MODELING AND SIMULATION OF A PERPETUAL PIGGING MECHANISM

By

IKHWAN BIN MD SHAHSAZIZAN

A project dissertation submitted in partial fulfillment

of the requirements of the

Bachelor of Engineering (Hons)

(Mechanical Engineering)

SEPTEMBER 2013

Supervisor: AP. Dr. Fakhruldin Mohd Hashim

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

MODELING AND SIMULATION OF A PERPETUAL PIGGING MECHANISM

By

Ikhwan Bin Md Shahsazizan

A project dissertation submitted to the
Mechanical Engineering Programme
Universiti Teknologi PETRONAS
In partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by,

____

(AP. Dr. Fakhruldin B Mohd Hashim)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
September 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 person.

(Ikhwan B Md Shahsazizan)

ABSTRACT

Demands in oil and gas industries on reliable quality of inspection in pipeline operation is increasing throughout the year, although intelligent PIGs are more capable than simpler conventional counterparts, they still have several setbacks such as cannot clean throughout the pipeline while inspection and only can move in several distance in a single flow. Pipeline is the most important medium to transport crude oil and gas to the terminal. In order to maintain the efficiency of the transportation, Conventional PIG is the best solution that can act as a pipeline cleaner and also Intelligent PIG as a pipeline inspector to detect any corrosion and leakage. A proper research work has been made, an improvement in which a prototype of an Intelligent PIG is developed with respect to the benchmarked of the pipeline crawler drive mechanism to clean and inspect throughout the oil and gas pipeline on entering and leaving the pipeline from a single exit.

This project is aimed to develop the assembly of a CAD-based model of an experimental intelligent PIG drive mechanism and simulate to show that the PIG model is able to travel in both contra-flow and in-flow direction based on the research work that has been made. CATIA software was used to review and developed the CAD-based model assembly on changing all constrains to meet the specific requirements. Meanwhile, for simulations using DMU Kinematics was used to demonstrate the movement of the PIG drive mechanism in a pipeline using a suitable joints and constrains.

The final outcome of this project is a demonstration of the experimental PIG crawler drive mechanism CAD-based model assembly are correctly develop with the suitable constrains and shows that the PIG travel in the pipeline on both contra-flow and in-flow direction.

ACKNOWLEDGMENT

First and foremost, thanks to Almighty for giving the strength to carry out the Final Year Project for Mechanical Engineering course successfully. The author believe without His blessing and pleasure, the author will not be reaching the completion and accomplishment of this project.

Deepest appreciation dedicated to author’s supportive supervisor AP. Dr. Fakhruldin Mohd Hashim for his guidance and professionalism towards this Final Year Projects, September 2013. The tremendous supervision by him is helpful to lead to project accomplishment. Besides that, special thanks also goes to author’s examiner Mr. Mui'nuddin Bin Maharun, Dr. Mark Ovinis and Dr. Varaha Venkata Lakshmi Narasimha Rao Tad for his relevant and valuable advises on author’s project in order to obtain better future result.

Deep gratitude as well for Mohamad Azmi Bin Md Haniffa for his continuous cooperation in providing ideas to do the modeling and simulation for the Perpetual Pigging mechanism using CATIA V5 software. Some of their ideas were generating solution towards author’s problem facing throughout the project implementation.

The author would like to extend his thanks to his supportive family that given the motivation on completing this project. Not to mention, to those who has directly or indirectly involve in this project, for their support and motivation during the implementation and undertaking of this project.

TABLE OF CONTENT

List of Figures

List of Table

List of Abbreviations

Abbv	**Definitions**
UTP	Universiti Teknologi PETRONAS
DMM	Drive Mechanism Module
UJ	Universal Joint
TM	Turbine Module
FCM	Flow Control Module
PIG	Pipeline Inspection Gauge

CHAPTER 1

INTRODUCTION

1.1 Background

PIG is known as Pipeline Inspection Gauge which is inserted into the pipeline and travels throughout its entire length. There are two types of PIG that are usually used by companies to maintain the efficiency of the production pipeline that is conventional pigging that cleans the pipeline from any disturbances, and Intelligent PIG that inspects the condition of the pipeline. Common PIG usually propelled by the pressure of the flowing fluid or gases. Nowadays, demands on reliable quality of inspection in pipeline operation is increasing throughout the year, although intelligent PIGs are more capable than simpler conventional counterparts, they still have several setbacks [1].

In order to overcome such difficulties in pigging, several developments of contra-flow crawler was made with the purpose of entering and leaving the pipeline from a single exit. The crawler crawls in the contra-flow direction and returns to the flow after the return mechanism is triggered in special conditions at the end of the pipeline.

1.2 Problem Statement

Based on a previous research, Kresnajaya [2] has proposed a PIG design in which the force exerted by the fluid energy was converted into rotational energy through the turbine impeller. Meanwhile, Azmi [3] had improved the design based on calculation and theoretical assumption. Based on the improvement, an Intelligent PIG prototype is developed with respect to the benchmarked of the pipeline crawler drive mechanism. Therefore, modeling and simulation of the PIG has to be analyzed to determine whether the PIG crawler drive mechanism can travel in both contra-flow and in-flow directions.

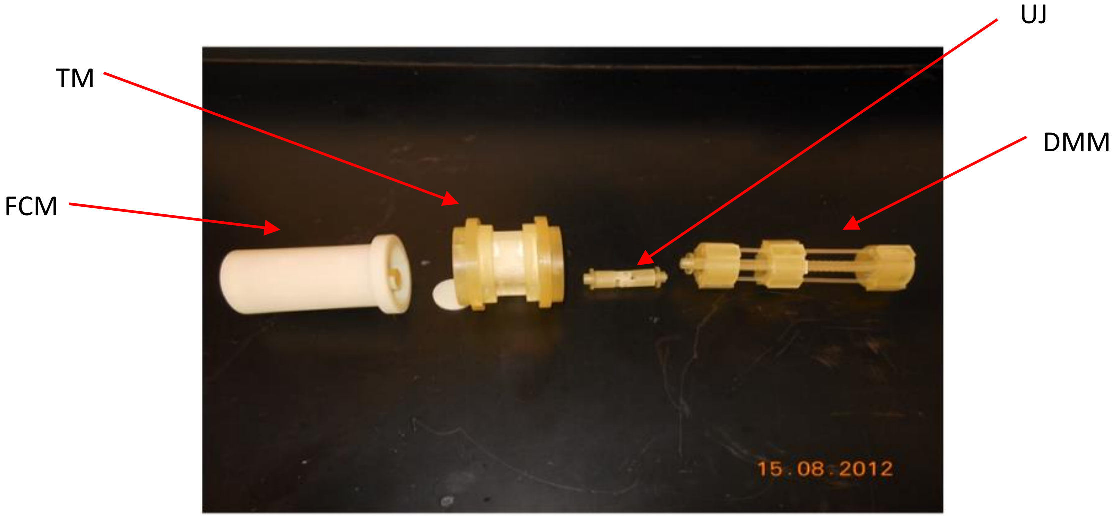


Figure 1: Photo shot of PIG prototype design assembly arrangement. [4]

1.3 Objectives

i) To develop the assembly of a CAD-based model of an experimental intelligent PIG using CATIA software.

ii) To simulate forward and reverse drive mechanism movement of the PIG model that able to travel in both contra-flow and in-flow direction using DMU kinematics in CATIA software.

1.4 Scope of Work

i) To analyze and improvised all the assembly constrains of the CAD-based model drive mechanism of an intelligent PIG to meet the specific requirements using CATIA software.

ii) To simulate the drive mechanism movement using joints and constrains of DMU kinematic in CATIA software to meet the functional requirements of the PIG model.

CHAPTER 2

LITERATURE REVIEW

The literature review of this research work will be divided into two categories which are (1) Drive mechanism and turbine module of an Intelligent PIG, (2) Modeling and Simulation using the CATIA CAD software.

2.1 Drive mechanism and turbine module of an Intelligent PIG

The latest development of pipeline contra-flow crawler is reported in [5]. The working principle for this crawler is that the equipped battery will power the electromotor via the gear reducer. Then, torque produced will be transferred to the drive shaft which consists of a double - screw. The structure of this development is stated in figure 2 below, that contains; 1-pipeline, 2- supporting wheel, 3-slip, 4-supporting bar, 5-Spring, 6-nut, 7- drive shaft, 8-crawlingcube, 9-gear reducer, 10-electromotor, 11-wire, 12-battery.

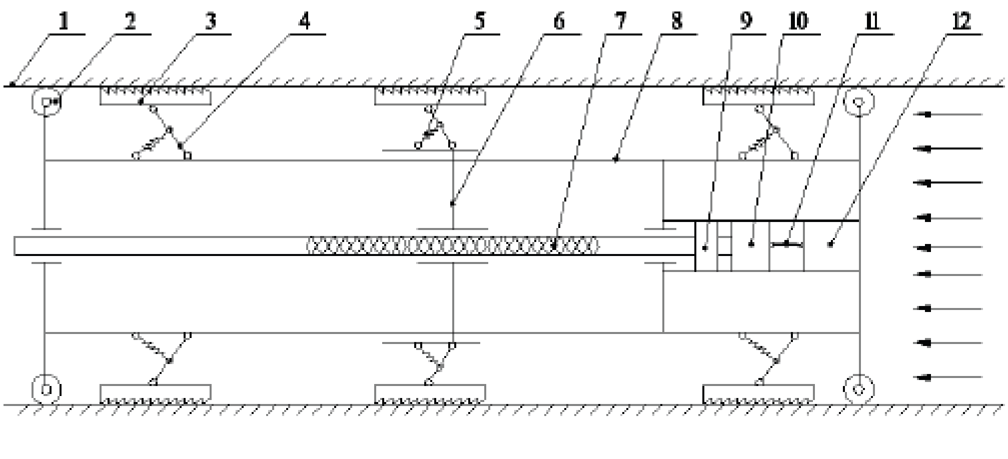


Figure 2: Design of the New Contra-Flow Crawler. [5]

The movement of the crawler is fragmented into two mechanism stages in one cycle motion. The nut and supporting bar's movement are synchronized when the nut moves from the left side of the head to the right side of the head. It will be moving in a contra - flow direction. When the nut reaches the right side of the head it will automatically enters reverse screw direction that direct it back to the left head meanwhile the supporting bar fixed on the crawling tube. The mechanism that travels contra-flow is because of the reacting force between the nut and shaft.

This concept was generated based on an invention produced from a joint effort between Astec Developments Ltd. Corporation and Subsea Integrated Group (SIG) with Durham Pipeline Technology (DPT).

Figure 3: Contraflow Tetherless Mechanical Pipeline Crawler. [1]

The crawler concept of Astec Development consists of four major modules: (1) turbine module, (2) tractor module, (3) wax cutting module, and (4) return module. The wheel supported tractor is energized by the turbine. Oscillate movement of forward, backward, outward and inward is controlled by elastic leg on the supporting wheels. The return spring-valve will close when the crawler is being triggered and a large pressure drop emerges that can push the PIG return with enough friction.

Figure 4: 10" Genesis SIG Tool. [6]

Genesis SIG tool is a tethered crawler powered by electric linear drive reciprocators. The main drive for this PIG is sliding brushes which are mounted on the electric linear drive. At the starting position the brush will point backwards. Both of front brush will drive the PIG contra-flow while the back brush is to hold the position of the PIG with lower sliding resistance than the brushes on the power stroke.

Table 1: Summary of Chronological Developments of Contra-Flow Crawler 1.

Crawler Type	Mechanism Actuator	Pattern of Movement	Means of Power Source	Direction of Crawler	Type of Drive	Production Flow	Crawler Motion
Novel self-drive PIG 2005 [7]	Turbine driven brushes via double-screw thread	Crawling	Tetherless	Bidirectional	Self-Drive	Uninterrupted	Continuous
ThruFlow 2010 [1]	Electric linear driven brushes	Crawling	Tethered	Bidirectional	Self-Drive	Uninterrupted	Continuous
New contra-flow Crawler 2011 [6]	Battery powered electromotor driven brushes via double screw	Crawling	Tetherless	Bidirectional	Self-Drive	Uninterrupted	Continuous

2.2 Modeling and Simulation using CATIA CAD software

CATIA is a high end classification Computer Aided Design (CAD) software tool that can be used to provide a suite of surfacing, reverse engineering, and visualization solutions to create, modify, and validate complex innovative shapes. DMU Kinematics is a simulation program that can be done in CATIA to show the mechanism motion, moving parts, assembly constrain and mechanism analysis of the CAD model.

Modelling processes:

1) Sketch

Sketch is the starting step to draw the base shape of the component with required diameter on a specific plane by using either random sketch or with extra features such as 2D fillet, chamfer, circle, eclipse, etc.

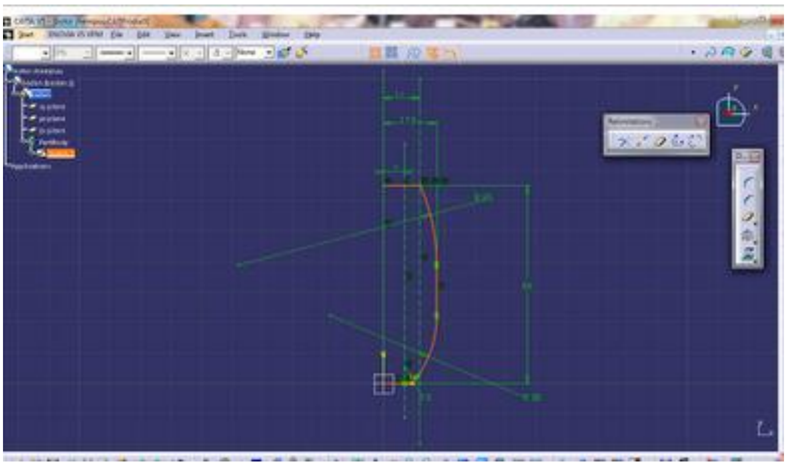


Figure 5: Sketching process. [8]

2) Part Design

This process is the 3D shaping part that will be extruded from the base sketch from process 1. From an extruded shape, the part can be modified by using extra features same as process 1. The difference is that these adjustments need to be made on the shape of the part that requires isometric view. Meanwhile, process 1 was only to consider on a 2D sketch base with front, left, right and bottom view.

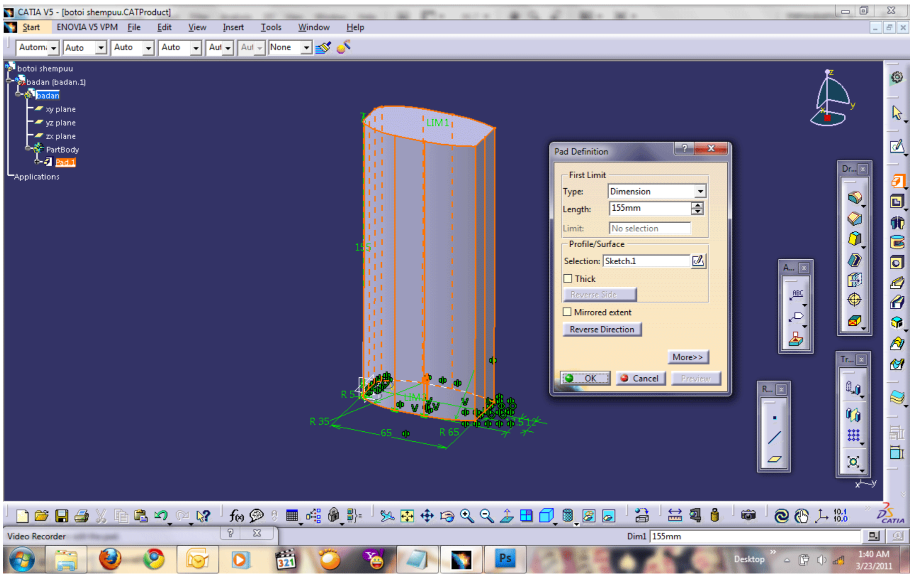


Figure 6: 3D Part design process. [8]

3) Assembly Design

Assembly is where all the parts that were produced are combined together with a feature known as "Coincident Constrain".

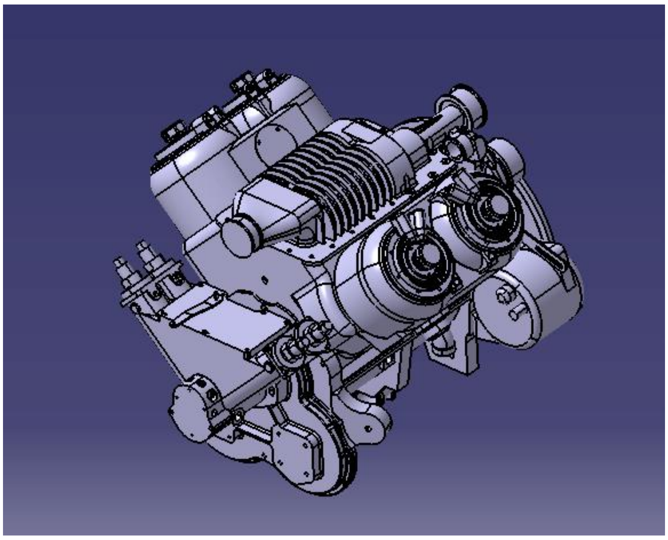


Figure 7: Assembly of 3D parts. [9]

DMU Kinematic is divided into two types of simulation, they are simulation with law and simulation with command [10]. For every simulation a variable need to be determined, depending on the requirement of the toolbar of the specified simulation. Below is an example of simulation with command and the example of the basic simulation assembly process corresponding to the kinematics mechanism.

1) Entering the Workbench

   i. Select Digital Mockup -> DMU Kinematics from the Start menu. The DMU Kinematics workbench is loaded and an empty document opens.

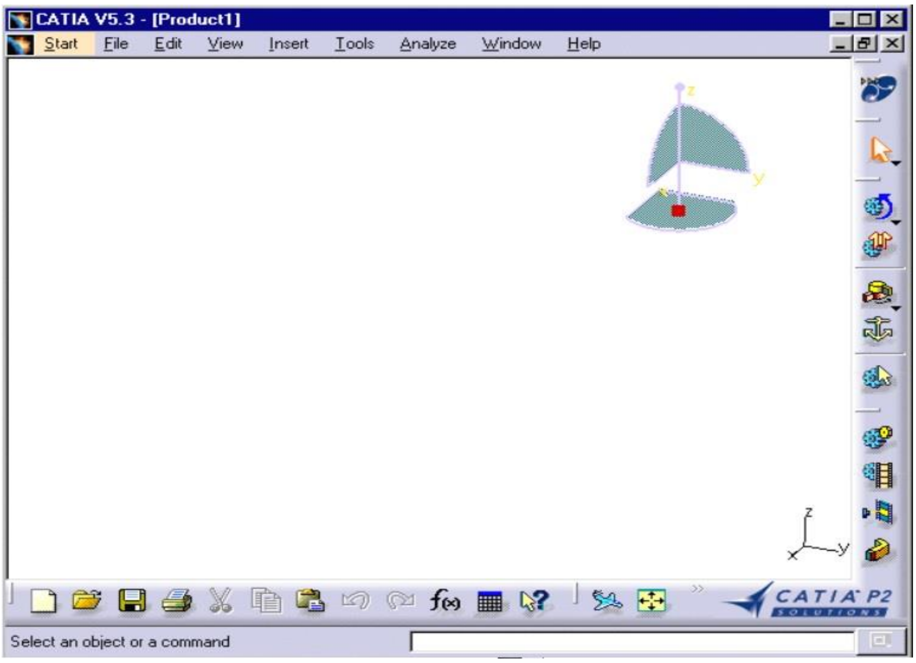


Figure 8: Select DMU Kinematics. [10]

   ii. Select File -> Open from the menu bar

   iii. Select the rods.CATProduct document. Click Open to open the selected file. The specification tree is displayed showing all the selected products.

Figure 9: Open File. [10]

iv. Select the products in the tree, then select Edit -> Design Mode. Now expand the tree to show all the design components of the products.

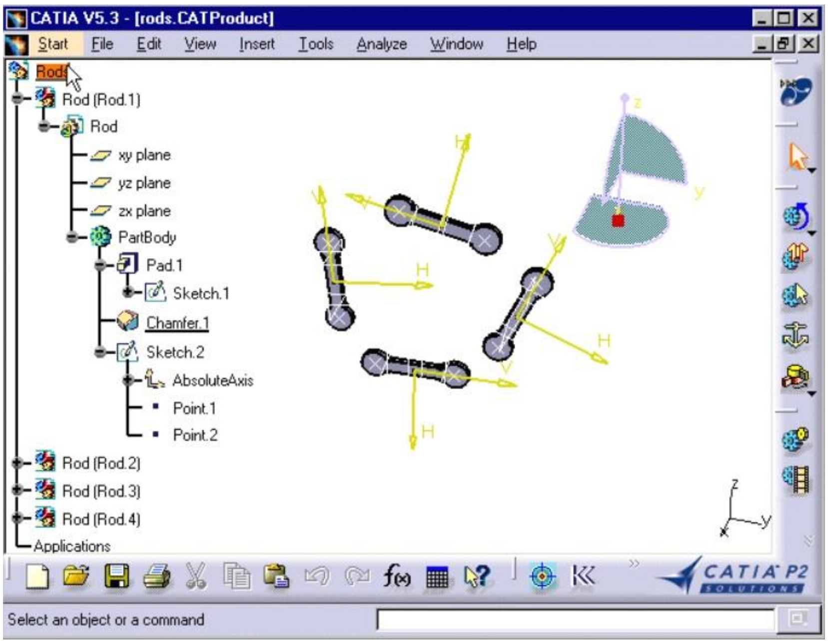


Figure 10: Expand tree. [10]

2) Defining a Command

i. Double-click the joint 3 in the specification tree. The Joint Edition dialog box is displayed.

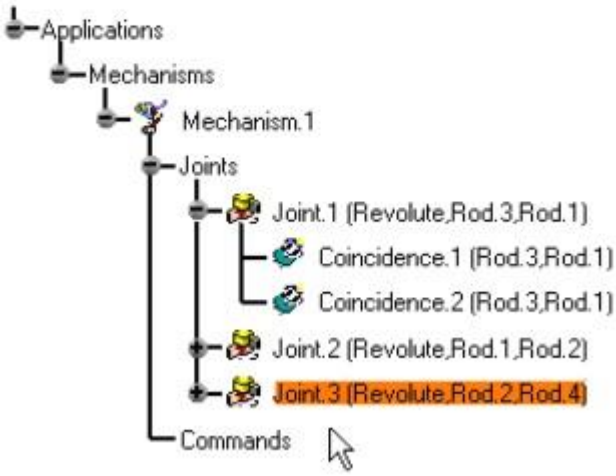


Figure 11: Specification tree. [10]

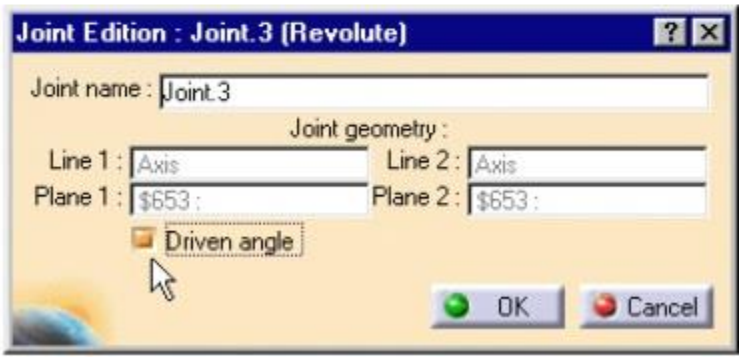


Figure 12: Dialog box. [10]

ii. Activate the Driven angle option. The command will be an angle type command.

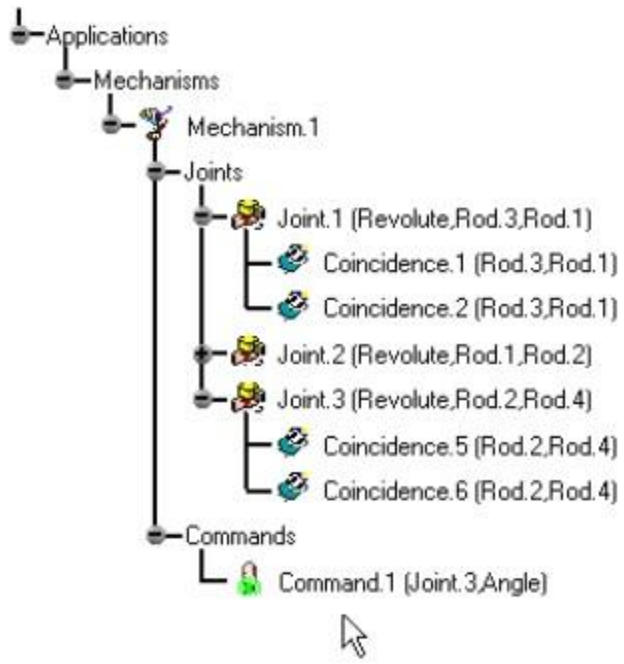


Figure 13: Command. [10]

iii. Click Ok to confirm your operation. The command is identified in the specification tree.

3) Defining a Fixed Part

i. Click the Fixed Part icon from the DMU Kinematics toolbar or select Insert->New Fixed Part from the menu bar. The New Fixed Part dialog box is displayed.

Figure 14: New Fixed Part dialog box. [10]

ii. Select the Fixed Part either in the geometry area or in the specification tree.

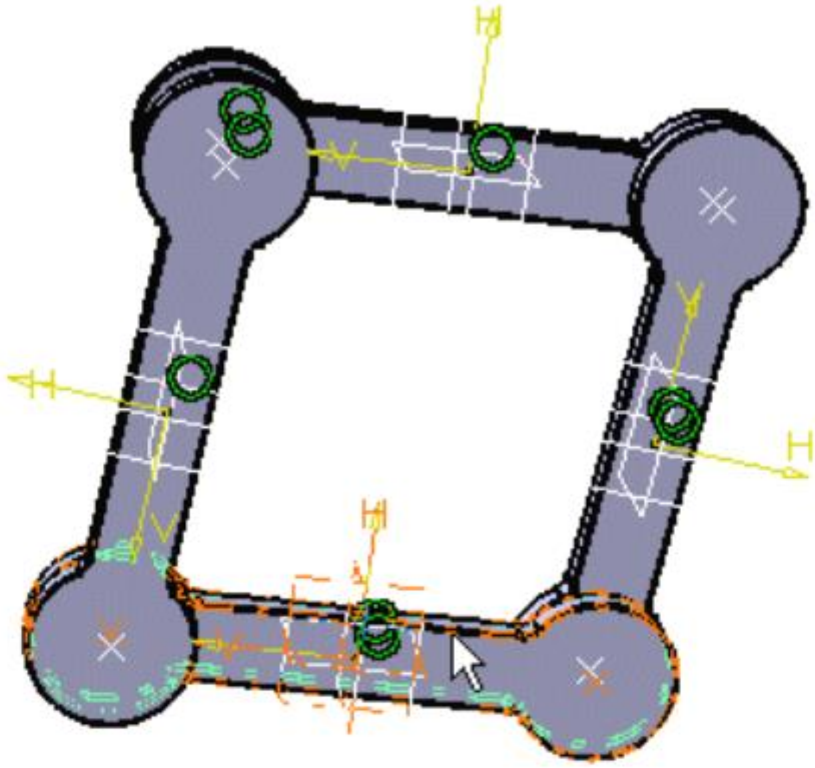


Figure 15: Select Fixed Part. [10]

iii. The fixed Part is automatically defined.

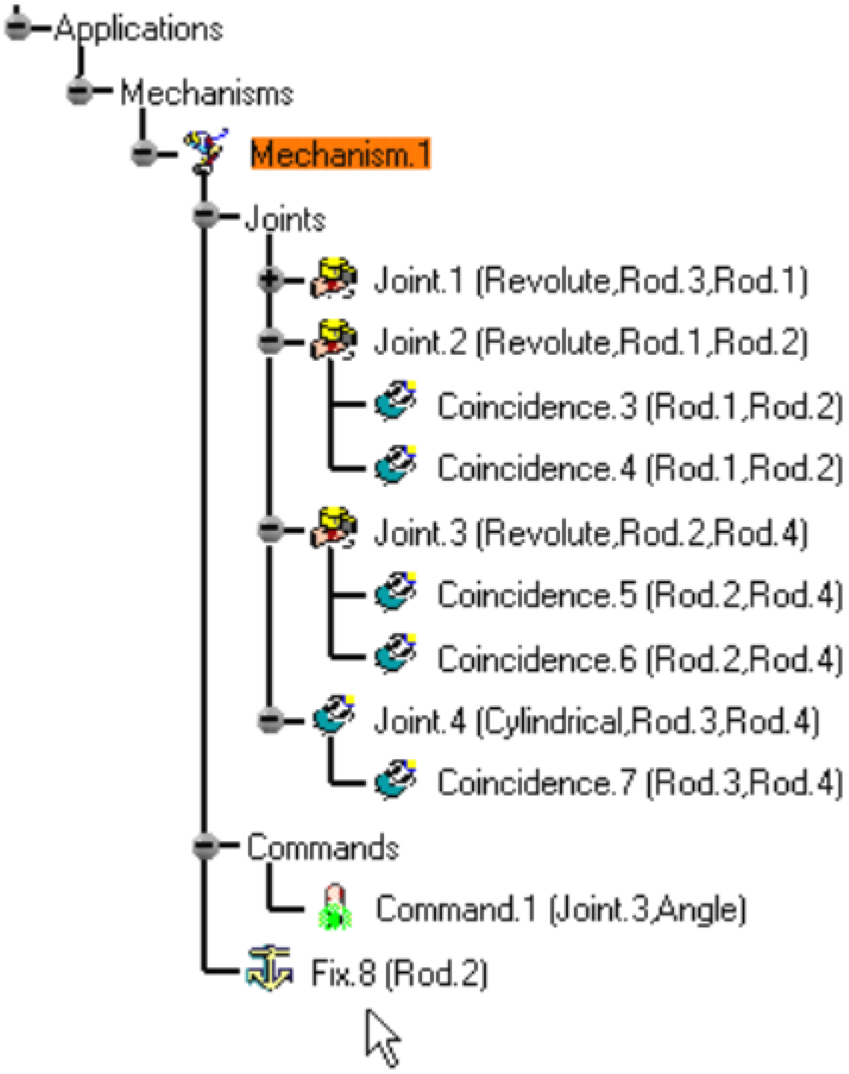


Figure 16: The fixed part is identified in the specification tree. [10]

4) Simulation the result

i. Click the Simulation with Commands icon. The Kinematic Simulation dialog box displays: The command of the kinematics mechanism are available as shown opposite.

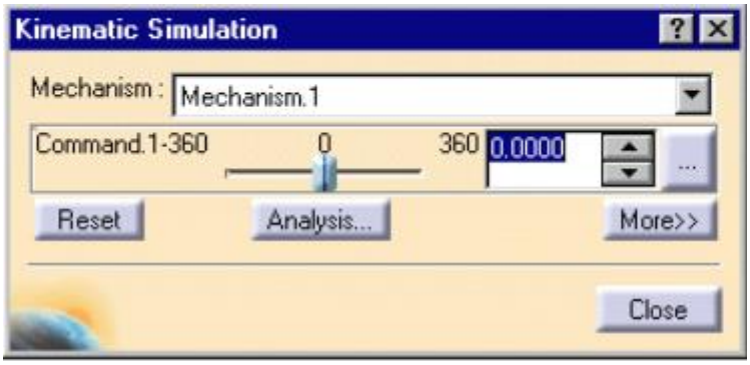


Figure 17: DMU Kinematics Command. [10]

ii. Manipulate the slider of the command. The kinematics mechanism moves accordingly.

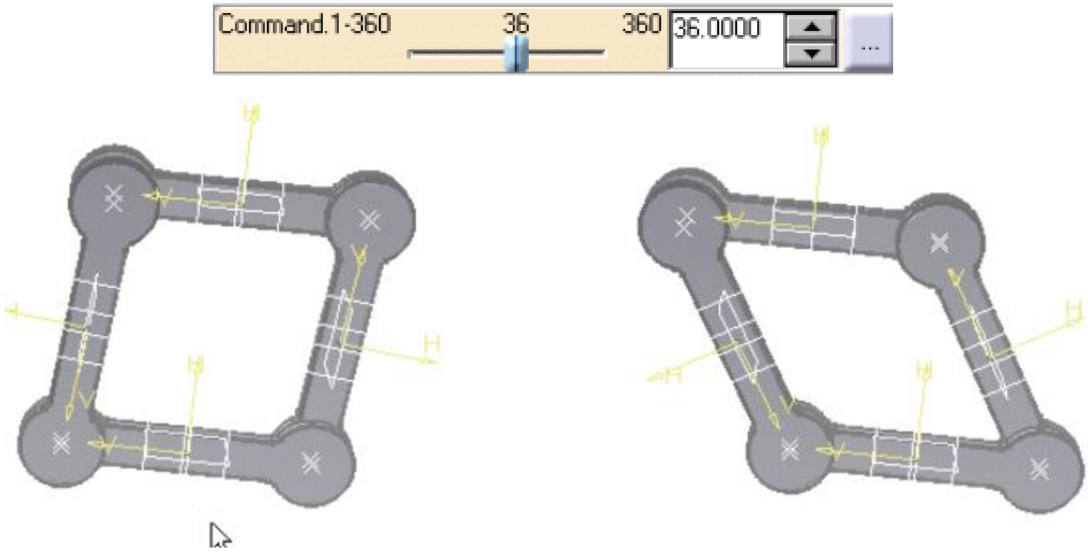


Figure 18: Kinematics mechanism movements command. [10]

iii. Use the manipulator in the geometry area. Move the mouse over a joint. The driven joint highlights and the manipulator appears. Drag the model with the left mouse button.

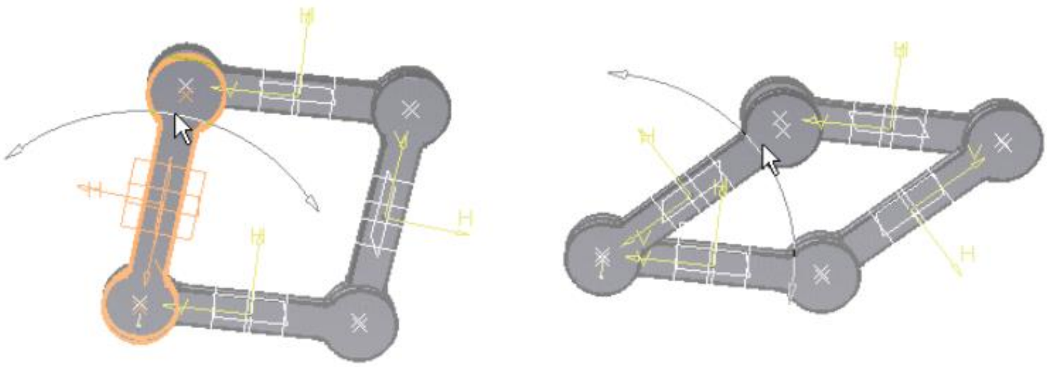


Figure 19: Driven joint manipulator. [10]

CHAPTER 3

METHODOLOGY

3.1 Introduction

This project focuses on the main parts of the experimental PIG that is the drive mechanism, turbine module and Universal joint. Knowledge and research that was gained during the earlier stage of this project gave the idea to produce a flow chart that comprises of all the stages of task involved during modeling and simulation.

This project will consider the calculation by Kresnajaya [2] and drive mechanism movement analysis by Azmi [3] in operating and defining the drive mechanism simulation constrain.

3.2 Project Flow Chart

Figure 20 shows the key stages of the project undertaken, the main key stages are:

i. Preliminary research work / Literature review
ii. Modeling development / Correction
iii. Simulation

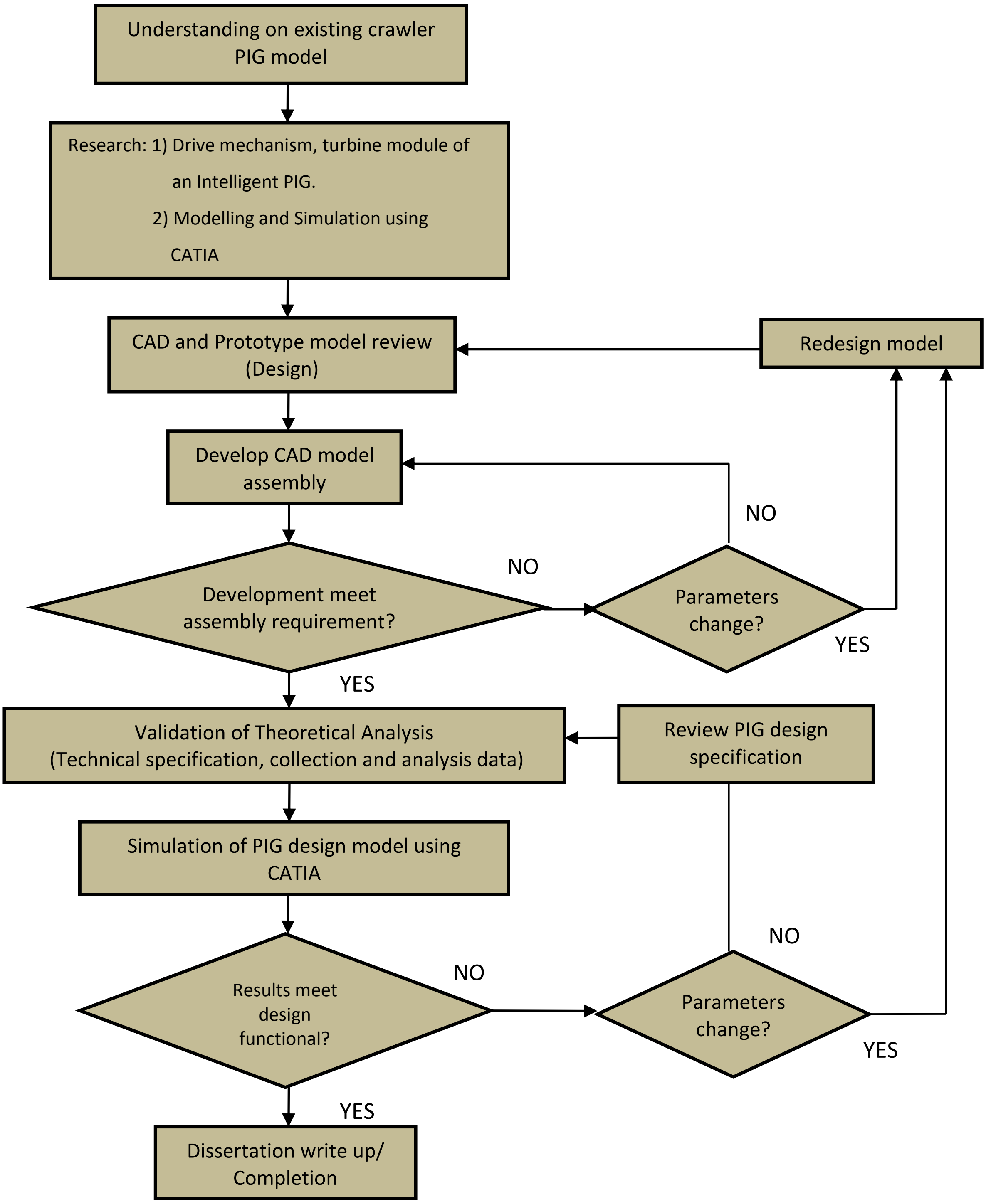
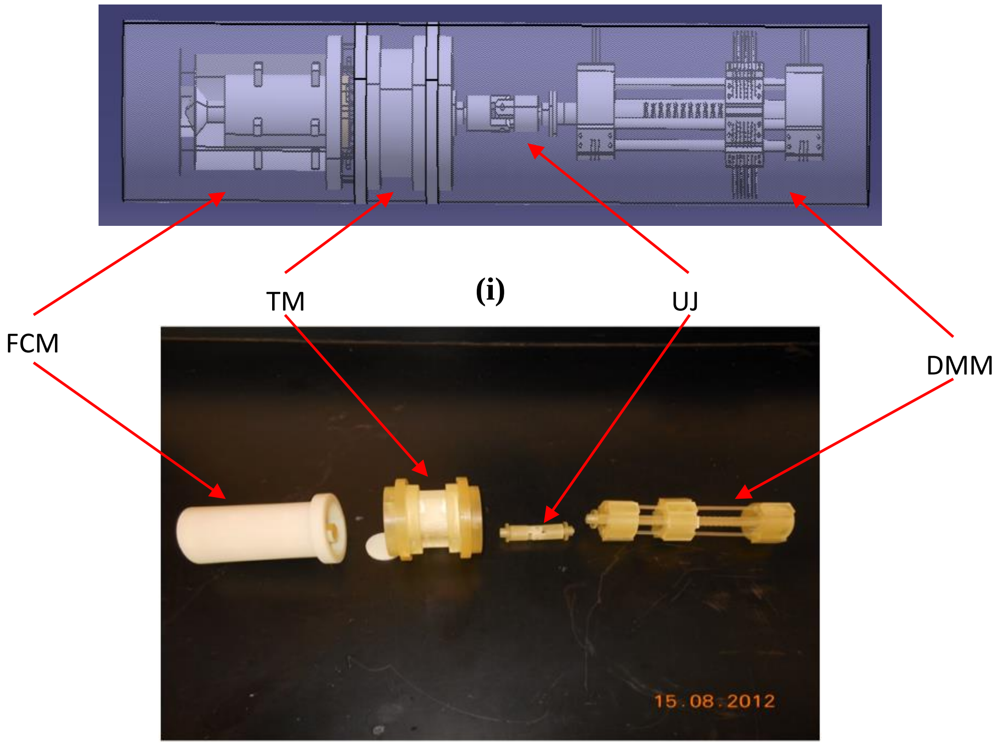


Figure 20: Flowchart of PIG Simulation

The first stage to conduct this research is to understand the existing PIG CAD model and prototype in term of calculation and drive mechanism. Design of the CAD model needs to be checked with existing prototype so that it matches the assembly criteria. If any problems were identified in the PIG design assembly, corrections will be made. This cycle will be repeated until the assembly requirement is reached.



(i)

(ii)

Figure 21: Complete modelling of PIG and Prototype design. [4], [7]

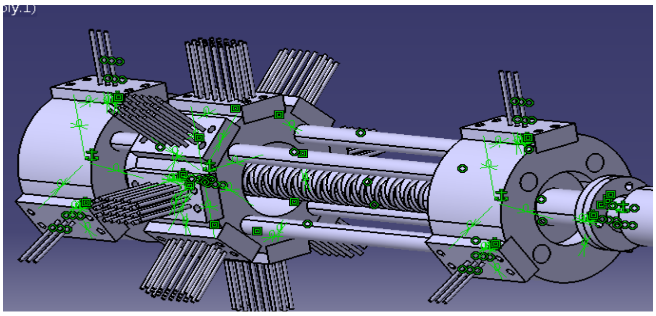


Figure 22: Drive Mechanism module with aligned holder bar. [7]

The second stage of the research work is to compare the existing PIG with similar work by experts on theoretical analysis data such as technical specification, data collection and data analysis. Calculation and analysis by Kresnajaya [2].

Rotational speed of the drive mechanism is:

$$\boldsymbol{\omega_{DM} = v_n \,.\, 2.\pi \,/\, I}$$

Where ω_{DM} is the rotational speed of the drive mechanism, v_n (= 0.033 m/s) is the desired PIG speed, and I is the pitch of the double screw.

Time of the follower (moving brush) to travel along the entire length of double screw in one cycle motion is:

$$\boldsymbol{t_n = L \,/\, v_n = L.2.\pi \,/\, \omega_{DM}.\, I}$$

Where t_n is the time of the follower to travel along the entire length of double screw in one cycle motion, L is the length of the double screw, ω_{DM} is the rotational speed of the drive mechanism, and I is the pitch of the double screw.

The time of drive mechanism to travel forward in one cycle motion is:

$$\boldsymbol{t_m = L \,/\, v_m = L.2.\pi \,/\, (\omega_{DM})_p.\, I}$$

Based on the value of L = 150mm and I = 10 mm, the calculated results is summarized in table 2.

Table 2: Calculated result of follower travelling time, drive mechanism time in one cycle motion, rotational speed of follower and drive mechanism.

Descriptions	Results	Remarks
Follower travelling time, $\mathbf{t_n}$	1.052 s	
Drive mechanism time, $\mathbf{t_m}$	4.5 s	
Rotational speed of follower, $\boldsymbol{\omega_{DM}}$	89.51 rad / s	Rotational speed of double thread screw when moving brush moving forward
Rotational speed of drive mechanism, $\boldsymbol{(\omega_{DM})_p}$.	21 rad / s	Rotational speed of double thread screw when PIG body moving forward

With the calculated propulsion force of 2114.95 N by the drive mechanism, the PIG design is capable to travel with a speed of 0.033 m/s in both directions.

This is the crucial step that needs to be done before simulation of PIG is conducted. The result of the simulation will be evaluated and if it didn't meet the design requirement, PIG analysis data need to be validated again before dissertation write up/completion. The cycle will continue to reach the required specification.

Table 3: Gantt chart

	FYP Schedule Timeline	**FYP I** **(20 May – 23 Aug 2013)**														**FYP 2** **(23 Sept – 27 Dec 2013)**													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**Introduction** *Understanding Project Description/existing crawler PIG model																												
2	**Literature Review** *Research on drive mechanism and turbine module of an Intelligent Pigging *Research on Modelling and Simulation on CATIA.																												
3	**Develop CAD model assembly** *Assemble PIG model in CATIA																												
4	**Simulation of PIG design model in CATIA** *Validation Theoretical Analysis *Technical Specification/ Data collection *Data analysis *PIG design simulation																												
5	**Dissertation write up**																												

Completed In Progress To be done Milestone

CHAPTER 4

RESULT AND DISCUSSION

4.1 Modeling (Develop CAD-based model assembly)

In Final Year Project 1, a CAD-based model assembly was analyzed and corrected using CATIA V5R20 software. All the parts were developed and assembled by Azmi [3], with the formula function by Kresnajaya [2]. From the assembly, few measurement were adjusted before simulation was made and that is the main scope of work for this paper work. If one of the parameter changed the assembly will be scattered around because all the parts were link with each other. **Figure 14** show the complete assembly after analyze and correction.

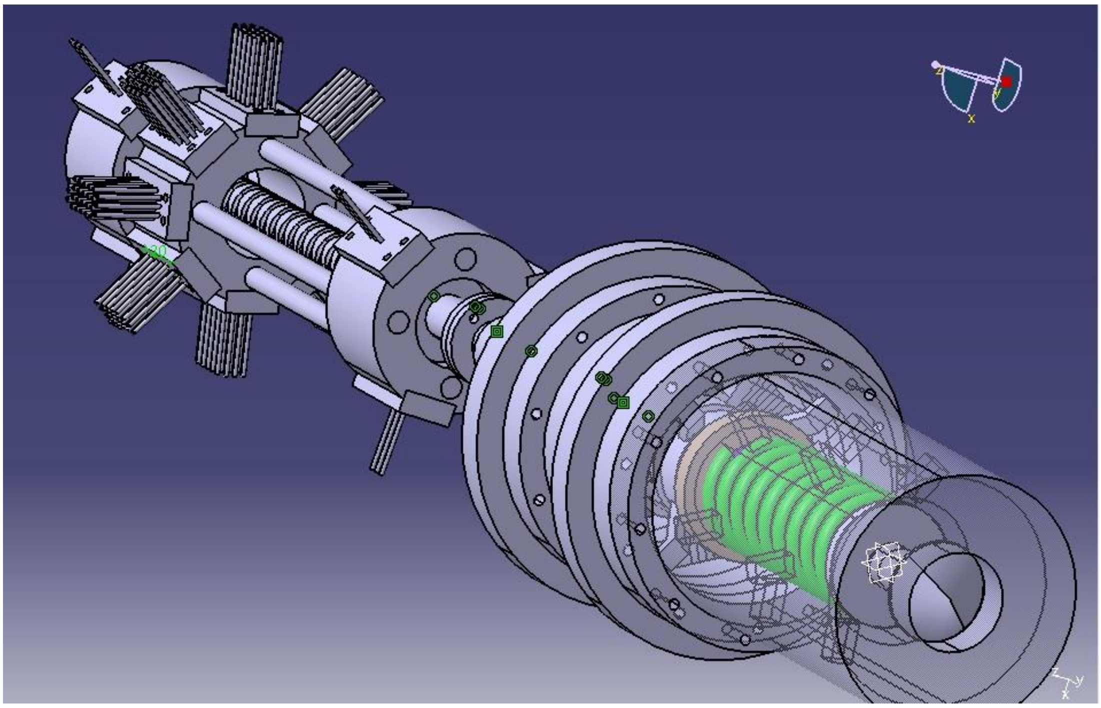


Figure 23: Complete model of PIG drive mechanism after correction.

To accomplish the assembly as **figure 14** several steps need to be taken. Each of this assembly need to be carefully connected so that it won't scattered when it is being updated or simulated.

The steps are:

1) Analyse all constrain of the assembly.

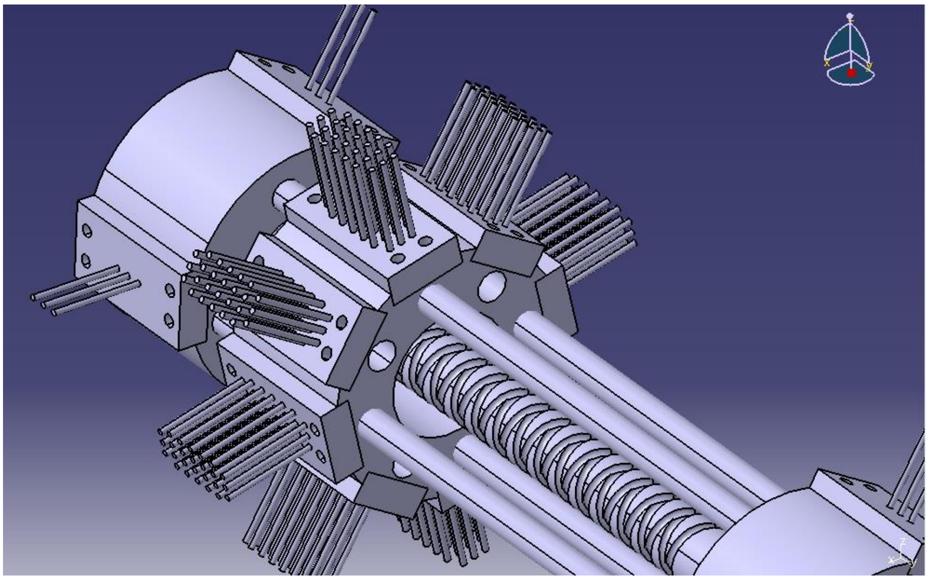


Figure 24: Correction need to be change on CAD-based model.

2) Deleting the constrain link on each assembly.

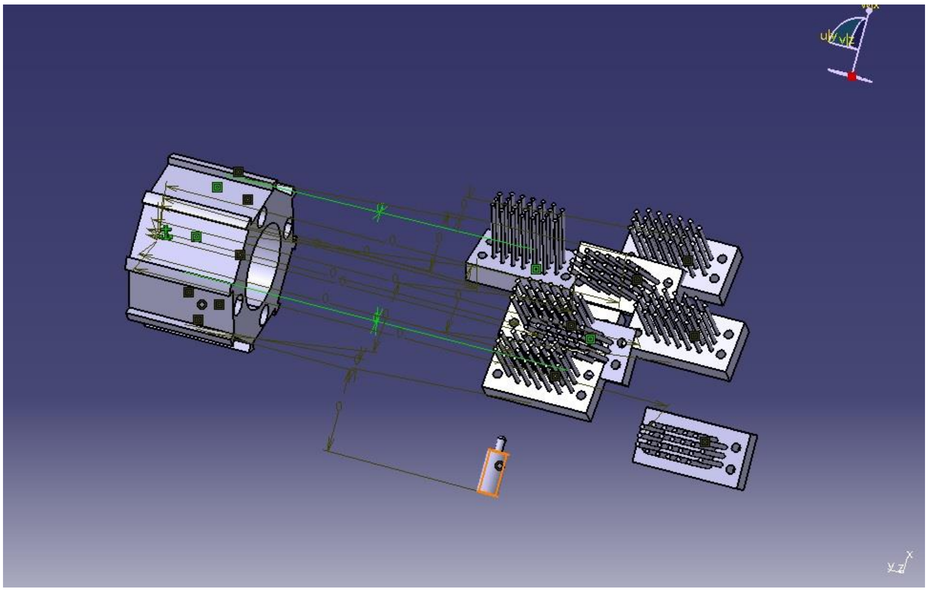


Figure 25: Deleting link on assembly.

3) Assembly with new constrain and attach it to the drive mechanism assembly.

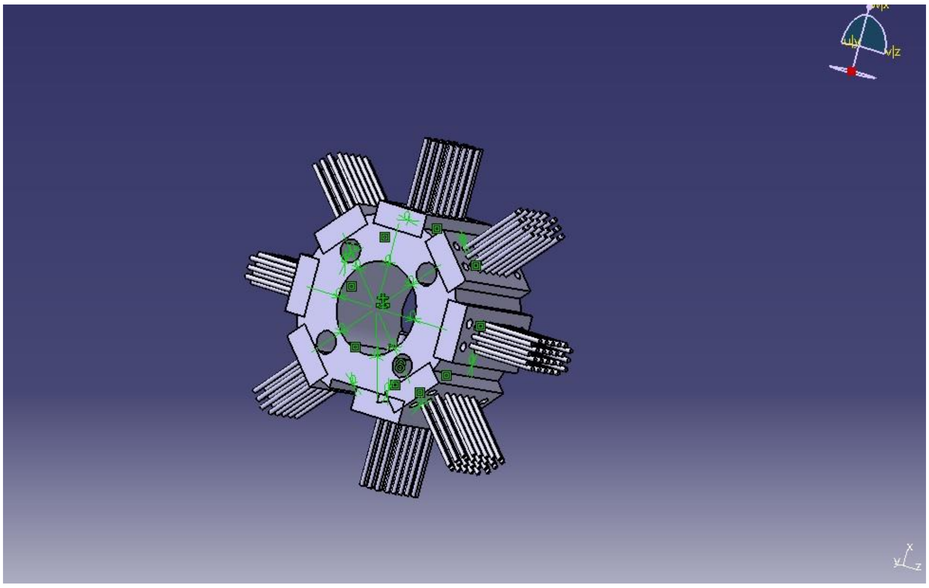


Figure 26: Assembly with new link.

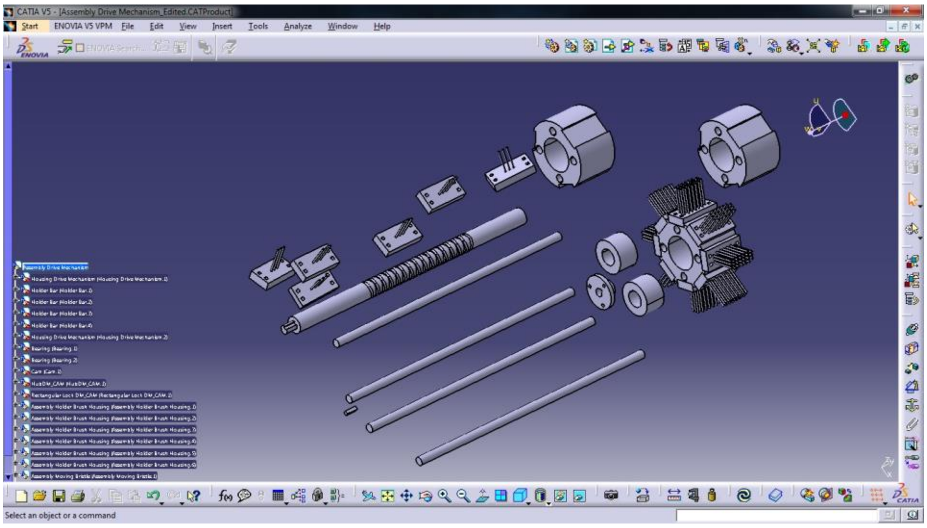


Figure 27: Assemble drive mechanism with new link.

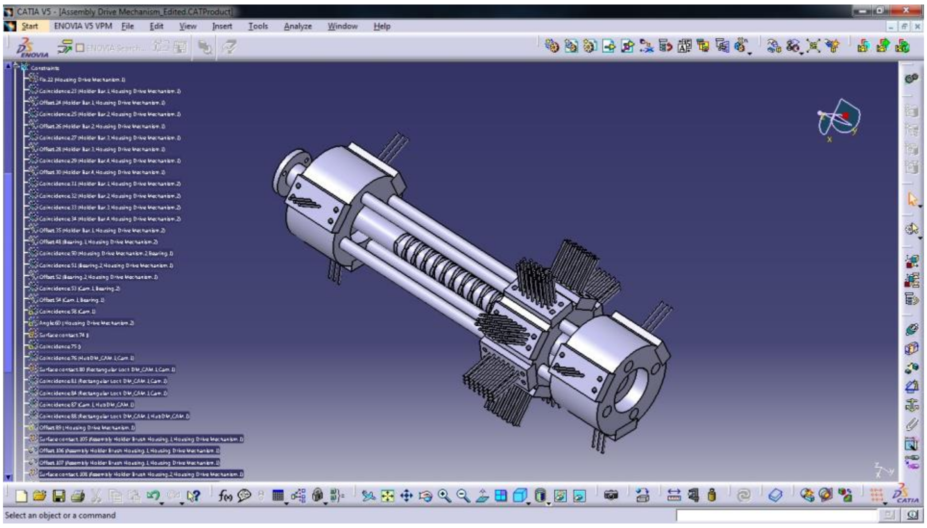


Figure 28: Complete new assembly link for drive mechanism.

4.2 Simulations (DMU Kinematics)

Simulation of the PIG models are made using CATIA V5R20 software and all the specifications and assembly were based on to literature review from previous researcher. Using DMU Kinematics in CATIA V5R20, before applying the calculation in the simulation, constrain and command need to be determine on each part of the assembly such as Fix, Revolve Joint, Prismatic Joint, Cylindrical Joint, Screw Joint, Spherical Joint, Planar Joint, Rigid Joint, Point Curve Joint, Slide Curve Joint, Roll Curve joint, Point Surface Joint, universal Joint, CV Joint, Gear Joint, Rack Joint, Cable Joint and Axis Based Joint. This simulation are divided into four main mechanism that are:

i. Moving bristle movement for mechanism 1

ii. Forward movement of the PIG for mechanism 2

iii. Poppet movement for mechanism 3

iv. Backward movement of the PIG for mechanism 4.

4.2.1 Moving bristle movement for mechanism 1

Main objective for mechanism 1 is to show the moving bristle moved on the thread when the turbine blade were spinning by the pipeline flow. This mechanism are determined by 7 command containing three joints which are Fix, Revolve Joint and Prismatic Joint.

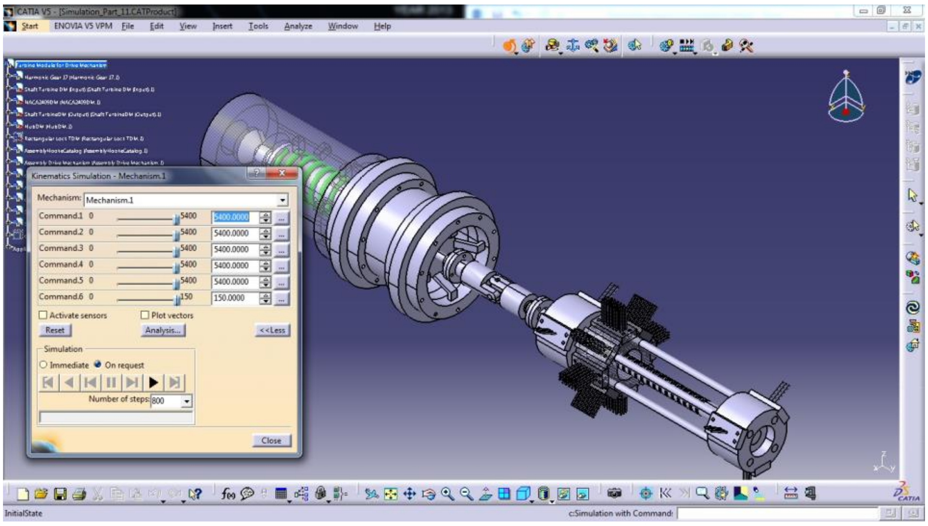


Figure 29: Mechanism 1.

Steps on determining command for mechanism 1 are shown below:

1) Insert PIG assembly and change the setting to DMU Kinematics at Start > Digital Mockup > DMU Kinematics.

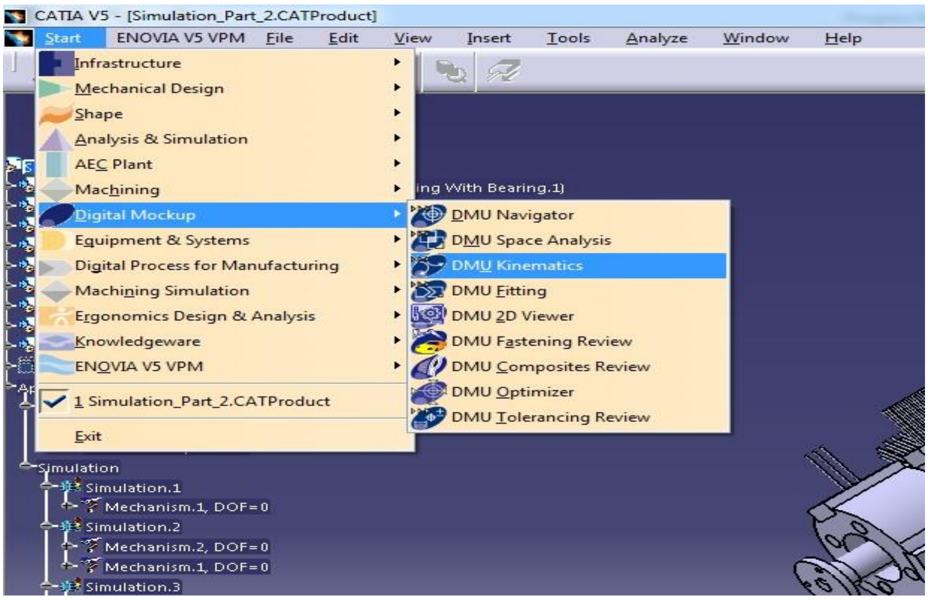


Figure 30: Change to DMU Kinematics Settings.

2) The first command is to select the Harmonic gear as fix part and create a new mechanism before determining the fix component. This fix feather is used as a reference point for any joint so that they will be in the same angle and length movement.

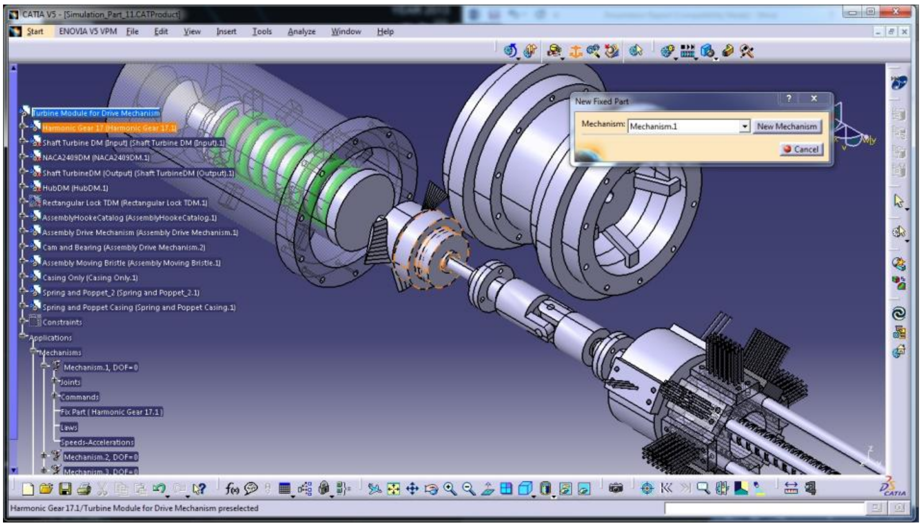


Figure 31: Create new mechanism and Fix part.

3) First revolve joint is determined between the harmonic gear as fix part and the Turbine blade. The criteria for this joint was that the harmonic gear and Turbine blade lie in the same line and plane. Angle driven need to be check to determine it’s a rotational movement by angle.

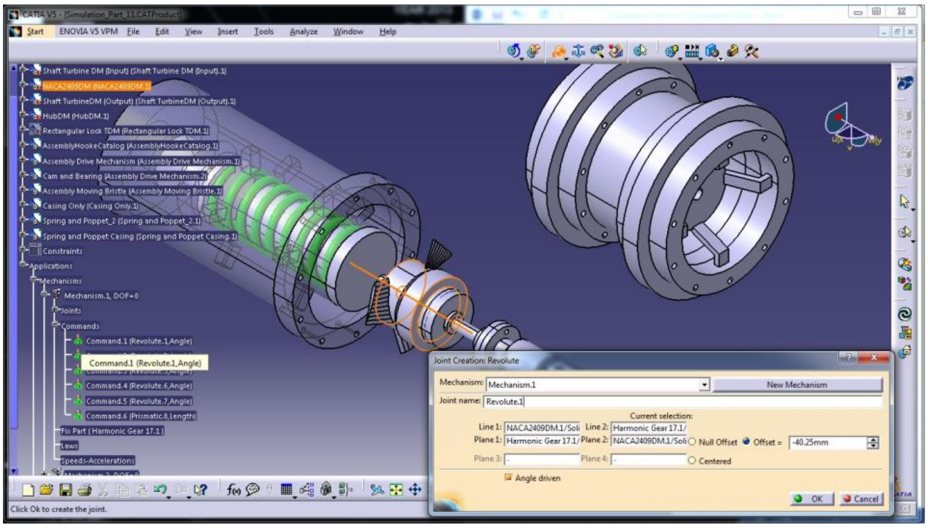


Figure 32: Revolve joint for Harmonic gear and Turbine blade.

4) The third command is for the second revolve joint for HUB and Harmonic gear. Line and plane was determined for each component and select angle driven for the rotational via angle. The HUB and shaft had to be determined differently because CATIA detect the component as a stand-alone part.

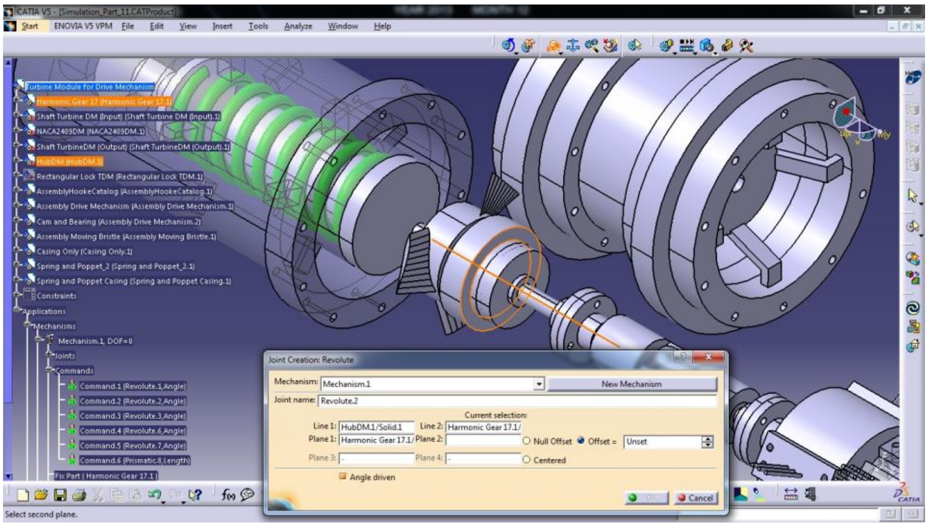


Figure 33: Revolve joint for Harmonic gear and HUD.

5) Repeat step 4 for Universal joint with Harmonic gear, Cam with Harmonic gear and Shaft with Harmonic gear.

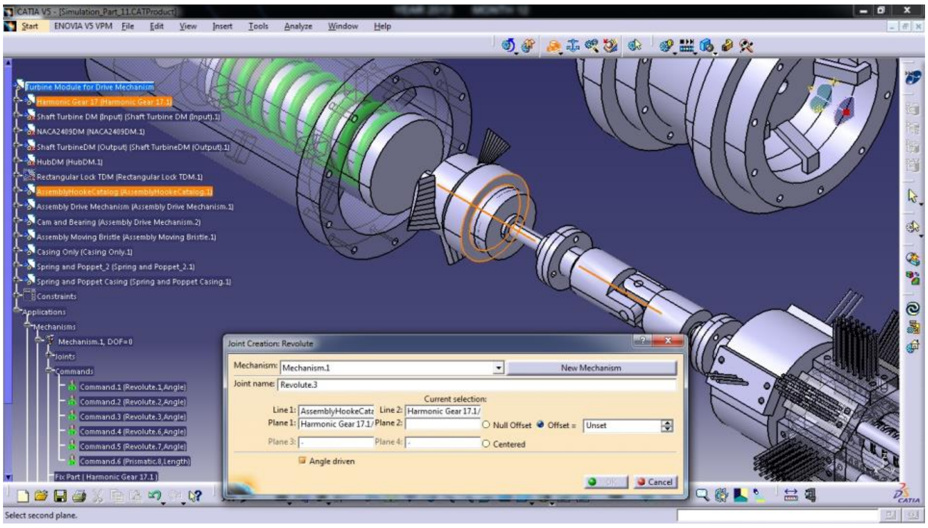


Figure 34: Revolve joint for Harmonic gear and Universal joint.

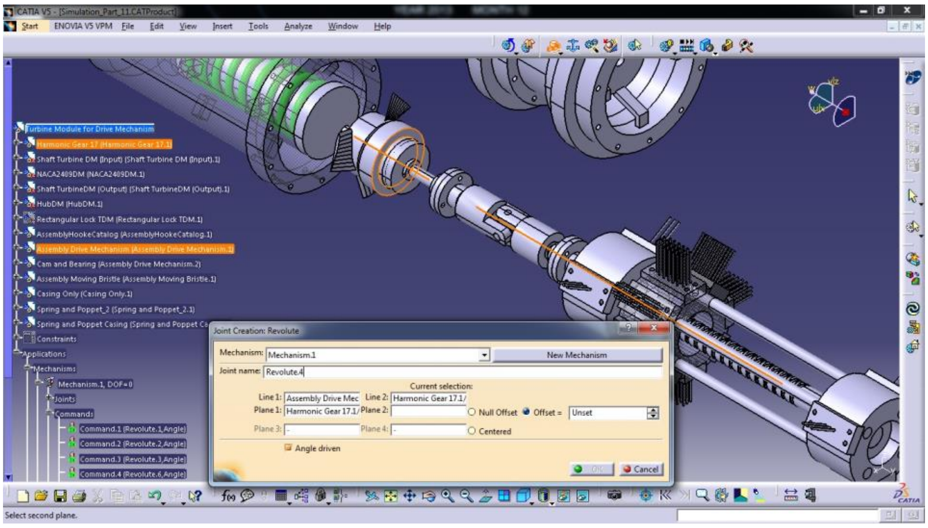


Figure 35: Revolve joint for Harmonic gear and Cam.

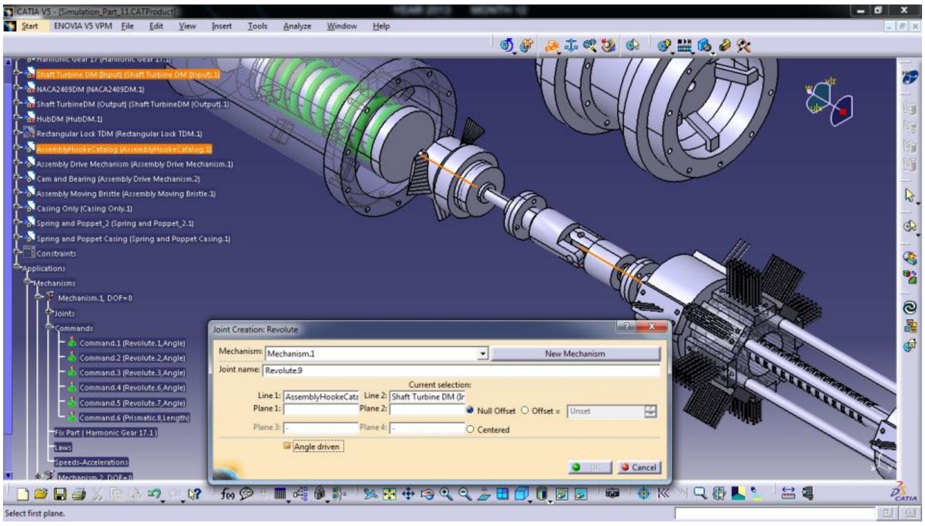


Figure 36: Revolve joint for Harmonic gear and Shaft.

6) Last command for mechanism 1 is the Prismatic joint for Harmonic gear and Moving bristle. The criteria for this joint is the line and surface of the movement via the yz axis. This joint is moved based on length determined on the simulation control box.

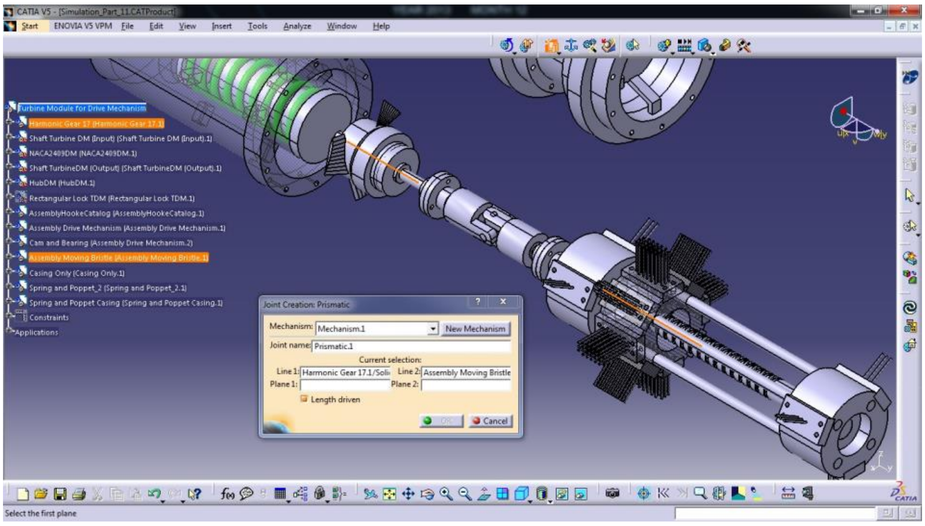


Figure 37: Prismatic joint for Harmonic gear and moving bristle.

7) When all of the commands were defined and all constrain were made sure not to be redundant, a notification box will appear and said that the mechanism can be simulated.

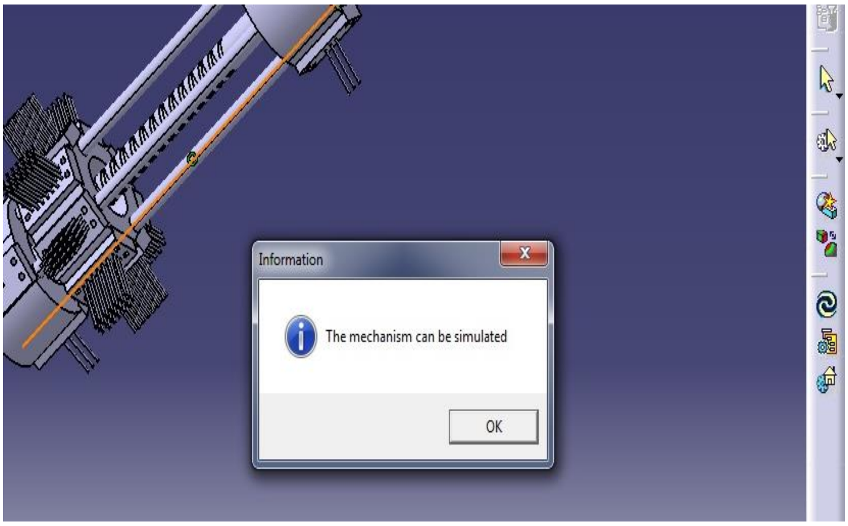


Figure 38: Mechanism can be simulated.

The last step on simulation is to adjust the settings in the command box. The first value that had to be determined is the length of the thread that is 150mm with 15 pitch for the moving bristle path. Meanwhile rotational angle for other command are determined with the equal speed that need to be find while simulating. The value that can correlate with the Moving bristle are 5400 for rotational angle (15 pitch X 360 degrees/pitch = 5400).

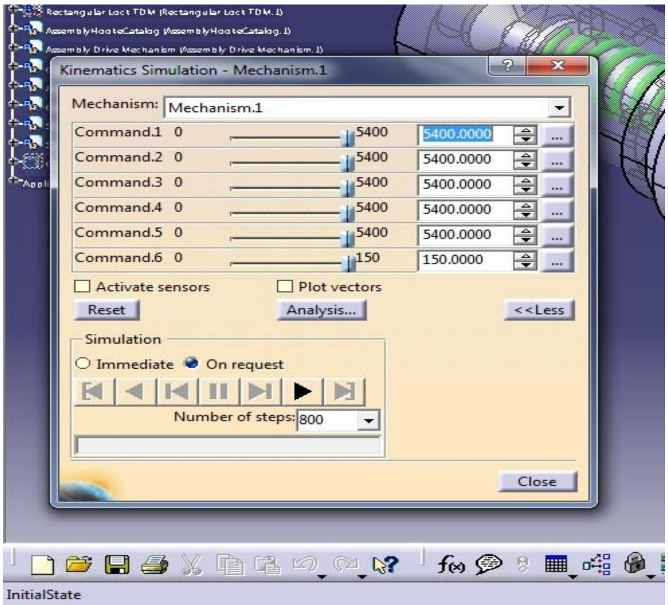


Figure 39: Simulation value command.

4.2.2 Forward movement of the PIG for mechanism 2.

Main objective for mechanism 2 was to show the PIG move forward while the moving bristle stays at the current position. This mechanism are determined by 12 command containing three joint that is Fix, Revolve Joint and Prismatic Joint. The command is the same as mechanism 1 but this is longer because in mechanism 1 only shows the movement of the moving bristle meanwhile for mechanism 2 was to show the movement of the PIG forward.

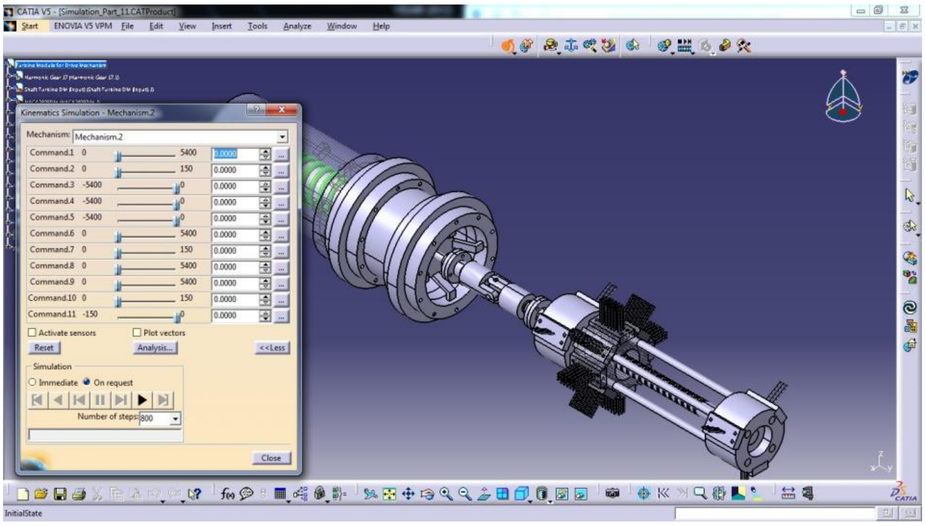


Figure 40: Mechanism 2.

Steps on determining command for mechanism 2 are shown below:

1) Create new mechanism and fix part for this mechanism is the moving bristle. Determining the rotational angle command is the same as step 3 – 5 in mechanism 1.

2) Prismatic Joint are defined between moving bristle as the fix part with the turbine casing, poppet casing and the holder bar with brush holder assembly on the yz plane.

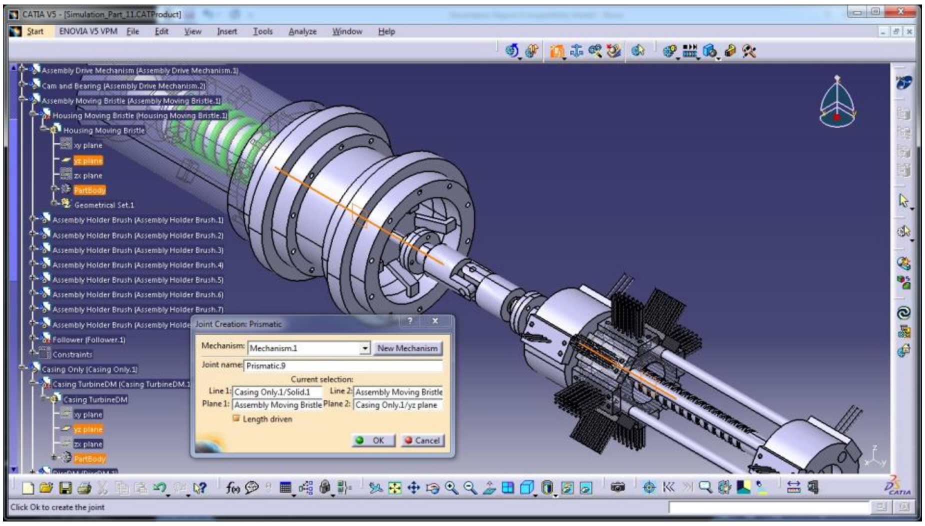


Figure 41: Prismatic joint for moving bristle and turbine casing.

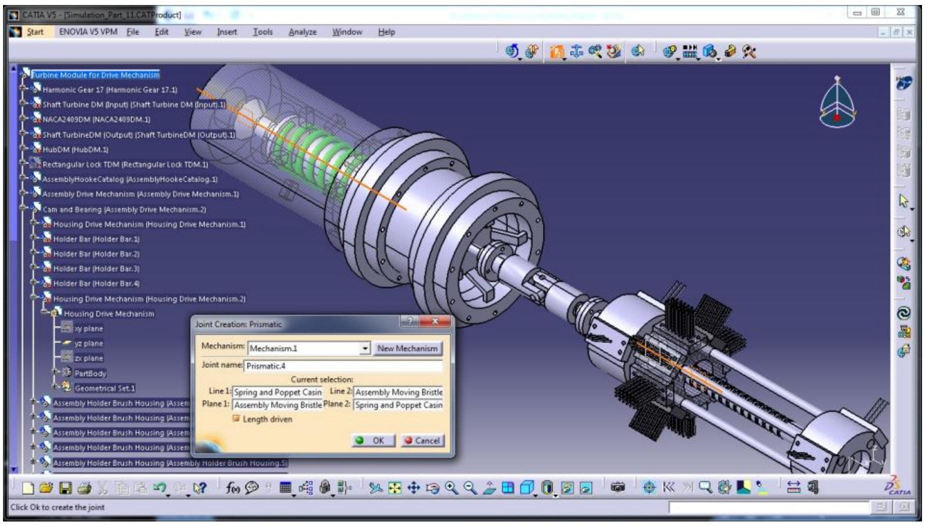


Figure 42: Prismatic joint for moving bristle and poppet casing.

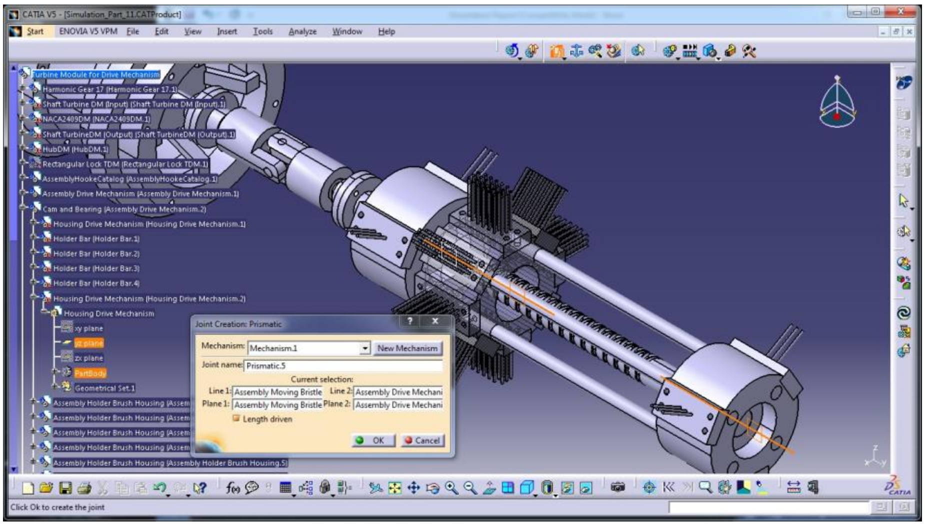


Figure 43: Prismatic joint for moving bristle and holder bar with brush holder.

3) Last step is the same as step 7 in mechanism 1 which were to define the value of each command depending on the suitable rotational, length and speed constrain.

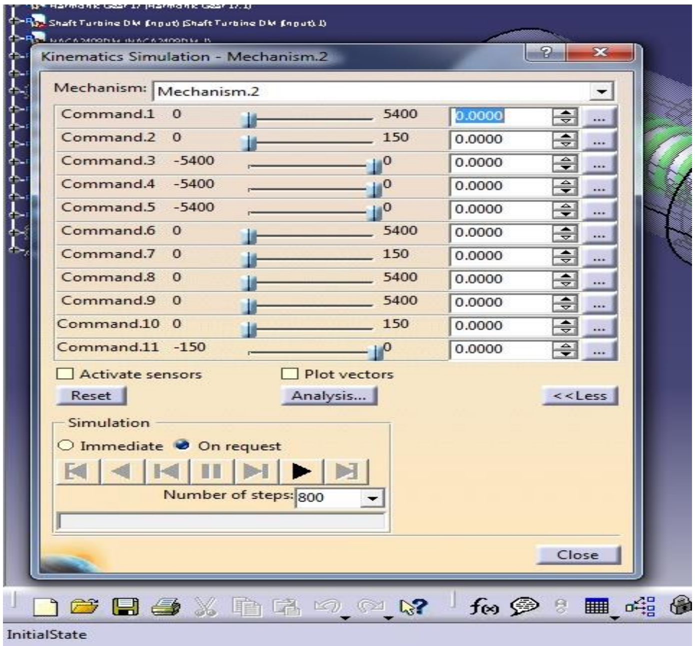


Figure 44: Settings for mechanism 2.

4.2.3 Poppet movement for mechanism 3.

Main objective for mechanism 3 is to show the poppet movement on blocking the pipeline flow and to allow the flow to enter PIG to rotate the turbine blade. This mechanism are determined by only 1 command that was the Prismatic Joint.

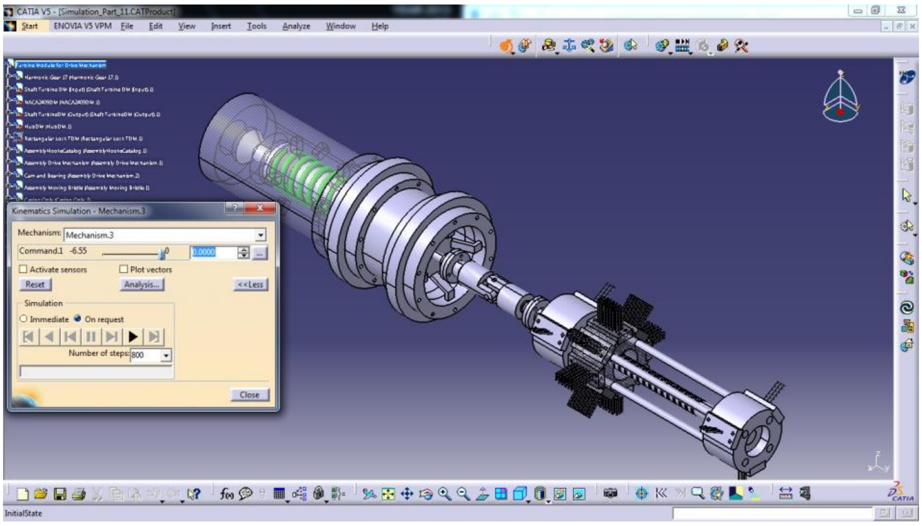


Figure 45: Mechanism 3.

Steps on determining the command for mechanism 3 was by using prismatic joint between Poppet and Turbine casing as the fix part.

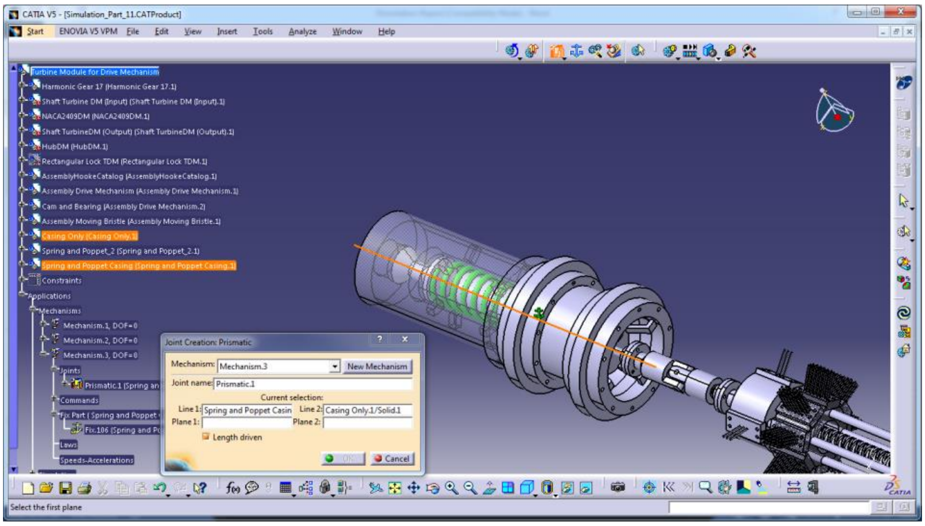


Figure 46: Prismatic joint for Poppet and Turbine casing.

Value for prismatic joint of mechanism 3 was only 6.55 because that is the only allowable gap that found through simulating.

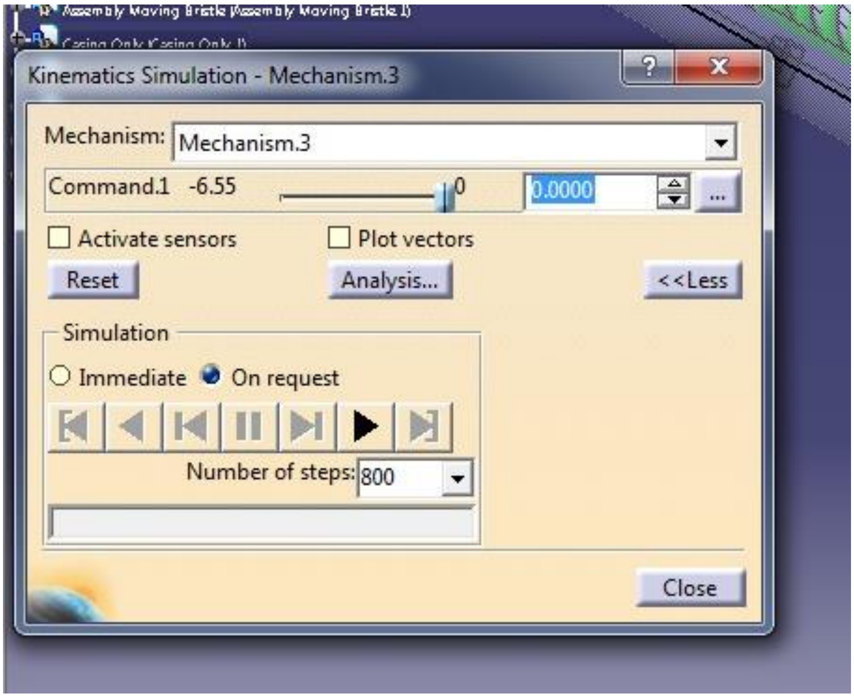


Figure 47: Settings for mechanism 3.

4.2.4 Backward movement of the PIG for mechanism 4.

Main objective for mechanism 4 was to show the PIG move backward while all the parts stays at the current position. This mechanism are determined by 12 commands containing only two joints that were Fix and Prismatic Joint. The command is almost the same as mechanism 2 but this mechanism only use prismatic joint to show the backward movement in static position without any rotational angle.

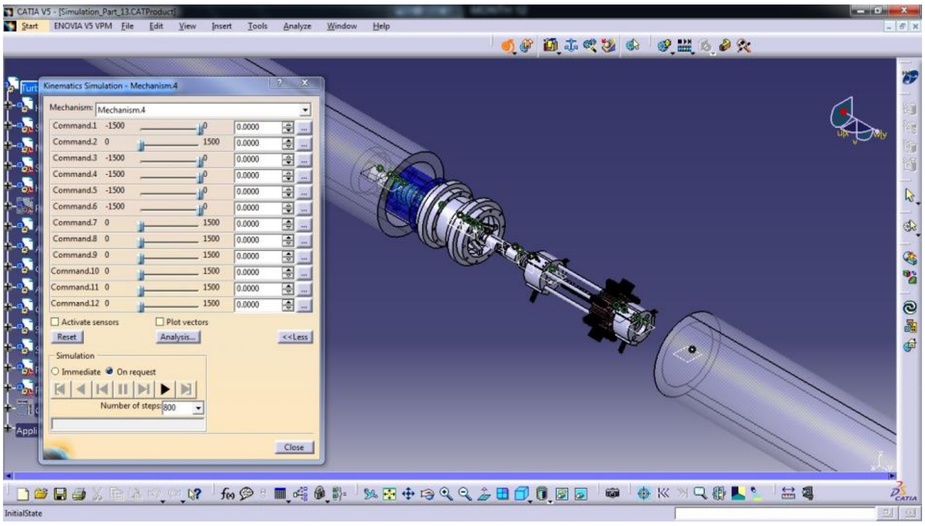


Figure 48: Mechanism 4.

Steps on determining command for mechanism 4 are shown below:

1) Pipeline is defined as Fix part because only the PIG are moving.

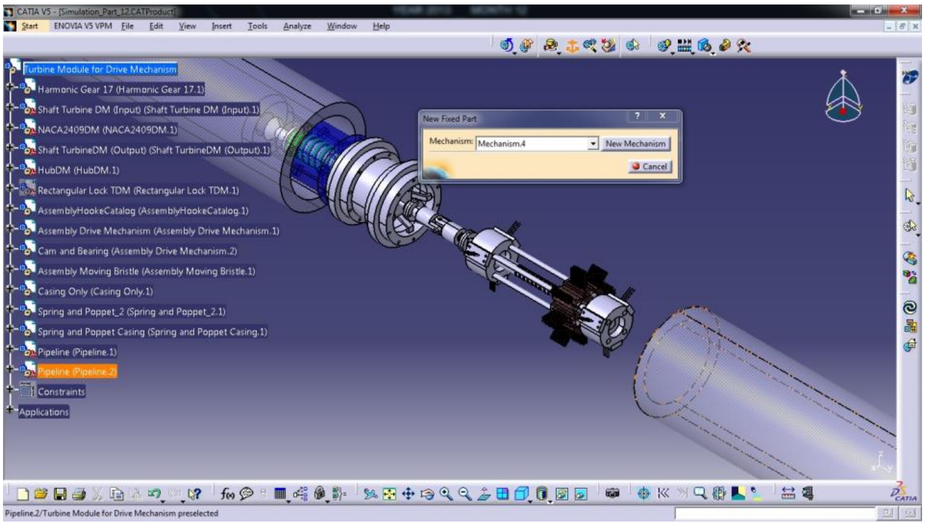


Figure 49: Pipeline as fix part.

2) All assemblies and stand-alone parts were defined as prismatic joint with the pipeline to get the same result on speed and length while simulating. The parts were:-

   i. Moving Bristle
   ii. Assembly Bar and Brush holder
   iii. Shaft (x2)
   iv. Universal Joint
   v. HUB
   vi. Turbine Blade
   vii. Harmonic Gear
   viii. Turbine Casing
   ix. Poppet Casing
   x. Poppet assembly
   xi. Cam and Bearing assembly

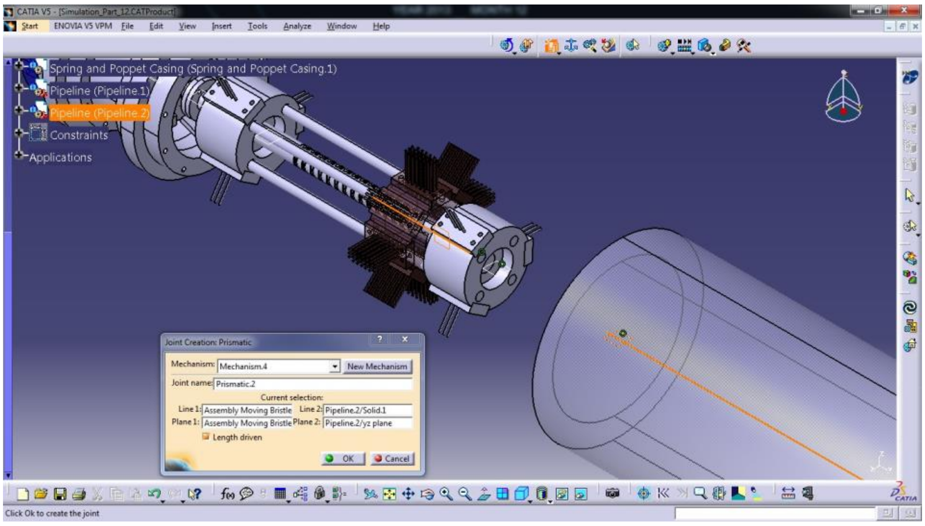


Figure 50: Example Prismatic joint for mechanism 4 (Moving Bristle with Pipeline).

3) Lastly, after defining all constrains and commands of mechanism 4 the value will be assume as 150 because of the distance of the pipeline in the 3D model and enough to show how the PIG move backward when the Poppet close the flow of the PIG.

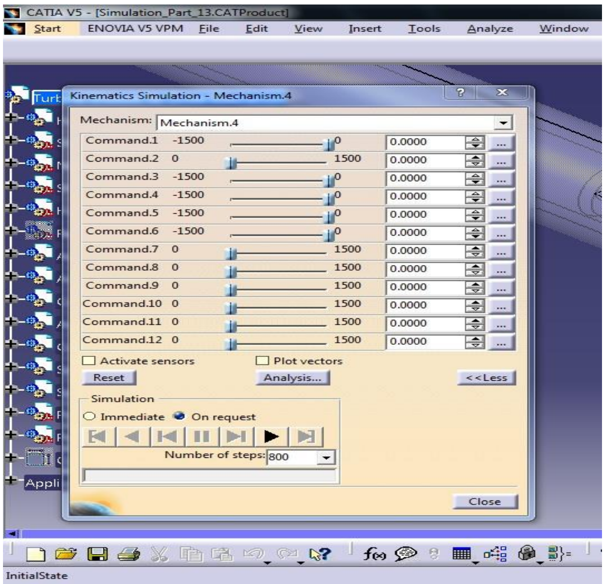


Figure 51: Settings for mechanism 4.

4.3 Discussion and Limitation

All the mechanism were successfully simulated to show the PIG can travel in in-flow and contra-flow movement. But to get the accurate value as calculated by Kresnajaya [2] were hardly to be defined with several limitation that are:-

i. Double thread was hard to define and it needs further in-depth research and simulation, to show if it can be used for reverse and forward movement.

ii. Lack of time, guides (experts) and knowledge to implement several previous calculation by Kresnajaya [2] in the simulation.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

Throughout this research of the project, the author has looked for several approaches and alternatives in order to implement the right procedure and simulation for this project. During the development stage, experimental PIG drive mechanism assembly was developed and simulated in CATIA software.

5.1 Conclusion

In conclusion the author had completely corrected the experimental PIG crawler drive mechanism CAD-based model assembly with the suitable constrains. In this process there are important steps that need to be taken to achieve the correct assembly and meet the specific requirement by Azmi [3]. The steps is to analyse the CAD-based model assembly constrains, improvements was made if the constrain didn't meet the requirement by deleting those constrain link and assemble it with a new constrains. There were several problems occurs when determining the assembly between the Moving Bristle and Cam that is to assemble the Follower on the Double Thread. The Double Thread being detect as a whole and cannot detect as a line itself. So, the follower cannot be coincident between the double thread. To solve this problem the author had to check the assembly requirements data and defined the Follower as a distance coincident between Moving Bristle and Drive Bristle as long the Follower is between the Double Thread with the correct distance. Meanwhile, the other component are successfully assembled.

Secondly, the author successfully simulated and shows the forward and backward drive mechanism movement of the PIG that travel in the pipeline on both contra-flow and in-flow directions. To show simulated movement in DMU Kinematics there are features and joints that need to be determined such as Fix, Revolve Joint, Prismatic Joint, Cylindrical Joint, Screw Joint, Spherical Joint, Planar Joint, Rigid Joint, Point Curve Joint, Slide Curve Joint, Roll Curve joint, Point Surface Joint, universal Joint, CV Joint, Gear Joint, Rack Joint, Cable Joint and Axis Based Joint. But for this project the author only used Fix, Revolve Joint and Prismatic Joint. This simulation are divided into four main mechanism that are:

i. Moving bristle movement for mechanism 1.

   Main objective for mechanism 1 is to show the moving bristle moved on the thread when the turbine blade are spin by the pipeline flow. This mechanism are determined by 7 command containing three joint that is Fix, Revolve Joint and Prismatic Joint.

ii. Forward movement of the PIG for mechanism 2.

   Main objective for mechanism 2 is to show the PIG move forward while the moving bristle stays at the current position. This mechanism are determined by 12 command containing three joint that is Fix, Revolve Joint and Prismatic Joint. The command is the same as mechanism 1 but this is longer because in mechanism 1 only shows the movement of the moving bristle meanwhile for mechanism 2 is to show the movement of the PIG forward.

iii. Poppet movement for mechanism 3.

   Main objective for mechanism 3 is to show the poppet movement on blocking the pipeline flow and to allow the flow to enter the PIG to rotate the turbine blade. This mechanism are determined by only 1 command that is the Prismatic Joint.

iv. Backward movement of the PIG for mechanism 4.

   Main objective for mechanism 4 is to show the PIG move backward while all the parts stays at the current position. This mechanism are determined by 12 command containing only two joint that are Fix and Prismatic Joint. The command is almost the same as mechanism 2 but this mechanism only use prismatic joint to show the backward movement in static position without any rotational angle.

A few problems occurs to determine the joints between the Follower and double thread because as said before that the double thread detect as a whole. So, to determine the mechanism is impossible. As the solution, the author decide to use a linear movement of the Cam while rotating using Prismatic and Revolve Joints. The length and pitch of the movement is based on calculation that is 150mm and 15 pitch meanwhile the rotational angle for revolve joints are determined by mathematical calculation that are 15 pitch X 360 degrees/pitch = 5400. By this calculation the movement of the Follower are smoothly move on the Double Thread path. Lastly, the author would like to conclude that this project had meet all objectives.

5.2 Recommendation

Due to the time constraint and unavailability of skilled personnel, several information such as coincident between the Double Thread and Follower were unable to be obtained. So the position were assume between the Moving Bristle and Drive Bristle using suitable length, hence it is recommended for further in-depth research and simulation of the Double Thread, to show if it can be used for reverse and forward movement. By using DMU Kinematics simulation with laws, the results will be more accurate and efficient. Other than that correlating the calculation result with the simulation are hardly to be apply since there are lack of knowledge in CATIA Simulation software. The author recommended that with an availability of an expert will improve the efficiency of this project since this project has a huge potential to be used by oil and gas industries.

REFERENCES

[1] Z. Hu and E. Appleton. Dynamic characteristics of a novel self-drive pipeline pig. IEEE Transactions on Robotics. vol. 21. pp. 781-789. 2005. http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1512338

[2] Pancakarsa K.P., "Design of Contraflow Cleaning Pig For Pipeline Maintenance," M.S. Thesis, Dept. Mechanical Eng., Universiti Teknologi PETRONAS, Malaysia, 2009.

[3] Mohamad Azmi Md Haniffa, and Fakhruldin Mohd Hashim. "Development Of An Intelligent Pig Prototype For Hydrate Removal In Deepwater Pipeline," Symposium, Dept. Mechanical Eng., Universiti Teknologi PETRONAS, Malaysia, Jan., 2010

[4] Mohamad Azmi Md Haniffa, and Fakhruldin Mohd Hashim. "Development Of An Intelligent Pipeline Inspection Gauge (PIG) Prototype For Inspection In Deepwater Pipeline," Symposium, Dept. Mechanical Eng., Universiti Teknologi PETRONAS, Malaysia, 18 Sept., 2012

[5] W. Liu, M. Zeng, and S. Zhang. Design and kinematical analysis of the contra-flow crawler in pipeline. Presented at Int. Conf. on Electrical and Control Engineering (ICECE 2011). Yichang. China. June 2011.

[6] K. Swinden. Pigging the unpiggable with next generation thruflow crawlers. December 2010.
http://www.pipeguild.com/Document.Doc?id=361

[7] Mohamad Azmi Md Haniffa, and Fakhruldin Mohd Hashim. "Development of an Intelligent PIG Prototype for Deepwater Pipeline Inspection," Symposium, Dept. Mechanical Eng., Universiti Teknologi PETRONAS, Malaysia, May, 2012

[8] BKMetalx, "Unique shaped bottle design in Catia" Retrieved, 30 June, 2013. Available at:

http://worldofcadcam.com/2011/11/29/unique-shaped-bottle-design-in-catia.html

[9] Ken Tashiro. “Elysium's CADfeature Boosts Automation of Data Translation Tasks”. Retrieved, 30 June, 2013
Available at:
http://www.elysiuminc.com/news/newsdetail.asp?nid=234

[10] ENOVIA LCA. DMU Kinematic Simulator. Version 5 release 14.Retrieved on 27 June, 2013.
Available at:
http://www.catia.com.pl/tutorial/z2/dmu_kinematics_simulator.pdf

[11] B. Nicholson (2004); Smart Utility Pig Technology In Pipeline Operations: In PPSA Aberdeen Seminar.

[12] D.G. Ullman; *The Mechanical Design Process*, 3rd ed., McGraw Hill, Singapore, 1997.

[13] John A. Schey; *Introduction To Manufacturing Processes*, 3rd ed, McGraw Hill, USA, 2000.

[14] F. Esmaeilzadeh, D. Mowla, M. Asemani,”Mathematical modeling and simulation of pigging operation in gas and liquid pipelines”, Journal of Petroleum Science and Engineering, vol. 69, pp.100–106, 2009.Available:
http://www.sciencedirect.com/science/article/pii/S0920410509001703

[15] J.Y. Li, S.Y. Jiang, Y. Wang, L. M. Ren and X.H. Gao, ‘’ Study on speed control system of in-pipe robot power self-supported by fluid”, Proceedings of the 2009, presented at IEEE International Conference on Mechatronics and Automation, Changchun, China, August 2009.Available:
http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5246682

[16] E. Appleton, and N.W. Stutchbury, ” Novel brush drive robotic tractor for sewer and water main inspection and maintenance”, Industrial Robot: An International Journal, vol. 27, Iss: 5, pp.370 – 377, 2000.Available:
http://www.emeraldinsight.com/journals.htm?articleid=1454211

[17] C. R. Torres Jr.,Paul T. Manzak; Jack E. Miller, Houston TX (US),” Variable speed pig for pipeline application”, US Patent 6,370,721 B1, April 2002.Available:
http://www.patentstorm.us/patents/6370721/description.html

[18] U. Thuenemann, and J. W. Kuipers,” The development of a new single section intelligent inspection tool designed to provide active speed control”, APIA Company Member News, 2003.Available:
http://www.Roseninspection.Net/MA/Articles/Australianpipeliner_2003-08.pdf

[19] Z. Wang, and H. Gu, “A Bristle-based pipeline robot for ill-constraint pipes”, IEEE/ASME Transactions On Mechatronics, vol. 13, no. 3, June 2008**.**
Available:
http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4542815

[20] S.D'Arcy, B. Newman, G. Broze., “A contraflow tetherless mechanical pipeline crawler”, presented at OTC 15259-MS, Offshore Technology Conference, Houston, Texas, May 2003.
Available:
http://www.onepetro.org/mslib/app/?paperNumber=OTC-15259-MS&societyCode=OTC

[21] Z. Hu and E. Appleton, “Dynamic characteristics of a novel self-drive pipeline pig,” IEEE Transactions On Robotics, vol. 21, pp. 781-789, 2005.
Available.
http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1512338

[22] B. Stoltze,” A new pipeline cleaning technology: hydraulically activated power pigging (HAAP TM), presented at PPSA Aberdeen Seminar, 2007.
Available:
http://www.ppsa-online.com/papers/2007-8-Stoltze.pdf