analysis of the system components and their relationship within the high level discrete system [8]. Table 1 illustrates the differences between the traditional design process and the reverse engineering process.

Traditional Design Process	**Reverse Engineering Process**
Need → Design data → Prototype & Test → Product	Product → Disassembly → Measure & Test → Design Recovery → Prototype & Test → RE Product

Table 1: Traditional versus reverse engineering design process [8].

Nevertheless, according to the paper entitled *Reverse engineering in CAD model reconstruction of customized artificial joint* written by Yan-Ping Lin, Cheng-Tao Wang and Ke-Rong Dai, in a normal automated manufacturing environment, the operation sequence usually starts from product design via computer-aided design

(CAD) techniques, and ends with generation of machining instructions required to convert raw material into a finished product. In contrast to this conventional manufacturing sequence, reverse engineering represents an approach for the new design of a product that lacks an existing CAD model [9]. The author is just focusing on a particular design which only being tested without fabricating the prototype. The typical process of RE begins with the digitization from the surface of an existing part as shown in the Figure 2 where physical model is scanned using the 3D scanner and producing the digital model for the point pre-processing and surface fitting. Then a solid 3D construction is done for the CAM/NC processing.

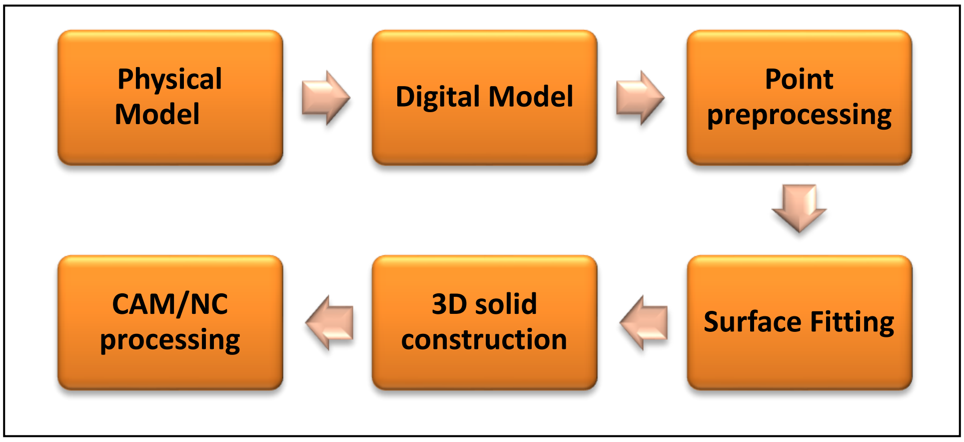

Figure 2: The process of reverse engineering

2.2 Benefits using the non-contact method (3D scanner) in reverse engineering.

In the previous years, there has been an increasing demand from the industrial framework, of both hardware and software tools with increased simplicity and efficiency in production process [10]. One of the areas where this demand is the greatest is three-dimensional (3D) acquisition and processing of free forms in space. Whenever complex, free form surfaces have to be measured in short time, and a very high measurement accuracy in not required, wide-area laser scanners and whole-field optical digitisers represent valid alternatives to CMMs. They are faster, may provide the 3D shape of the object in seconds, and are reasonably less expensive than CMMs [11]. Authors have described the benefits of using 3D scanner rather than CMM but without the justification on the actual size of scanned object versus the cost of the 3D scanner or the CMM. New scanning technologies are emerging that have potential to further enhance the quality of 3D object scans. This system generates dense volumetric scans where the detailed scans can be generated quickly, and the wide scanning volume reduces the importance of the angle at which the tracking light hits the target object [12]. The authors have shown a good example but it is limited to a few objects only.

2.3 3D ViuScan Scanner

3D ViuScan as shown in Figure 3 is one of the handyscan 3D that stand out as the most accurate portable 3D scanners on the market. The scanner is developed so that it could be use whenever we need them to. The scanner features guarantees accuracy no matter the environment, part set-up or the user's level of experience. The manufacturer of the scanner focuses on three main aspect which are TRUportability, TRUaccuracy and TRUsimplicity [13].

Figure 3: 3D Viuscan scanner

The TRUportability shows the aspect on the portability of the scanner. The scanner is fits into a case the size of a carry-on where it is handheld and lightweight because the scanner weights about 1 kg. It can be use from plant to plant and use it in-house or on site. Furthermore, it has no mechanical constraints where it has a flexible stand-off distance which makes it possible to reach confined areas. The TRUaccuracy means that it has a high accuracy where it could generate accurate, repeatable, high resolution 3D data. Moreover, it has a dynamic referencing where the optical reflectors are used to create a reference system that's "locked" to the part itself. User can move the object any way he wants during scanning session. Changes in surrounding environment have no impact on data acquisition quality or accuracy. It also can produce reliable constant results across all work conditions or environments. Besides, the scanner is a data acquisition system and its own positioning system. This means that no external tracking or positioning devices is required. It uses triangulation to determine its relative position to the part in real time. The scanner can be calibrated as often as necessary (day-to-day basis or before each new scanning session) where it takes about 2 minutes and guarantees optimal operation.

The third aspects that the manufacturer focuses on are TRUsimplicity. This scanner features a user-friendly model where it has a very short learning curve, no matter the user's experience level. It also a versatile product where it has a virtually limitless 3D scanning no matter the part size, complexity, material or colour. It also has a resume function where a few positioning targets can be used to instantly resume scanning after a pause [13].

The author from Creative Planet Network also agrees that the 3D ViuScan scanner is one of the best 3D scanner because the scanner comes with inexpensive software pushing 3D images far from the initial markets of feature film and national advertising, it's becoming more useful than ever to be able to capture 3D in the field. This self-positioning, handheld laser scanner is claimed to deliver hyper-realistic results thanks to features such as simultaneous texture and geometry acquisition, realtime rendering, true-color acquisition through a built-in lighting system, adjustable uniform texture resolution, and automatic 100-percent-accurate texture mapping. The image showed in Figure 4 shows the portability of the scanner where it fits in a brief case [14].

Figure 4: Full setoff 3D ViuScan scanner in its brief case.

2.4 Oil and gas component: Drill Bit.

Drill bit is defined as the item placed at the end of the drilling string into the earth. The drill bits cut and chip small pieces of rock as the pipe rotates where it is the mechanism that cuts into the ground layers to reach the gas deposit or to cut a core sample. Bits usually rotate 50-300 revolutions per minute depending upon the hardness of the strata through which it is boring [15]. On one particular bit run, the cost are composed of the time based operating cost of the drilling facility, the duration required to drill the bit run interval (i.e rate of penetration), trip frequency, determined from the length of the internal over which the bit can be kept drilling (bit life), and the price of the bit itself. This means that drilling cost is a strong function of the rate of penetration (ROP) and life provided by the bit. This in turn means that the suitability of a bit design for drilling in a given interval is a major factor in bit run cost [16]. Authors has stated about the cost but without showing the example on the actual cost basis on a particular bit. Besides, there are a few numbers of different types of drill bits. Steel Tooth Rotary Bits are the most common types of drill bits, while Insert Bits are steel tooth bit with tungsten carbide inserts. Polycrystalline diamond Compact Bits use synthetic diamonds attached to the carbide inserts. Forty to 50 times stronger than steel bits, Diamond Bits have industrial diamonds implanted in them to drill extremely hard surfaces. Furthermore, hybrids of these types of drill bits exist to tackle specific drilling challenges [17]. The source has also stated that hybrid of the types of drill bit is exist but they don't specified a few example on which drill bit can be hybrid.

On the other hand, in one well, there are number of different drill bits may be inserted and used where different configurations work better on different formations. Additionally, drill bits have to be changed due to wear and tear [17]. The sample of drill bits can be seen in Figure 5a and Figure 5b.

Figure 5a: Drill Bit sample 1

Figure 5b: Drill Bit sample 2

2.5 Finite Element Analysis (FEA)

Finite Element Analysis (FEA) is a computer model of a material or design that is analyzed to get specific results. It is used in existing or new product refinement. A company can verify a proposed design to meet client's specifications subject to manufacturing or construction. Modifying an existing product or structure is utilized to improve or qualify the product for a new service condition. If the model fails, FEA is very useful to help designer to modify back the design to meet the targeted condition. FEA help analyst to predict failure due to unknown stresses by showing problem areas on an object and giving chances for designers to see all of the theoretical stresses within. This method can help to reduce manufacturing costs and time rather than making and testing the real component [18]. The sample of a FEA study is shown in Figure 6.

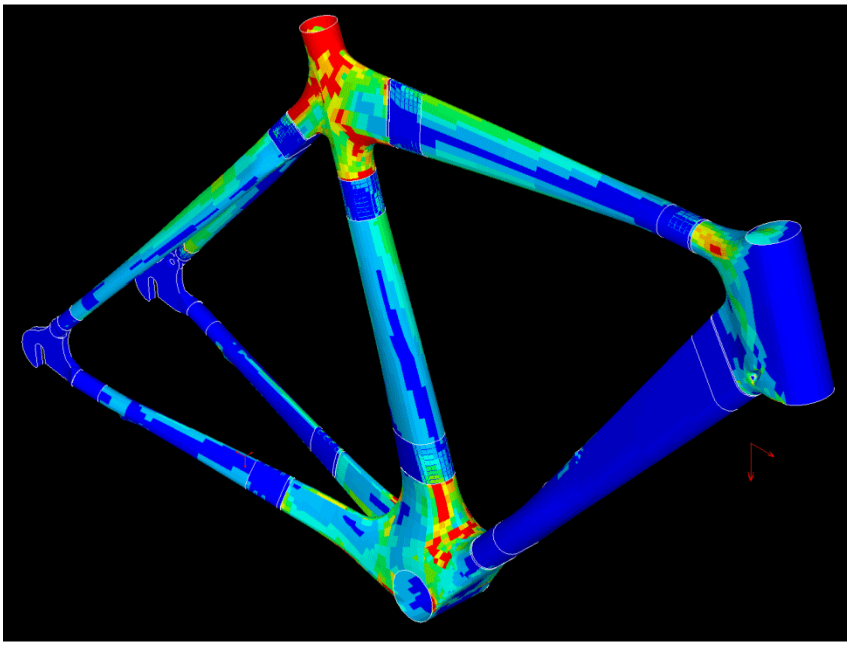

Figure 6: Sample of FEA study on bicycle body

As in the Finite Element Analysis, there are two types of analysis that could be done for this project which is the stress analysis and thermal analysis. Residual stress is usually defined as the stress which remains in mechanical parts which are not subjected to any outside stresses. Residual stress exists in practically all rigid parts, whether metallic or not (wood, polymer, glass, ceramic, etc). It is the result of the metallurgical and mechanical history of each point in the part and the part as a whole during its manufacture. Residual stresses can be characterized by the scale at which they exist within a material [19].

- Type I Stresses: Macro-stresses occurring over distances that involve many grains within a material.

- Type II Stresses: Micro-stresses caused by differences in the microstructure of a material and occur over distances comparable to the size of the grain in the material. Can occur in single-phase materials due to the anisotropic behaviour of individual grains, or can occur in multi-phase material due to the presence of different phases

- Type III Stresses: Exist inside a grain as a result of crystal imperfections within the grain.

While the thermal analysis is one of the branches of materials science where the properties of materials are studied as they change with temperature. This analysis is very important to know the minimum and maximum temperature that an object can withstand without any failure during its operation. We can also know the critical area on an object so that we can pay more attention on that area. Thermal loading is loaded to the object during this analysis in order to see the change of behaviour of the object. Thermal loading is based on the worst condition that the object will go through along its operation [20].

CHAPTER 3

Methodology

The process of the RE for this study is started with the preparations of the physical model that will be the selected subject for the RE process. Then there are four main steps which are scanning and digitizing physical surface of the object, processing captured data from the scanning, creating 3D CAD based on the cloud model, and finally the fabrication of the prototype with the analysis documentation. The process of overall RE is illustrates in the Figure 7.

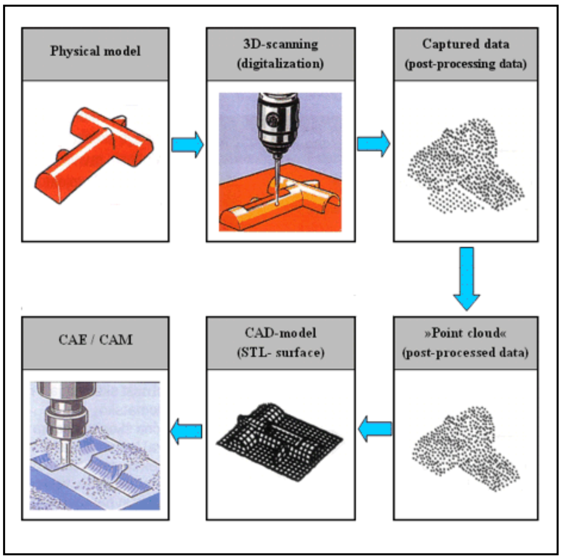

Figure 7: Overall Process of Reverse Engineering

This project is following the basic step in Reverse Engineering but with a few additional steps in order to accommodate the objectives of this project. The full steps in order to complete this project is shown in the process flow on Figure 5.

3.1 Scanning /Digitization of the Drill Bit.

As shown in Figure 8, a RE scanner which is the 3D ViuScan scanner will be used for the scanning process. The 3D ViuScan scanner is a non contact laser scanning device which is available and own by UTP which it located in the one of the Mechanical Department laboratory. One of the processes that will be done in this project is the digitization of the drill bit. Digitization is the process of data acquisition of the drill bit in order to get the cloud model of it. In general, the digitization process is consisting of two stages: scanning and surface model generation. Training on the handling of the scanner will be provided before the scanning process get started in order to understand the full use of the scanner and gets the hands on experience before the testing on the drill bit. The system of this scanner is laser based, so it is capable to capture very high detailed surface. Upon the complete capture of the object, the cloud model is evaluated, which is then transferred on to the 3D modelling software so that it can be converted into 3D CAD model.

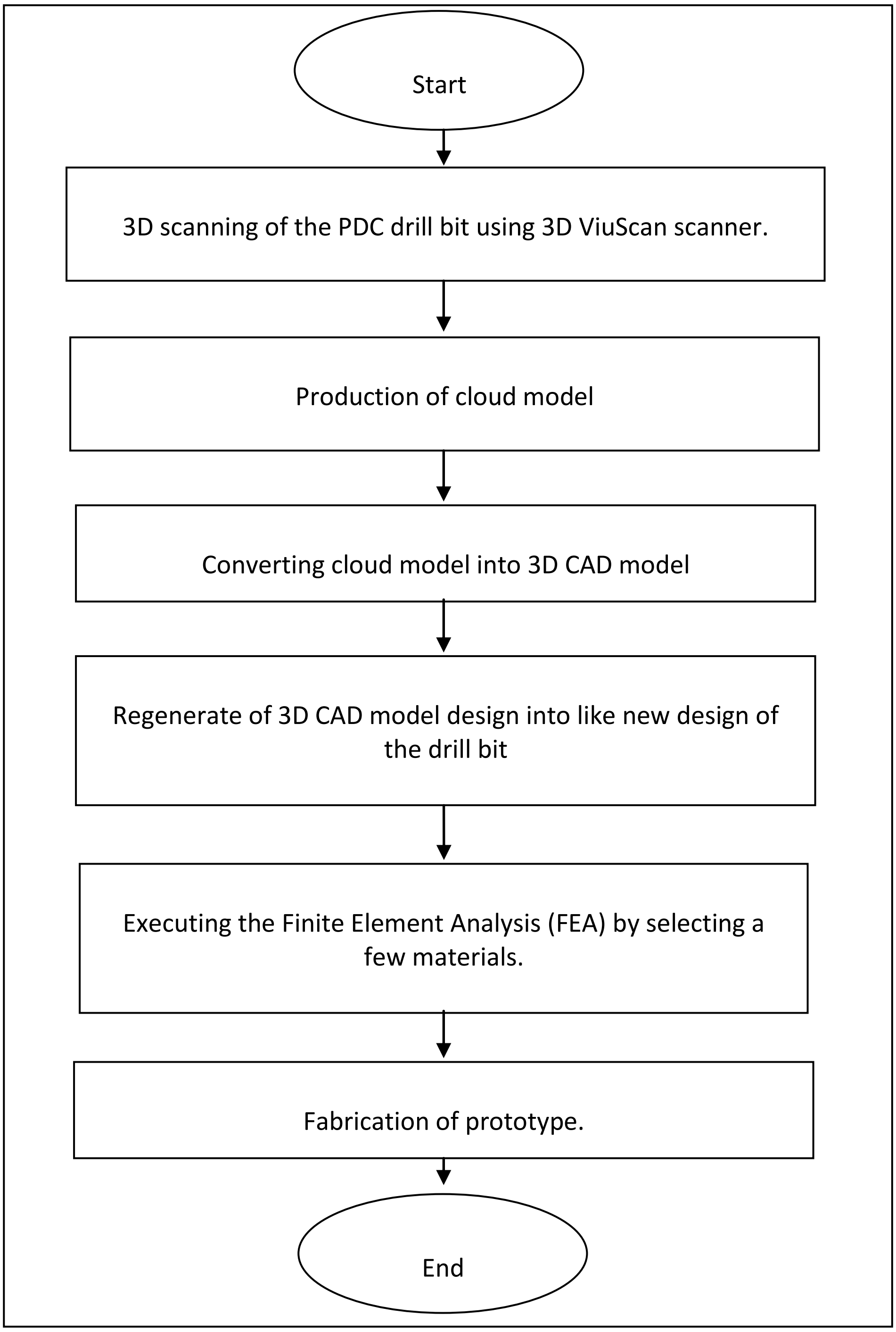

Figure 8: Overall Process Flow of the Project

3.2 Processing Captured Data

Processing captured data from scanning process is a very important phase in RE. There are a few numbers of different 3D-digitalization systems that have been developed such as laser scanner, pantographs, CCD cameras, and coordinate measuring machines (CMM) and the computer tomography (CT). Model generated by most of these machines is not perfect due to the presence of noise and measuring errors as well as generation of too many numbers of points. A few steps as stated below need to be done in order to get a good result before converting into cloud model:

- Noise and error filtering.
- Reducing the number of points.
- Joining different scanned models
- Wiping parts of the model.
- Improving particular part of scanned sections.

3.3 Converting Cloud Model into 3D CAD Model

The 3D model of the drill bit then will be converted into the 3D CAD model. This process is done using 3D modelling software. As for this project, CATIA and ANSYS will be the 3D modelling software. Modelling will be made exactly based on the cloud model obtained from scanning process. The construction curves are generated at first. Then surface can be created by meshing the construction curves generated earlier. Any modification to be made on the model is done in this process. The modified model is called the reverse engineered model. After the completion of the modelling process, final 3D CAD model can be assessed and analysed whether it meets the objective of the project. Shown in Figure 9 is an example of a 3D CAD model converted from cloud model.

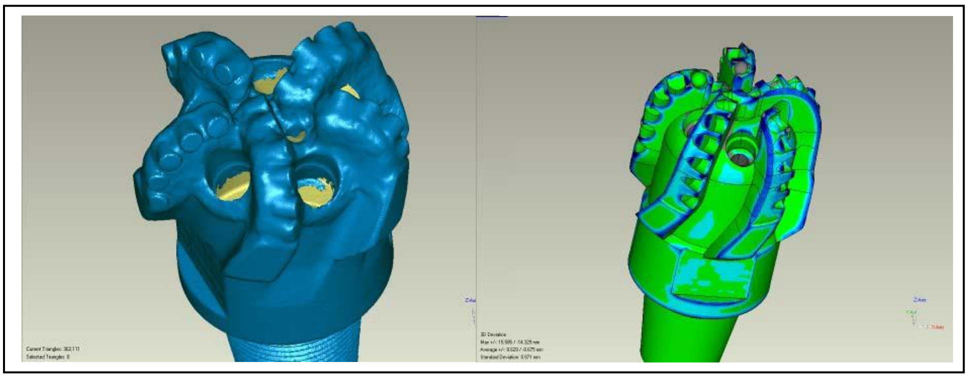

Figure 9: Example of 3D CAD model converted from cloud model

3.4 Editing, Finite Element Analysis (FEA) and Fabrication of the Prototype.

The product from the scanned model of the worn drill bit will then edited so that a perfect drill bit could be produced. Then, the FEA will be executed on the new design produce with a few selection of material. At the end of the project, a prototype will be fabricated from the drawing of the 3D CAD model.

3.5 Gantt chart and Key Milestones

Semester January 2013

Activities / No. of Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Literature Review														
Identify feasible oil and gas component for the project														
Drill bit model selection					1									
Scanning drill bit into cloud model								2						
Convert cloud model into 3D CAD model														

Semester May 2013

Activities / No. of Week	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Convert cloud model into 3D CAD model and regenerate like new design				3										
Analysis on the drill bit 3D CAD							4							
Fabricate the modified drill bit model								5						

(yellow box)	**Project Progress**
1	Key Milestone 1: Oil and Gas component identified
2	Key Milestone 2: Cloud model obtained
3	Key Milestone 3: Rebuilt 3D CAD model completed
4	Key Milestone 4: Drill Bit FEA analysis completed
5	Key Milestone 5: Fabrication of prototype completed

Revised Gantt chart and Key Milestones

The Gantt chart and the Key Milestones has been revised due to the problem faced on the licensing of the software needed for the 3D scanning which is the main part of the study. The scanning is being done in the May Semester 2013.

Semester January 2013

Activities / No. of Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Literature Review														
Identify feasible oil and gas component for the project														
Drill bit model selection					1									
Scanning drill bit into cloud model														
Convert cloud model into 3D CAD model														

***The 3D scanning cannot be done in Semester Jan 2013 as there is an issue with the licensing of the software that is required for the scanning process.**

Semester May 2013

Activities / No. of Week	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Scanning drill bit into cloud model					2									
Convert cloud model into 3D CAD model and regenerate like new design							3							
Analysis on the drill bit 3D CAD								4						
Fabricate the modified drill bit model								5						

(yellow box)	**Project Progress**
☆1	Key Milestone 1: Oil and Gas component identified
☆2	Key Milestone 2: Cloud model obtained
☆3	Key Milestone 3: Rebuilt 3D CAD model completed
☆4	Key Milestone 4: Drill Bit FEA analysis completed
☆5	Key Milestone 5: Fabrication of prototype completed

CHAPTER 4

Result

In the result section, it is divided by 4 main parts which is the Scanning, 3D CAD, Design Improvement and also the Finite Element Analysis.

4.1 Scanning

The PDC drill bit has been scanned by using the 3D scanner and the cloud model has been obtain. The result of this part is mainly on the step in producing the cloud model so that it could be convert into the 3D CAD drawing for the design step. The scanning equipment setup and the scan object setup is shown in Figure 10. While Figure 11 shown is the initial scanning image of the drill bit with all the facets and noise has been removed.

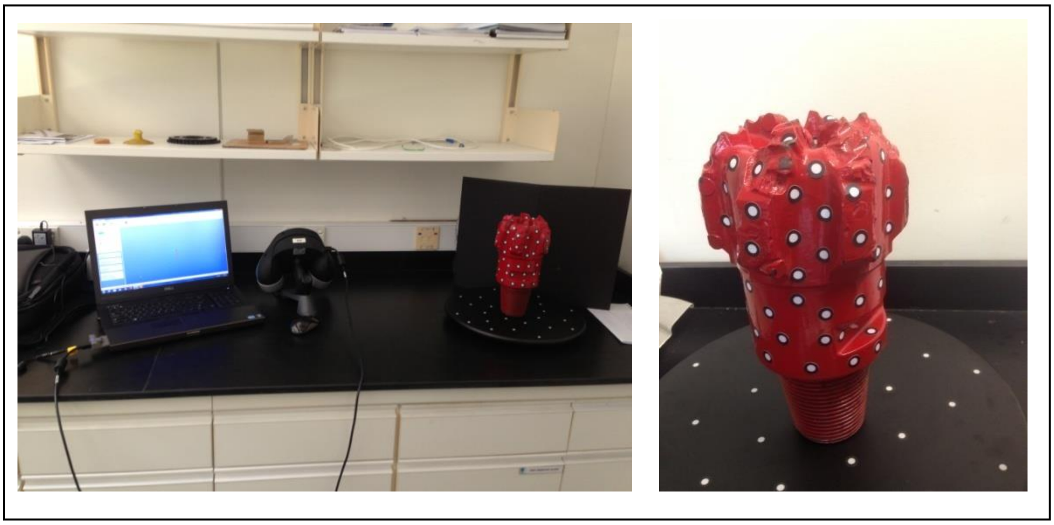

Figure 10: 3D scan setup.

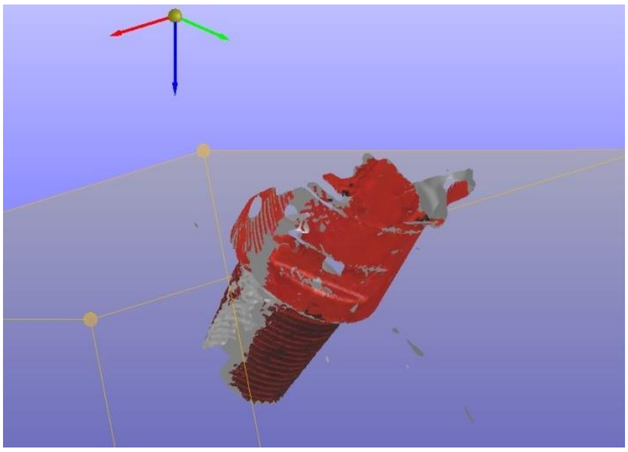

Figure 11: Initial Scanning

As seen in the Figure 11, only part of the object is being scan and the scanning need to be continued until a perfect figure has been obtain. The scanning process is being done continuously in one week. Figure 12 shown a more completed figure of the drill bit after a few session of scanning has being done. However, the figure obtain is still not perfect due to some parts has not being scan well and a few small holes was detected and the scanning need to be done to make it complete.

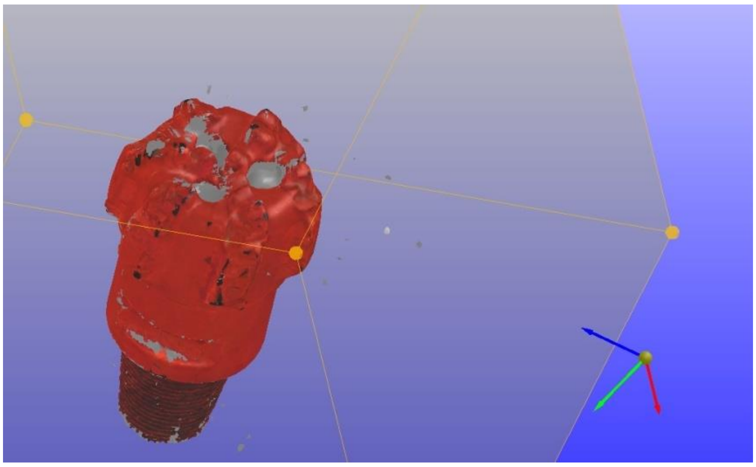

Figure 12: Scanned image of PDC drill bit.

In the final scanning of the PDC drill bit, a lot of noise has been created as the scanning is being done repeatedly. The noise may be produce by the small particles in the air and the scanner is too sensitive with the surrounding. The figure in Figure 13 shows the image of the scanned object with the noise created where the noise is in black and purple colour.

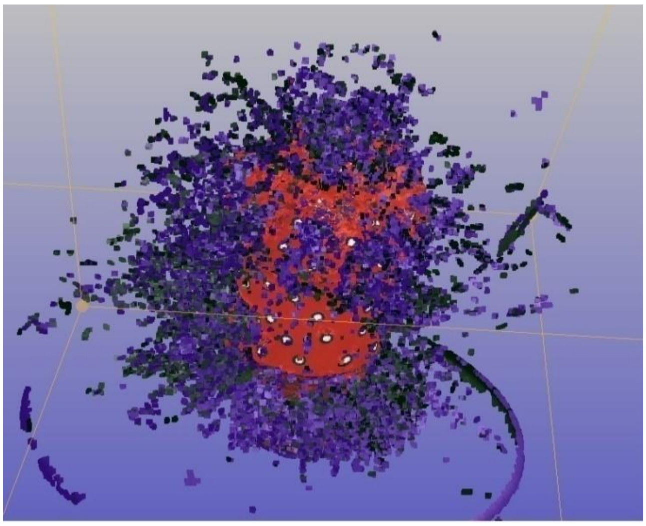

Figure 13: Final scanning with noise created.

When the scanning process has been completed, the cloud model can be edited by using the VXelement software which is also used during scanning. This software has the capability to remove the noise automatically, but, some of the noise is being read as an object, so some facets has been produced as shown in Figure 14.

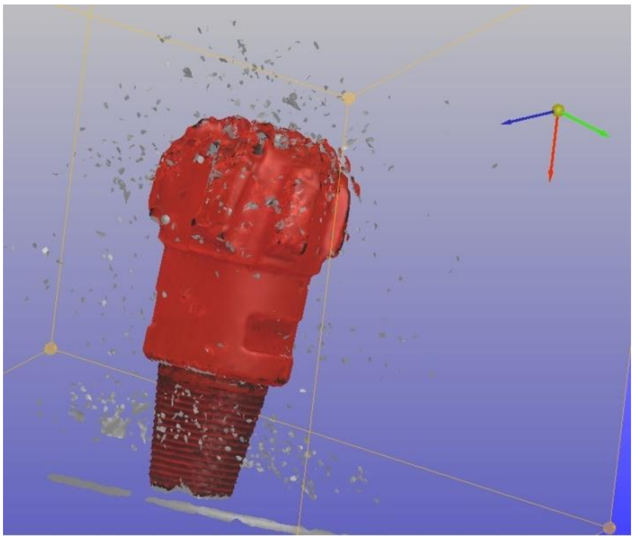

Figure 14: Final scanning with facets forms.

In order to remove the facets, editing need to be done by deleting the facets. The software has a feature to automatically delete the facets and object that does not required by the user. As shown in Figure 15, the left one shows the initial setup while on the right side is the image of the Remove Isolated Patches has been set from small to more nearer to larger.

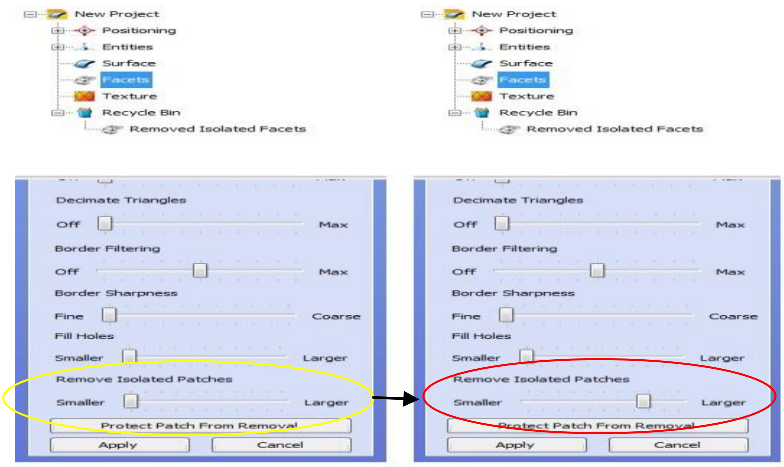

Figure 15: Step to remove the facets.

By clicking the Apply button, a small to medium facets that is not connected to the drill bit image will be removed. In Figure 16 shows the deleted facets where it is being save in to the recycle bin if need to be used later while Figure 17 shows the image where all the facets has been deleted and the cloud model of the PDC drill bit is obtain.

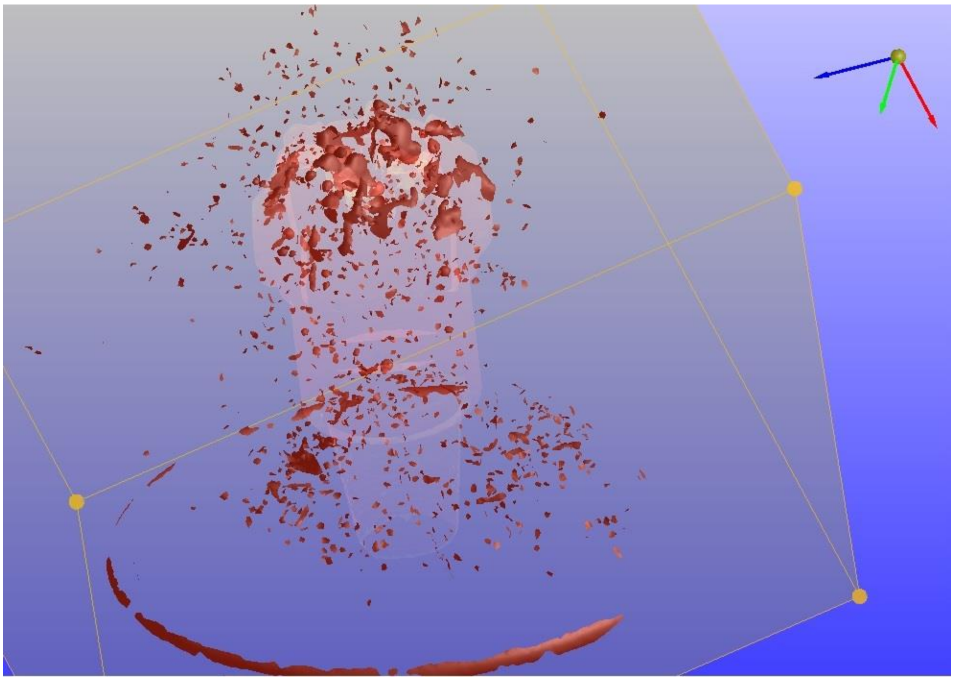

Figure 16: Deleted facets.

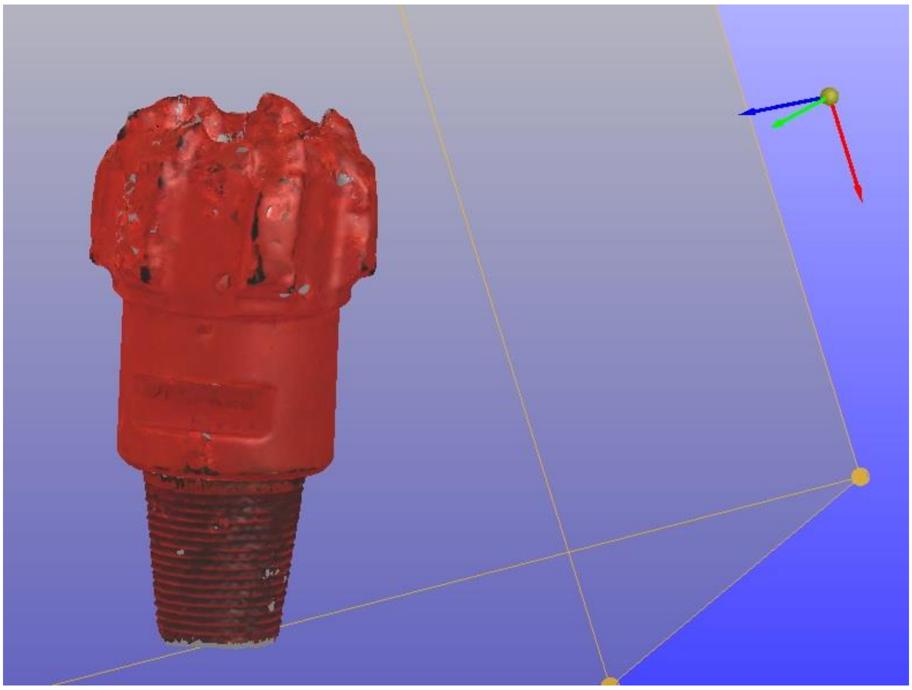

Figure 17: After the facets that are not required is deleted and remove.

As the cloud model of the PDC drill bit has been edited and obtain, it can be transferred to designing software to obtain the 3D CAD drawing and for further changes on the design. Shown in Figure 18 is the zoom in image of the PDC drill bit obtain.

Figure 18: Cloud model of PDC Drill Bit.

4.2 3D CAD

The cloud model obtain from the 3D scanning process is then save to a file format that can be read by the designing software. Then, the 3D CAD of the PDC drill bit is produced as shown in Figure 19. The designing software being use to obtain the 3D CAD drawing is GeoMagic12.

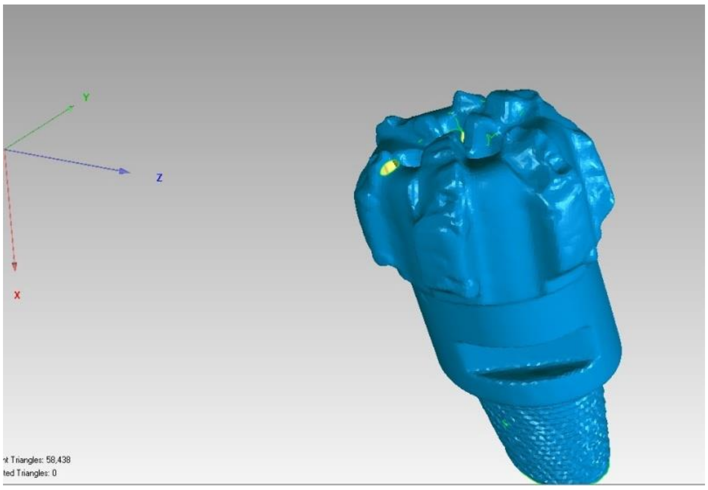

Figure 19: 3D CAD drawing of scanned PDC drill bit.

The image in the Figure 20 is the isometric view of the drill bit and Figure 21, Figure 22, and Figure 23 shows the top, front and side view of the 3D CAD drawing of the PDC drill bit. The 3D CAD model can be edited to make further design improvement or further analysis.

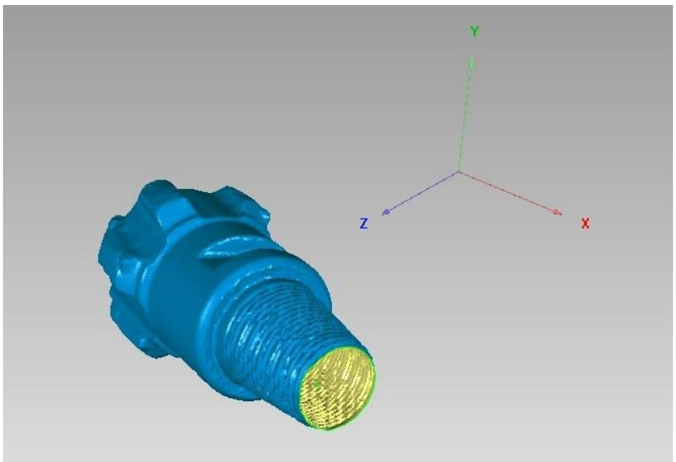

Figure 20: Isometric view of PDC drill bit.

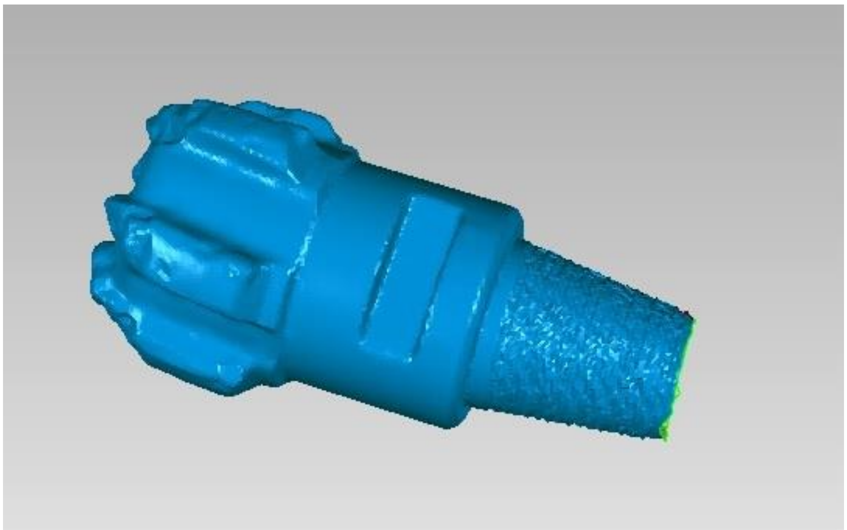

Figure 21: Top view of PDC drill bit

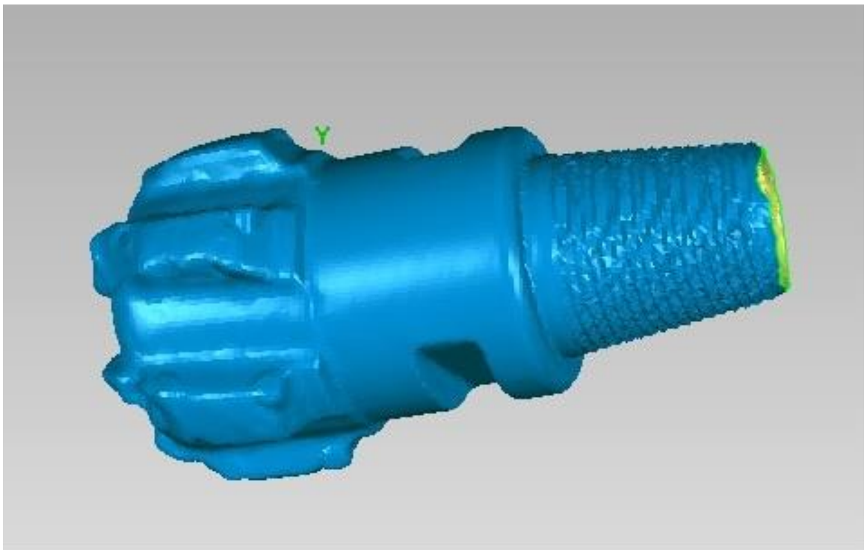

Figure 22: Front view of PDC drill bit

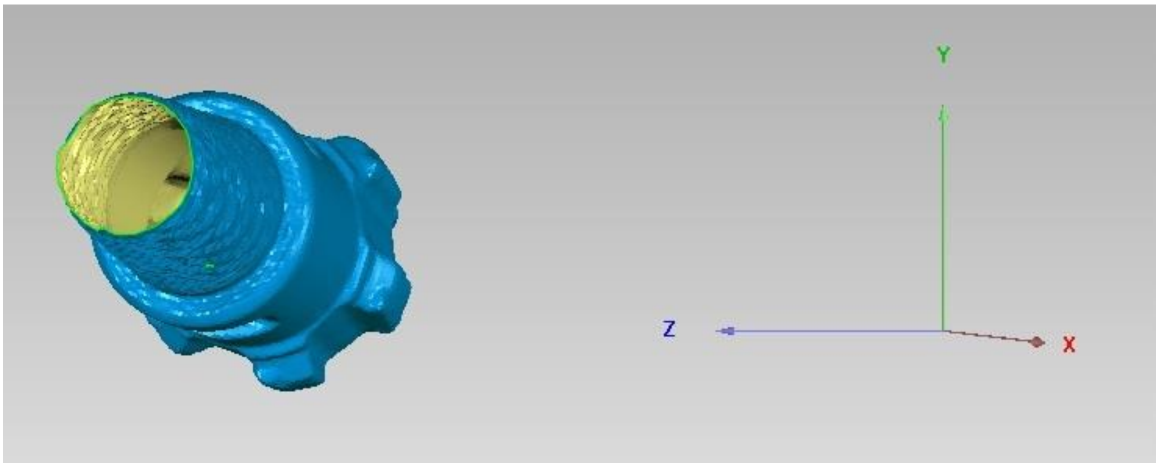

Figure 23: Side view of PDC drill bit

Shown in Figure 24 is the closed up view of the 3D CAD model of the drill bit from two different views. The closed up view is important to see and analyse the wear and tear of the drill bit.

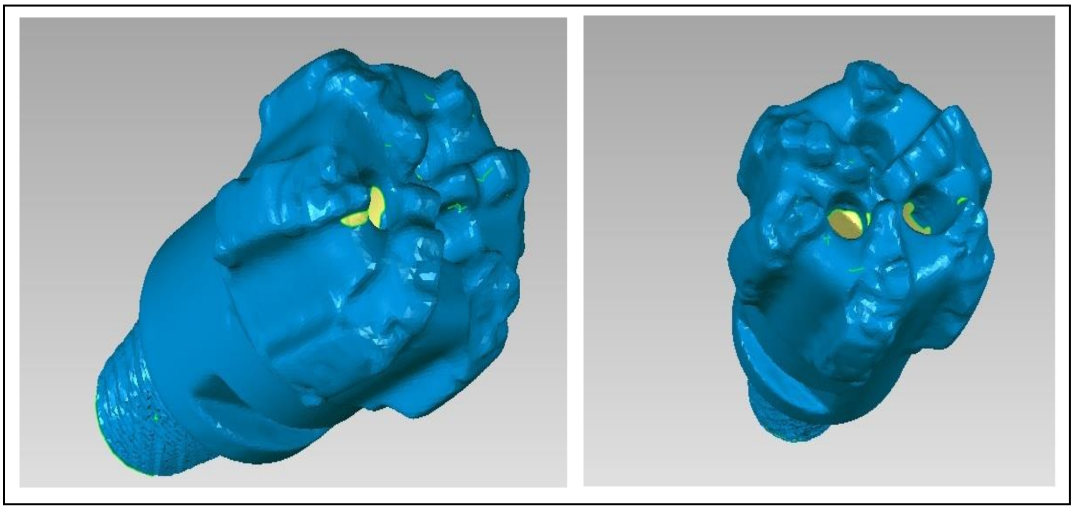

Figure 24: Closed up view of PDC drill bit

The rough dimension of the scanned PDC drill bit also has been obtained by using the feature in the GeoMagic12 software. As shown in Figure 25 is the dimension from top to bottom which is noted by the Point 1 to Point 2. The length is 285mm.

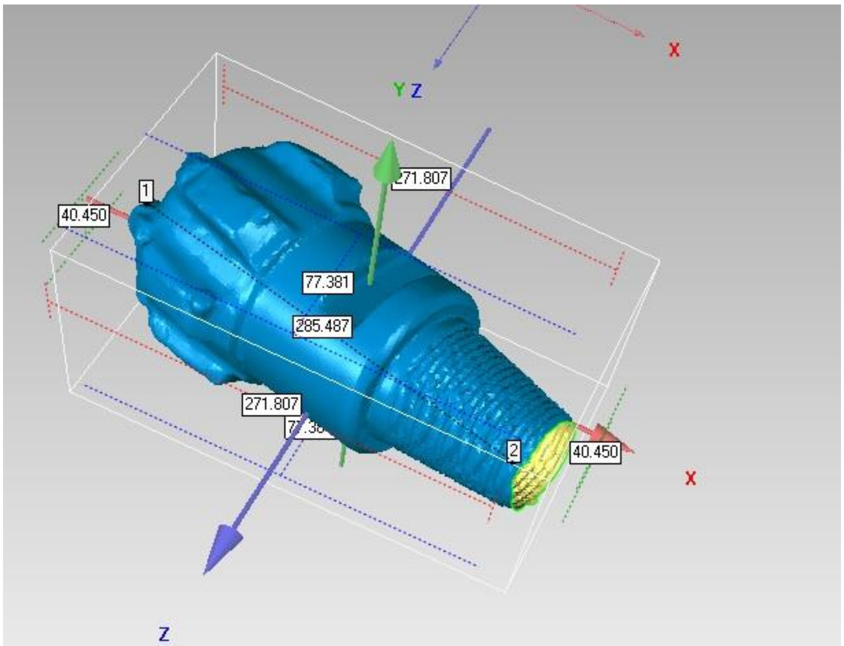

Figure 25: Rough dimension

One of the best feature of the GeoMagic12 software is the mesh doctor where meshing could be done automatically to remove spikes and automatically smoothes the surface of the 3D CAD model. A trial on the mesh doctor has been made and the final image obtain as shown in Figure 26.

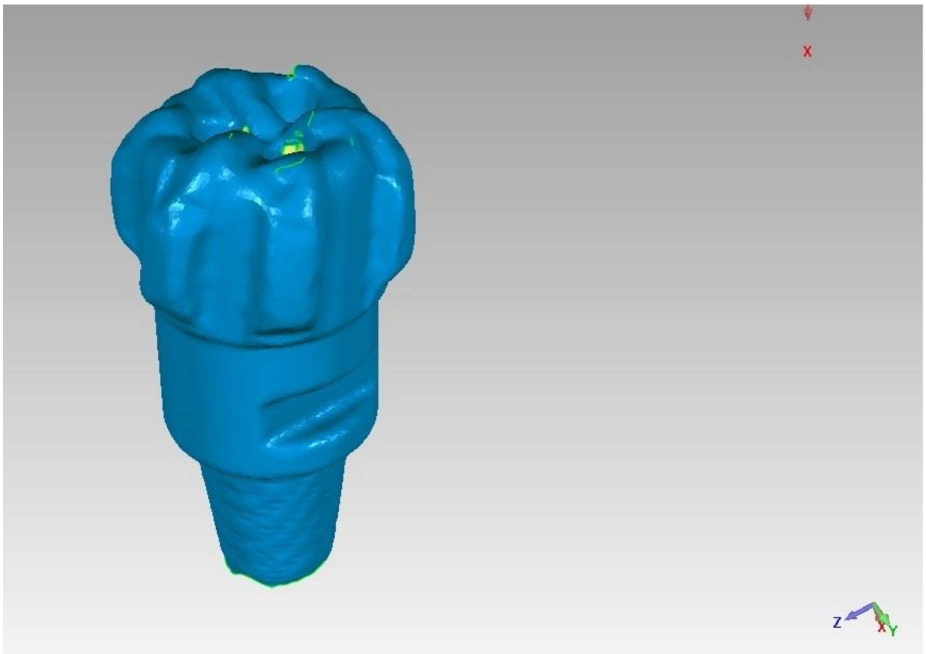

Figure 26: Mesh doctor result.

However, the result obtain has made the 3D CAD model too smoothes and most of the wear and tear cannot be seen. It also has created an image which is far from the real object if compared. As for this project, mesh doctor will not be used.

4.3 Design Improvement

One of the objectives of this project is to regenerate the 3D CAD model of the PDC drill bit into a like new design of PDC drill bit. The step in producing the like new design of the PDC Drill Bit is started with the following processes as shown in Figure 27.

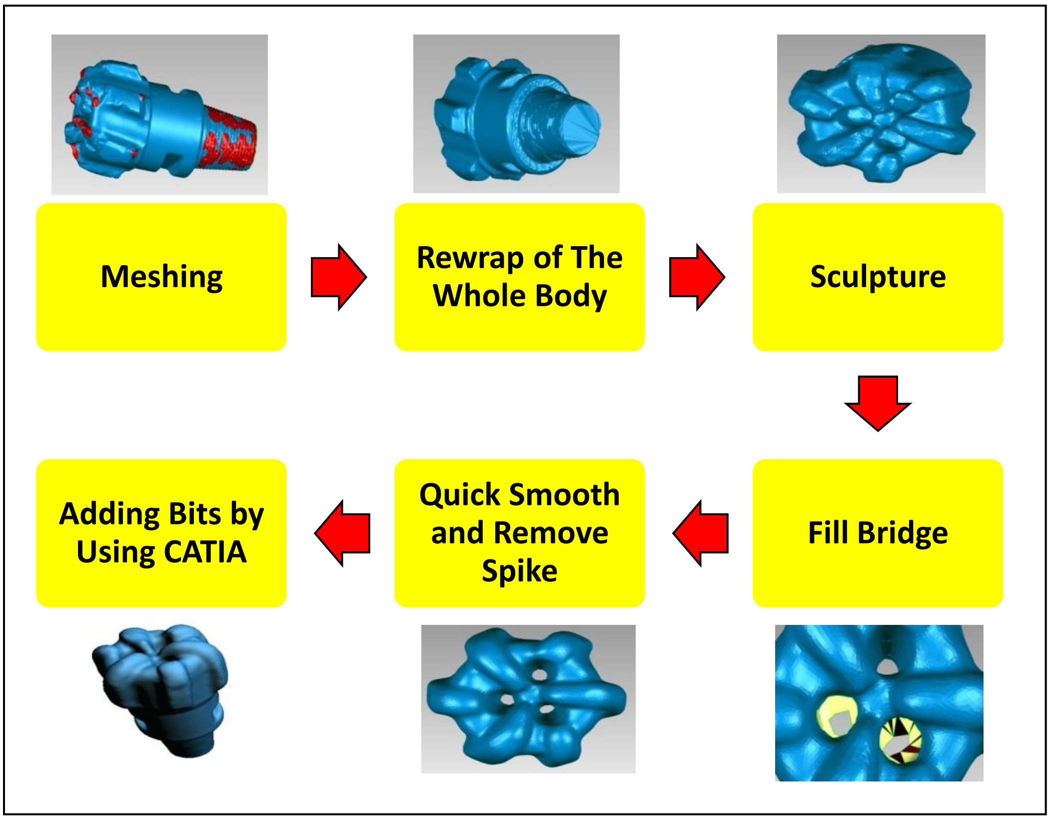

Figure 27: Process to produce the like new design of PDC drill bit.

After the 3D CAD model of the worn drill bit is obtain, the process of producing a like new design started with the meshing process where the selected area that is most affected by the noise is being repaired so that a more smooth surface is obtained. Then, the CAD model is being rewrap to make it to be a solid body. When the body is being scan, only the surface of the object is being produced, this is why we need to rewrap the whole object so that it will be a solid and it will be easier to perform the editing process on a solid model. The process of sculpture is then being done. This process is the most important and the longest process in order to reshape the model where the part of the worn side is filled and repaired. As the process of sculpture is done, the hole on the model need to be done so that it would follow the actual product where it has three hole from the top to middle body of the bit. To create the hole and to make sure that the hole is being created by following the actual bit, fill bridge process is being use. From the surface part of the hole that has being scan, a bridge is created on the inside and a hole is created. There are three holes being created in this project as the actual product has three holes only. When the major part of the bit has being repaired and the main body has shown it like new design, quick smooth and remove spike has been done to produce a more clean and smooth 3D model. Moreover, the spike on the thread at the bottom part of the model has also been removed. Lastly, final editing is being done by using the CATIA, the design editing software, to insert the bit on each blade and also refining on the model. The final product of the like new design is being shown in Figure 28 below.

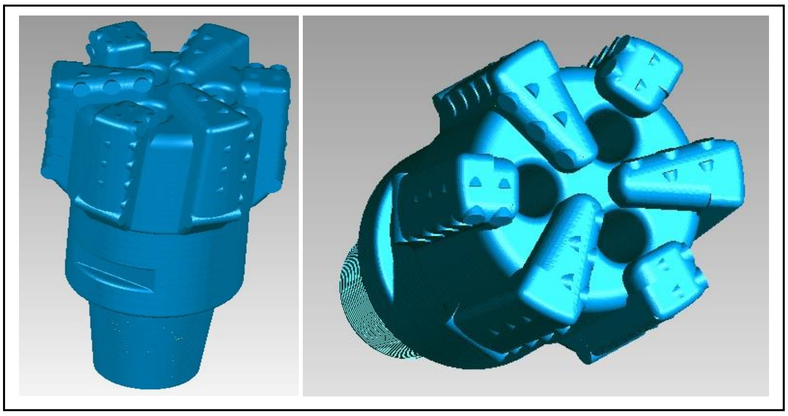

Figure 28: 3D CAD model of like new design

Besides the like new design, a modification on the design has also being done where the focus areas are the blade height, bits shape, and number of hole where the drilling mud will flow out. The modification option is being made based on the studies done by others in order to improve the efficiency of the drill bit and also increase its lifetime. The first design improvement is to replace the regular flat shape bit to a conical bit as shown in Figure 29 where the material is still remain the same.

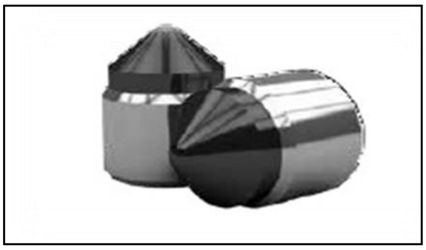

Figure 29: Conical shape bit

The conical diamond element provides an innovative cutting structure enhancement that significantly increases a PDC bit’s performance. The element enables high-point loading to fracture rock more efficiently for increased durability and rate of penetration (ROP) across a wide range of formations and operating parameters [21].

Furthermore, the height of the blade has also being considered in the design improvement. The height of the blade has been increase so that it will create clearer path for the drilling fluid to flow out from the bit to the surface. The path will help the direction of the fluid and also it will easier to push up the rock cuttings. The sample of the PDC that has a high blade height is shown in Figure 30.

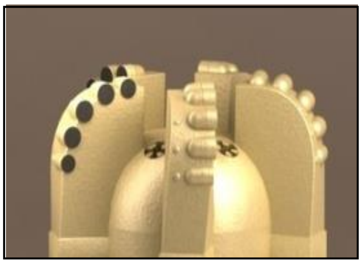

Figure 30: PDC bit with high blade.

A study by the Schlumberger from a real life problem has been done in order to cater the problem faced by the customers. One of the solutions is to increase the blade height where PDC bits from Viking Bits have a cost-effective matrix or steel body with increased blade height for efficient cuttings evacuation and increased ROP. Designed using IDEAS integrated drill bit design platform, the bit's advanced cutting structure produces smooth torque response in the curve while its depth-of-cut reduces cutter loading, minimizing vibration during transitional drilling [22].

Lastly, the design improvement is being focus on the nozzle area where the drilling fluid is supplied during drilling operations. As shown in Figure 31, an increased number of nozzles are being chosen rather than the standard number of nozzle.

Figure 31: Increased number of nozzle.

The feature is mainly for anti-balling purposes but it also has advantages on increasing cleaning, cooling, and cuttings evacuation with available hydraulic flows; higher flow rates with minimal increase in pump pressure, and reduced risk of bit balling. From the advantages gained, it has benefits the PDC bit by having a superior ROP and bit life where a longer drilling interval eliminates tripping [23]. The final product of the completed design from all the design improvements is shown in Figure 32.

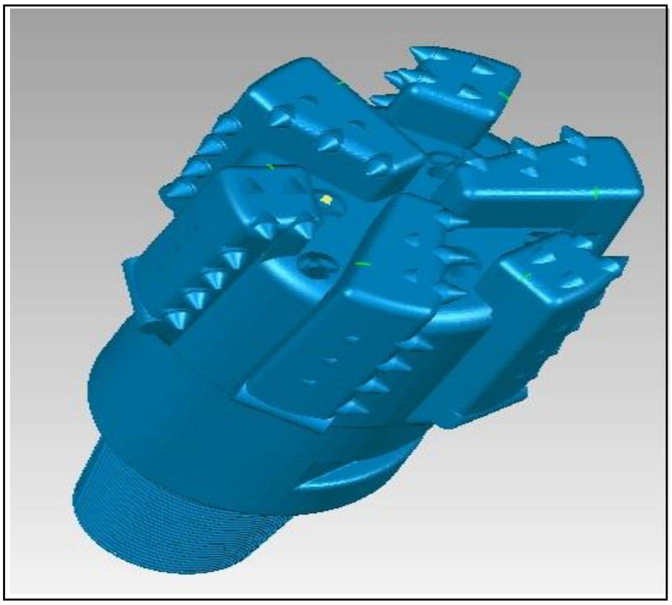

Figure 32: Improve design of PDC Drill Bit.

The improve design has included all the improvement discuss in this project report, where the improvement is focus on three main part or area which are the blade height, nozzle area and the shape of bits. In this project, the improve design is based on the studies done by other respected company and were not tested by the student.

4.4 Finite Element Analysis

An analysis on the like new design has been done to locate the most highly affected area during drilling. However, in this Finite Element Analysis (FEA) study, the drill bit design is tested using the stress analysis where the drill bit is in a static condition. The end result of the FEA study of the drill bit is being shown in Figure 33 where the red colour contour shows the weakest part of the drill bit.

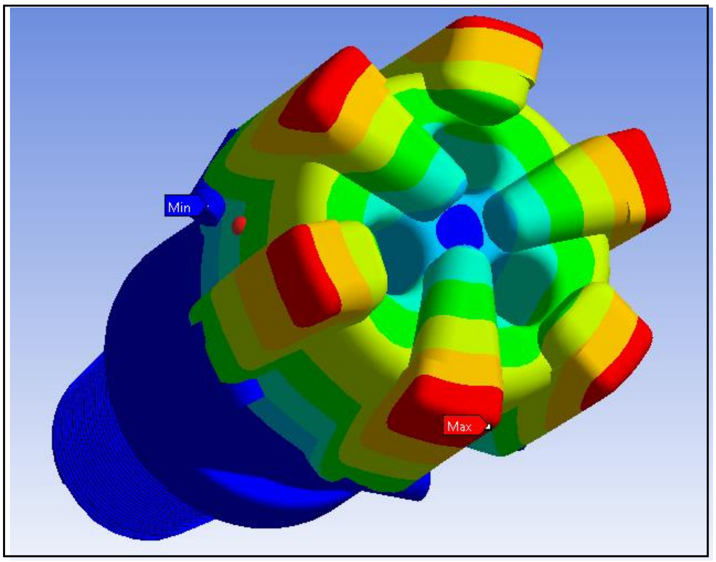

Figure 33: Result of stress analysis in FEA study of drill bit.

As being compared with the actual worn drill bit, the location of the most affected or worn is about the same. This has shown that the area should be more focus on improving the design in order to reduce the weak area. Without reverse engineering, this analysis could not been done and compared with the actual product. It has really shown that reverse engineering on the worn drill bit is important to get the closest result that could explain the worn that occur on the drill bit during drilling.

However, the stress analysis is only one of the analysis that could be done in order to get a more accurate result or reasoning on the worn part of the actual worn drill. Other analysis should be done and compared so that a more specific result could be obtained.

4.5 Production of prototype

The prototype model of the 3D CAD model of the reverse engineered worn PDC drill bit has been produce by using the 3D Printer by using the rapid prototyping method. The drill bit shown in Figure 34 is the prototype of the reverse engineered PDC drill bit from the actual worn drill bit and the size of the prototype is 40% from the actual size. While Figure 35 shown the prototype of the like new design of the PDC drill bit and Figure 36 shows the improve design drill bit prototype model. The entire prototype is being printed in one time and follows the exact design with the 3D CAD model produce in the design editing software.

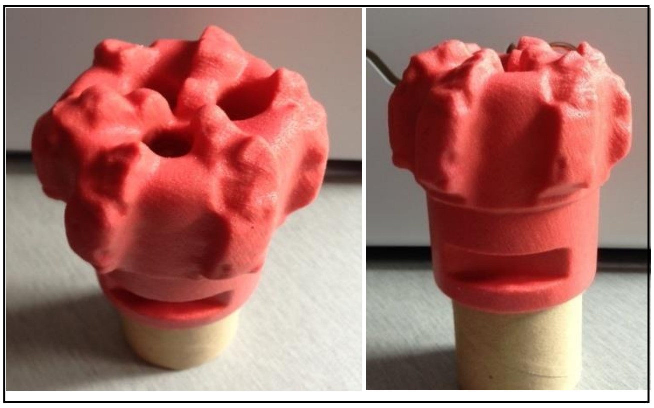

Figure 34: Prototype of RE worn PDC bit.

Figure 35: Prototype of like new design PDC bit.

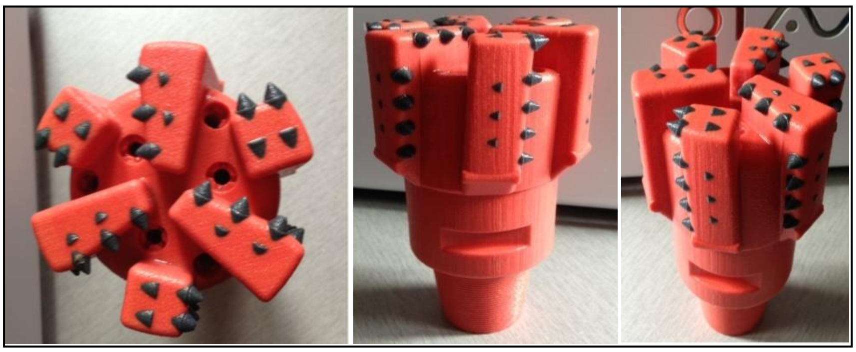

Figure 36: Prototype of improve design PDC bit.

CHAPTER 5

Conclusion

The 3D CAD model of the actual worn drill bit has been produce and the like new design of the drill has successfully produced. Reverse engineering has shown that the problem of not having the blue print of the design could be solved where an actual design could be produce in 3D CAD model and a further analysis could be done on the 3D CAD model. The Finite Element Analysis (FEA) on the like new design of the drill bit has shown that the area that would mostly deform is at the same place that occurs on the worn drill bit. Furthermore, apart from the like new design, an improve design where a few improvement element has been added and produced. This has really shown that reverse engineering is very useful for improvement design for a short time and does not really need an expert in 3D design.

It is recommended that further analysis can be done on the improved design of the PDC drill bit to study its performance and make alteration if needed. It is also suggested that a study on the Rate of Penetration (ROP) on the prototype could be done for a further study. Besides, producing the new design of the hybrid design for the drill bit will be a great study in order for the continuation on this project. These suggestions for further improvement could not be done in this project because of the restriction of sources and time constrain. This project will show that RE is a very important technology for the manufacturing of the component that does not have the blue print and further analysis could be done from the scanned object.

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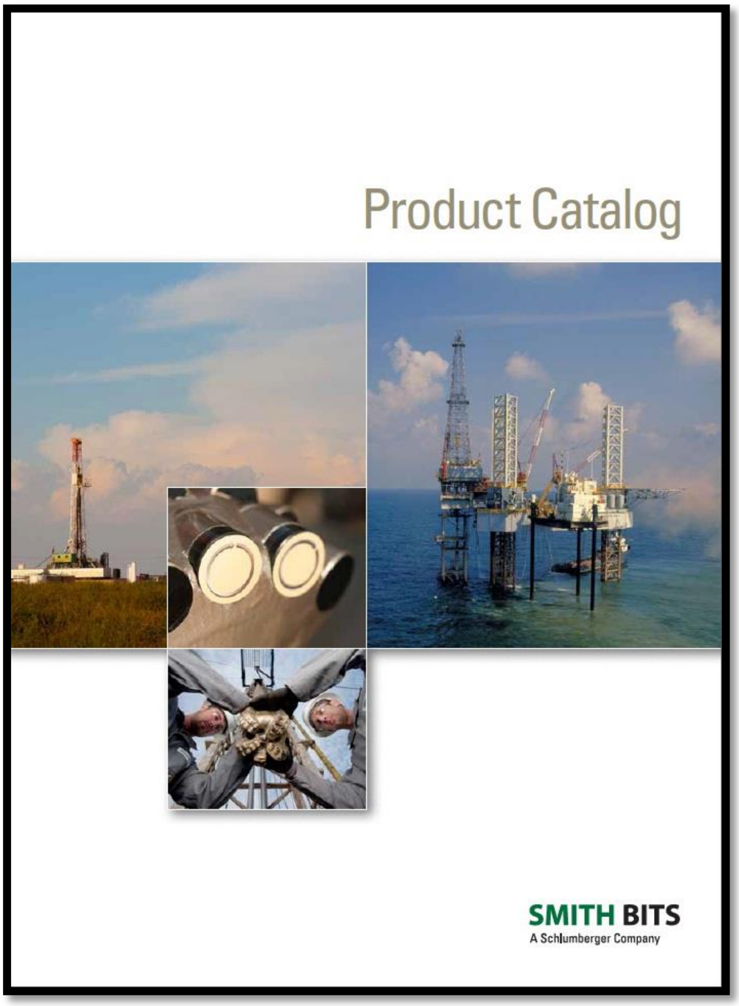
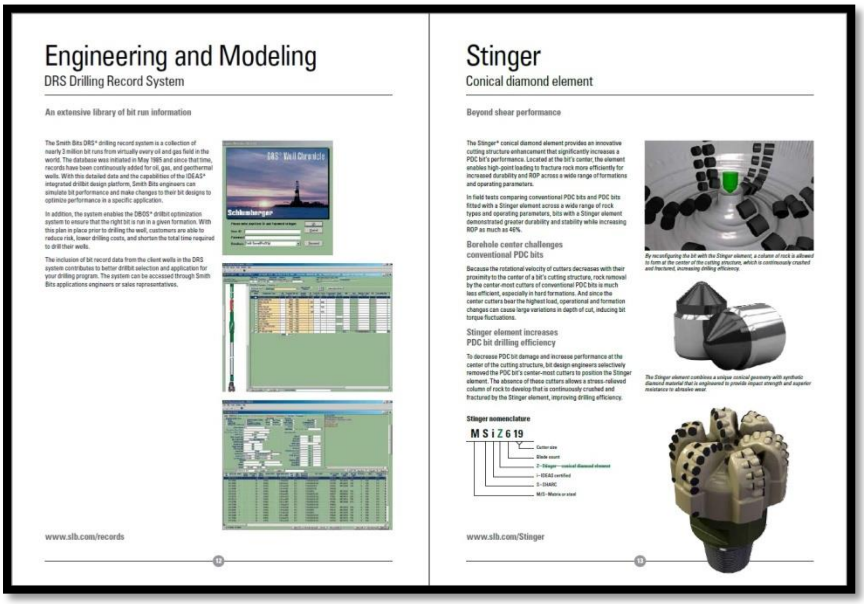
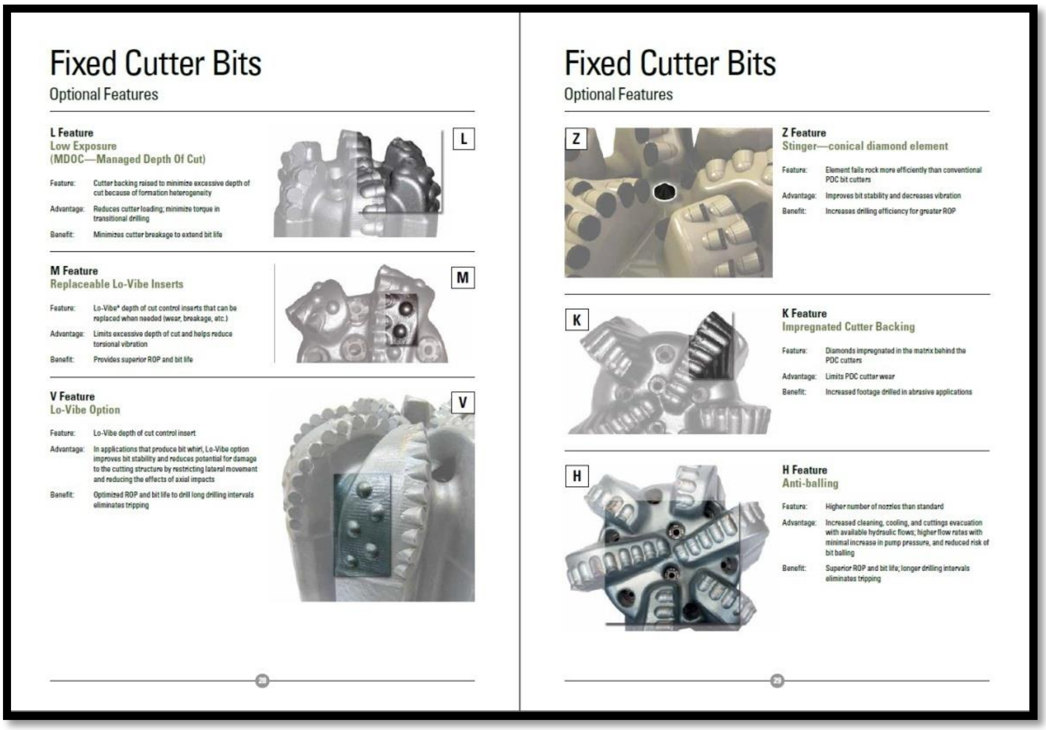
Appendix

Catalog 1 (Partially from actual catalog.)







Fixed Cutter Bits

Optional Features

L Feature
Low Exposure (MDOC—Managed Depth Of Cut)

Feature: Cutter backing raised to minimize excessive depth of cut because of formation heterogeneity
Advantage: Reduces cutter loading; minimize torque in transitional drilling
Benefit: Minimizes cutter breakage to extend bit life

L

M Feature
Replaceable Lo-Vibe Inserts

Feature: Lo-Vibe* depth of cut control inserts that can be replaced when needed (wear, breakage, etc.)
Advantage: Limits excessive depth of cut and helps reduce torsional vibration
Benefit: Provides superior ROP and bit life

M

V Feature
Lo-Vibe Option

Feature: Lo-Vibe depth of cut control insert
Advantage: In applications that produce bit whirl, Lo-Vibe option improves bit stability and reduces potential for damage to the cutting structure by restricting lateral movement and reducing the effects of axial impacts
Benefit: Optimized ROP and bit life to drill long drilling intervals eliminates tripping

V

28

Fixed Cutter Bits

Optional Features

Z

Z Feature
Stinger—conical diamond element

Feature: Element fails rock more efficiently than conventional PDC bit cutters
Advantage: Improves bit stability and decreases vibration
Benefit: Increases drilling efficiency for greater ROP

K

K Feature
Impregnated Cutter Backing

Feature: Diamonds impregnated in the matrix behind the PDC cutters
Advantage: Limits PDC cutter wear
Benefit: Increased footage drilled in abrasive applications

H

H Feature
Anti-balling

Feature: Higher number of nozzles than standard
Advantage: Increased cleaning, cooling, and cuttings evacuation with available hydraulic flows; higher flow rates with minimal increase in pump pressure, and reduced risk of bit balling
Benefit: Superior ROP and bit life; longer drilling intervals eliminates tripping

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Fixed Cutter Bits Product Line

Directional PDC Drill Bit
Matrix or steel bits for improved directional response

SHARC* High-Abrasion-Resistance PDC Drill Bit
Matrix or steel bits for improved durability and wear resistance

Spear* Shale-Optimized Steel-Body PDC Drill Bit
Steel-body PDC drill bits for improved performance in shales

Standard PDC Drill Bit
Premium performance with excellent durability

Kinetic Drill Bits
Matrix bits for high rotary speed applications including positive displacement motors (PDMs) and turbodrilling

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Fixed Cutter Bits

Directional PDC Drill Bit

IDEAS certification for directional bits ensures excellent steering response and improved performance

IDEAS* integrated drillbit design platform and field experience have shown that a single bit design can provide exceptional performance with a variety of directional drilling systems, if it is dynamically stable. The earlier perception was that each type of rotary steerable system (RSS) or steerable motor BHA required its own bit design with highly specialized directional features.

Directional bits with IDEAS certification are stable and produce less torque and stick/slip in transitional drilling. The risk of time-consuming and costly trips due to vibration and shocks is greatly reduced.

Type	Size Availability, in
SDi613	17½
SDi616	13½
MDi416	6⅛
MDi513	5⅞, 6⅛, 6¾, 7⅞, 8¾
MDi516	6⅛, 8½
MDi519	8¾, 14
MDi613	6¾, 8½, 8⅝, 9½, 9⅞
MDi616	8½, 14¾
MDi619	12¼, 14½, 16, 17½
MDi713	5⅞
MDi716	8½, 12¼, 14¾
MDi719	8½, 10⅝, 12¼, 14½
MDi813	5⅞, 8¾, 12¼, 14½, 14¾, 16½
MDi816	8⅜, 8½, 10⅝, 12¼, 13¾, 17½, 18⅛, 18¾

Type	Size Availability, in
SD519	16, 17¼
MD519	8½, 12¼
MD611	5⅞
MD613	6, 6⅛
MD616	6, 8¾, 9⅞, 12¼, 14¾
MD619	8½, 9½, 12¼, 17
MD813	8½
MD816	6, 6⅛, 8½, 9½, 12¼, 16½
MD819	12¼
MD913	8½, 12¼
MD916	8½, 12¼
MD919	12¼, 13½

Directional nomenclature

M D i 6 16

- Cutter size
- Blade count
- i—IDEAS certified
- D—IDEAS directional certified
- M/S—Matrix or steel

www.slb.com/directional

12¼-in MDi616

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For review of the actual catalog,

Catalog 2 (Partially from actual catalog.)

Classic PDC Drill Bits

Genesis

Extremely reliable bits that combine advanced technology and a revolutionary design process to achieve excellent performance and consistency in defined applications.

Genesis Cutters
Continuous research in diamond interface design, diamond table thickness and diamond-edge geometry has provided cutters with greater impact and abrasion resistance. With a vast array of cutters to choose from, our engineers can custom design each bit's cutting structure with the ideal combination of aggressiveness and durability for the application.

Account Representative
Application Engineer
SOLUTION
Research Engineer
Design Engineer

Drilling Application Review Process (DART)
Each new PDC design project receives the personal attention of an integrated, multifunctional team comprising design, research and applications engineers and a field sales representative. The team conducts an in-depth analysis from each specialized perspective. This DART process improves communication with the customer; reduces costly, time consuming iterations; and maximizes your ultimate solution.

10

SmoothCut Technology
Patented, depth-of-cut control technology, ensures cutter damaging peak loads are minimized by balancing the workload over more cutters. SmoothCut technology limits bit reactive torque response without limiting bit aggressiveness and ROP.

Standard
Genesis

Lateral Movement Mitigator™ (LMM)
Patented LMM reduces vibration severity and protects shoulder cutters from impact loads.

Standard
Genesis

Chordal Drop
Innovative design concepts allow greater borehole coverage. Combined with LMM, chordal drop delivers enhanced bit stability.

Genesis XT PDC bit

XT bits drill at a lower cost-per-foot with tough abrasion-resistant Z cutters. These tough bits have advanced PDC drilling into interbedded formations typically drilled by roller cone bits.

Zenith-Series Cutters
Innovative diamond-cutter technology enables Z series cutters to maintain a sharp, efficient cutting edge when drilling through a wide variety of formations in extreme downhole conditions.

Genesis D PDC bit

Designed for both motor and rotary steerable applications, the Genesis D bits enhance a system's ability to deliver a quality hole precisely on target.

Its patented depth-of-cut control technology uses engineered bearing surfaces to lower the bit's torque response to additional weight. The results - improved toolface control without sacrificing ROP.

11

PDC Diamond Drill Bits

PLATINUM I CLASSIC I STANDARD

Hughes Christensen line of PDC bits with advanced technology and a revolutionary design process achieves maximum performance in a defined application.

Product Lines

Platinum Drill Bits

Quantec™ PDC (Q) Our most advanced bits utilize diamond volume management (DVM), superior cutters, optimized hydraulics and a unique stability technology.

Quantec Force™ PDC (QF) A new generation of cutter and stabilization technology delivers supreme performance in a wide range of environments.

Classic Drill Bits

Genesis ZX™ (HC-ZX) The ZX product line adds Zenith-series cutters and secondary cutting elements to the Genesis product to help you drill further, faster.

Genesis XT™ (HC-Z) PDC bits with advanced abrasion-resistant Zenith-series cutters advance PDC bits into interbedded formations.

Genesis™ (HC) A premium line of PDC bits that utilize advanced technology and a revolutionary design process to achieve maximum performance in a defined application.

Standard Drill Bits

Triton™ PDC (FC) Our modestly priced bit delivers reliable performance and a quality bore hole.

Nomenclature

Blank – Performance Drilling
D – D Technology
Application Specific
S – Steel Body
Blank – Performance Drilling
H – Hard Rock
Q D 5 06 H X
Product line
Blade Count
Backup Cutter Options
X – Single row of backup cutters
XX – Double row of backup cutters
Cutter Size
2 = 1/4 in. = 8 mm
3 = 3/8 in. = 11 mm
4 = 1/2 in. = 13 mm
5 = 5/8 in. = 16 mm
6 = 3/4 in. = 19 mm

Product Line Prefix
Q Quantec
HC Genesis Technology
FC Triton

Product Line Suffix
F Force Series of Quantec
Z Zenith Series Cutters

Specialty Products

GaugePro™ (XPR) A expandable, concentric hole-opening system that drills and reams simultaneously with minimal vibration and superior hole quality.

EZCase™ (EZC) A line of PDC bits designed to ream and drill new formations on liner or casing.

EZReam™ (EZR) The industry's only steel reaming shoe that is PDC drillable.

RWD2™ (RWD2) The line of ream-while-drilling tools is designed for specific hole-opening applications at a fraction of the cost and without the risks associated with bicenter bits and conventional underreamers.

HedgeHog (HH) A full line of impregnated diamond bits designed to drill the hardest and most abrasive drilling formations.

Natural Diamond (D, T) Surface set with natural diamonds of various grades and concentrations to drill a variety of harder, more abrasive formations.

BallaSet (S) Utilizes thermally stable polycrystalline diamond cutters to drill medium-to-hard formations.

SideTrack (ST) Line of PDC and natural diamond bits designed for sidetracking in soft formations. Performs well in rotary and downhole motor applications.

Speed Mill (DSM) Natural diamond bits designed for drilling casing windows.

Options

G3	Step Gauge	G8	Longer Gauge Than Standard	M1	ChipMaster Hydraulics	X	Backup Cutters
G5	In-Gauge PDC Trimmers	G9	Extended Sleeve	NSS	Nonstandard Shank	XX	Double Row of Backup Cutters
G6	Spiral Gauge	G12	Active Gauge Cutters	U1	Natural Diamond Updrill	XDO	EZCase Drillout
G7	TSP Diamond Gauge	K3	TCI Wear Knots	U3	PDC Updrill (3/8-in.)	Y	Box-Up Connection
				U4	PDC Updrill (1/2-in.)		

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