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Dato: 29.05.2015

Automated Assembly Of Propeller Head

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May 2015

Preface

This is a bachelor thesis written by students at Aalesund University College as part of the study program automation engineering. It is the final thesis for this course, and was carried out for Rolls-Royce Marine Propulsion in the spring semester of 2015. Rolls-Royce Marine Propulsion wants to investigate the possibilities for fully automated production, from raw goods to finished, assembled product. This thesis examines the assembly-part of this automated production.

We wish to acknowledge individuals for their contributions towards the production and guiding of the project and this report.

Aarset, Magne Vollan, for advice on writing the report.

Djupvik, Arild, for commitment towards the project.

Moulder, Lee, for providing 3D models.

Osen, Ottar, for guidance on the project.

Summary

This report was written by three students at Aalesund University College as a part of their bachelor thesis in Automation engineering. The thesis was given by Rolls-Royce Marine Propulsion, by Arild Djupvik. Supervisors were Ottar Osen and Houxiang Zhang.

The aim for the project was to automate the assembly of a propeller head, which was then done by hand. Assembling a propeller head by hand takes a lot of time, involves safety hazards and can damage the product. By automating the assembly, it is believed that safety and quality is improved, and time spent is reduced.

The task was to develop a scalable solution that is fully automated. The solution must utilize two robots and implement a control system with sensors. A system for handling and storing parts must be developed.

A PLC contains the control program of the automated process. A visualization of the robot cell was also developed. By implementing a laser distance sensor, the assembly process is autonomous and can react to different events.

To develop the solution, a hands-on approach was applied. Handling the parts and focusing on trial and error, inspired innovative thinking and gave solutions that were unique. Automating the assembly process increased quality, reduced the risk of injury and drastically reduced the time it takes to assemble a propeller head.

Terminology

Air pressure control switch: pressure switch that monitors air pressure and reports deviance from a preset level. Availability: the probability that a robot is available for service at the moment of need.[9] Cycle time: the period required to complete one cycle of an operation; or to complete a function, job or task.[46] Pendant: Control unit for the robots Photoelectric sensor: device used for measuring distances, or check for objects. Piston: Piston rod which adjusts propeller blade angle

Propeller head: Assembled propeller hub with parts

Propeller hub: houses all parts

Reliability: the probability that a robot will perform its specified mission according to stated conditions for a given time period.[9] Slide bearing: Sliding shoe which glides in the piston-trace

Thruster-disc: Crank pin ring which the propeller blades are mounted on

Abbreviations

2D: Two dimensional

3D: Three dimensional

ACK0: Even Affirmative Acknowledgement

ACK1: Odd Affirmative Acknowledgement

BCC: Block Check character

BSC: Binary Synchronous Communication

CCW: Counterclockwise

CW: Clockwise

ECAD: Electrical Computer Aided Design

ENQ: Enquiry

ETB: End of transmission block

ETX: End of text

FBD: Function Block Diagram

GNU: General Public Licence

GUI: Graphical user interface

IDE: Integrated Development Environment

IP: Internet protocol

ITB: Intermediate block

LCD: Liquid crystal display

LED: Light Emitting Diode

MAG: Metal Active Gas

MCAD: Mechanical Computer Aided Design

PC: Personal Computer

PID: Proportional-Integral-Derivative

PLA: Polylactic Acid

PLC: Programmable Logic Controller

RS-232: Recommended Standard number 232

SFC: Sequential Function Chart

SOH: Start of heading
ST: Structured Text
STL: STereoLithography
STX: Start of text
TCP: Tool Center Point
TT: Tunnel Thruster
UDP: User datagram protocol
USB: Universal Serial Bus
VLC: Vidoe Line Client

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Chapter 1

Introduction

1.1 Background

Automation is a way of making a machine, a process or a system operate automatically. Traditional automation is often thought of as robots doing a repetitive tasks over and over again. This is often the case, but automation is not only a subject when it comes to industrial applications. Automation can be applied to just about any trade in the world. Anywhere you look around you, there is a system or an item which has used automation somewhere along the line.

Norway is a high-cost country with inhabitants who have high wages compared to other countries.[43] To be able to keep production and assembly in Norway, processes must be made more efficient. One way to increase effectiveness is to apply robots to the process.

Some arguments for robotizing are:

Robots...

1. do tedious and repetitive tasks, freeing humans to do intellectual work.
2. feel no pain or stress, and can do hard physical labor.
3. have high precision, ensuring the same outcome for every operation.
4. have the same cost in low cost countries as in any other country, and thus ensures production in the manufacturing company's country.
5. are often faster and cheaper than humans, giving an increased production, and lower cost per unit.
6. do not sleep or take breaks. It can be effective at all times.

1.2 Thesis

The task is to robotize the assembly of a propeller head. This assembly is today done by hand and is time consuming. The small clearance and the high weight of the parts make it difficult for humans to do the assembly by hand. The propeller head in this project is the smallest of the Autoflex TT (Tunnel Thruster) heads from Rolls-Royce Marine Propulsion (hereby referred to as Rolls-Royce). The bigger ones have the same components as the small ones, so a solution for the smallest model can be scaled to fit the bigger ones.

1.3 Presentation

This section briefly presents the system and tasks.

1.3.1 Robot and robot cell

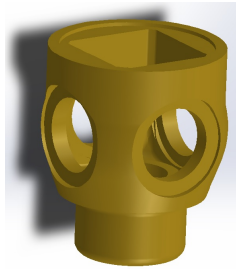
The system consists of two robots mounted on a support structure consisting of two I-beams with two square metal pipes between them. A cell is placed around the robots, fastened to the ground. The control cabinet outside of the robots, handles the power supply and servo-control of the robots. A PLC connected to the control cabinet controls the program which runs the robots.



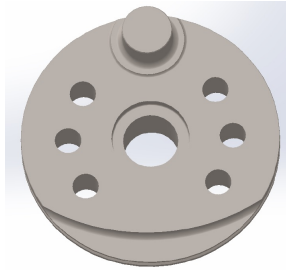
Figure 1.1: Robot cell

1.3.2 Propeller-head

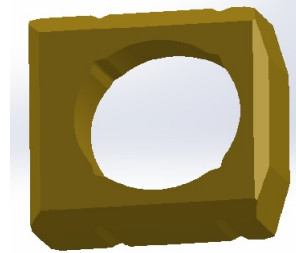
Figure 1.2 shows all the parts which are supposed to be assembled. There is a hub, four thruster-discs, four sliding bearings, and one piston.



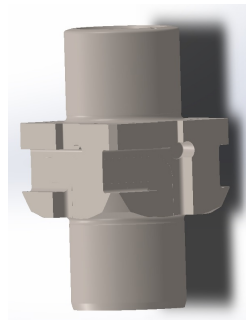
(a) Propeller-hub



(b) Thruster-disc



(c) Slide bearing



(d) Piston

Figure 1.2: Propeller parts

Figure 1.3 shows the propeller head fully assembled.

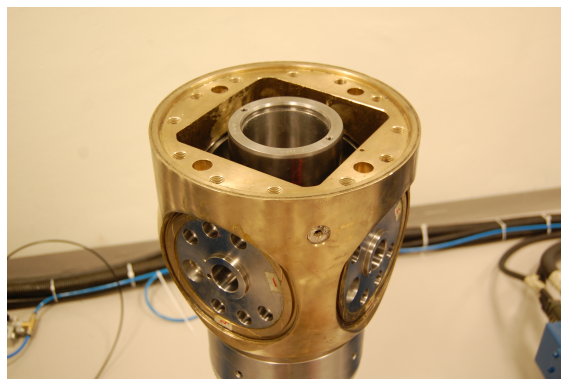


Figure 1.3: Assembled propeller head

1.4 Constraints

The project is limited to the assembly of the parts themselves inside the propeller head. This includes robot control, quality control, visualization, control system with GUI, development of tools and making a holder system for the parts. No consideration is taken regarding the placement and rotation of the propeller hub relative to the robots, assembly of o-rings, or mounting of the propeller blades.

Two Motoman industrial robots will work together to make the assembly as fast and safe as possible. A propeller hub is mounted on a pillar bolted to the same foundation as the robots. The robots will in turns, pick up parts and place them inside the head. The robots will then work together to lower a piston into place. The entire assembly process will be assisted and monitored by using a laser and a PLC (Programmable Logic Controller) connected to a digital touch screen.

1.5 Report setup

This introduction shortly presented an introduction to automation, the production procedure at Rolls Royce, a brief presentation of the system and tasks, and the constraints regarding the thesis.

Furthermore this report will present the theoretical basis and background, materials and methods used, results, some discussion about the results and finally draw a conclusion.

Chapter 2

Theoretical basis and background

2.1 Motoman

2.1.1 Yaskawa Motoman

As Yaskawa Motoman clearly describes on their homepage, "the company was founded in 1989 and is a leading robotics company in America. With more than 300,000 Motoman robots, 10 million servos and 18 million inverter drives installed globally, Yaskawa provides automation products and solutions for virtually every industry and robotic application; including arc welding, assembly, coating, dispensing, material handling, material cutting, material removal, packaging, palletizing and spot welding." [34]

2.1.2 Yasnac MRC

As Yaskawa Motoman describes in their overview of robot history, "the Yasnac MRC is the control system that controls the Motoman SK robots. This system can control up to 21 axis and can manage synchronized motions of two robots. It has a programming capacity of 2200 positions and the opportunity of 48 input and 48 output signals. These signals can for example be used to control tools which are mounted on the robot. " [33]

The Yasnac MRC takes care of the inverse kinematic for the robots. Inverse kinematic is calculations of the angle of each joints to reach a given position with a given orientation of the tool.

2.2 Programmable Logic Controller (PLC)

PLC originated in relay-based control systems and the first PLC came into commercial production when General Motors called for a replacement for the relay controllers. The first PLC's were relatively simple and their function was to replace the relay logic and nothing more. Afterwards, the opportunity got bigger and functions like counters and time delay came. The next step was the analog in- and output signals and arithmetical functions like comparison and adders.[18]

Today's PLC's come with complete development systems with many functions, examples and communication handling. Process-functions like Proportional-integral-derivative (PID) regulator, servo control and axis control are implemented.[18]

2.3 3D printing

3D printing offers a way of prototyping without investing a lot of time and money into a finished product. 3D printing is normally done by printing thin layers upon layers, creating a 3D model.

2.3.1 Replicator 2

The Replicator 2 is a Desktop 3D printer made by Makerbot Industry in 2012. The printer has a build plate of 285x153x155mm and can lay 0,1mm per layer. It has a single extruder which can print PLA plastic, a LCD display and a control pad for direct user interaction without the need for a PC. [52]

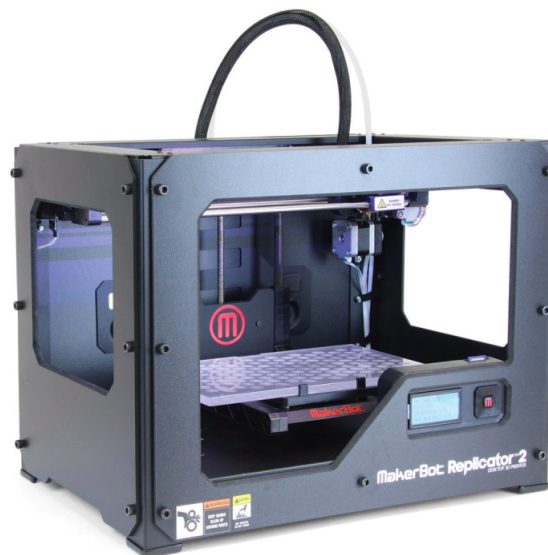


Figure 2.1: Replicator 2 [3]

2.3.2 Makerbot Desktop

Makerbot Desktop is a software solution made to use with Makerbot 3D printers. With this software you have the opportunity to generate print files from STereoLithography(STL) files. These print files can then be stored on a SD-Card, which can be read by the 3D printers.

2.4 Software

2.4.1 Solidworks

Solidworks is a 3D design solution for rapid creation of parts, assemblies, and 2D drawings. There are three types of Solidworks. In the basic version, you have the opportunity to choose what type of material you are going to use and specific tools for cutting sheet metal, weldments and surfacing. In a more complex version, you also have file management tools, advanced photorealistic rendering, automated cost estimation and much more. In the most complex version of Solidworks you have the opportunity to add powerful simulation and design validation to your 3D design solution as well as ECAD/MCAD collaboration, reverse engineering, and advanced wire and pipe routing functionality. [44]

2.4.2 Blender

Blender is an open-source 3D creation software. It is released under the GNU General Public Licence as free software.[17] This means that anyone can use it for any purpose, and anyone can distribute the software. It supports modeling, rigging, animation, simulation, rendering, video editing, game creation, and more. The software can be customized and additional tools can be added by scripting them in Python.

Blender is cross-platform and can be run on Linux, Windows and Macintosh.

The software is primarily developed and maintained by the Blender Foundation, but because of its open-source nature, anyone can further develop the suite. [16]

2.4.3 VLC media player

VLC media player is a free, open-source, media-software and framework which can play most media files. The media player is developed by the VideoLAN organization, a non-profit organization, composed of volunteers. The software works on almost any platform, including Windows, Android, iOS, Linux, Mac and Unix. Even though the software is multi-platform, it depends on native code for each platform. A separate install-file must be downloaded for the selected platform.[38]

2.4.4 Advanced Serial Port Monitor

Advanced Serial Port Monitor is a software that allows monitoring COM ports of various type, such as RS232, RS485 and RS422. [23]

2.5 Programming

2.5.1 Netbeans IDE

The NetBeans IDE is an open-source development environment for developing primarily Java. The application can also run java applications. It is written in Java and can be run on most operating systems. NetBeans contains all the basic modules for Java programming when you download it. NetBeans also allows extending other libraries. [35]

2.5.2 Codesys

Codesys is a free and equipment-independent programming system for PLC's, micro controllers and other hardware. Many equipment producers have chosen to use Codesys, such as WAGO and Kloeckner-Moeller.

Codesys contains a simulator, so that the program code can be tested without any hardware. It also contains a graphical visualization tool. [18]

2.5.3 Structured Text (ST)

ST is a high level programming language that have its strength in arithmetical calculations, number processing and handling of structured data types. There is a lot of similarity between ST and other high level languages like Pascal, C and C++, which make it quite easy to understand for people that have experience with programming. [18]

A program in ST primarily contains of choice sentences (IF and CASE), loops (FOR, WHILE, REPEAT) and instructions (statements). [18]

2.5.4 Function Block Diagram (FBD)

FBD is a graphical programming language that can describe the function between input variables and output variables. A function is described as a set of elementary blocks. Input and output variables are connected to blocks by connection lines. [18]

2.5.5 Sequential Function Chart (SFC)

SFC is a graphical programming language for representations of sequences. It is a good helping tool for making structured and sequential programs. The language is flexible and can be used in several levels, from the top level where the main conditions are described, to a more detailed level where single events within the main conditions are described. [18]

2.5.6 Java

Java is a computer programming language that is concurrent, class-based, object-oriented, and specifically designed to have as few implementation dependencies as possible. It intends to let application developers write a code once and run it anywhere, meaning that code that runs on one platform does not need to be recompiled to run on another. Java applications are typically compiled to byte code that can run on any Java virtual machine (JVM) regardless of computer architecture. Java is, as of 2014, one of the most popular programming languages in use, particularly for client-server web applications, with a reported 9 million developers. [36]

2.5.7 VLCJ, java integration

Java has very little support for playing media. Some newer frameworks that have some support, but not as wide of a reach as VLC has. VLCJ is a java framework for the VLC media player. This makes it possible to embed the powerful VLC media player into java, by binding it to the initial install of the media player. VLCJ offers almost all of the native functionality one can find in VLC media player.[42]

2.6 Communication

2.6.1 BSC LIKE protocol

The communication protocol between the PLC and the Yasnac MRC control panel uses the Binary Synchronous Communication (BSC) LIKE protocol.

2.6.2 Data link operation

IBM does a brilliant job of describing the data link operation of the BSC LIKE protocol in their manual: "The data link can be designed to operate either point-to-point (two stations) or multipoint (two or more stations). For point-to-point operation a contention situation exists, whereby both stations can attempt to use the communications line simultaneously. To minimize this possibility, a station bids for the line using the ENQ (enquiry) control character. The SYN SYN ENQ sequence (SYN SYN represents the synchronous idle characters) provides a concise signal for requesting control of the line, and thus leaves a maximum amount of time for line monitoring. If simultaneous bidding occurs, one station must persist in its bidding attempt to break the contention condition. Once a station gains control of the line, message transmission can start." [19]

CONTROL CHARACTER	HEX CODE	DESCRIPTION
SOH	01	<i>Start of Heading</i> denotes the start of the message heading data block.
STX	02	<i>Start of Text</i> denotes the end of the heading and the beginning of information data.
ETX	03	<i>End of Text</i> signals receiving station that all information data has been transmitted.
EOT	04	<i>End of Transmission</i> indicates the end of transmission of all data associated with a message.
ENQ	05	<i>Enquiry</i> requests a response from the receiving station.
DLE	10	<i>Data Link Escape</i> is used to modify the meaning of a limited number of subsequent characters.
NAK	15	<i>Negative Acknowledgment</i> indicates improper communication.
ETB	17	<i>End of Transmission Block</i> indicates the end of a particular block of transmitted data. ETB is used in place of ETX when data are transmitted in two or more blocks.
ACK0	10, 30	Even Affirmative Acknowledgment.
ACK1	10, 31	Odd Affirmative Acknowledgment.

Figure 2.2: Communication Control Characters [30]

2.6.3 Message blocks

As described in IBMs manual of the BSC LIKE protocol: "The message consists of one or more blocks of text data. The text is transmitted in blocks to provide more accurate and efficient error control. The text data is the body of the message and is identified by a start of text (STX) character immediately preceding each block of text. In addition, each block of text except the last is immediately followed by an end of transmission block (ETB) character or an intermediate block (ITB) character. The last block of text in a message is immediately followed by an end of text (ETX) character. The text of the message can be preceded by a heading that contains auxiliary information (e.g., station control, priority, etc.) pertaining to the following text data. The heading is identified by a start of heading (SOH) character immediately preceding it. For greater reliability, a unique character should always follow SOH to identify the heading function. The reason for this is to preclude the possibility of heading data being interpreted as text data, or vice versa, due to transmission errors. This unique character should not be used following STX. The percent (%) character should not be used for this purpose, as SOH% is presently used to identify request-for-test or station-dependent control messages. As each message block is completed, it is checked for transmission accuracy at the receiver before the transmission continues. (When VRC is used, each character is checked as it is received.)" [19]

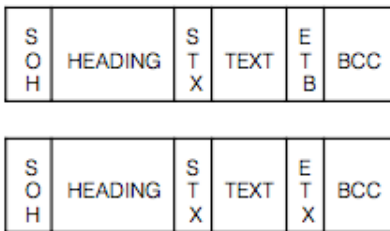


Figure 2.3: Data Transmission Format
[30]

2.6.4 Error control

As described in IBMs manual of the BSC LIKE protocol: "The Block Check Character (BCC) provides a method of checking the transmission block for errors. The BCC is a check value provided by the transmitting station, which allows the receiving station to compare its own calculated check value to the BCC sent by the transmitting station. The BCC is calculated using the summation of all the character data transmitted after the SOH or STX control characters. The summation ends when an ETB or ETX control character appears. These characters are included in the BCC calculation. The summation of the character data is used to create a two-character BCC, which is transmitted as the last two characters of the transmission block. The receiving station keeps track of its received characters and calculates its own BCC. To validate the data, the receiving station's calculated BCC is compared to the transmitted BCC. If the two BCCs match, the transmission is error free. The receiving station then responds with the appropriate ACK0 or ACK1 control characters to indicate a valid reception. The BCC calculation starts when either an SOH or STX control character appears. These characters are not included in the summation." [30]

Figure 2.4 provides an example of a BCC calculation for one transaction in the sequence used to save the job VACON from the MRC to the host computer. [30]

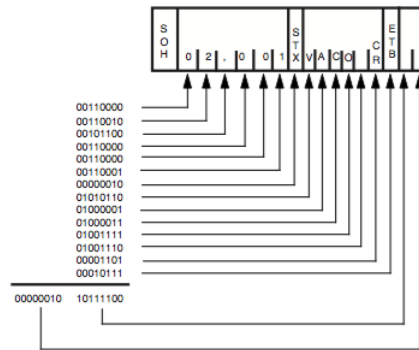


Figure 2.4: Example BCC Calculation [30]

2.6.5 RS232

Recommended Standard number 232(RS-232), is a communication standard developed several decades ago. It was widely used before the Universal Serial Bus (USB)-standard's entrance. The RS-232 has relative low transmission speed compared to the USB. Because of the shortcomings as a data interface, the standard is less used today, however, many older systems uses this type of communication.[13]

2.6.6 Modbus

The Modbus protocol is a messaging structure developed in 1979. Modbus is used for serial, master-slave/client-server systems to communicate between devices, usually between PLC's. The protocol is widely used in today's industry, and is also an open protocol, so anyone who wants to, can use it.[37]

2.6.7 Jamod

Jamod is a Java version of the Modbus protocol. It can be used to implement Modbus master/slave systems by serial communication or by IP. The protocol is a free and open source.[39]

Chapter 3

Materials And Methods

3.1 Materials

3.1.1 Hardware

Motoman SK16

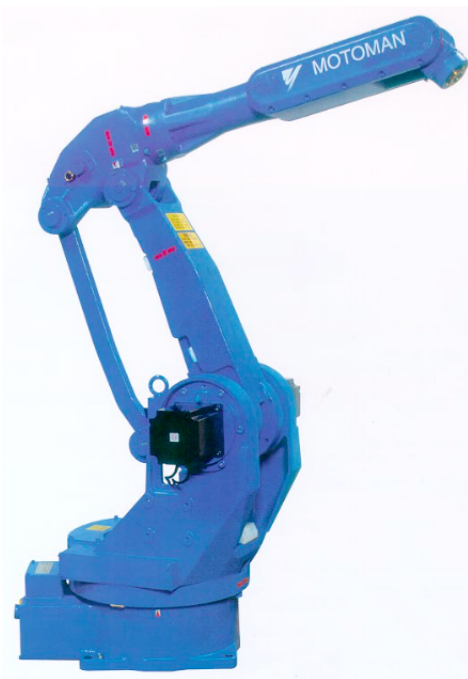


Figure 3.1: SK16 Robot [31]

The robots used in this project are the Motoman SK16 robots. They have six axis, a maximum workload of 16kg and a repeatability of +/- 1mm. [2]

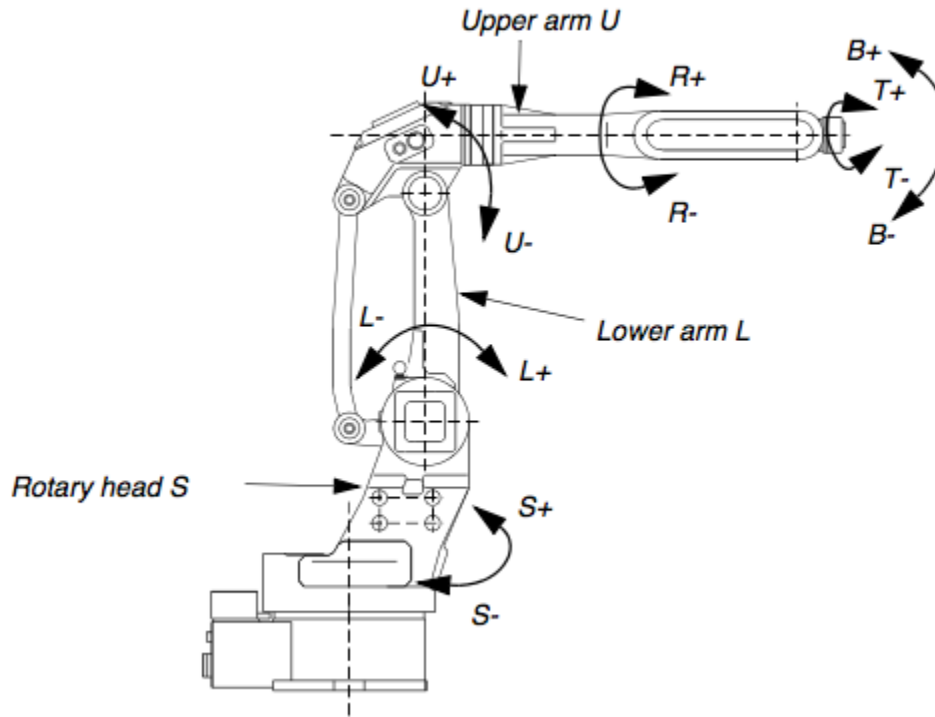


Figure 3.2: The axis on the SK16 robots [2]

Working area for each axis:

S-axis	+170° to -170°
L-axis	+150° to -90°
U-axis	+150° to -125°
R-axis	+180° to -180°
B-axis	+135° to -135°
T-axis	+350° to -350°

[2]

Maximum velocity for each axis:

S-axis	140°/s
L-axis	140°/s
U-axis	140°/s
R-axis	300°/s
B-axis	300°/s
T-axis	400°/s

[2]

Kuhnke HT-D25-F Electromagnet

Electromagnets used on the Magnet gripper.



Specifications:

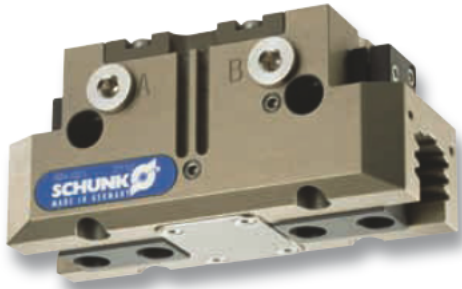
Holding-force	115N
Power	4W
Voltage	24VDC
Weight	50g
Operating temperature	-5 to +40°C

[27]

Figure 3.3: HT-D25-F Electromagnet [10]

SCHUNK PGN-plus 100/1

The air actuator used to operate the Air gripper. It is an universal 2-finger parallel actuator with large gripping force and high maximum torque. [41]



Specifications:

Stroke per finger	10mm
Closing force	660N
Opening force	725
Weight	0,81kg
Min operation pressure	2,5bar
Max operation pressure	8bar
Nominal operation pressure	6bar
Closing and opening time	0,07s
Operating temperature	-10 to +90°C
Repeat accuracy	0,01mm

Figure 3.4: PGN-plus 100/1 Actuator [41]

[41]

Camozzi 5/2 Single Solenoid Air-valve

The air valve used to control the actuator. It is a 5/2 monostable air-valve with one solenoid which has electropneumatic actuation and spring return. Suitable for operating double action cylinders and actuators. It has a flow rate of 700l/min and a operating pressure of 2,5 to 10bar. [7]



Figure 3.5: 5/2 Single Solenoid Monostable Air-valve [7]

Danfoss MBV 5000-2211 Test-valve

A pressure test valve for use in applications such as monitoring, alarm indication, shut-down and diagnosing on equipment. [8] In this project it is used to monitor the air pressure for the Air gripper.



Figure 3.6: MBV 5000-2211 Test-valve [29]

Danfoss MBC 5100 Pressure Control

A pressure control switch used with the MBV 5000 Test-valve.



Figure 3.7: MBC 5100 Pressure Control [28]

Air pressure Regulator

Regulator to limit the air-pressure to ensure that gripper and parts doesn't take any damage during operation.



Figure 3.8: Air pressure Regulator [4]

IMF Photoelectric Sensor

A photoelectric sensor that is used for quality control and to assist the robots during the assembly.



Figure 3.9: IMF Photoelectric Sensor [21]

Yasnac MRC

The control system that controls the SK16 robots, and a programming pendant which is used to move the robots and store move jobs.

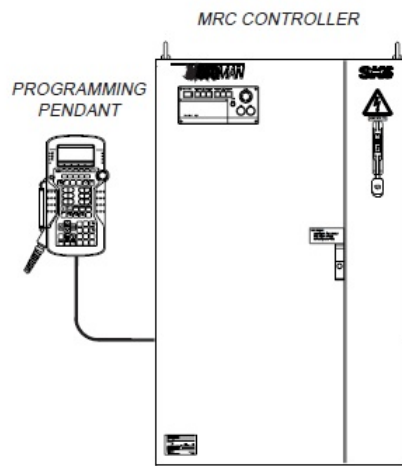


Figure 3.10: Yasnac MRC [32]

Wago 750-870 PLC

The PLC that is used in this project.

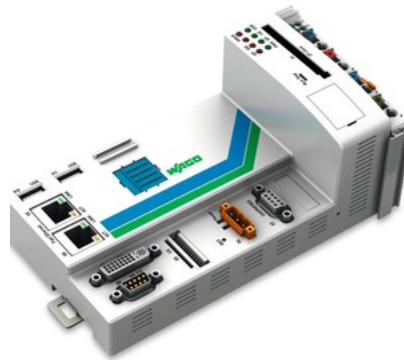


Figure 3.11: Wago 750-870 [48]

Wago 787-622 Power Supply

A power supply for use with the Wago PLC which can convert voltage from AC to DC. It is used to supply the 750-870 PLC with DC power.



Specifications:

Input voltage range	90-240VAC; 140-300VDC
Frequency	50 to 60Hz
Input current	0,85A at 230VAC
Output voltage range	22 to 28,8VDC
Output current	5A at 24VDC
Max output power	120W

[49]

Figure 3.12: Wago 787-622 [49]

Wago 750-478 Analog Input Module

A 2 channel Analog input module which can read analog signals from 0 to 10V. The module is used to read the analog signal from the Optical distance sensor.



Figure 3.13: Wago 750-478 [11]

Wago 750-431 Digital Input Module

An 8 channel digital input module which can read digital signals. The inputs goes low when the voltage lies between -3 to 5volt and high when the voltage lies between 15 to 30V. The module is used to read digital signals from the Yasnac MRC controller.



Figure 3.14: Wago 750-431 [12]

Wago 750-652 Serial Interface

A serial interface module which connects RS485/422 or RS-232 to the 750 series of Wago PLCs. The module is used to set up the RS-232 communication between the PLC and the Yasnac MRC controller.



Figure 3.15: Wago 750-652 [6]

Specifications:

Transmission channels	1TxD/1RxD, full duplex, half duplex 7/8bit data, 1/2 stop bit
Baud rate	9600baud (default) 300 to 115200baud
Line length	RS-485/422: max 1000m, RS-232: max 40m
Buffer	2560 bytes in / 512 bytes out
Current consumption	85mA

Wago 750-600 End Module

A end module that completes the internal data circuit and ensures correct data flow.



Figure 3.16: Wago 750-600 [47]

iiyama Pro Light T1731SR Touch-Screen

A 17" touchscreen that is used for displaying the GUI.



Figure 3.17: Pro Light Touch-screen [22]

Dell LCD screen

An LCD screen used for displaying the visualization.



Figure 3.18: Dell LCD screen [25]

3.1.2 Software

Codesys

The programming software Codesys, is used to develop the control program and the GUI which is loaded into the PLC.

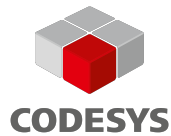


Figure 3.19: Codesys [50]

Netbeans IDE

The IDE Netbeans is used to program the control system for the visualization.



Figure 3.20: Netbeans IDE [26]

Blender

The 3D creation software Blender is used to create a 3D animation of the assembly.



Figure 3.21: Blender [5]

Solidworks

The 3D design solution Solidworks is used to design 3D models and 2D drawings of parts that needs to be created.



Figure 3.22: Solidworks [14]

Advanced Serial Port Monitor

Advanced Serial Port Monitor was used in the start of the project to monitor the communication protocol.



Figure 3.23: Advanced Serial Port Monitor

3.2 Schematics

3.2.1 Electromagnet circuit

Here the circuit for the magnet gripper tool is shown. The LEDs are wired in series with a 560ohms resistor to bring the voltage down. The magnets are wired in parallel.

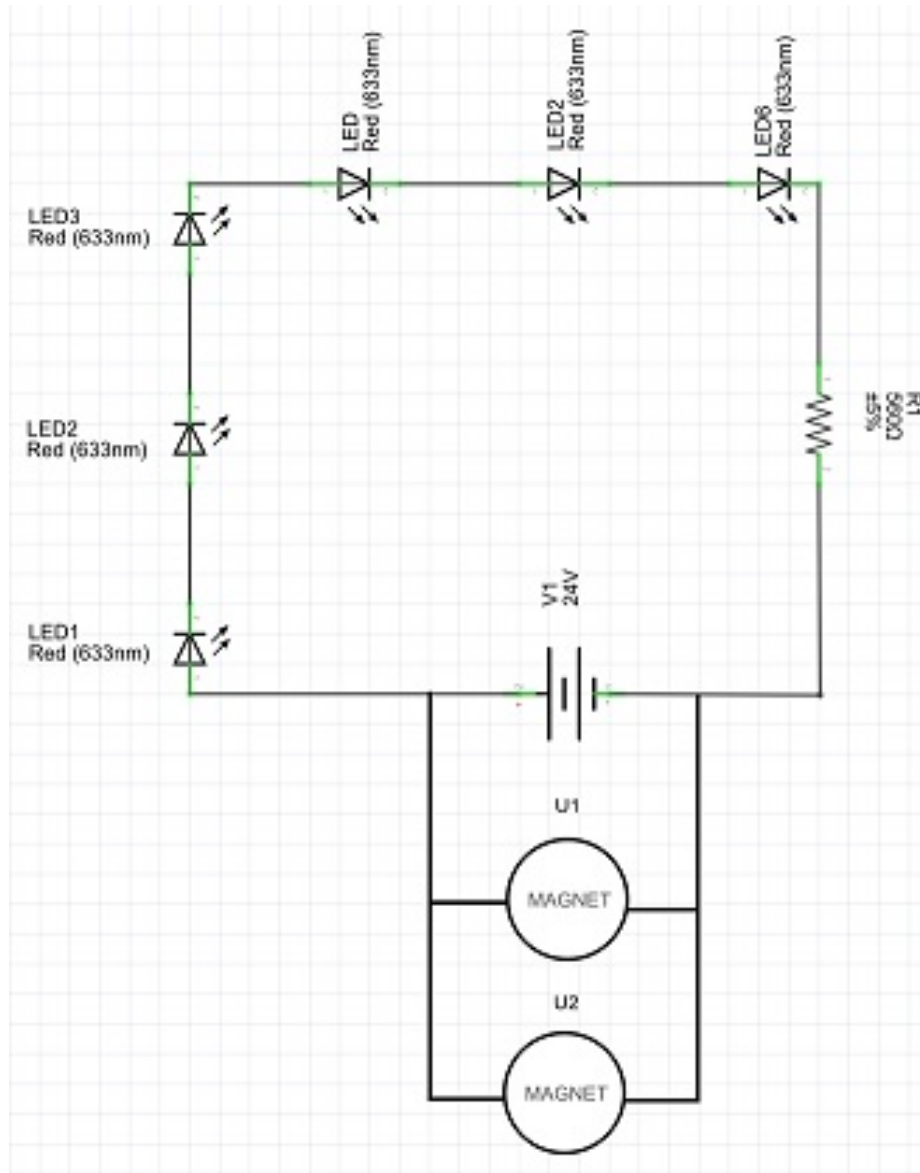


Figure 3.24: Electromagnet circuit

3.2.2 Air circuit

Here the air circuit for the Air gripper is shown. It is wired so that the gripper is always gripping outwards if power is turned off.

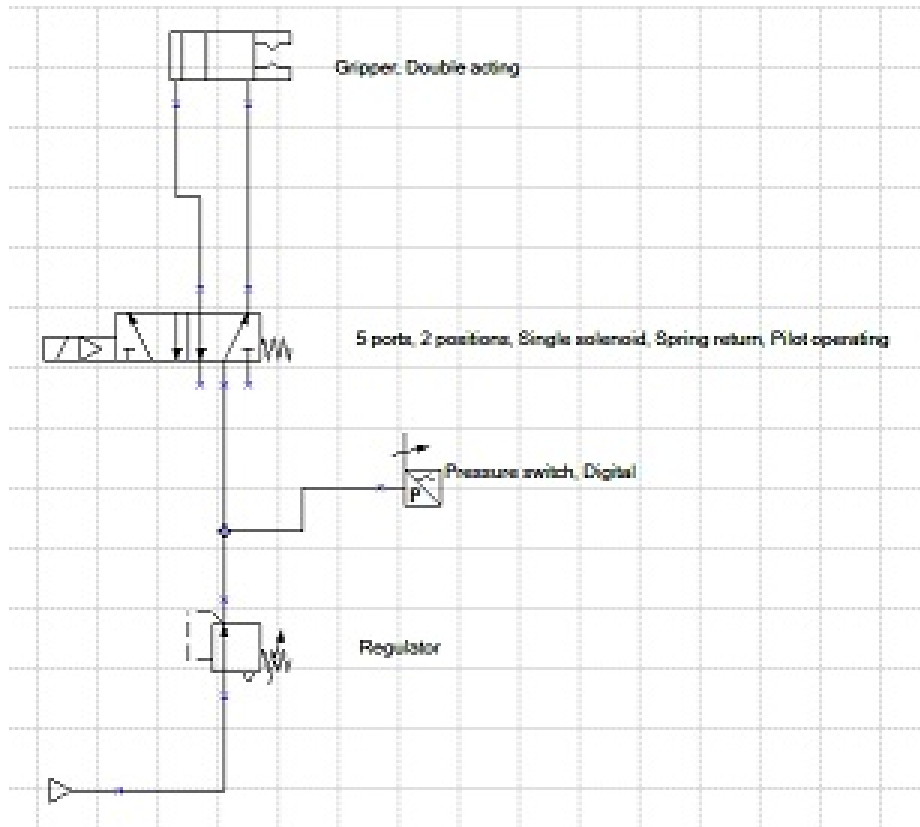


Figure 3.25: Air circuit

3.2.3 Communication line

Because the system is a "null modem", connection pins are connected as shown in Figure 3.26, between the PLC and the Yasnac MRC.[30]

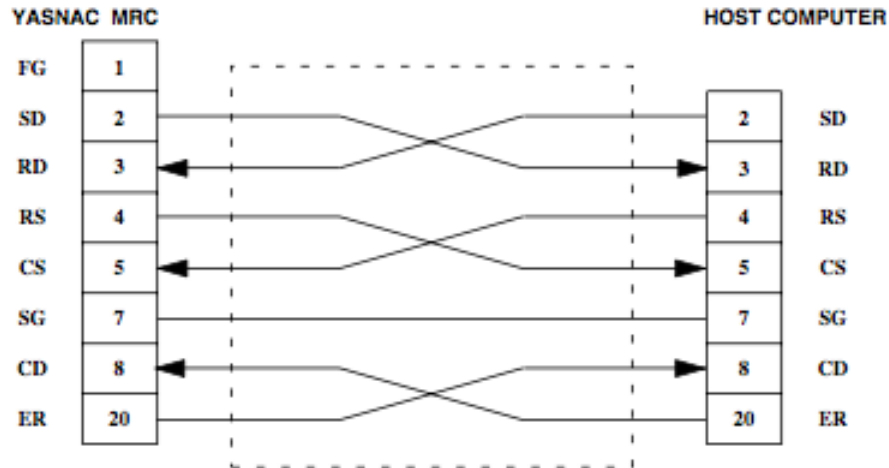


Figure 3.26: Connection for Playback Box (D-SUB25S)[30]

3.3 Design

In this project, the 3D design solution SolidWorks was used to design 3D models and 2D drawings of parts that needed to be created. This is a great solution to use because it is easy to learn and use the program and as described in the Theoretical basis and background chapter it has many opportunities. When a 3D model of a part is created in SolidWorks, it is possible to store it as an STL file, which is a type of file that easily could be used to make a print file for a 3D printer.

In this project, the use of 3D modeling and prototyping was crucial in the design part. When designing gripping tools for the robots it was quite useful to make a 3D model in SolidWorks, which then was printed out in a 3D printer. This made it easy to see if the gripper design could be used, or if modification was necessary. This will be described in the Prototyping-section. When the design was perfect, a 2D drawing with all the measurements was made and the gripper could be constructed in metal. This will be described in the Fabrication-section .

3.4 Fabrication

3.4.1 Propeller hub base

To secure the propeller hub onto the pillar between the robots, a rigid base was needed. Because of the big dimensions it was hard to find raw goods to machine the base, so the base was designed and sent over to Rolls-Royce to be fabricated. The base is a steel cylinder with four set screws placed in equal length around the cylinder to hold the propeller hub securely in place.

1. 4 set screws
2. Hollow bar

3.4.2 Magnet gripper

Two 24V electromagnets were used to be able to pick up the thruster discs. The electromagnets also kept the discs flat onto the gripping tool surface. Six red LED's were glued onto three 3D printed LED holders and then glued onto the gripping tool, one in front and one on each side. These LED's were used to indicate that the electromagnets were activated. Four brass studs were mounted onto the gripping tool, two in front and two underneath. These studs fit into the tapped holes on the thruster discs. This made the tool able to hold the discs and rotate them. The reason for using brass is that it is a softer material than steel[45] and it would therefore not damage the threads inside the tapped holes on the thruster discs when making contact. The softness of the material means that the studs will wear out. To make changing of the studs easy, a hole was milled in the surface of the gripper that was a bit smaller than the studs. The studs were then pressed into the hole. The studs can easily be pressed out and replaced.

The gripping tool consists of various shapes and sizes of flat iron parts that are welded together with a metal active gas (MAG) welding machine. The brass studs were machined in a lathe. To ensure great accuracy when making the holes for the brass studs, a milling machine with digital measuring system was used, instead of a regular drilling machine. See Figure 3.27.

List of materials used to fabricate the gripper:

1. 120x110x10 Flat iron
2. 120x30x10 Flat iron
3. 2 pcs 105x15x5 Flat iron
4. 2 pcs 90x15x5 Flat iron
5. 2 pcs 85x15x5 Flat iron
6. 2 pcs 24v electromagnets
7. 2 pcs 30mm \varnothing 14 brass axle
8. 2 pcs 22mm \varnothing 14 brass axle
9. 3 pcs WAGO 3 port lever cage clamp
10. 1 pcs WAGO 2 port lever cage clamp
11. Tec7 transparent glue
12. 6 pcs red LED's
13. 3 pcs LED holders
14. 10g of Red 0.75mm PLA plastic
15. Black spray paint

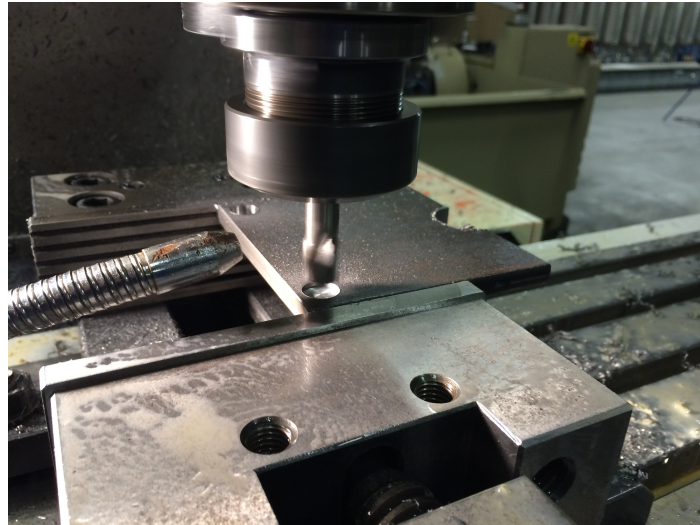


Figure 3.27: Milling holes for the brass studs



Figure 3.28: Testing fitment of gripper on the thruster disc

3.4.3 Air gripper

Since there were four different parts that needed to be gripped, one of the grippers had to have the ability to pick up three different parts. The air gripper has the ability to do so by taking advantage of the 2-way movement of the pneumatic actuator.

When it grips inwards it grips the slide bearing and when it grips outwards, it grips the piston or the thruster disc rotation tool. An air pressure reduction valve was mounted on the air supply to the pneumatic actuator to reduce the actuator gripping force so that the gripper would not damage the parts or the gripping tool.

To increase the friction on the contact surface where the tool grips the piston or the thruster disc rotation tool, some insulation was stripped of a power cord and glued onto the gripper with 2-component epoxy. To get a good grip of the slide bearing, a wedge was welded onto the contact surface where it grips the slide bearing. This would also mean that the bearing needed to have a slot on the side where the wedge should fit into. The gripper tool consists of 3mm metal pieces that were cut into correct size and shape, and then welded together with a MAG welding machine. Figure 3.27 shows alignment of the metal pieces and fastening of the parts before welding. To ensure great accuracy in the placement of the mounting holes, a digital milling machine was used to mill the holes, instead of a regular drilling machine. List of materials used to fabricate the gripper:

1. 3mm thick metal sheet
2. 4 pcs 6x20 allen key screws with washers
3. 1 pcs Wedge 8x30
4. 1 pcs Shunck air actuator
5. 20cm Power cord insulation
6. 2-component epoxy
7. Black spray paint

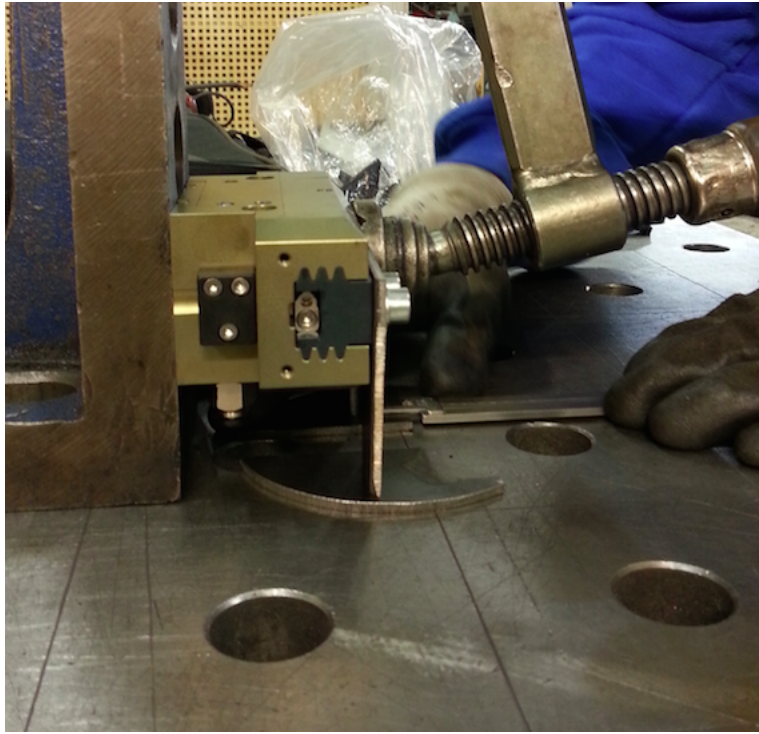


Figure 3.29: Alignment and fastening of the metal pieces before welding

3.4.4 Thruster-disc rotating tool

A tool for rotating the thruster discs that could be picked up by the air gripper was needed for one of the last stages of the assembly. This is simply a metal cylinder with a groove inside, where the air gripper can lock into. On the tool, there are brass studs which fits the tapped holes on the thruster discs. This makes it possible to rotate the discs. The cylinder and the studs are machined in a lathe. The holes for the studs were milled and then the studs were pressed inside the holes. The cylinder and the holder for the studs were welded together with a MAG welding machine.

List of materials used to fabricate the tool:

1. ϕ 110x22 steel axle
2. 110x25x10 Flat iron
3. 2 pcs 22mm ϕ 14 brass axle
4. Black spray paint

3.4.5 Holders

All the parts for the propeller head needed to have holders. The holders were designed, prototyped, and tested. After several design changes, a final design was chosen. The holders were printed in a 3D printer. The holders were designed to give easy access for the gripping tool to approach it and to pick up the part. There are four holders for the slide bearings, four for the thruster discs, one for the piston and one for the thruster disc rotation tool.

List of materials used to fabricate the holders:

1. 600g of Red 0.75mm PLA plastic (without the prototyping)

3.4.6 The kit

A kit for all the parts of the propeller head was needed. All the 3D-printed holders for the parts were mounted on the kit in a way that made it is easy for the robots to pick up the parts. The kit was made out of wood planks and a sheet of plywood. It was then assembled using wood screws and then painted black.

The piston is the heaviest part so it was placed near the robot to reduce the momentum on the joints for the robot. The other parts, thruster discs and the slide bearings, were placed in line on each side of the kit in a 45° angle for good seating of the parts and easy access for the robot to reach the parts.

List of materials used to fabricate the kit:

1. 3m 2x4" wood
2. 70cm 140x22 wood plank
3. 40cm 70x22 wood plank
4. sheet of plywood
5. black paint

3.4.7 Prototyping

Early on in the process of finding the right design for the tools and holders it was apparent that multiple solutions were possible to use. To determine which of the designs that were the best to use, the designs were drawn in 3D and 3D printed. By printing and testing, it was possible to see if the solution was applicable or not. The designs that were the most promising were worked on further. Prototypes makes it visible for all parties of the project to visualize how the solution is going to work. By prototyping, you can fail inexpensively, which again saves a lot of time and money. It also helped uncovering challenges and resolve any disagreement of which design was the best. With the team concentrating on different possible solutions, the whole team influenced each other to be innovative and think outside the box. "innovative teams generate innovative prototypes" [40]

3.4.8 Part modifications

To be able to assemble the parts using robotic arms, some modifications had to be done. The hole in the brass bearings are eccentric which means there is more weight on one side from the center of the hole than the other. This made the bearing turn out of position by gravity after it has been assembled onto the thruster discs. This was handled by milling material off one side to get the center of gravity close to the center of the hole in the bearing. This also made room for the wedge on the air gripper tool to fit in the bearing.



Figure 3.30: Slide bearing modification

The piston is the heaviest part that the robot has to pick up. The piston for this propeller head weighs 22.5kg. To get a secure grip that could not slip, a 3mm deep groove inside the top of the piston was milled (Figure 3.31). The gripper tool can lock into the groove, securing the piston from falling down when it is transported from the kit to the propeller hub.

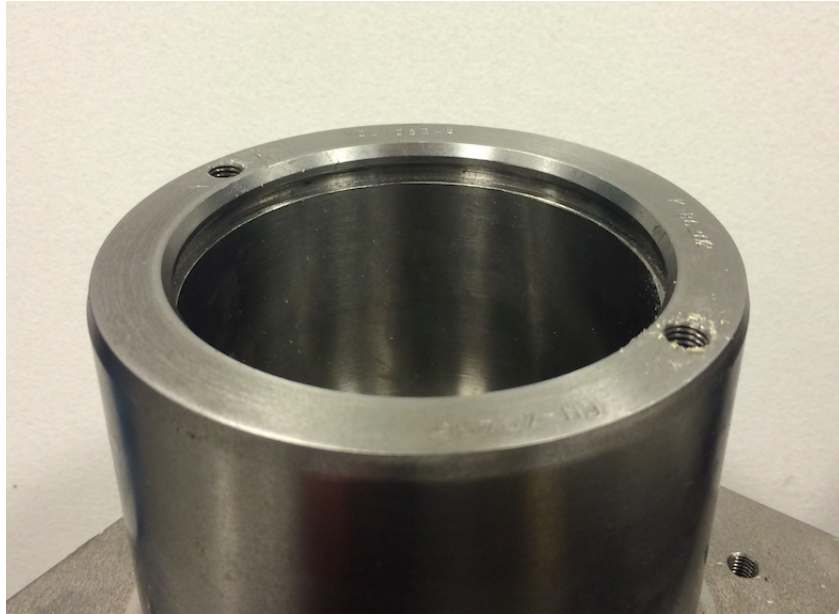


Figure 3.31: Piston with the groove

3.5 Photoelectric sensor

In the ceiling above the robot cell, an IFM photoelectric sensor was mounted. It can measure distances between 0.2 and 10m and it has output signal between 4mA/0V and 20mA/10V.[20]

The sensor was used to check that no parts were missing before assembling the parts inside the propeller hub. It was also used when positioning the piston. The piston and the propeller hub are both square so the piston needed to be in the correct position before lowering it into the propeller hub.

Later in the assembly sequence, when the piston was lowered further into the propeller hub, the robots were controlling the descent of the piston by getting input from the laser. If the robot tried to lower the piston but did not see an increase in distance from the laser, it rose the piston to the previous position and tried again. If an increase in distance was observed, the descent continued.

3.6 Quality Control

By using the laser that was mounted in the ceiling, the parts were checked before they were assembled in the propeller hub. Just before the robot brings the part inside the propeller hub, it takes the part to the location where the laser beam strikes the part. If the part is in place and the laser beam strikes it, the assembly process continues. If the beam does not strike the part, the robots go to initial position and a status message is stored in the log to inform the user of what part is missing from the assembly. The reason for doing this quality control, is to prevent that incomplete propeller heads are assembled.

3.7 Robot Control

3.7.1 Kinematic

The Yasnac MRC controls all kinematics, so no work was done with the kinematics.

3.7.2 Tool Center Point (TCP)

The tool center point, is the point in relation to which robot position is defined. These points are defined as relative to the outer position of the last joint on the robot and is the point where the robot moves around when for example the linear movement is used. By using TCP you have the opportunity to use different kinds of tools on the robot.[1] In this project two tools were used, with 3 TCP configurations per tool. To be able to rotate the discs inside the propeller head, the center point of the disc in relation to the tool had to be measured. For this purpose, a dial indicator was used. See Figure 3.32.

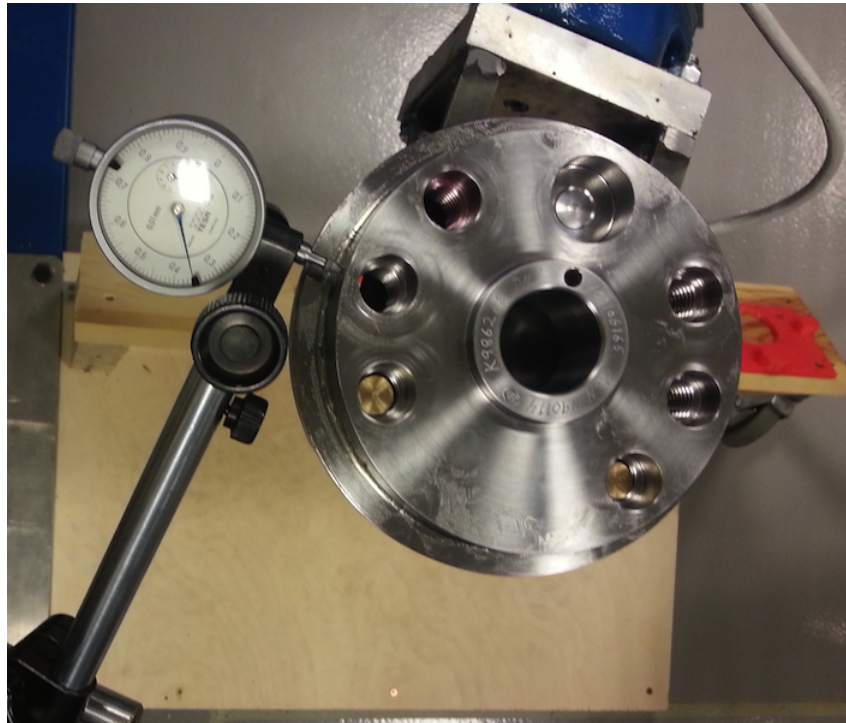


Figure 3.32: Calibrating tool center point

3.7.3 Movements and velocity

There are several different types of movements and velocities for the robots. The movements decide how the robots move between the programmed positions and the velocity decide how fast this happens. [1]

In this project it was used two types of movements, the joint movement and the linear movement. When the joint movement is used, all of the axis of the robot move around their center point independently. The velocity for these types of movements are specified as an amount of percent of full speed (100%). [1]

When the linear movement is used, the robot moves linearly between the programmed position by using the TCP. For these types of movements there are several ways to control the velocity. In this project, there were used two different ways. One way is to specify how fast the TCP moves between the positions. This is specified by millimeters per second and the maximum speed is 1500mm/sec. Another way is to set a limit for the rotation speed when the TCP is standing still. This is specified as degrees per second and the maximum speed is 360 °/sec. [1]

3.8 Safety

3.8.1 Environment

To ensure the safety of the operators and the environment around the two robots, a safety cage is placed around the robots. However, the robots can reach the cage walls due to their circular work-area. This cage was installed by Rolls-Royce a few years ago and is fitted with two emergency switches on each side of the front of the cell and a limit switch on the cage's door. In addition to these three switches, there is one emergency stop switch on the robot control cabinet and one on the pendant. The emergency switch on the cage's door makes it impossible for the robots to operate when anyone enters through the door.



Figure 3.33: Robot Cell

3.8.2 Robots

The robots are fitted with a "collapse-hinge" which means that if the robot crashes into an object, and thus exceeding the set moment of inertia, the current joint will loosen. A micro switch also ensures that the robot stops. The joint can be reset.[1] To reduce possibilities of damage to operator and environment, the robots moment of inertia-limit was set to half of the factory set limit. This was done by contacting Motoman, Norway and retrieving the password-key for factory settings, and follow instructions from Motoman.

3.8.3 Control cabinet

The control cabinet houses all the electronics needed for the robots and has an in-voltage of 400V and in-current of max 14,4A. For any operation inside the cabinet, the main power source was turned off, power cord removed, and then the cabinet was opened by a certified operator.

3.8.4 Pendant and manual operation

The pendant is mounted onto the control cabinet via a safety-switch. When the pendant is lifted from the mount, the robots speed are reduced to safety-speed, which is 250mm/s. The pendant also has a "dead-mans-switch", a switch which is placed beneath the handle of the pendant. This switch has three positions: [1]

1. Not Pressed: Stop
2. Slightly pressed: Manual control
3. Completely pressed: Stop

This is to ensure that the operator always is present and aware of his/her operations during manual control.

3.8.5 System errors

A system error, such as a communication error between the PLC and the MRC will cause the GUI to be inactive, and the operator will no longer be able to control the process via the GUI. The operator will then have to access the MRC control cabinet to pause the process. All the emergency switches are still active during a communication failure. A system error which compromises human safety is seen as very unlikely.

3.9 Availability

The systems availability is normally calculated by modeling the system as a connection of modules in serial and/or in parallel. In this report, no mathematics have been applied to calculate availability, and there has not been much focus on this subject. However, some steps were taken to reduce chance of failure and crashes.

3.9.1 Materials

If the robots crashes into an object, or applies too much force upon one of its joints, the joint will give in. This ensures that the joint will not take any damage, requiring service. The electromagnets used on one of the gripping tools ensures that the thruster discs stays on the tool. To an operator, the activation of the electromagnets isn't visible. As a caution, the LED lights were connected to the power supply of the tool, so that when the electromagnets are activated, the lights were as well. By notifying the operator, he/she can see if

the electromagnets are activated at the right time.

3.9.2 Assembly

The operating pressure of the Schunk gripper is 2,5 - 8bar. A operating pressure of 6 bar was chosen to ensure that the parts and gripper were not damaged, but that the gripper could still maintain enough strength to hold onto the parts. This was chosen by testing various pressures. To limit the pressure, a pressure reduction valve was mounted on the main pressure input for the system. To ensure that the robots do not operate with too low pressure, causing the gripping tool to not have adequate pressure to grip items, a pressure switch was added for the system. When the air pressure in the system drops below 5 bar, the pressure switch signals the system and the system stops operation. The air control to the Schunk gripper was wired so that in case of a power failure to the system, the Schunk gripper would always grip outwards, or stay in the outwards position. This ensures that the piston will never be dropped in case of a power failure.

To reduce chance of damage to parts, the assembly process stops if parts are missing.

The software runs on a standard PLC. In an event of a PLC-failure, a new one can easily be found and replace the broken one. The same goes for control screens and computer.

3.10 Graphical user interface (GUI)

To operate the system, a GUI was created using Codesys. This interface is accessible through web visualization, so it is possible to control the system remotely using a web browser. In this interface it is possible to turn on/off the system, start the assembly, check position to each joint on both robots, and stop the assembly. The progress of the assembly is printed into a log, from which the user can check what has happened. Manual control of the robots is also possible by switching into manual mode. To gain access to the manual menu, a code needs to be inserted. The code is: 2015.

In the manual control panel it is possible to move the robots in linear or joint motion type and activate or deactivate the gripping tools.

3.11 Visualization

All of the parts and the entire robot environment was drawn in 3D using SolidWorks and Blender. The robots were created before 3D drawing was popular, so all Motoman could supply, was 2D drawings. However, a representative from Motoman in Southern Africa was able to extract 3D models from these 2D drawings and sent them to us. After finishing the 3D models, they were exported as STL-files. This file format made it possible to import all

drawn 3D models into Blender for animation, Makerware for 3D printing, and SolidWorks for detailed drawing or schematics.

A live, real time visualization was tested, but because of the high traffic between the PLC and Yasnac MRC controller for this operation, the communication line crashed often. It was then decided that an animation of the sequence should be made, and played back, so for operators it seems like the visualization is real-time. The entire environment, including robots, holders for the parts, parts themselves, tools and foundation were imported into Blender to create a digital environment which was scaled to real life. All distances and measurements are very close to real life, making the animation easier to complete.

The robots have six axis to control. Without employing the same kinematic model from the Yasnac MRC to the robots within Blender, it was hard to recreate identical movements within Blender. Implying kinematics on the models proved difficult. Separating the joints and control rotation around its pivot point was seen as a better solution. From the pendant, it was possible to extract the motor pulse, which correlates to the joint positions. By finding max pulse per joint and dividing it by max range in degrees, a resolution was found. This made it possible to convert motor pulse to angles, and apply the angles directly into the Blender environment. Each joint has negative and positive values, and different ranges. Therefore, separate resolutions must be found for the positive angles, and the negative angles.

Joint	Max pulse	Max angle	Resolution(pulse per angle)
S+	286635	170°	$\frac{1686}{1^\circ}$
S-	-286635	-170°	$\frac{-1686}{1^\circ}$
L+	101745	150°	$\frac{678}{1^\circ}$
L-	-152915	-90°	$\frac{-1699}{1^\circ}$
U+	254660	150°	$\frac{1697}{1^\circ}$
U-	-212415	-125°	$\frac{-1699}{1^\circ}$
R+	159840	180°	$\frac{888}{1^\circ}$
R-	-159840	-180°	$\frac{-888}{1^\circ}$
B+	120015	135°	$\frac{889}{1^\circ}$
B-	-120015	-135°	$\frac{-889}{1^\circ}$
T+	177450	350°	$\frac{507}{1^\circ}$
T-	-177450	-350°	$\frac{-507}{1^\circ}$

[1]

Note: Because of the tools equipped by the robots, the max rotation around the B axis was not measured directly. By rotating the joint 180° (measured by a spirit level), and reading the pulse, an estimate was found for the resolution. In turn, the max pulse was calculated using this resolution.

$$180^\circ = 160000\text{pulses} \quad (3.1)$$

$$\text{Pulse per degree} = \frac{160000}{180} = \frac{889\text{pulses}}{1^\circ} \quad (3.2)$$

$$\text{Max degrees} = 135^\circ [1] \quad (3.3)$$

$$\text{Max pulse} = (4.3) * (4.2) = 135^\circ * \frac{889\text{pulses}}{1^\circ} = 120015\text{pulses} \quad (3.4)$$

The range is the same for negative angles and positive angles.

The pendant has all the steps of the assembly programmed into it. It is possible to manually drive a selected robot to a given step. By moving the robots to the step and reading the pulse of each joint, it is possible to calculate the corresponding angle by the formula:

$$\frac{\text{pulse}}{\text{resolution}} = \text{degrees} \quad (3.5)$$

Example: The S-joint is at 2000 pulses.

$$2000 * \frac{1}{\left(\frac{1686}{1^\circ}\right)} = 1,19^\circ \quad (3.6)$$

Due to the assembly process being unpredictable, a true playback movie is not possible to achieve. However, by letting the control program control the visualization, it can pause/play/rewind/fast forward the visualization, making it follow the robots movements, even when the process varies in time.

Chapter 4

Results

4.1 Tools

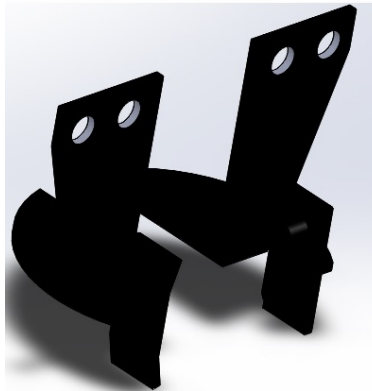
4.1.1 Air gripper

As described in the Material and Methods chapter, the Air gripper had to be able to pick up 3 different parts: the slide bearing, piston and the thruster disc rotating tool. Here the result are presented. Figure 4.1 shows a 3D model of the gripper, that is drawn in Solidworks, and the fully constructed gripper in metal, mounted on the robot.

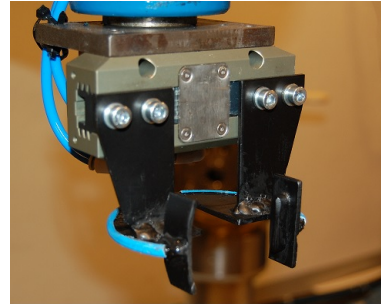
When the robot picks up the bearings, the wedge that is welded on the gripper, goes smoothly into the slot on the bearing. This makes sure that the bearing doesn't move in any directions during the transport from the kit to the propeller hub, and holds it stable when it puts it on the thruster disc.

The gripper worked as planned and the robot didn't meet any issues when picking up the three different parts.

The blue power cord insulation that is stripped of a power cord and glued on the gripper is working as planned, but wears out after some assemblies and therefore needs to be replaced regularly. When the gripper picks up the thruster disc rotating tool and rotates the discs, the cord insulation makes sure that there is enough friction to avoid slipping inside the groove. Likewise when the robot rocks the piston and tries to lead it down the propeller housing at the end of the assembly, the cord insulation makes sure that there is enough friction between the Air gripper and the groove inside the piston.



(a) 3D Model of gripper



(b) Gripper mounted on the air actuator

Figure 4.1: Air Gripper

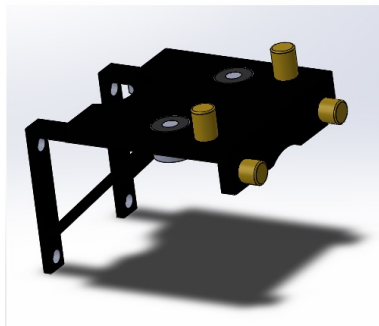
4.1.2 Magnet gripper

Here the result of the Magnet gripper is presented. Figure 4.2 shows the 3D model and the constructed gripper mounted on the robot. The Magnet gripper has two functions. It picks up the thruster discs and can also rotate the them.

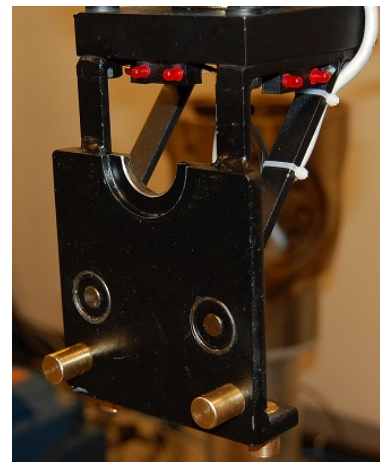
The gripper works as planned and the robot does not have any issues when picking up, or rotating the discs.

When the robot picks up the thruster discs, the two brass studs and the milled groove in the front/top of the gripper make sure that the discs fits perfectly. The two electromagnets make sure that the discs lies flat on the gripper.

When rotating the thruster discs, the two other brass studs and the other milled groove located in the bottom of the gripper, are utilized. The two studs fits two of the six tapped holes in the discs with a clearance of 3mm on each side. The groove perfectly fits the circular exalted edge at the back of the discs.



(a) 3D Model of gripper

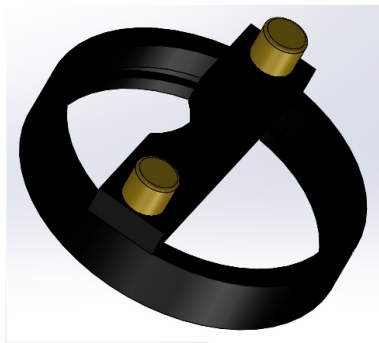


(b) Gripper mounted on the robot

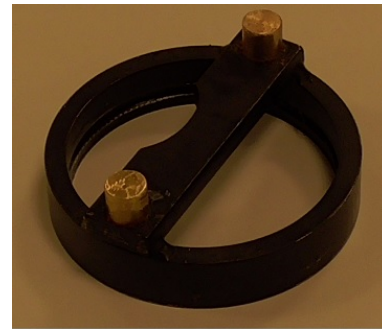
Figure 4.2: Magnet Gripper

4.1.3 Thruster disc rotating tool

Here the result of the thruster disc rotating tool is presented. Figure 4.3 shows a 3D model of the tool and the constructed tool in metal. As described in the Materials And Methods chapter, the function of this tool is to rotate two of the discs after the piston is placed into the propeller housing. The tool worked as planned and the air gripper doesn't meet any issue when picking up the tool. The groove make sure that the air gripper perfectly locks into the tool.



(a) 3D Model of tool

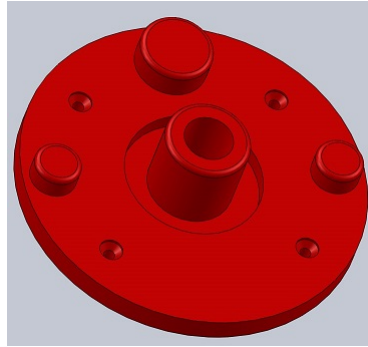


(b) Picture of tool

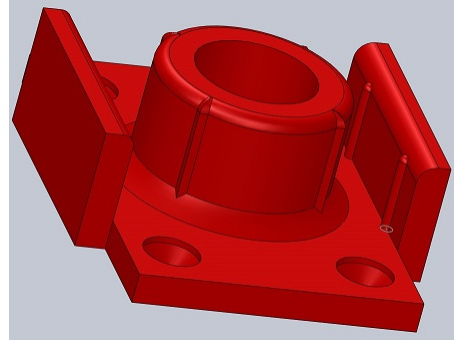
Figure 4.3: Thruster disc rotation tool

4.2 Holders

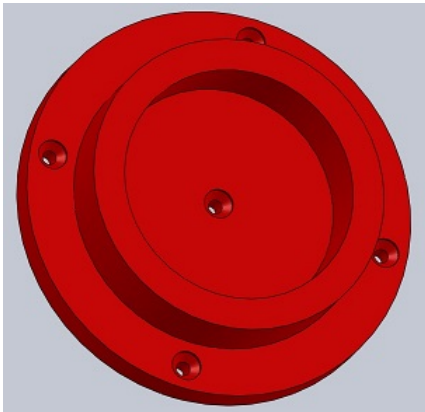
As described in the Materials and Methods chapter, all the parts needed to have holders to securely place them on the kit. The Thruster disc rotating tool also needed to have place to lie when not in use. Here the results of the holders are presented. All the holders are 3D drawn in Solidworks, and then later 3D printed in red PLA plastic. Figure 4.4 shows the 3D models of the holders. All the parts perfectly fit the holders.



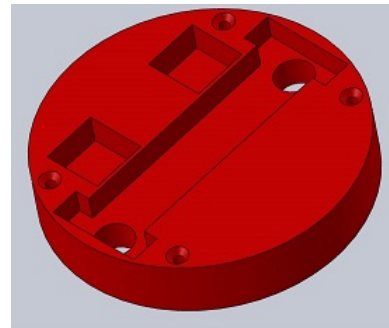
(a) Disc Holder



(b) Bearing Holder



(c) Piston Holder



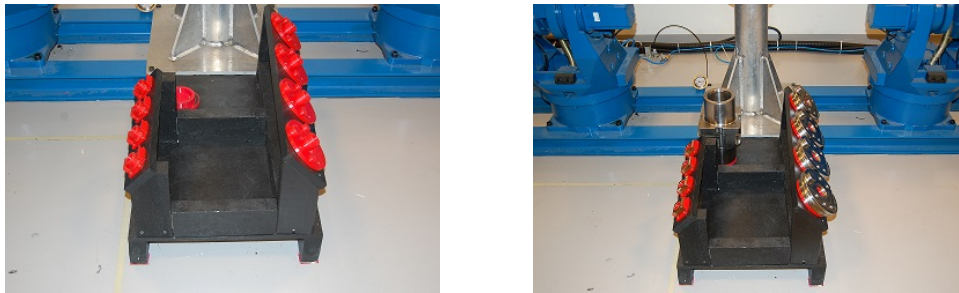
(d) Thruster disc rotating tool Holder

Figure 4.4: 3D models of the holders

4.3 The kit

Here the result of the Kit is presented. Figure 4.5 shows the kit without all the parts(a) and with all the parts(b). The 3D printed holders are fastened with wood screws on the kit in a 45° angle so that the robots have easy access to the parts.

The robots do not meet any issues when approaching and picking up the parts.



(a) The empty Kit

(b) Kit with parts

Figure 4.5: The Kit

4.4 Propeller hub base

Figure 4.6 shows the result of the Propeller hub base. The base is fastened on to the pillar with machine screws and then the propeller hub is fastened into the base with four set screws. When the set screws are tighten properly the hub is steady and doesn't move.

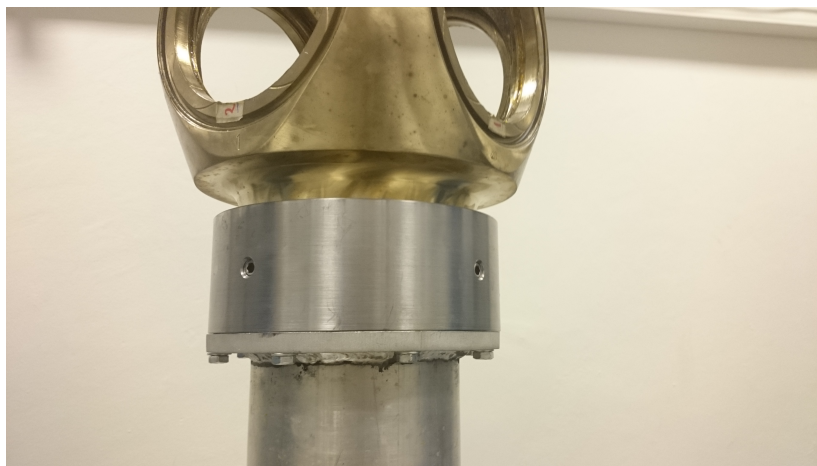


Figure 4.6: Propeller hub base

4.5 Visualization

On the Dell monitor, the operator can preview the assembly, giving even more control on how the assembly process works. The visualization is an animated sequence of the assembly in playback, designed to give the operator an overview of the process. The animation can be controlled via the GUI. The GUI controls the animation by setting internal addresses on the PLC to a known integer.

The set numbers are:

1. = start
2. = pause
3. = reset
4. = start with delay

The java program running on the PC checks for these numbers on the PLC repeatedly. This allows the PLC program to control the animation for different events.

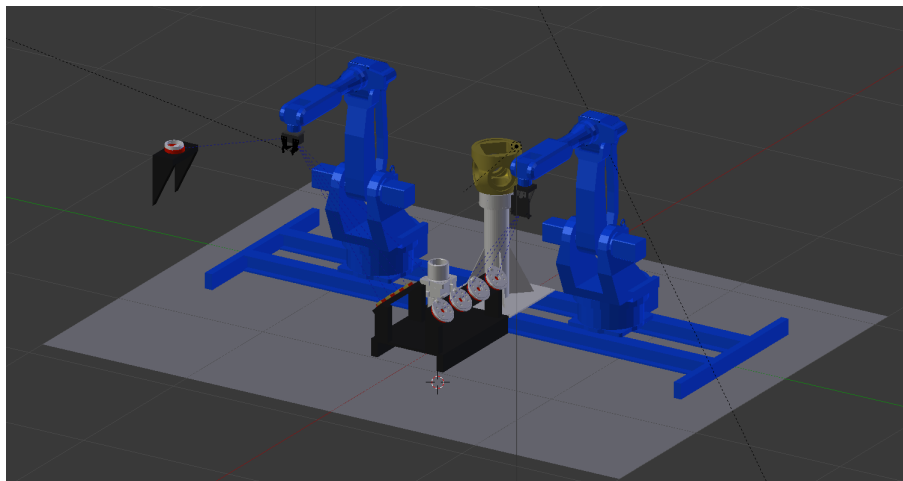


Figure 4.7: Blender environment

4.6 GUI

4.6.1 Main screen

This is the Graphical User Interface (GUI). From here, the operator can control the system with a touch screen. Figure 4.8 shows the main screen of the user interface. From here the operator can turn on/off power for the robots, stop the robots by pressing the hold button and reset the assembly sequence in the program and the communication protocol. The start button starts the assembly process. The two position buttons show the position of each joint axis on the robots.

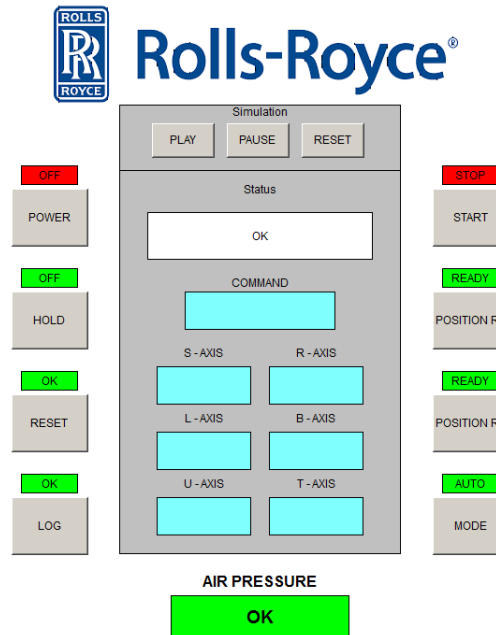


Figure 4.8: The Main screen of the user interface

It is possible to control the visualization preview with the three buttons: play, pause and reset. The status window shows the current status for the system. The command window shows the current command that is sent to the Yasnac MRC controller. The axis windows show the position of each joint for the robots when the position buttons are pressed. The air pressure indicator informs the operator that the air pressure is OK for operation.

4.6.2 Log screen

When the log button is pressed, a log screen appears in the GUI. Here all the status messages are stored (Figure 4.9). If something goes wrong during the assembly, the operator can see what went wrong. For example, if a thruster disc was missing, the disk number would appear in the log.

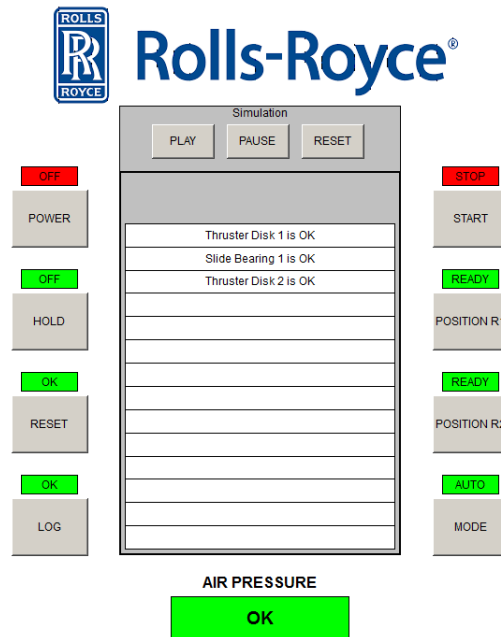


Figure 4.9: The log screen

4.6.3 Code screen

The mode button is used when the operator wants to control the robots manually. Here the operator can control each robot incrementally. To gain access to the manual control screen, the operator needs to type in a four digit code. This code is used to make sure that no unauthorized personnel gets access to the manual control screen. (Figure 4.10).

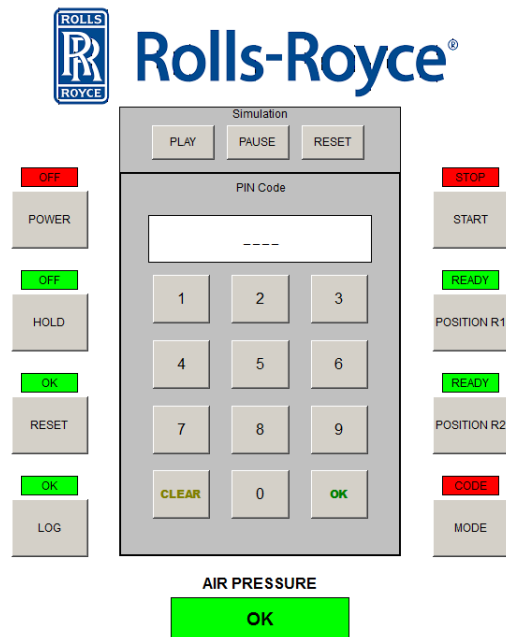


Figure 4.10: The code screen

4.6.4 Manual control screen

In the manual operation screen shown in Figure 4.11, the operator can move the robots incrementally in different lengths, adjust the angle of the gripping tools, and activate or deactivate the gripping tools. The RES POS button is used when the operator wants to move both the robots to their initial positions.

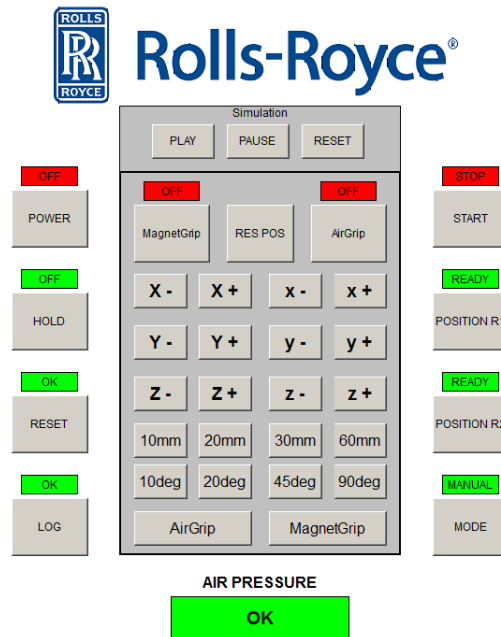


Figure 4.11: The manual control screen

4.6.5 Human failures

If the operator gets access to the code for the manual control, there is a possibility that the operator can accidentally crash the robots. If a person tries to enter the cage, the servo power is turned off.

However, from manual control, the operator is able to damage parts and tools. The robots can not take any damage from human failure, because of the low moment of inertia-limit.

4.7 Photoelectric sensor

At first when the photoelectric sensor was tested in the project, it did not meet our expectations. The 0-10V signal from the sensor to the PLC was inaccurate. Testing with 4-20 mA signal gave the same result, so an median filter was implemented on the signal in Codesys. This was the solution to the problem and now the signal is stable enough to use. Another issue that was discovered later in the project was that the laser was moving slightly. The photoelectric sensor was mounted on a bracket which wasn't rigid. This was handled by pinching a mark in the propeller hub so that the laser beam could be checked for correct position before assembly.

4.8 Signal flow

Figure 4.12 shows the signal flow between the main components of the system.

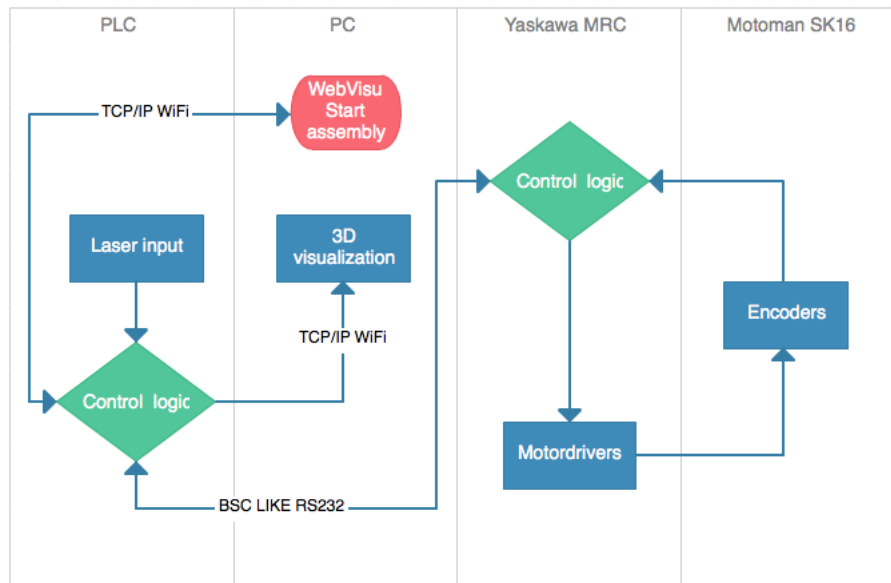


Figure 4.12: Signalflow

Every system uses normal and widely supported communication protocols, and can be run on a wide variety on devices.

4.9 Program Structure

4.9.1 Java

Figure 4.13 shows a class diagram that describes the program structure in Java. MainClass creates and starts two threads, PLCCom and VisualizationDisplayer. These two threads run simultaneously.

The PLCCom-thread sets up a Modbus communication with the PLC and reads a value from a specified register address in the local memory of the PLC.

The VisualizationDisplayer thread displays the visualization and uses the value from the PLCCom thread to control it.

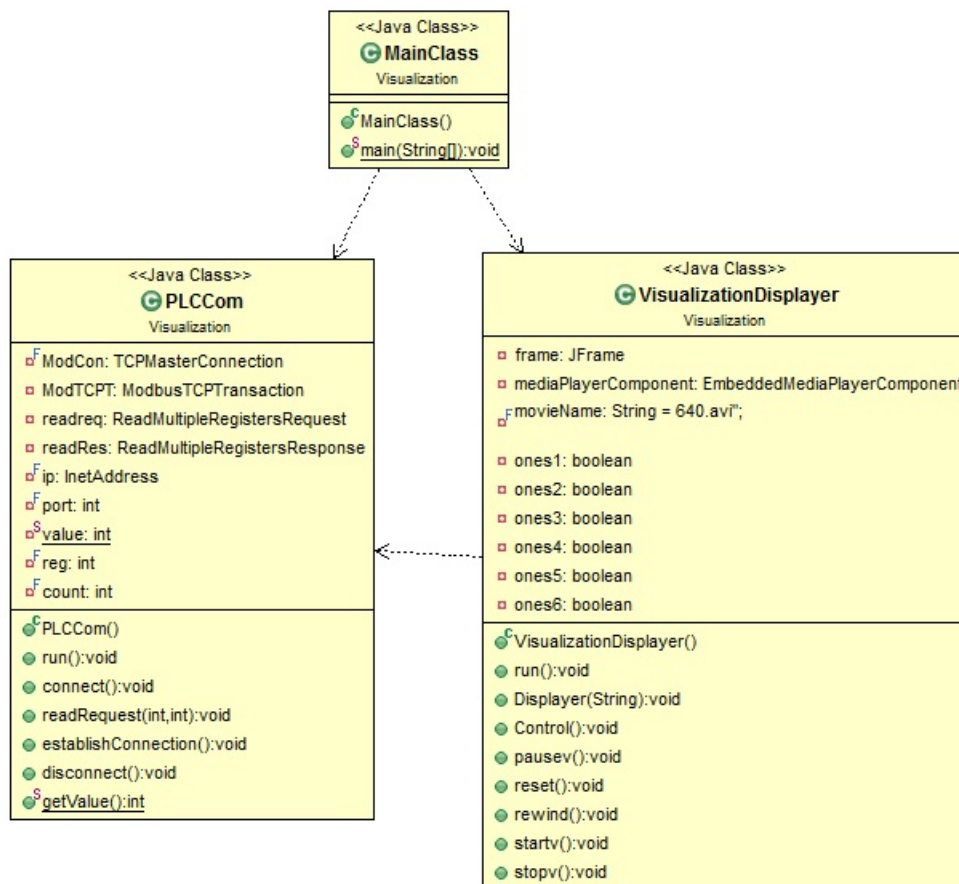


Figure 4.13: Structure Java

4.9.2 PLC

Figure 4.14 shows an overview of the structure in the PLC program. There are five tasks: Assembly, Com, GUI, ManualControl and Pressure.

The AssemblyTask holds the AssemblySequence, which uses some triggers and timers, the input signal from the photoelectric sensor and a function that updates the Log for the GUI.

The ComTask creates the BSCLikeProtocol and sets up the communication between the PLC and the Yasnac MRC.

The GUITask holds the control logic for the GUI. This includes the code-panel for the manualcontrol, some conversion from ASCII to decimal to use in the position readings and some timers and triggers to use for the visualization control.

The ManualControlTask holds the program for the manual control of the robots and some timers and triggers.

The PressureTask holds the program that reads the digital input signal from the Pressure Control Switch. If the air pressure is too low, the assembly is stopped.

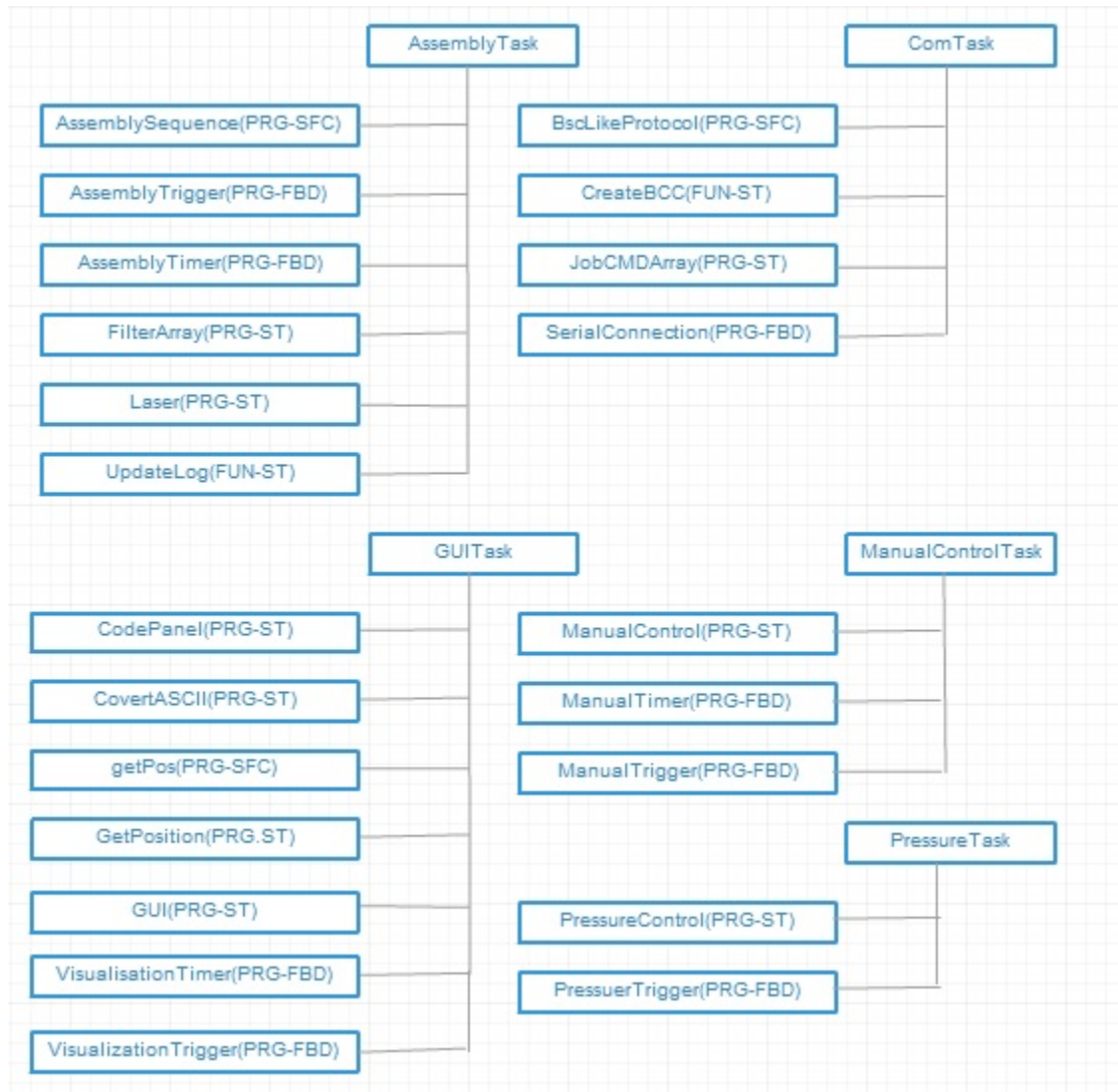


Figure 4.14: Structure PLC

4.10 Assembly Sequence

Figure 4.15 shows the first step of the assembly sequence, when the second robot picks up the first thruster disc. The Magnet gripper holds on to the thruster disc and as shown in Figure 4.15 the red LED's are illuminated to indicate that the electromagnets are activated.

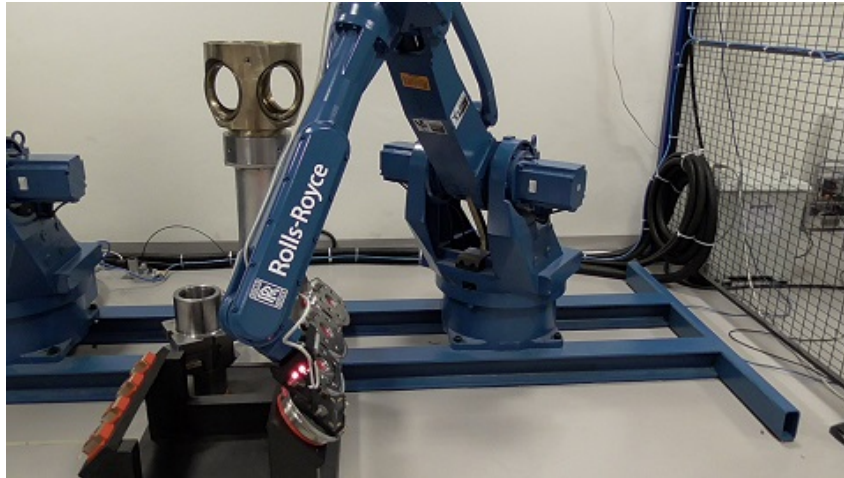


Figure 4.15: Robot grabs the first thruster disc

Figure 4.16 shows the next step of the assembly. Here the robot leads the thruster disc towards the propeller hub and stops under the laser beam from the photoelectric sensor for a quality control. By using the photoelectric sensor value, the program determines whether the disc is missing or in place. If the disc is missing the assembly stops and the robots slowly move to their initial positions. A message then appears in the GUI to inform the operator that the disc was missing.

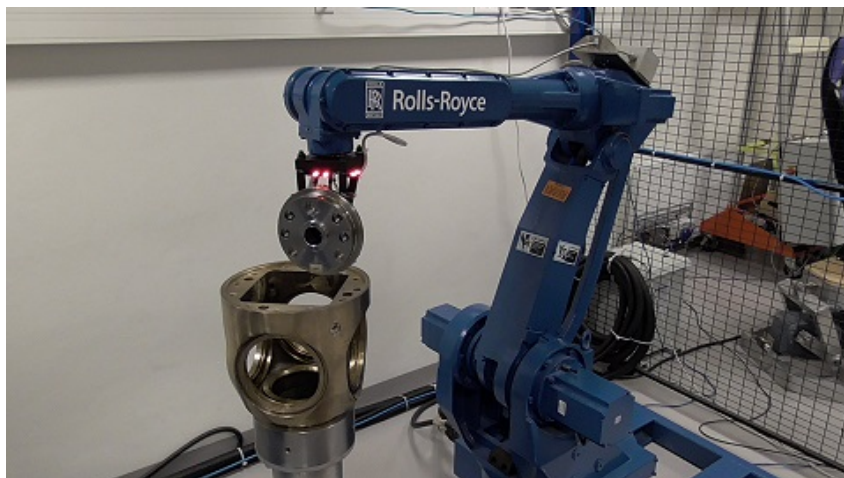


Figure 4.16: Robot holds a thruster disc under the laser beam

Figure 4.17 shows the robot lowering the thruster disc down into the propeller hub and Figure 4.18 shows the robot placing the thruster disc at its place in the hub. When the thruster disc is placed, the electromagnets are turned off and the robot waits for 200ms to let the coil in the electromagnets discharge, thus losing its magnetic field. Then the robot tilts the gripper 10° away from the thruster disc before it moves back. This is to make sure that the disc is completely released from the gripper.

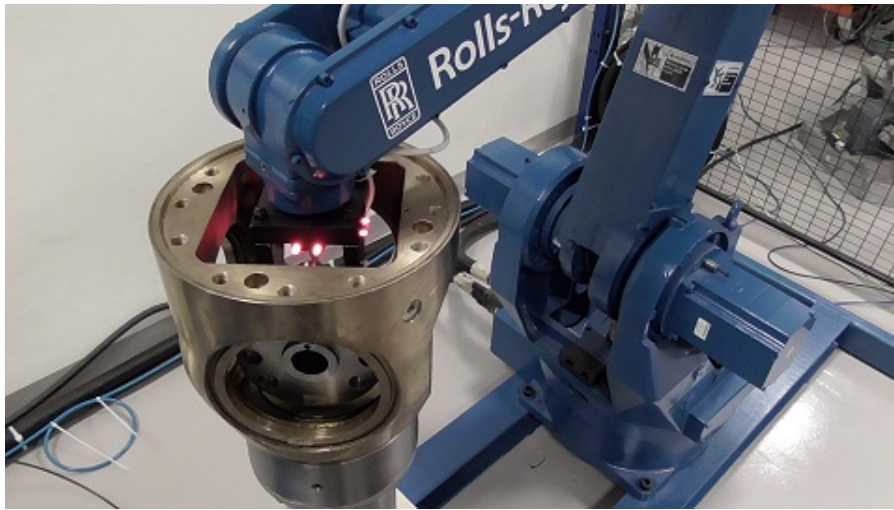


Figure 4.17: Robot lowering a thruster disc into the propeller hub

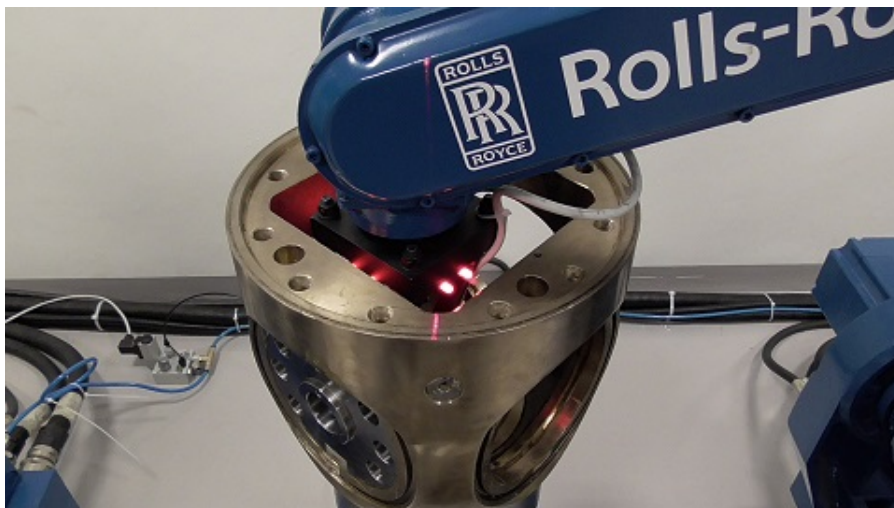


Figure 4.18: Robot places a thruster disc in its place in the propeller hub

Figure 4.19 shows the robot when it is finished placing the first Thruster disc. From here, the robot goes down to the kit to bring the next thruster disc.

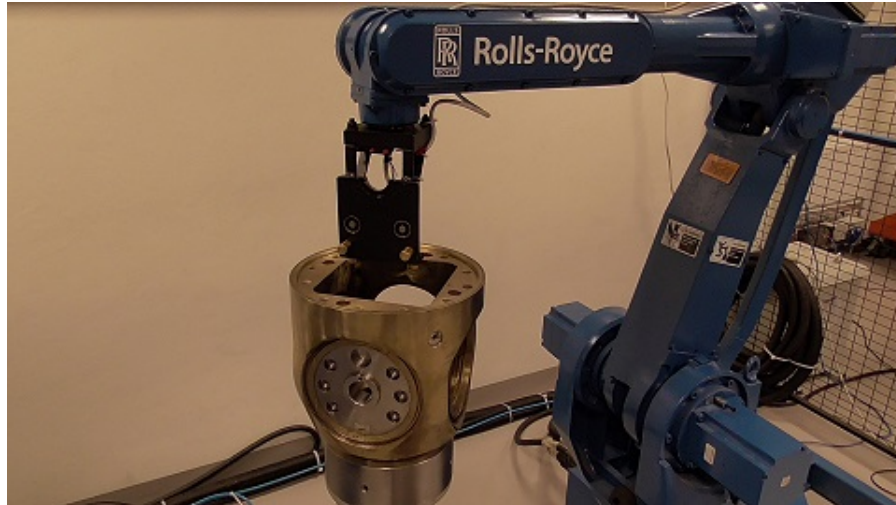


Figure 4.19: Finished placing the thruster disc

When the second robot has picked up the first thruster disc and begun to lower it into the propeller hub, the first robot is commanded to pick up the first slide bearing. Figure 4.20 shows the robot when it picks up the bearing. The Air gripper grips inwards, picking up the bearing.

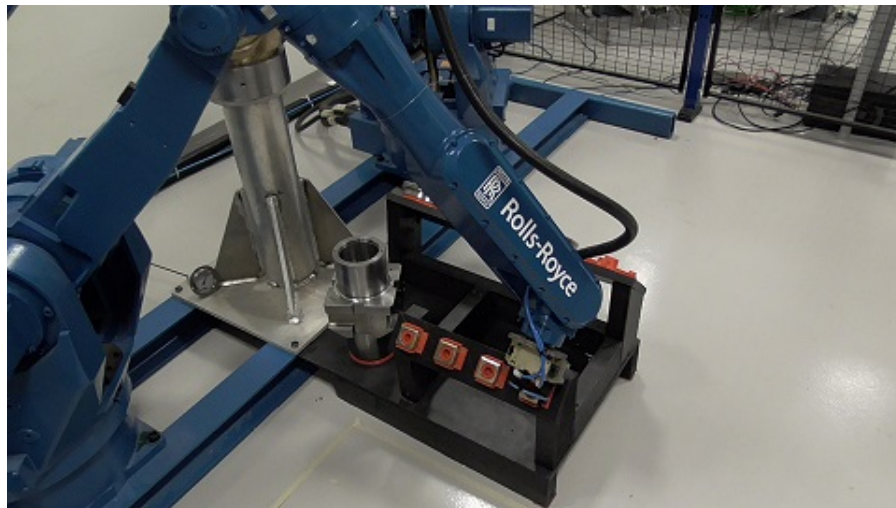


Figure 4.20: Robot grabs the first bearing

When the first slide bearing is picked up, the robot leads it up to the laser beam from the photoelectric sensor for quality control. This control is done in the same way as the quality control of the discs. Figure 4.21 shows this step, and the picture clearly shows the laser beam as it strikes the bearing.

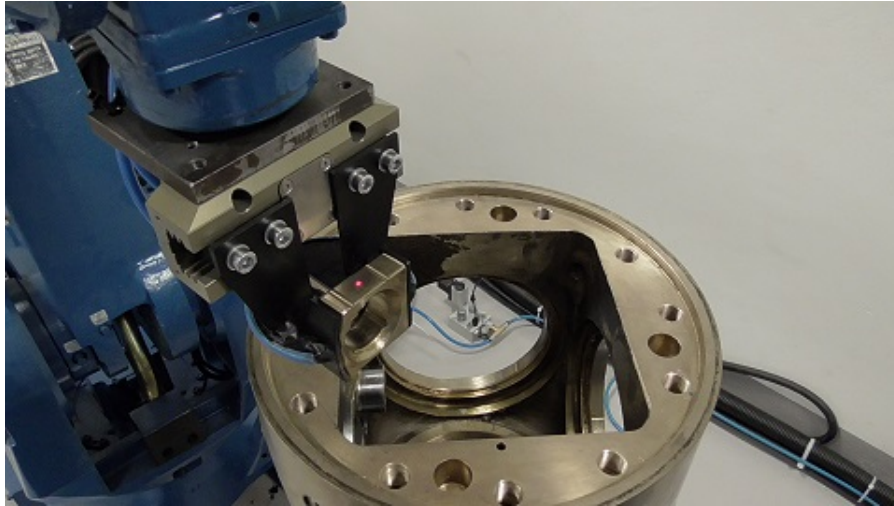


Figure 4.21: Robot holds a slide bearing under the laser beam

Figure 4.22 shows the robot when it is ready to assemble the slide bearing on the thruster disc. Figure 4.23 shows the robot placing the bearing on the first thruster disc.

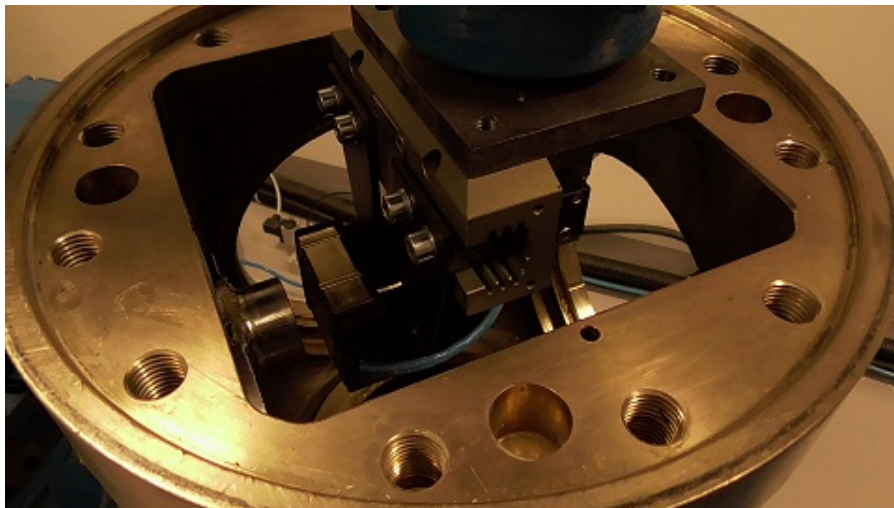


Figure 4.22: Robot lowering a slide bearing into the propeller hub

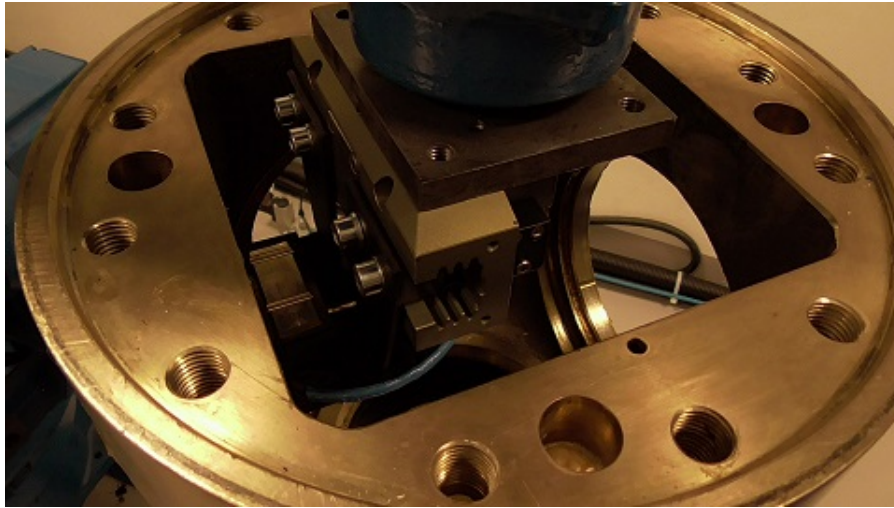


Figure 4.23: Robot places a slide bearing onto a thruster disc

Figure 4.24 shows the robot when it is done placing the slide bearing. The Air gripper releases the bearing and the robot moves away from the bearing before going up.

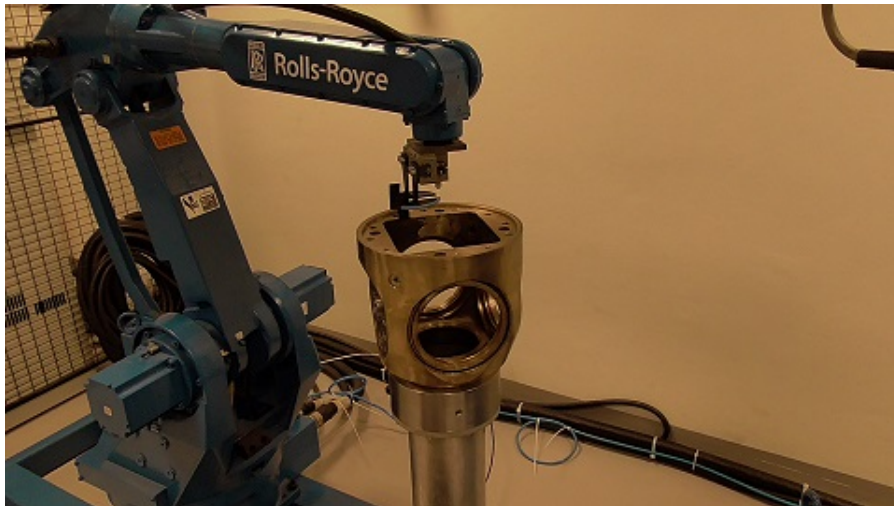


Figure 4.24: Finished placing the bearing

The two robots now simultaneously work together to place the rest of the thruster discs and slide bearings. All the thruster discs and slide bearings are quality controlled by the photoelectric sensor and if something is missing, a message appears in the GUI, telling the operator what number of thruster disc or slide bearing that was missing.

After all the thruster discs and slide bearings are placed, the second robot goes back to its initial position and the first robot moves down towards the piston to pick it up. Figure 4.25 shows the robot as it is picking up the piston. It uses the Air gripper and grips outwards to lock into the groove in the piston to get a secure grip.

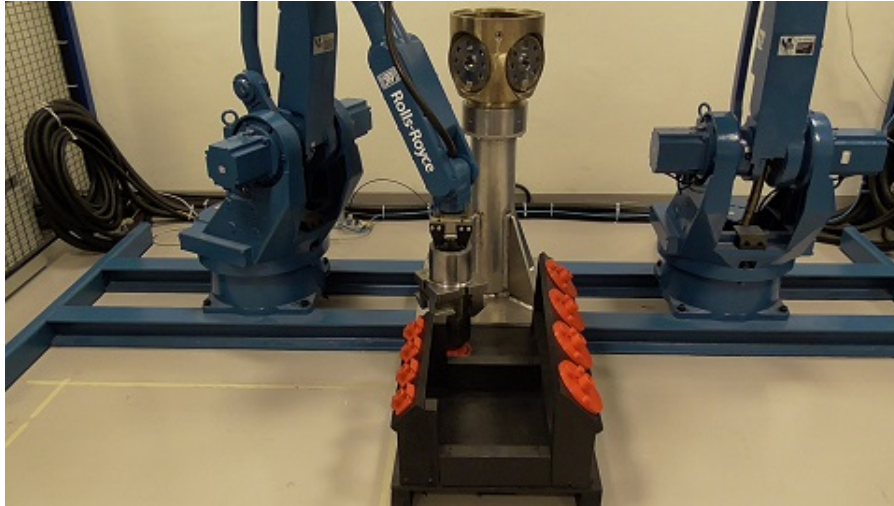


Figure 4.25: Robot grabs the piston

After the robot has grabbed the piston, it moves up towards the propeller hub. Since the piston can be placed on the kit in any angle, the robot has to get assistance from the photoelectric sensor to adjust the piston to correct angle in relation to the propeller hub before lowering it. The robot moves the piston under the laser beam and starts rotating it CCW (Counterclockwise). When the laser beam strikes the piston, the robot stops rotating, it then continues to rotate CCW at a lower speed. When the laser beam goes outside the edge of the piston, the robot immediately stops rotating. Now the robot rotates the piston exactly 13.5 degrees CW (Clockwise) to adjust it into the right angle in relation to the propeller hub. Figure 4.26 shows the robot as it is adjusting the piston.

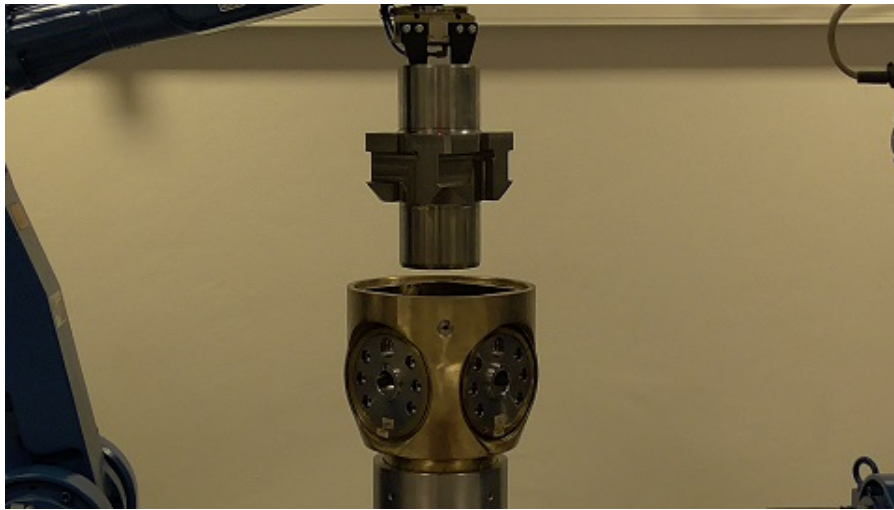


Figure 4.26: Robot adjusts the piston

Figure 4.27 shows the robot as it is lowering the piston into the propeller hub. It then releases the piston and moves up again.

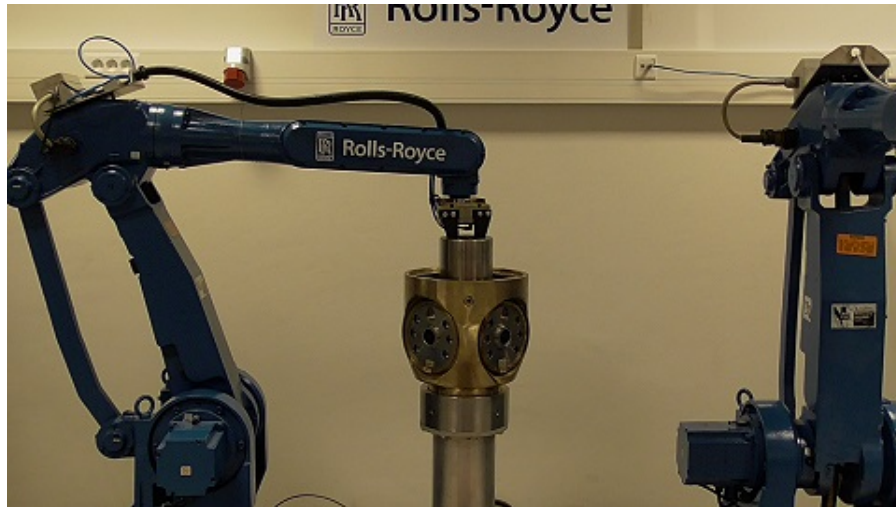


Figure 4.27: Robot lowering the piston into the propeller hub

After the robot has placed the piston, it moves towards the Thruster disc rotating tool to pick it up. Figure 4.28 shows the robot as it picks up the tool. It uses the Air gripper and it is gripping outwards into a groove, the same principle as on the piston.



Figure 4.28: Robot picks up the thruster disc rotation tool

Now both robots move towards the propeller hub to rotate the four thruster discs slightly, so that the piston moves further down. First the two robots simultaneously rotate the thruster discs in front of the propeller hub and afterwards they simultaneously rotate the thruster discs in the back of the propeller hub. Figure 4.29 shows the robots when they are rotating the thruster discs in front of the propeller hub.

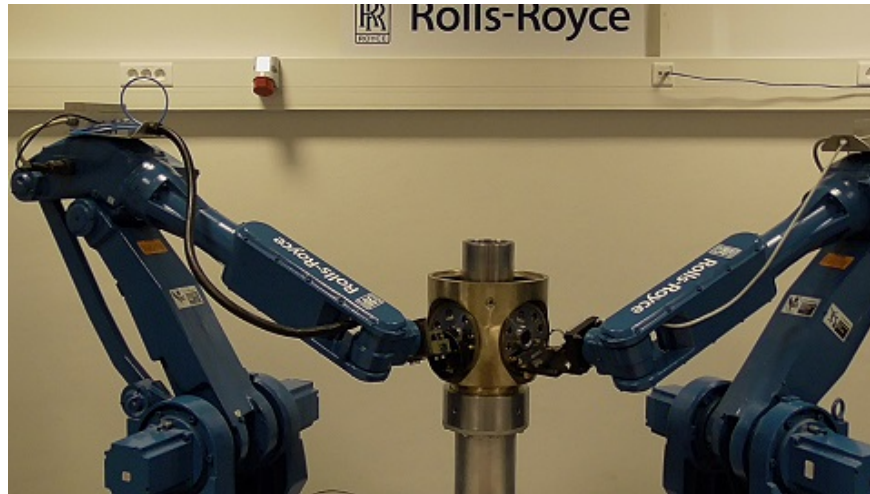


Figure 4.29: Robots rotating thruster discs

After rotating the thruster discs, the second robot moves back to its initial position and the first robot puts the Thruster disc rotating tool back into its holder. Then the first robot moves towards the propeller hub again to grip the piston and lowers it further down into the propeller hub. This is the last and most crucial part of the assembly. Here all the thruster discs are going to rotate in the CCW direction and the piston is going to be lowered into the hub at the same time.

When the robot has gripped the piston, it rocks it by rotating rapidly 6° left and 6° right two times. This is to push the thruster discs in place, so that the piston doesn't lock up when being led further down.

The robot now tries to lead the piston further down. The photoelectric sensor is used to check if the piston moves smoothly down or if it locks. The control program in the PLC, first stores the laser beam value, then the robot moves down 3mm and then does the rocking again. Now the stored laser beam value is checked up against the current laser beam value and if the piston has moved more than 1,5mm the process is repeated. If the piston has moved less than 1,5mm it is considered as stuck and the robot therefore moves the piston 3mm up. Then it does the rocking again and tries to lower it. If the robot has tried to loosen the piston for more than 5 times, the assembly stops and is considered as failed.

If the value of the laser beam reaches a given value, the robot lowers the piston with a speed of 2mm/sec while it also holds the thruster discs in place by rotating the Air gripper slowly in the CCW direction. Throughout this lowering process, the laser beam value is checked

every 1.5 second. If the piston has moved more than 2mm per 1.5 second, the lowering process continues, if the piston has moved less than 2mm per 1.5 second, the robot does the rocking movement again and continues the lowering process.

If the robot has to do the rocking motion more than 5 times, the piston is considered as stuck and the assembly is therefore stopped. If the laser beam value reaches a given value, the piston is considered as lowered. Then the robot stops and turns 6° in the CW direction to release any tension that has built up before releasing the piston. The robot then moves up and resumes initial position. The assembly is now completed.

Figure 4.30 shows the robot as its lowering the piston further down the propeller hub.

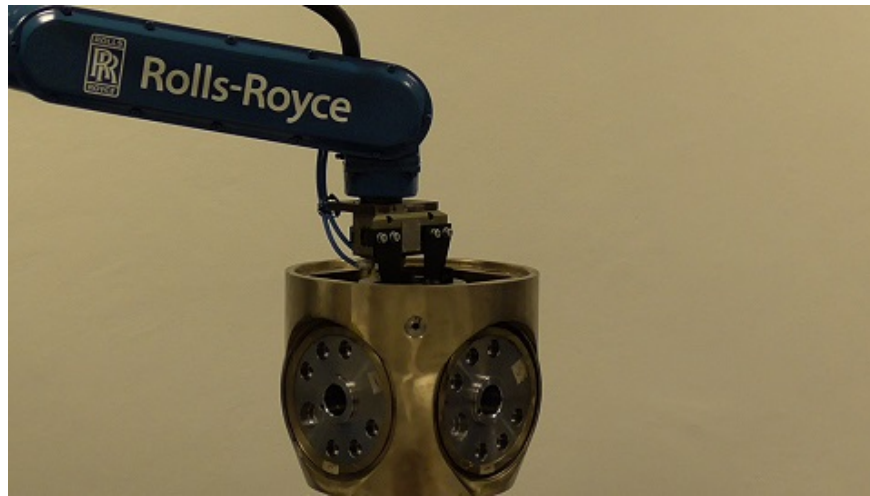


Figure 4.30: Robot lowering the piston further down into the propeller hub

Figure 4.31 shows the completely assembled propeller head.

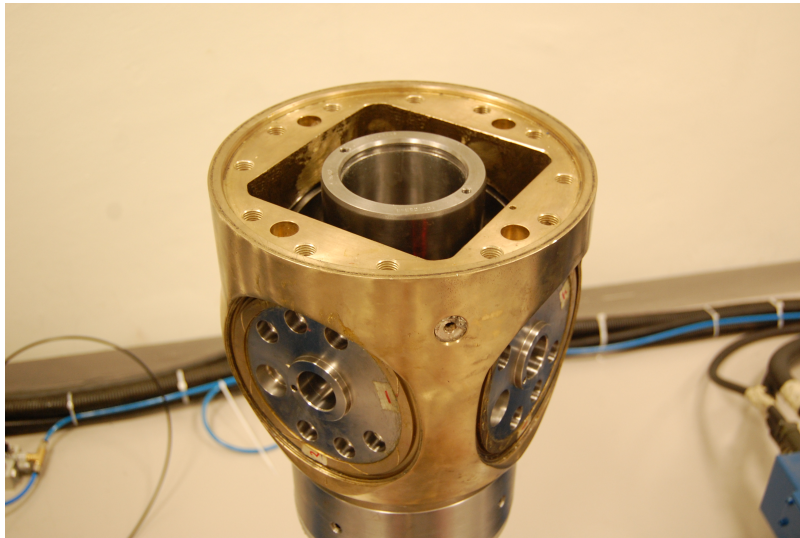


Figure 4.31: Assembled propeller head

4.11 Assembly data

In manual assembly, the average time for an experienced technician to assemble the propeller head is about 7 minutes, depending on technique. Assembling the parts with the robots, including quality control and rotating the piston is done in approximately 3 minutes, depending on the time it takes to rotate and lower the piston.

4.12 Robot cycle time analysis

This cycle time was taken of an assembly video.

No.	Sequence description	Time	Time elapsed
1	Place first thruster disc	0:09	0:09
2	Place first slide bearing	0:08	0:15
3	Place second thruster disc	0:11	0:20
4	Place second slide bearing	0:10	0:25
5	Place third thruster disc	0:10	0:30
6	Place third slide bearing	0:11	0:35
7	Place fourth thruster disc	0:11	0:41
8	Place fourth slide bearing	0:11	0:46
9	Place piston in propeller hub	0:44	1:30
10	Grab thruster disc rotation tool	0:05	1:35
11	Rotate thruster discs	0:11	1:46
12	Place thruster disc rotation tool	0:04	1:50
13	Grab piston in propeller hub	0:07	1:57
14	Lower piston into propeller hub	1:08	3:05
15	Release piston and go to initial position	0:07	3:12

4.13 Secondary effects

4.13.1 Costs

The estimations done in this section are simply meant to give an overview of automatic assembly versus manual assembly. They do not consider power for the robots/cranes, cost for operator, or maintenance. The calculations are based on a robot cell only doing these assemblies. The report does not go into detail about this subject and further investigation is suggested.

The robots used for this project are not commercially available and can only be purchased used. A similar setup, but newer and with a more advanced control system costs 239 736 NOK.[15] Adding shipping, safety cage, setup, gripping tools and programming, the estimated price for the entire process will be 300 000 NOK.

Bigger robots which can assemble the whole range of propeller heads, could cost 700 000 NOK.

A worker who does the assembly for Rolls-Royce costs about 800NOK per hour.[Appendix 1]

Smallest heads

In our own research an assembly time of 7 minutes and 14 seconds has proven to be average for the smallest head.

In comparison, the automated assembly uses 3 minutes and 12 seconds.

Rolls Royce marine produces about 50 of the smallest heads per year[Appendix 1].

$$\text{Difference in time per head} = 0,121h - 0,053h = 0,068h. \quad (4.1)$$

$$\text{Difference in percentage} = \frac{0,121h}{0,053h} = 228\%. \quad (4.2)$$

$$\text{Savings per assembly} = 0,068h * \frac{800NOK}{h} = 54,4NOK. \quad (4.3)$$

$$\text{Savings per year} = 54,4NOK * \frac{50}{year} = \frac{2720NOK}{year}. \quad (4.4)$$

$$\text{Time to break even} = \frac{300000NOK}{\frac{2720NOK}{year}} = 110years. \quad (4.5)$$

$$\text{Operating hours} = 0,053h * 50 = 2,65h\text{per year}. \quad (4.6)$$

All heads

To compare the whole range with manual vs automated assembly, the average assembly time is about 2,5-3 hours.[Appendix 1] This time estimate includes correction of eventual damage during assembly, insertion of o-rings and other small parts which has not been assembled by the robots. To be able to compare the robots performance to a worker, an estimate of 2 hours assembly time is calculated. These 2 hours include damages that needs correction and greasing.

The robots will not use much more time assembling the bigger heads than they do assembling the smallest ones. An assembly time of 3 minutes is seen as average. Rolls-Royce produces 800 propeller heads per year in total.[Appendix 1]

$$\text{Difference in time per head} = 2h - 0,05h = 1,95h. \quad (4.7)$$

$$\text{Difference in percentage} = \frac{2h}{0,05h} = 4000\%. \quad (4.8)$$

$$\text{Savings per assembly} = 1,95h * \frac{800NOK}{h} = 1560NOK. \quad (4.9)$$

$$\text{Savings per year} = 1560 * \frac{800}{year} = \frac{1248000NOK}{year}. \quad (4.10)$$

$$\text{Time to break even} = \frac{700000NOK}{\frac{1248000NOK}{year}} = 0,56years. \quad (4.11)$$

$$\text{Operating hours} = 0,05h * 800 = 40h\text{per year} \quad (4.12)$$

4.13.2 Reliability

During the projects time, multiple assemblies have been performed. With the final version of the control-system, a success-rate has been determined to 8/10 attempts, giving an 80% chance of success.

4.13.3 Availability

As stated in the costs-section, the operating hours per year are 2,65 h or 40 h, depending on solution.

The down-time of the cell will vary greatly depending on robots chosen and scheduled maintenance suggested by the company which sells the robots. Normal down-time events are:

1. Replacing rubber on Air gripper, due to wear. Downtime: 30 min.
2. Replacing brass studs due to wear. Downtime: 1 h.
3. Resetting assembly because of errors. Downtime: 5 min - 60 min.
4. Regular maintenance. Downtime: Unknown
5. Power failure. Downtime: Unknown
6. Unknown events. Downtime: Unknown

No investigation has been done to calculate availability during an entire year.

Chapter 5

Discussion

5.1 Load cell

A load cell is a transducer that is used to create an electrical signal whose magnitude is directly proportional to the force being measured.[51]

Mounting a load cell onto a robot will give the robot a sense of feel so that the robot can be more adaptive in the assembly process.

To check that parts are not missing, finding the correct position of the piston and lowering the piston down into the propeller hub, there has, in this project been used a photoelectric sensor. Using a load cell would have done the assembly faster and more adaptive. The part of the assembly where the robots take the part under the laser beam to check that the part is not missing, could have been done by using a load cell, just by measuring the weight of the part that should have been picked up. This would have saved some time because the robot would not have to stop under the laser beam to get confirmation that the part is there.

The part of the assembly where the robot turns the piston into correct position for lowering the piston into the propeller hub, could have been managed by a load cell in a way that the robot turns the piston until it touches a spring loaded axle, and then reads out an increase in signal from the load cell. This would make it even more precise than using laser. The last part of the assembly where the piston is being lowered into the propeller head, the load cell could have been used to sense if the piston has become stuck or not. In this project, to protect the robots from being damaged, the inertia limit was set to half the factory set force, to stop the robots if they crashed into something or got stuck. With a load cell, the robots could have sensed that something was wrong and stop.

Shown in Figure 5.1 is a 3-Axis load cell. This load cell has independent load bridges F_x , F_y and F_z tension and compression, 10N to 50kN force range and 1mV/V output.[24]

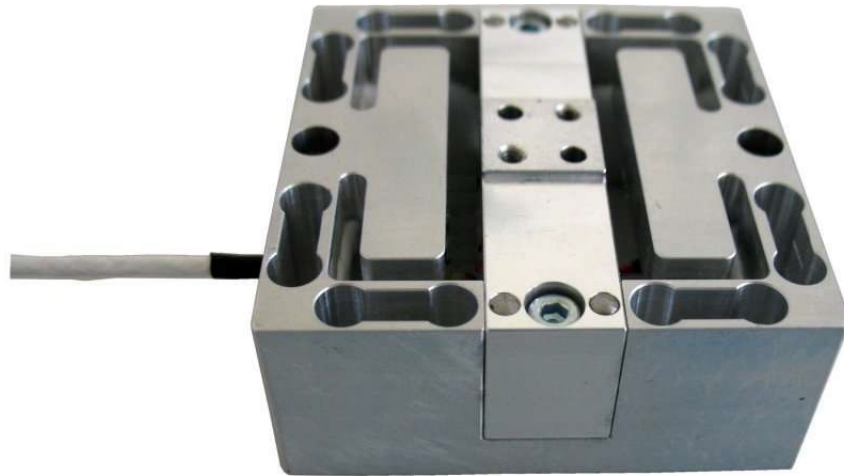


Figure 5.1: 3-Axis Load Cell

5.2 Gripping tool improvement

There are improvement potential on the Air gripper. During the project it was concluded that the Air gripper was a bit weak in a way that it would flex and bend when a lot of force was applied. This was seen especially when the piston was being brought up to the propeller hub where it would flex a bit. The gripper is made out of 3mm metal sheet. A better solution would have been to use 5mm metal sheet instead. This would make the gripper more rigid. To increase the friction when the gripper grips the piston and the thruster disc rotation tool, power cord insulation has been applied to the tool. It does not last very long and had to be replaced during the project. A better solution to this would have been to have small teeth like the ones that is seen on pliers to increase the friction metal to metal. A better design solution for the Air gripper would have been to put brass studs on to the Air gripper so that it would not been necessary to use the Thruster disc rotation tool, this would also improve the cycle time.

5.3 Reducing robot cycle time

An average assembly time with the robots take 3 minutes and 12 seconds. There are 2 sequences of the assembly that takes a lot of time. The step where the piston is adjusted to the correct angle in relation to the propeller hub could have been done by using a fixed position for the piston as mentioned earlier. By looking at the video of the assembly, it would, without the laser adjustment take about 20 seconds to grab the piston and lower it inside the propeller hub. It takes 44 seconds to do this with the laser adjustment. The other sequence that takes a lot of time is the last part where the robot is lowering the piston inside the propeller hub to complete the assembly. It would be more efficient to use a load cell to sense if the piston was locking up. The load cell would have been more suitable for this than the laser and therefore the robot could have lowered the piston at a faster rate. This would have reduced the time to about 30 seconds, in this project it takes 1 minute and 8 seconds. The total time saved on these two steps would be 62 seconds, putting the total assembly time down to 2 minutes and 10 seconds.

5.4 Computer vision

In this project there is a photoelectric sensor that checks that the part is on the gripper before installing it inside the propeller hub, this takes up some cycle time, because the robot has to hold the part under the laser for 750ms. A faster solution to this would have been to use computer vision to recognize the parts before installing it in the propeller hub. Just by taking a picture of the part and recognizing the part. This could have been done without the robot stops for taking the picture. The total time saved for this step would be 6 seconds, putting the total assembly time down to 2 minutes and 4 seconds.

5.5 Live visualization

The visualization in this project is an animation that is played in parallel with the assembly process. A better solution would have been to have real-time angle values from the joints of the robots. This would have give a more precise visualization of the assembly process.

5.6 Secondary effects

5.6.1 Costs

From the results presenting the time it takes to break even on the investment of the robot cell, it is safe to say that a robot cell only assembling the smallest propeller head will not be financially viable. Saving 2720 NOK per year would be negligible compared to the cost of maintenance and buying new robots during the 110 years it takes to break even.

A robot cell which can assemble all propeller heads could however break even in a little over half a year. This is assuming the robot cell does nothing else the entire time. This will give the robot cell a lot of free time, which it can do other tasks, and increasing efficiency and reducing the time it takes to break even.

5.6.2 Reliability

A success-rate of 80% would not be sufficient for a industrial application. The low success-rate is mostly due to disturbances on the laser sensor. The laser sensor is mounted on the ceiling, which moves, thus changing the rotating-angle of the piston. Fixing the laser to a rigid object or using a load-cell would greatly improve the success rate.

5.6.3 Availability

Due to inexperience and lack of data, we are not able to produce good numbers on the availability of the robots. The availability also greatly depends on the robot used. The downtime on the cell used for this project has been quite low, and the main incident is replacement of rubber and resetting the assembly due to system errors.

5.6.4 Quality

The parts are not perfectly machined in today's assembly. Because of this, workers must machine the parts and get rid of any imperfections. As a result of the robots not being able to see the parts, the parts must be machined perfectly. By machining the parts perfectly, and avoiding damage during assembly, the overall quality of the finished product will be greater than today.

5.6.5 Safety

Since no human involvement is needed to assemble the propeller heads, we remove the human element in relation to safety. Today's assembly is done by hand and operators experience crushing-injury when assembling.[Appendix 1] From this we can conclude that the automated assembly is safer than today's assembly.

5.7 Robot cell

5.7.1 Amount of robots

The robot cell used for this project has two robots working together, making it quite versatile. A single robot with long reach could possibly do the task by its own, but this solution might face problems with rotating the discs. We experienced locking of the piston when rotating disc by disc.

Multiple robots could also work together, and would most likely complete the assembly faster, however the benefit would be negligible, and this solution would offer more challenges with timing and transportation of the parts to the robot cell.

If all models are supposed to be assembled within the same cell, robots with bigger lifting capacity must be acquired.

5.7.2 Rotating base

A rotating base could be used together with robots, making it easier to position the propeller hub onto the base. It could also be used during the assembly, but there hasn't been much investigation on this subject.

5.7.3 Tool-changer

In an industrial application of this robot cell, a tool-changer would be necessary. Because of the limited time and funds, the group has not investigated this. A tool-changer would make it possible to develop other types of grippers. The cell would also be more versatile and other types of assemblies would be possible.

5.7.4 The kit

The holder for all the parts is made out of wood that is painted black. Due to the tension in the wood material when bolting it together, it was discovered that the kit was moving slightly by the months it stood on the floor. The movement was very small, but enough that it was causing some problems for the robot to pick up the parts. The solution to this was that the position where it picks up the part had to be re-calibrated during the project. A better solution would have been to make the whole kit in sturdy plastic or welding a kit in metal.

5.7.5 Fixed position for the piston

In this project the piston can be positioned on the kit in any rotation. The laser will help adjusting it to correct angle before lowering it into the propeller hub. This takes up assembly time and it would be better to have a fixed position for the piston on the kit. The reason for doing this in the project was to show that the robots can work in an adaptive way, not just a program that runs over and over doing the exactly the same each time.

Chapter 6

Conclusion

The project was completed as planned, and fulfills all requirements set by the group and Rolls-Royce. The robots can assemble the propeller head with no human involvement, and drastically reduces the time it takes to assemble a propeller head, compared to manual assembly. The solution is also scalable, so a scaled implementation of this system can be applied to bigger heads. The system can control itself and react to different events, making the cell autonomous and reliable.

Even though the assembly time could be reduced by using more modern robots and more advanced sensors, the group is confident in the solution, and believes that it is good regarding the time and funds available.

For the robot cell to be economically viable, the robot cell implemented need to be utilized as much as possible. By only performing assembly of propeller heads, the cell will not be using its full potential. A load cell, a tool changer and a transportation system will give the system greater universality.

Working close together this semester has required project-managing and communication skills. The project has been efficient by dividing fields and tasks across group members. By doing this, the group members have been able to dive deep into their respective fields and produce great results. The group has had daily meetings and presented every field to each other. We believe that this has increased system-understanding and secured compatibility. By drawing 3D models and prototyping them with 3D printers, the group has made sure that every part works and fits like they should. Doing this, the group has not needed to develop faulty models in the machine shop, saving money and time. The group believes that using prototypes and 3D models gives a more hands-on experience, inspiring creativity.

The completed work has shown that automated assembly can reduce the assembly time with a minimum of 228% in relation to manual assembly. By implementing visualization and preview options, operators will have full control over the assembly. The solution presented will not only complete the assembly faster, but also cheaper, safer and with a higher product quality. Most importantly it is shown that by using robots as a part of the total manufacturing-process it is possible to keep production in Norway.

Bibliography

- [1] Motoman Robotics AB. Operatorsmanual yasnac mrc, 1995.
- [2] Motoman Robotics AB. Service manual sk16, 1995.
- [3] FAB LAB BCN. Picture 3d printer. <http://tinyurl.com/printerImage>, downloaded: 05.05.15.
- [4] Biltema. Trykkregulator med manometer. <http://tinyurl.com/nlrmthj>, downloaded: 26.05.15.
- [5] Blender. Blender logo. <http://download.blender.org/institute/BlenderDesktopLogo.png>, downloaded: 28.05.15.
- [6] Conrad. Picture serial interface. <http://tinyurl.com/SerialImage>, downloaded: 28.05.15.
- [7] Factory Controls. Camozzi air-valve manual, 2015.
- [8] Danfoss. Mbv 5000 test-valve manual, 2011. <http://tinyurl.com/DanfossMBV5000>, downloaded: 07.05.15.
- [9] Balbir S Dhillon. *Applied Reliability and Quality*. Springer London, 2007.
- [10] Directindustry. Picture magnet. <http://tinyurl.com/MagnetPicturee>, downloaded: 28.05.15.
- [11] ebay. Picture analog input module. <http://tinyurl.com/analogImage>, downloaded: 28.05.15.
- [12] ebay. Picture digital input module. <http://tinyurl.com/inputImage>, downloaded: 28.05.15.
- [13] ARC Electronics. Rs232 tutorial on data interface and cables, 2010. <http://www.arcelect.com/rs232.htm>, downloaded: 16.05.15.
- [14] Enginoor. Solidworks logo. <http://tinyurl.com/solidworksLogo>, downloaded: 28.05.15.
- [15] Exapro. Price example motoman sk 16, 2015. <http://tinyurl.com/o4al717>, downloaded: 27.05.15.
- [16] The Blender foundation. About blender, 2015. <http://www.blender.org/foundation/>, downloaded: 19.05.15.

- [17] The Blender foundation. Blender licenses, 2015. <https://www.blender.org/about/license/>, downloaded: 19.05.15.
- [18] Dag Håkon Hanssen. *Programmerbare Logiske Styringer*. 2010.
- [19] IBM. General information - binary synchronous communications, 1970. <http://tinyurl.com/BSCAbout>, downloaded: 12.05.15.
- [20] IFM. Ifm photoelectric sensor manual, 2012. <http://www.ifm.com/mounting/704991UK.pdf>, downloaded: 14.05.15.
- [21] IFM. Photoelectric sensors, 2015. www.ifm.com, downloaded: 14.05.15.
- [22] iiyma. Picture touch screen. <http://tinyurl.com/iiymaImage>, downloaded: 28.05.15.
- [23] Software Informer. Advanced serial port monitor, 2015. advanced-serial-port-monitor.software.informer.
- [24] Interface. 3axx 3-axis load cells, 2015. <http://tinyurl.com/loadCellAbout>, downloaded: 12.05.15.
- [25] Japansoftpc. Picture dell screen. <http://tinyurl.com/dellSImage>, downloaded: 28.05.15.
- [26] Jelastic. Netbeans logo. <http://tinyurl.com/netbeansLogo>, downloaded: 28.05.15.
- [27] Kuhnke. Magnet manual. <http://tinyurl.com/magnetManual>, downloaded: 05.05.15.
- [28] Mandmcontrols. Picture pressure control. <http://tinyurl.com/pressureConImage>, downloaded: 28.05.15.
- [29] Mandmcontrols. Picture test valve. <http://tinyurl.com/valveImage>, downloaded: 28.05.15.
- [30] Motoman. Motoman mrc controller, data communications manual, 1997.
- [31] Yaskawa Motoman. Industrial robot motoman-sk16, 1996.
- [32] Yaskawa Motoman. Yasnac mrc communication manual, 1997.
- [33] Yaskawa Motoman. Motoman robot history, 2012. <http://tinyurl.com/motomanHistory>, downloaded: 09.05.15.
- [34] Yaskawa Motoman. Yaskawa motoman, 2015. <http://www.motoman.com/about/default.php>, downloaded: 09.05.15.
- [35] Netbeans. Netbeans, 2015. <https://netbeans.org/features/index.html>, downloaded: 19.05.15.
- [36] Oracle. Java, 2015. <http://tinyurl.com/javaAbout>, downloaded: 19.05.15.
- [37] Modbus Organization. Modbus, 2015. <http://www.modbus.org/faq.php>, downloaded: 20.05.15.
- [38] VideoLAN organization. Vlc media player, 2015. <http://www.videolan.org/vlc/>, downloaded: 19.05.15.

- [39] Jamod project. Jamod, 2010. <http://jamod.sourceforge.net/>, downloaded: 20.05.15.
- [40] Michael Schrage. *Serious Play*. Harvard Business School Press, 1999.
- [41] Schunk. Phn-plus manual, 2015. <http://tinyurl.com/SchunkPHN>, downloaded: 09.05.15.
- [42] Caprica Software. Vlcj, 2015. <http://tinyurl.com/vlcjAbout>, downloaded: 19.05.15.
- [43] Lars Svennebye. Lønnsnivå og kjøpekraft i oecd-landene, 2011. <http://tinyurl.com/ssbCosts>, downloaded: 21.05.15.
- [44] Dassault Systemes. Solidworks, 2015. <http://www.solidworks.com/>, downloaded: 19.05.15.
- [45] INC Ted Pella. Material hardness tables. <http://tinyurl.com/hardTable>, downloaded: 26.05.15.
- [46] M.tech Robotics Thomas Nirmal. Robot cycle time analysis, 2013. <http://www.slideshare.net/nirmal304/robot-programing>, downloaded: 27.05.15.
- [47] Wago. Picture end module. <http://tinyurl.com/WagoMImage>, downloaded: 28.05.15.
- [48] Wago. Wago 750-870 manual. <http://tinyurl.com/wageImage>, downloaded: 03.05.15.
- [49] Wago. Wago 787-622 power supply manual, 2014. <http://tinyurl.com/wagoPower>, downloaded: 08.05.15.
- [50] Wikipedia. Codesys logo. <http://tinyurl.com/codesysLogo>, downloaded: 28.05.15.
- [51] Wikipedia. Load cell, 2015. <http://tinyurl.com/ybcgt9o>, downloaded: 12.05.15.
- [52] Wikipedia. Makerbot industries, 2015. <http://tinyurl.com/makrBot>, downloaded: 09.05.15.

Appendix A

Interview with Rolls-Royce

This interview is done to map the costs and time of manual assembly at Rolls-Royce Marine Propulsion. None of the numbers in this interview are exact, but offer an estimate to the actual cost. The interview is done by email between the group and Arild Djupvik 26.05.2015. Question will be abbreviated to Q, and answer will be abbreviated to A.

Q1: What does a worker cost per hour for Rolls-Royce?

A1: A worker costs about 800 NOK per hour.

Q2: How many propeller heads of the smallest models do you produce?

A2: We produce about 50 of the smallest propeller heads per year.

Q3: How many propeller heads do you produce in total?

A3: Rolls Royce Marine produce about 800 propeller heads per year.

Q4: How long time does a worker use to assemble a propeller head by hand?

A4: A worker uses about 2,5-3 hours on average to assemble a propeller head.

Q5: Do you experience any injuries (long term or sudden) during assembly?

A5: We have experienced some cases of crush-injuries.

Q6: Do damage to parts/product occur during assembly?

A6: In a lot of cases, the worker has to disassemble the propeller head and file away dents or bumps because the parts jams during the assembly.

Appendix B

Pre Project Report

BACHELOROPPGAVE – FORPROSJEKT RAPPORT

TITTEL:

Forprosjekt til Bacheloroppgave – Montering i småskalaproduksjon

KANDIDATNUMMER:

IKKE GITT. Se 3.1 for studentnummer

DATO: 21.01.15	EMNEKODE: IE303612	EMNE: Bacheloroppgave	DOKUMENT TILGANG: - Åpen
STUDIUM: AUTOMATISERINGSTEKNIKK		ANT SIDER/VEDLEGG: 10 / 1	BIBL. NR: - Ikke i bruk -

OPPDRAGSGIVER(E)/VEILEDER(E):

Rolls Royce ved Arild Djupvik / Ottar Osen

OPPGAVE/SAMMENDRAG:

Denne forprosjektrapporten inneholder planlegging av bacheloroppgave gitt av Rolls Royce.

Oppgaven går ut på å automatisere monteringen av et propellhode for Rolls Royce.

Propellhodet består av propellhode, thruster-skiver, messing-lager og thruster-stempel.

Monteringen gjøres i dag for hånd, men det er nå aktuelt å undersøke om det er hensiktsmessig å automatisere denne monteringen. Oppgaven vil bestå av PLS-styring, robotkontroll, prototyping/konstruering av gripeverktøy og se om endring av komponenters design vil gjøre monteringen enklere å robotisere.

Rapporten inneholder blant annet beskrivelse og organisering av prosjektgruppen, ansvarsområder, styringsgruppen. Videre inneholder rapporten beskrivelser av avtaler mellom oppdragsgiver og prosjektgruppen, problemstilling, delmål, risikoanalyse, fremdriftsplan og møteplanlegging.

Til slutt beskriver den utstyrbehov og forutsetninger for gjennomføring.

Denne oppgaven er en eksamensbesvarelse utført av student(er) ved Høgskolen i Ålesund.

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1 INNLEDNING

Grunnen til at denne oppgaven ble valgt var at gruppen ønsket en oppgave som var mulig å realisere og ha et samlet mål å jobbe mot. Å få jobbe med automatisering i liten skala er aktuelt i dagens industri og gruppen føler seg motivert og inspirert til å jobbe med dette. Gruppen har erfaring fra blant annet PLS-programmering, bildebehandling og server-klient-systemer. Gruppen skjønner omfanget av oppgaven og er belagt på å legge det arbeid som kreves inn i prosjektet.

Rolls Royce Marine er en stor og viktig aktør i det maritime næringsliv. Det er en spennende bedrift som medlemmene i gruppen har interesse for.

Som det går frem fra Rolls-Royce sine hjemmesider, har de en verdensledende posisjon innen design, utvikling, forsyning og support av produkter og systemer for kunder på tvers av kloden. Med hovedfokus på blant annet drivkraft, har Rolls-Royce over 4000 kunder, og utstyr på 30 000 fartøy rundt om i verden [1].

Den grunnleggende problemstillingen for denne oppgaven er å automatisere monteringen av propellhode. Oppgaven er beskrevet under Oppgave/Sammendrag tidligere i denne rapporten.

Formålet med oppgaven er å automatisere monteringen for å øke presisjon, effektivitet, sikkerhet og frigi arbeidskraft.

2 BEGREPER

Propellhode – Propellhodet er hovedenheten alle andre komponenter monteres i.

Thruster-skiver – Flens som monteres på propellhodet

Thruster-stempel – Stempel som flyttes inn og ut for å rotere propellbladene.

Messing-lager – Lager som monteres på thruster-skivene for å forsørge passform og glid i stempelet.

PLS – Programmerbar logisk styring. Robust «datamaskin» som brukes i industrisammenheng.

Prototyping – Realisert designløsning i første versjon.

Elektro-tunglab – Lokale hos HIALS. Lab utstyrt med div verktøy og maskiner.

HIALS – Høgskolen i Ålesund.

Kontrollskapet – Skap hvor komponenter for å styre robotarmene sitter.

Automatisere – Å gjøre automatisk (av seg selv).

Robotisere – Å gjøre slik at roboter tar seg av oppgaven.

Dropbox – Nettbasert lagringsprogram.

Gantt-diagram – Oversikt i tabell og grafisk format for å visualisere prosjekt- planlegging og -styring.

GUI – Graphical User Interface (Grafisk brukergrensesnitt).

IDE – Integrated Developer Environment (utviklingsverktøy)

3 PROSJEKTORGANISASJON

3.1 Prosjektgruppe

Studentnummer
101176
110441
120407

Tabell 1 - Studentnummer

3.1.1 Oppgaver for prosjektgruppen - organisering

Oppgavene for prosjektgruppen er å jobbe sammen mot delmål og til slutt hovedmål. Gruppen må dokumentere alle løsninger og modelleringer. Det legges fokus på å ha et godt samarbeid både innad i gruppen og mot styringsgruppen.

3.1.2 Oppgaver for prosjektleder

Prosjektlederen skal koordinere prosjektarbeidet. Prosjektleder skal sørge for at de respektive arbeidsoppgavene fullføres og at gruppens medlemmer forholder seg til de rammer for prosjektstyringen som er satt.

3.1.3 Oppgaver for sekretær

Sekretæren skal organisere dokumentasjon, skrive møteinnkallinger, møtereferat og daglig hendelseslogg.

3.1.4 Oppgaver for øvrige medlemmer

- Alle medlemmer er selv ansvarlige for de respektive oppgavene som de får tildelt.
- Medlemmene må forsøke å opprettholde god lagdynamikk og benytte seg av hverandre og de ressurser som er tilgjengelig.

3.2 Styringsgruppe (veileder og kontaktperson oppdragsgiver)

Som skrevet i PDF-dokumentet «Hovedprosjektet: Retningslinjer for Styring og Rapportering», fra Fronter skal Prosjektgruppen selv etablerer en Styringsgruppe bestående av interne og eksterne veiledere. Prosjektgruppen skal forholde seg til Styringsgruppen. Styringsgruppen skal påse at prosjektarbeidet gjennomføres i henhold til tidsplan og prosjektspesifikasjon. Alle beslutninger som har konsekvens for det videre prosjektarbeidet skal godkjennes av Styringsgruppen [2].

Styringsgruppen består av arbeidsgiver Rolls Royce ved Arild Djupvik og Arnt Dahle, og veiledere fra HIALS; Ottar Osen og Houxiang Zhang.

Navn	E-post	Telefon	Stilling/rolle
Ottar Osen	oo@hials.no		Supervisor
Houxiang Zhang			Supervisor
Arnt Dahle	arnt.dahle@rolls-royce.com		Kontakt hos Rolls Royce
Arild Djupvik	arild.djupvik@rolls-royce.com	951 02 318	Kontakt hos Rolls Royce

4 AVTALER

4.1 Avtale med oppdragsgiver

Ingen spesielle avtaler er avklart.

4.2 Arbeidssted og ressurser

- Arbeidsplassen er elektro-tunglab i lab-bygget ved HIALS. Rommet er tilgjengelig ved bruk av nøkkelkort. Åpningstider er mandag til fredag 07:00 – 21:00, lørdag og søndag 09:00 – 17:00.
- Arbeidsplassen er utstyrt med diverse redskap og elektroverktøy. Det er også her robotarmene og kontrollskapet befinner seg. Gruppen har tilgang til de fleste fasiliteter ved lab-bygget.
- Blant andre er Ottar Osen, Arild Djupvik og labansvarlig Anders Sætersmoen er tilgjengelige for gruppen for rådgivning og ressursinnhenting.
- Prosjektgruppens medlemmer har tilgang til skolens virtuelle skrivebord hvor diverse programvare er tilgjengelig. De har også tilgang til Microsoft Dreamspark, hvor mye av Microsofts programvare ligger tilgjengelig.

- Prosjektgruppen er ikke informert om noe hemmelighold angående prosjektet.
- Prosjektgruppen følger standardavtalen som sier at rapportering skjer hver andre uke, når møteinnkalling gjøres.

4.3 Gruppenormer – samarbeidsregler – holdninger

- Alle skal møte i rett tid.
- Medlemmene skal behandles med respekt
- Det er fokus på pålitelighet og samarbeid
- Sikkerhet er høyeste prioritet
- Brukerne skal benytte korrekt verneutstyr og ta nødvendige forholdsregler når endringer gjøres i/på kontrollskapet og/eller robotarmene. Dette gjelder også ved bruk av annet verktøy.

Prosjektgruppen ønsker å ha et høyt nivå av profesjonalitet og utøve dette ovenfor alle interessenter. Gruppen ønsker å presentere seg selv som pålitelige, hardtarbeidende og ærlige. Disse holdningene håper gruppen å utstråle gjennom hele prosjektets varighet.

5 PROSJEKTBEKRIVELSE

5.1 Problemstilling - målsetting - hensikt

5.1.1 Problemstilling

Oppgaven utdelt fra Rolls Royce omhandler å automatisere monteringen av et propellhode. Propellhodet består av flere komponenter med ulik utforming. Monteringen av dette propellhodet foregår i dag for hånd, men det er nå aktuelt å undersøke om det er hensiktsmessig å automatisere denne prosessen. Det er dette gruppen skal forsøke å gjennomføre og evaluere.

5.1.2 Hovedmål

Automatisere monteringsprosessen av et propellhode ved hjelp av to robotarmer. Løsningen må være effektiv og skalerbar.

5.1.3 Delmål

- Utvikle monteringsbase og gripeverktøy.
- Designe et kommunikasjonssystem mellom robotarmer, PLS og datamaskin.
- Programmere monteringssekvens.
- Designe brukergrensesnitt.
- Ferdigstille prosjektet.
- Dokumentere/rapportere funn og utviklingsprosess.

5.1.4 Effektmål

Ved vellykket prosjektgjennomføring vil arbeidsgiver kunne oppnå økt sikkerhet, tidsbesparing, kostnadssparing på lang sikt og øke effektivitet.

5.1.5 Resultatmål

Prosjektet skal monne ut i et automatisert system som er klart til bruk.

Prosjektgruppen skal levere designløsninger på monteringsverktøy, gripeverktøy og eventuelle modifikasjoner på komponenter. Designene skal være gode løsninger og de må være skalerbare.

5.1.6 Prosessmål

Prosjektgruppen vil gjennom dette prosjektet utvikle sine kunnskaper innen prosjektering, 3D modellering og visualisering, programmering, produktdesign og prosjektplanlegging.

5.2 Krav til løsning eller prosjektresultat – spesifikasjon

Løsningen må være skalerbar. Monteringen i dette prosjektet foregår på det minste propellhode Rolls Royce leveres per i dag. Automatiseringen må kunne foregå like godt på små modeller som på store. Løsningen må også være sikker og pålitelig i en industriell sammenheng.

Prosjektet er fullført når prosjektgruppen har kommet til en fornuftig måte å automatisere monteringsprosessen på. Arbeidet må også dokumenteres og løsninger må beskrives godt. Dette gjelder også tegninger og spesifikasjoner på gripeverktøy og eventuelt andre verktøy som skal brukes til monteringen.

5.3 Planlagt framgangsmåte(r) for utviklingsarbeidet – metode(r)

I prosjektstyringen formuleres det først mål som danner grunnlaget for planlegging. Dette innebærer gjennomføring, omfang og tid (se Gantt-diagram). Disse målene gjennomføres og deretter vurderes/følges opp.

Prosjektet ansees som et forsknings- og utviklingsprosjekt der det ikke er klart om målet er mulig å nå eller ikke. Prosjektet er noe dynamisk og det endelige målet/resultatet er ikke gitt.

Systemutviklingsmetoden som prosjektgruppen benytter er «prototyp»-modellen. I denne modellen lages en midlertidig versjon av produktet, deretter design, kode og testing. Fordelen med denne modellen er at både bruker og designere får prøve ut funksjonene og deretter endre programmet som nødvendig. Dette gir en god tilbakemelding fra brukere slik at designere og kodere kan jobbe fra det brukerne ønsker. Ulempen er at det kreves god planlegging, god kommunikasjon og store designendringer kan være vanskelig å få til.

5.4 Informasjonsinnsamling – utført og planlagt

Robotsystemet som skal brukes til dette prosjektet er ett oppsatt og komplett system for styring av to robotarmer. Det foreligger dokumentasjon i form av manualer som beskriver hvordan robotarmene skal programmeres og opereres. I tillegg til dette foreligger det også systemløsninger og rapporter fra tidligere Bacheloroppgaver.

Videre kan informasjon hentes fra pålitelige kilder på internett eller i bøker. Oppdragsgiver og veileder er også gode kilder for pålitelig informasjon.

5.5 Vurdering – analyse av risiko

Det er flere risikoelementer med mulig fatal utgang. Derfor må gruppen ha klare retningslinjer derom noen av tilfellene oppstår.

5.5.1 Tap av gruppemedlem/styringsgruppe

Tap av gruppemedlem regnes som usannsynlig, men klare retningslinjer er opprettet. Under tap av gruppemedlem regnes:

- Splid mellom gruppemedlemmene hvor en eller flere av gruppemedlemmene ikke lenger er aktiv/melder seg ut av samarbeidet. I dette tilfellet må styringsgruppen kontaktes og prosjektet må innsnevres slik at arbeidsmengden er overkommelig.
- Sykdom/uføre. Ved kortvarig sykdom (1 uke eller mindre). De andre gruppemedlemmene må gjøre sitt ytterste for å dekke den sykmeldtes oppgaver, og ha tett dialog sammen. Ved sykdom mellom 1 til 2 uker, må gruppen omorganisere de utdelte oppgavene.

Ved dødsfall/ langtidsvarig sykdom (2 uker eller mer) må styringsgruppen kontaktes og prosjektets mål må vurderes omdefinert slik at de gjenværende gruppe-medlemmene har mulighet til å utføre prosjektet.

Ved tap/ langvarig utilgjengelighet av medlem i styringsgruppe, må respektive organisasjon kontaktes slik at vedkommende kan erstattes.

5.5.2 Tap av utstyr

Tap av utstyr kan forekomme i store deler av prosjektet. Dette gjelder alt fra PC til robotarmer. Under tap av utstyr regnes det med at utstyret ikke lenger kan brukes eller ikke er forsvarlig å bruke i dets nåværende tilstand. Bestillinger som ikke leveres, regnes også som «tap». Dersom utstyr skades eller det oppstår funksjonsfeil, må tilstrekkelige handlinger utføres. Handlingene varierer etter alvorligheten på utstyret.

Enkle skader eller komponentfeil som ikke regnes som kritiske for prosjektet, skal forsøkes erstattet/repasert, men kun i en kort stund slik at prosjektets fremdriftsplan ikke forskyves.

Ved skader eller komponentfeil som regnes som kritiske for prosjektets utførelse, skal styringsgruppen kontaktes umiddelbart og løsning utrettes. Dersom utstyret ikke kan repareres eller erstattes, må prosjektets mål omdefineres slik at prosjektgruppen kan best mulig oppnå det nye målet og samtidig jobbe effektivt ut prosjektperioden.

5.5.3 Tap av data

Gruppen jobber via skyløsningen «Dropbox». Dropbox lagrer alt på sine egne servere, men samtidig lagres dette lokalt på hver datamaskin. Tap av data regnes derfor ikke som en alvorlig risiko. Dersom mot all formodning at tap av data skulle skje, lagrer Dropbox slettet data i 30 dager. Dette kan da gjenopprettes.

5.6 Hovedaktiviteter i videre arbeid

Nr	Hovedaktivitet	Ansvar	Kostnad	Tid/omfang
A1	Robotkontroll			
A1.1	Robotkontroll fase 1.	Benjamin		4 uker
A1.2	Robotkontroll fase 2.	Steffen		5 uker
A3	Komponent konstruksjon	Steffen/Benjamin		4 uker
A4	Software	Øyvind		4 måneder
A5	Møter	Øyvind		Periodisk

Se vedlegg 1. Gantt Diagram for detaljerte aktiviteter.

5.7 Framdriftsplan – styring av prosjektet

5.7.1 Hovedplan

Listen under punkt 5.6 viser hvilke hovedaktiviteter som er lagt opp i prosjektet. Den første hovedaktiviteten vil inneholde 2 faser. Den første hovedaktiviteten (A1) deles inn i to faser. Fase A1.1 og A1.2. I den første fasen (A1.1) vil det settes fokus på å bli kjent med hvordan robotarmene styres. Dette innebærer kommunikasjon mellom PC, PLS og kontrollere, samt laging og kjøring av jobber. Fase 2 (A1.2) setter fokuset mot å lage de nødvendige jobbene som skal til for å utføre monteringssekvensen. Det skal også lages en form for brukergrensesnitt som jobbene kan kjøres fra. Den andre hovedaktiviteten (A2) inneholder alt av design og konstruksjon av gripeverktøy og eventuelt andre verktøy som skal brukes i monteringsprosessen. Her kommer også testing og ferdigstilling av verktøy inn som en sentral del.

I den tredje hovedaktiviteten (A3) kommer programvare inn. Dette omhandler alt i fra brukergrensesnitt (GUI) til visualisering.

Fjerde hovedaktivitet (A4) omhandler møter mellom prosjektgruppen og styringsgruppen.

5.7.2 Styringshjelpemidler

I dette prosjektet vil Gantt-diagram bli brukt som ett styringshjelpemiddel. I ett slikt diagram kan man legge inn aktiviteter, tidsbruk, arbeidsfordeling, ansvar osv. Milepæler kan også settes inn. Dette dokumentet skal oppdateres i henhold til gruppens progresjon.

5.7.3 Utviklingshjelpemidler

Til dette prosjektet trengs flere utviklingshjelpemidler. Alt i fra IDE for programmering til prosjektplanleggings-verktøy. Følgende hjelpemidler ansees som aktuelle:

- Codesys
- Netbeans IDE
- Solidworks
- Microsoft Word
- Microsoft Project
- Advanced Serialport Monitor

5.7.4 Intern kontroll – evaluering

Hvert enkelt medlem har selv ansvar for å gjennomføre oppgavene sine. Disse oppgavene vil igjen bli vurdert ved hver framdriftsrapport. Eventuelle avvik vil oppdages da.

Et delmål er oppnådd når beskrivelsen av målet med nødvendig dokumentasjon er utført. Ett hovedmål er oppnådd når alle delmålene fram mot dette hovedmålet er oppnådd.

5.8 Beslutninger – beslutningsprosess

Det er prosjektgruppen i samarbeid med styringsgruppen som har valgt den foreslåtte oppgaven fra Rolls Royce.

Ved mindre avgjørelser som ansvarsfordeling, tidsplanlegging osv., kan prosjektgruppen ta på egen hånd. Store avgjørelser som endringer i endelig mål og andre spørsmål som vil endre utfallet av prosjektet må utføres i lag med styringsgruppen.

6 DOKUMENTASJON

6.1 Rapporter og tekniske dokumenter

I tillegg til denne forprosjektrapporten skal det lages framdriftsrapporter før hvert møte med styringsgruppen. Disse skal revidere oppgavene som var planlagt for den innværende perioden og vise oppgaver for den neste perioden. Ved hjelp av slike rapporter vil gruppen klare å opprettholde planer og rutiner som er satt for prosjektet.

Det skal utarbeides en bachelor-rapport som inneholder nødvendig bakgrunns-teori, metoder for å oppnå målet, de utarbeidede resultatene, diskusjon om resultater og metoder, og en endelig konklusjon.

Det skal også utarbeides tekniske dokumenter som tegninger og spesifikasjoner av gripeverktøy og eventuelt andre verktøy som skal brukes.

7 PLANLAGTE MØTER OG RAPPORTER

7.1 Møter

7.1.1 Møter med styringsgruppen

Møter skal holdes ca. hver 14 dag med styringsgruppen såfremt gruppen har noe å rapportere/diskutere. Ved hendelser eller endringer som regnes som dramatiske, kan det kalles inn til ekstraordinært møte. Før møtene skal styringsgruppen ha tilsendt framdriftsrapport per epost for perioden siden sist møte. Det skal klart fremlegges agenda for møtet i samme epost.

7.1.2 Prosjektmøter

Gruppen sitter samlet i elektro-tunglab hver dag. I begynnelsen av hver arbeidsdag går gruppen gjennom arbeidsoppgavene til hvert enkelt medlem for dagen. I løpet av dagen noteres det i journalen hva som blir sagt og gjort. Ved slutten av arbeidsdagen oppsummeres journalen.

7.2 Periodiske rapporter

Gruppen skriver framdriftsrapport for hver 14-dag. Denne rapporten beskriver planlagte oppgaver, fullførte oppgaver, avvik og oppgaver for neste periode. Arbeidsjournal oppdateres hver dag.

8 PLANLAGT AVVIKSBEHANDLING

Dersom fremdriften ikke går som planlagt, skal prosjektgruppen samles for møte og revurdere fremdriftsplanen. Avhengig av problemets størrelse/art, må prosjektgruppen bestemme seg for å endre tidsfrister, velge vekk oppgaver, eller jobbe overtid. Overtid foretrekkes. Dersom drastiske endringer må gjøres, må prosjektgruppen og styringsgruppen være enige.

Det er opp til hvert enkelt gruppemedlem å styre sine respektive ansvarsområder. Det er også den ansvarliges oppgave å informere de andre medlemmene om eventuelle avvik og/eller tids-avvik.

9 UTSTYRSBEHOV/FORUTSETNINGER FOR GJENNOMFØRING

Se punkt 5.7.3.

Disse programmene ønsker vi å benytte eller tilsvarende programvare. Gruppen ønsker også et visualiseringsverktøy som kan benyttes til visualisering av monteringsprosessen

10 REFERANSER

[1] <http://www.rolls-royce.com/marine/about/index.jsp> - nedlastet 26.01.15, 11:46

[2] Dokument «Hovedprosjektet: retningslinjer for styring og rapportering», lagt ut av Ottar Osen under «meldinger» 13.1.2015 - nedlastet 19.1.2015, 08:30

VEDLEGG

Vedlegg 1

Gantt-diagram

Appendix C

Progress report 1

ID303612 Bacheloroppgave	Prosjekt Automatisert montering i småskalaproduksjon	Antall møter denne perioden Intern: 2 Veileder: 0 Styringsgruppe: 1	Firma - Oppdragsgiver Rolls Royce - Marine	Side 1 av 6
Rapport fra prosess Framdriftsrapport	Periode/uke(r) Uke 3	Antall timer denne perioden (ca). 49	Prosjektgruppe (navn) Benjamin Skinnes, Steffen Sunde og Øyvind Strømsheim	Dato 16.01.15

Framdriftsrapport Bacheloroppgave

Hovedhensikt / fokus for arbeidet i denne perioden

Kommunikasjon

Planlegging

Arbeidsfordeling

Planlagte aktiviteter i denne perioden

1. Rydde/ordne til arbeidsområdet
Beskrivelse: Rydde arbeidsområdet og lage system
Mål: Sørge for et rent og oversiktlig arbeidsområde
Deltakere: Øyvind
Ansvarlig: Øyvind
2. Koble til PLS og kommunisere
Beskrivelse: Koble til Wago PLS, kommunisere og sette I/O. Dette skal gjøres over ethernet kabel og via CoDeSys
Mål: Sørge for at enheten fungerer og kan brukes
Deltakere: Benjamin, Steffen og Øyvind
Ansvarlig: Øyvind
3. Styre robotarmene manuelt
Beskrivelse: Bruke pendanten til å styre begge robotarmene manuelt
Mål: Sørge for at manuell kontroll er mulig og at armene fungerer
Deltakere: Steffen og Øyvind
Ansvarlig: Steffen
4. Kalle på jobber
Beskrivelse: Bruke pendanten til å kalle på jobber som ligger lagret på pendanten
Mål: Lære hvordan «jobber» og kalling på disse fungerer
Deltakere: Steffen
Ansvarlig: Steffen
5. Kalibrering
Beskrivelse: Sørge for at begge robotarmene er kalibrert
Mål: Kalibrering av robotarmene skal være korrekt slik videre arbeid kan fortsette
Deltakere: Benjamin, Steffen og Øyvind
Ansvarlig: Benjamin
6. Kobling mellom PC og kontroller
Beskrivelse: Lage fysisk kobling mellom PC og kontroller
Mål: Dette steget må gjøres før vi kan kommunisere.
Deltakere: Benjamin og Øyvind

Ansvarlig: Benjamin

7. Kommunikasjon mellom PC og kontroller
Beskrivelse: Koble PC til kontroller og sende forespørsler, kalle på jobber og motta respons.
Mål: Sjekke om direkte kommunikasjon mellom PC og kontroller er mulig uten PLS som mellomledd.
Deltakere: Benjamin, Steffen og Øyvind
Ansvarlig: Benjamin og Steffen

8. Motta propellhode og undersøke montering
Beskrivelse: Arild skal levere propellhode og vise oss monteringen
Mål: Lære hvordan propellhodet er konstruert, og hvordan det monteres
Deltakere: Arild, Benjamin, Steffen, Øyvind
Ansvarlig: Arild

9. Gripeverktøy til propellhode
Beskrivelse: Undersøke hvilke gripemuligheter vi har, eller må konstruere for å kunne håndtere propellhode-komponenter.
Mål: Få et overordnet blick på hva vi må konstruere og hvordan slik vi kan effektivt håndtere komponenter.
Deltakere: Benjamin, Steffen, Øyvind
Ansvarlig: Benjamin

10. Gantt diagram
Beskrivelse: Opprette Gantt diagram for videre planlegging
Mål: Få et overordnet blick over hva som må gjøres fremover
Deltakere: Benjamin og Øyvind
Ansvarlig: Øyvind

11. Dropbox-mappe
Beskrivelse: Dropbox-mappe og arkivsystem må opprettes. Alle medlemmer og interessenter må få tilgang.
Mål: Opprette et felles filarkiv som alle har tilgang til.
Deltakere: Steffen
Ansvarlig: Steffen

Virkelig gjennomførte aktiviteter i denne perioden

Planlagte:

1. Rydde/ordne til arbeidsområdet
Bemerkninger:

2. Koble til PLS og kommunisere
Bemerkninger: Kommunikasjon via CodeSys ble ikke gjennomført. Kommunikasjon via ethernet via Netbeans og Jamod ble istedenfor fullført.

3. Styre robotarmene manuelt

Bemerkninger:

4. Kalle på jobber

Bemerkninger:

5. Kalibrering

Bemerkninger: Den tidligere gruppen fortalte oss at robotarmene er kalibrert. Dette ble ikke videre undersøkt.

6. Kobling mellom PC og kontroller

Bemerkninger: Koblet fra PC via USB -> RS232 -> Kontroller.
Ny kabel måtte loddes.

7. Kommunikasjon mellom PC og kontroller

Bemerkninger: Kommunikasjon ble forsøkt gjennom koblingen med programmet «Advanced Serial port monitor». Det kom respons fra kontrolleren, men den svarer ikke på «enq»-meldingene som ble sendt. **Ikke fullført**

8. Motta propellhode og undersøke montering

Bemerkninger: Propellhode ble ikke levert. **Ikke fullført**

9. Gripeverktøy til propellhode

Bemerkninger: Propellhode ble ikke levert. **Ikke fullført**

10. Gantt diagram

Bemerkninger: Midlertidig Gantt diagram er påbegynt, men venter på programvare fra Max Mork i faget «Ingeniørfaglig systemteknikk og systemutvikling». **Ikke fullført**

11. Dropbox-mappe

Bemerkninger:

Ikke-planlagte:

1. Kontormateriell - Skjermer

Bemerkninger: For å få full utnyttelse av arbeidsområdet og forbedre effektivitet. Anders Sætersmoen og Kjell Inge Tomren er kontaktet og vi venter svar. Foreløpig tilbakemeldinger er positive. **Ikke fullført**

Beskrivelse av/begrunnelse for eventuelle avvik mellom planlagte og virkelige aktiviteter

Se bemerkninger under de respektive aktivitetene.

Beskrivelse av /begrunnelse for endringer som nå ønskes i selve prosjektets innhold eller i den videre framgangsmåten - eller framdriftsplanen

Det ønskes ikke å bruke PLS'en, men å benytte RS 323-kanalen til kontrolleren. PLS'en kan eventuelt brukes til å styre gripeverktøyene, men det er foretrukket å bruke eventuelle relé som er integrert i kontrolleren dersom de eksisterer.

Hovederfaring fra denne perioden

Gruppen har kjennskap til robotarmene, hvordan de fungerer og styres. Det ønskes å bruke Java til styringen og bildebehandlingen i prosjektet. Hvordan kommunikasjonen skal foregå er under vurdering og undersøkelse.

Hovedhensikt/fokus neste periode

1. Kommunikasjonen skal være i orden.
Ansvarlig:
2. Designe og konstruere gripeverktøy.
Ansvarlig:
3. Kunne kalle på jobber via ekstern PC (helst Java).
Ansvarlig:
4. Designe og konstruere evt jig til propellhodet.
Ansvarlig:
5. Lage fullstendig Gantt-diagram.
Ansvarlig:
6. Opprette evt bildebehandlingsprogram
Ansvarlig:

Planlagte aktiviteter neste periode

1. Kommunikasjon mellom PC og kontroller
Beskrivelse: Koble PC til kontroller og få kontroller til å respondere på «enq»-meldinger
Mål: Sjekke om direkte kommunikasjon er mulig.
Deltakere: Benjamin, Steffen og Øyvind
Ansvarlig: Benjamin og Øyvind
2. Kalle på jobber fra PC
Beskrivelse: Videre arbeid fra oppgave 1. Etter kommunikasjon er opprettet, skal en jobb som ligger lokalt på pendanten utføres.
Mål: Sørge for at det er mulig å kalle på jobber fra ekstern PC
Deltakere: Benjamin, Steffen og Øyvind
Ansvarlig: Benjamin og Øyvind
3. Hente posisjonsdata fra pendant
Beskrivelse: For å kunne visualisere robotarmene, trenger vi posisjonsdata fra enkoderene. Det må undersøkes om det er mulig å hente slik data, og eventuelt hvordan den skal overføres til PC og Java.
Mål: Undersøke mulighetene for visualisering
Deltakere: Benjamin, Steffen, Øyvind

Ansvarlig: Benjamin

4. Motta propellhode og undersøke montering
Beskrivelse: Videre gjennomføring fra forrige periode. Arild skal levere propellhode og vise oss monteringen
Mål: Lære hvordan propellhodet er konstruert, og hvordan det monteres
Deltakere: Arild, Benjamin, Steffen, Øyvind
Ansvarlig: Arild
5. Gripeverktøy til propellhode
Beskrivelse: Videre gjennomføring fra forrige periode. Undersøke hvilke gripemuligheter vi har, eller må konstruere for å kunne håndtere propellhode-komponenter.
Mål: Få et overordnet blikk på hva vi må konstruere og hvordan slik vi kan effektivt håndtere komponenter.
Deltakere: Benjamin, Steffen og Øyvind
Ansvarlig: Benjamin(Mekanisk) og Steffen(3D)
6. Konstruere jig
Beskrivelse: Dersom propellhodet må stå på en jig, må denne designes og konstrueres.
Mål: Opprette en stabil arbeidsplattform for montering.
Deltakere: Benjamin, Steffen og Øyvind
Ansvarlig: Benjamin(Mekanisk) og Steffen(3D)
7. Gantt diagram
Beskrivelse: Videre gjennomføring fra forrige periode. Opprette Gantt diagram for videre planlegging
Mål: Få et overordnet blikk over hva som må gjøres fremover
Deltakere: Benjamin og Øyvind
Ansvarlig: Øyvind
8. Bildebehandling
Beskrivelse: Opprette grunnlaget for et bildebehandlingsprogram i Java og OpenCV
Mål: Kunne prosessere bilder og returnere relevant informasjon
Deltakere: Øyvind
Ansvarlig: Øyvind
9. Rydding av elektriske skap
Beskrivelse: De elektriske skapene er rotete med mange tvilsomme koblinger. Dette bør rettes opp i slik at arbeidsområdet blir rent og vi er sikre på at koblingene er korrekte.
Mål: Opprette system og et trivelig arbeidsmiljø.
Deltakere: Øyvind
Ansvarlig: Steffen
10. GUI / Brukergrensesnitt
Beskrivelse: Opprette brukergrensesnitt med hjelp av trykkfølsom skjerm evt på PC.
Mål: Gi brukeren en enkel måte å overvåke og styre prosessen.

Deltakere: Øyvind Ansvarlig: Øyvind	
Annet Gruppetdynamikken fungerer. Gruppen føler at den er godt i gang og ser både utfordringer og potensial i oppgaven.	
Ønske om /behov for veiledning, tema i undervisningen – drøfting ellers Dersom kommunikasjonen ikke opprettes kunne gruppen tenkt seg å forhøre med Ottar ang temaet. Gruppen ønsker programvare for 3D-modellering. Helst SolidWorks. Gruppen lurert på om det virkelig er nødvendig å skrive 10 oppgaver som skal jobbes med. Dette virker i overkant mye. Ønsker koblingsskjema over hele systemet.	
Godkjenning/signatur gruppeleder Benjamin	Signatur øvrige gruppedeltakere Steffen, Øyvinds

Appendix D

Progress report 2

ID303612 Bachelor	Project Automated small scale assembly.	Meetings this period Internally: 3 Council: 1 Management:	Firm Rolls Royce - Marine	Page 1 of 6
Type Progress report	Period Week 3-6	Working hours this period: 250	Project group Benjamin Skinnes, Steffen Sunde og Øyvind Strømsheim	Date 05.02.15

Focus for this period.

Communication
Planning
Design
Construction

Planned activities this period

1. Communication between PC and Controller.
Description: Connect PC to Controller and make controller respond to "ENQ"-messages.
Goal: See if direct communication is possible.
Participants: Benjamin, Steffen and Øyvind
Responsible: Benjamin and Øyvind

2. Call jobs from PC
Description: Extension of activity 1. Execute a job located on the pendant.
Goal: Make sure that it is possible to call jobs from external PC
Participants: Benjamin, Steffen and Øyvind
Responsible: Benjamin and Øyvind.

3. Retrieve position data from the pendant.
Description: To be able to visualize the robot arms, we need position data from the robot arms. This must then be extracted to a PC.
Goal: See if visualization is possible.
Participants: Benjamin, Steffen, Øyvind
Responsible: Benjamin.

4. Receive propeller head and learn assembly.
Description: Task from last period.
Goal: Learn how the propeller head is constructed and assembled.
Participants: Arild, Benjamin, Steffen and Øyvind
Responsible: Benjamin

5. Grippers for propeller head
Description: Task from last period. Check what grippers we must develop to handle the propeller head components.
Goal: Get an overall look of what we need to construct so that we can effectively handle components.
Participants: Benjamin, Steffen and Øyvind
Responsible: Benjamin(Mechanical) and Steffen(3D drawing)

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Type Progress report	Period Week 3-6	Working hours this period: 250	Project group Benjamin Skennes, Steffen Sunde og Øyvind Strømsheim	Date 05.02.15

6. Construct jig.

Description: If the propeller head must be mounted on a jig, the jig must be designed and constructed.

Goal: Have a stabile working platform for mounting.

Participants: Benjamin, Steffen and Øyvind

Responsible: Benjamin(Mechanical) and Steffen(3D drawing)

7. Gantt diagram

Description: Task from last period. Create Gantt diagram for planning work.

Goal: Get an overall look on the tasks required for the project.

Participants: Benjamin and Øyvind

Responsible: Øyvind

8. Image processing

Description: Create a basic interface for image processing in Java and OpenCV (if needed)

Goal: Be able to process pictures and return relevant data.

Participants: Benjamin and Øyvind

Responsible: Øyvind

9. Clear the electrical cabinet.

Description: The electrical cabinet is quite messy. It should be cleaned and checked for faulty wiring.

Goal: Establish system and a good work-environment.

Participants: Øyvind

Responsible: Steffen

10. GUI

Description: Create GUI via Java or a pressure-sensitive screen.

Goal: Give the user a simple way to monitor and control the process.

Participants: Øyvind

Responsible: Øyvind

Actual finished activities this period.

Planned:

1. Communication between PC and Controller.

Notes: **Completed.** Established via PC-PLC-Controller.

2. Call jobs from PC.

Notes: **Completed.** Called via Codesys/PLC. Also controlled “start”, “hold”, servo power, etc.

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Type Progress report	Period Week 3-6	Working hours this period: 250	Project group Benjamin Skinnen, Steffen Sunde og Øyvind Strømsheim	Date 05.02.15

3. Retrieve position data from the pendant.
Notes: **Completed.** Retrieved and displayed in CodeSys
4. Receive propeller head and learn assembly.
Notes: **Completed.**
5. Grippers for propeller head
Notes: **Under way.** Grippers are almost completely designed and prototyped by 3D-printer.
6. Construct jig.
Notes: **Under way.**
7. Gantt diagram
Notes: **Completed.**
8. Image processing
Notes: **Dropped.** Currently no need for image processing.
9. Clear the electrical cabinet.
Notes: **Under way.** Partially completed. Efforts were focused at designing and constructing grippers/jigs.
10. GUI
Notes: **Under way.** Currently have a simple GUI in Codesys. Would like to use Java later.

Not-planned

1. Created own job
Notes: Created own job using the pendant. Both circular and linear motion. Tool stabilization was also activated. Speed was shifted.
2. Assembled disk.
Notes: By using a makeshift gripper, a job was created which held one part and fitted it directly into the propeller head.
3. Jig for holding components.
Notes: Jigs for holding different components were designed. Not yet 3D-modeled or prototyped.
4. Reduction valve.
Notes: Fitted a pressure-reduction valve on the robots air-supply. This is to be able to regulate the maximum pressure.

Deviation

See "notes" under the activities.

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Type Progress report	Period Week 3-6	Working hours this period: 250	Project group Benjamin Skinnes, Steffen Sunde og Øyvind Strømsheim	Date 05.02.15

Description of changes which changes the projects contents or procedure.

Together with Ottar, it was decided to use the PLC for running the logic. The PLC is robust and safe.
The PC can run image processing, GUI, etc..

Experience from this period

The group has an overview of what is to come and the different tasks required to reach the end goal.
The group has designed necessary equipment and is working on prototyping. The estimated time for design and construction may be underestimated.
The group has more understanding of, 3D-drawing works, robot control and project planning.

Focus next period

1. Job creation and control.
Responsible: Benjamin
2. Design, construction and testing
Responsible: Steffen
3. GUI
Responsible: Øyvind

Planned activities next period

1. Design gripper 1
Description: Finish 3D model.
Goal: Make a model which can be prototyped
Participants: Steffen
Responsible: Steffen
2. Construct gripper 1
Description: Construct gripper 1 prototype. If design is ok, construct version 1.
Goal: Check if design is usable
Participants: Benjamin, Steffen and Øyvind
Responsible: Steffen
3. Test gripper 1
Description: Testing of the grippers on the components.
Goal: See if the gripper is usable and fulfills requirements regarding strength and versatility.
Participants: Benjamin and Steffen
Responsible: Benjamin

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Type Progress report	Period Week 3-6	Working hours this period: 250	Project group Benjamin Skinnes, Steffen Sunde og Øyvind Strømsheim	Date 05.02.15

4. Design gripper 2
Description: Design gripper 2 in 3D
Goal: Make a model which can be prototyped.
Participants: Steffen
Responsible: Steffen
5. Construct gripper 2
Description: Construct gripper 2 prototype. If design is ok, construct version 1.
Goal: Check if design is usable
Participants: Benjamin, Steffen and Øyvind
Responsible: Steffen
6. Test gripper 2
Description: Testing of the grippers on the components.
Goal: See if the gripper is usable and fulfills requirements regarding strength and versatility.
Participants: Benjamin and Steffen
Responsible: Benjamin
7. Design jig(s)
Description: Draw the jig which the components are placed upon.
Goal: Design a jig that works for all components which both the robot arms can reach.
Participants: Steffen and Øyvind
Responsible: Øyvind
8. Construct jig(s)
Description: Construct jig prototype. If design is ok, construct version 1.
Goal: Check if design is usable
Participants: Benjamin, Steffen and Øyvind
Responsible: Steffen
9. Test jig(s)
Description:
Goal: See if the jig is usable and fulfills requirements regarding strength and versatility.
Participants: Benjamin and Steffen
Responsible: Benjamin
10. Create jobs for testing grippers
Description: Creation of jobs required for testing gripper- and jig- strength and precision.
Goal: With the help of these jobs, it will be clear if the designs are usable or not.
Participants: Benjamin and Øyvind
Responsible: Benjamin

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Type Progress report	Period Week 3-6	Working hours this period: 250	Project group Benjamin Skinnes, Steffen Sunde og Øyvind Strømsheim	Date 05.02.15

11. Design and program simple GUI

Description: Design, program and test a GUI using Java and make sure it can call jobs via PLC.

Goal: Make controls for the process

Participants: Øyvind

Responsible: Øyvind

12. Research-trip to Sperre Industries

Description: Øyvind has a contact at Sperre Industries. They have invited the group to take a look at their robotic-cell.

Goal: See for design solutions and inspiration.

Participants: Benjamin, Steffen and Øyvind

Responsible: Øyvind

Div.

The group has reached some milestones and is pleased with their progress.

The group is eager to start the assembly of the propeller head.

Need/wish for council, teaching, etc.

The group wants the schematics for the different components. This will make it easier for drawing. The group wants approval/input from Arild on concepts and drawings of the grippers, jigs and modification on components.

Approval, group leader

Benjamin

Approval of other members

Steffen, Øyvind

Appendix E

Progress report 3

ID303612 Bachelor	Project Automated small scale assembly.	Meetings this period Internally: 2 Council: 1 Management: 1	Firm Rolls Royce - Marine	Page 1 of 6
Type Progress report	Period Week 6-10	Working hours this period: 160	Project group Benjamin Skinnen, Steffen Sunde og Øyvind Strømsheim	Date 05.02.15

Focus for this period.

Job creation and control
Grippers, holders, design, 3D printing, construction, testing
Using laser as range sensor
Visualization/Simulation

Planned activities this period

1. Design gripper 1
Description: Finish 3D model.
Goal: Make a model which can be prototyped
Participants: Steffen
Responsible: Steffen

2. Construct gripper 1
Description: Construct gripper 1 prototype. If design is ok, construct version 1.
Goal: Check if design is usable
Participants: Benjamin, Steffen and Øyvind
Responsible: Steffen

3. Test gripper 1
Description: Testing of the grippers on the components.
Goal: See if the gripper is usable and fulfills requirements regarding strength and versatility.
Participants: Benjamin and Steffen
Responsible: Benjamin

4. Design gripper 2
Description: Design gripper 2 in 3D
Goal: Make a model which can be prototyped.
Participants: Steffen
Responsible: Steffen

5. Construct gripper 2
Description: Construct gripper 2 prototype. If design is ok, construct version 1.
Goal: Check if design is usable
Participants: Benjamin, Steffen and Øyvind
Responsible: Steffen

6. Test gripper 2
Description: Testing of the grippers on the components.
Goal: See if the gripper is usable and fulfills requirements regarding strength and versatility.
Participants: Benjamin and Steffen

Responsible: Benjamin

7. Design jig(s)

Description: Draw the jig which the components are placed upon.

Goal: Design a jig that works for all components which both the robot arms can reach.

Participants: Steffen and Øyvind

Responsible: Øyvind

8. Construct jig(s)

Description: Construct jig prototype. If design is ok, construct version 1.

Goal: Check if design is usable

Participants: Benjamin, Steffen and Øyvind

Responsible: Steffen

9. Test jig(s)

Description:

Goal: See if the jig is usable and fulfills requirements regarding strength and versatility.

Participants: Benjamin and Steffen

Responsible: Benjamin

10. Create jobs for testing grippers

Description: Creation of jobs required for testing gripper- and jig- strength and precision.

Goal: With the help of these jobs, it will be clear if the designs are usable or not.

Participants: Benjamin and Øyvind

Responsible: Benjamin

11. Design and program simple GUI

Description: Design, program and test a GUI using Java and make sure it can call jobs via PLC.

Goal: Make controls for the process

Participants: Øyvind

Responsible: Øyvind

12. Research-trip to Sperre Industries

Description: Øyvind has a contact at Sperre Industries. They have invited the group to take a look at their robotic-cell.

Goal: See for design solutions and inspiration.

Participants: Benjamin, Steffen and Øyvind

Responsible: Øyvind

Actual finished activities this period.

Planned:

1. Design gripper 1

Notes: **Completed.**

2. Construct gripper 1

Notes: **Completed.**

3. Test gripper 1
Notes: **Completed.** Need a small modification
4. Design gripper 2
Notes: **Completed**
5. Construct gripper 2
Notes: **Completed**
6. Test gripper 2
Notes: **Completed.** Need a small modification on center of gravity and wedge.
7. Design jig(s)
Notes: **Completed**
8. Construct jig(s)
Notes: **Completed**
9. Test jig(s)
Notes: **Completed**
10. Create jobs for testing grippers
Notes: **Progressing.**
11. Design and program simple GUI
Notes: **Completed**
12. Research-trip to Sperre Industries
Notes: **Completed.**

Not-planned

13. Using laser
Notes: Mounted a laser on the wall to see if it is suitable for controlling whether the disks are flat on the gripper surface or not. Also mounted a laser on the ceiling to see if the piston has dropped or not, and find its orientation.
14. Interview with Aftenposten
Notes: Aftenposten and NTNU-entourage came to see our project and interview us about the HIALS/NTNU fusion. They were very impressed. We showed them the car-simulator as well.
15. Discovered a malfunction with the 3D printer
Notes: Had to invest a lot of time to calibrate and investigate the errors.

Deviation

See “notes” under the activities.

Description of changes which changes the projects contents or procedure.

- Using lasers that can detect distance to an object are being used for detecting whether the parts are correctly mounted on the gripper tool or if the parts are mounted on the gripper at all.
- Also using a laser for determining how far the piston has gone into the propeller head. Also finding the orientation of the piston.
- Decided to use an additional tool which the pneumatic gripper tool can lock on to. This tool will turn the thruster disks to let the piston drop into the propeller head.

Experience from this period

- 3D modelling and 3D printing are very important before the actual construction. This helps reduce time in workshop and cuts the material-costs.
- From one job on the pendant, it is possible to call additional jobs within that job. This allows parallel control.
- The robots can be shut down if the momentum exceeds a set threshold.
- Laser signal is more stable using 0-10V than 4-20mA. Got even better results using a function from the OScat-library for Codesys called "ArrayMean" which is a mean filter.

Focus next period

1. Job creation.
Responsible: Steffen
2. Control via Codesys
Responsible: Benjamin
3. Visualization
Responsible: Øyvind

Planned activities next period

1. Job creation for disks
Description: Create all the jobs necessary for assembly
Goal: Make the assembly smooth and without any faults
Participants: Benjamin and Steffen
Responsible: Steffen
2. Job creation for bearings
Description: Create all the jobs necessary for assembly
Goal: Make the assembly smooth and without any faults
Participants: Benjamin and Steffen
Responsible: Steffen
3. Job creation for piston

Description: Create all the jobs necessary for assembly
Goal: Make the assembly smooth and without any faults
Participants: Benjamin and Steffen
Responsible: Steffen

4. Bearing-processing

Description: Mill a trace in all the bearings and check for equilibrium
Goal: Reach equilibrium in weight. So that the bearings won't turn when assembled.
And lock the bearing in place when it is gripped.
Participants: Benjamin, Steffen and Øyvind
Responsible: Benjamin

5. Pneumatic gripper-modification

Description: Modify the tool by sanding down the materia. And welding a wedge on it.
Goal: Get a secure and good fit
Participants: Benjamin
Responsible: Benjamin

6. Esthetics

Description: Paint the gripper tools and the jig
Goal: Make the parts look good and give the grippers rust-protection
Participants: Benjamin and Øyvind
Responsible: Øyvind

7. Warning LED

Description: Mount warning-LEDs on the magnet-gripper tool
Goal: Make the user aware when the magnet is activated
Participants: Øyvind
Responsible: Øyvind

8. Check reliability for using laser

Description: Decide if the lasers are suitable for quality control
Goal: Develop a system/mechanism for quality control
Participants: Benjamin and Steffen
Responsible: Benjamin

9. Tool 3

Description: Finish turning tool for the pneumatic gripper and construct jig/holder
Goal: Use the gripper to turn disks
Participants: Benjamin and Steffen
Responsible: Steffen

10. Visualization

Description: Keep working on visualization and server/client communication with python and Blender

Goal: Give the user/observer an overview of the process
Participants: Øyvind
Responsible: Øyvind

11. CAD drawings of robots

Description: Try to get a hold of 3D models of the robots.
Goal: To get 3D models so we won't have to draw them ourselves.
Participants: Steffen and Øyvind
Responsible: Øyvind

Div.

- The group has reached some milestones and is pleased with their progress.
- The group scheduled end of project to be in the end of April. The supervisor for automation, Rekdalsbakken has sent a message saying the project must be completed by the end of May. This leads to some rescheduling.

Need/wish for council, teaching, etc.

The group wants more information about power-cells and the possibility for using/buying a pressure-switch.

Approval, group leader

Benjamin

Approval of other members

Steffen, Øyvind

Appendix F

Progress report 4

ID303612 Bachelor	Project Automated small scale assembly.	Meetings this period Internally: 2 Council: 1 Management:	Firm Rolls Royce - Marine	Page 1 of 5
Type Progress report	Period Week 11-15	Working hours this period: 160	Project group Benjamin Skinnen, Steffen Sunde og Øyvind Strømsheim	Date 10.04.15

Focus for this period.

Job creation
Control via Codesys
Visualization

Planned activities this period

1. Job creation for disks
Description: Create all the jobs necessary for assembly
Goal: Make the assembly smooth and without any faults
Participants: Benjamin and Steffen
Responsible: Steffen

2. Job creation for bearings
Description: Create all the jobs necessary for assembly
Goal: Make the assembly smooth and without any faults
Participants: Benjamin and Steffen
Responsible: Steffen

3. Job creation for piston
Description: Create all the jobs necessary for assembly
Goal: Make the assembly smooth and without any faults
Participants: Benjamin and Steffen
Responsible: Steffen

4. Bearing-processing
Description: Mill a trace in all the bearings and check for equilibrium
Goal: Reach equilibrium in weight. So that the bearings won't turn when assembled.
And lock the bearing in place when it is gripped.
Participants: Benjamin, Steffen and Øyvind
Responsible: Benjamin

5. Pneumatic gripper-modification
Description: Modify the tool by sanding down the materia. And welding a wedge on it.
Goal: Get a secure and good fit
Participants: Benjamin
Responsible: Benjamin

6. Esthetics
Description: Paint the gripper tools and the jig
Goal: Make the parts look good and give the grippers rust-protection

Participants: Benjamin and Øyvind

Responsible: Øyvind

7. Warning LED

Description: Mount warning-LEDs on the magnet-gripper tool

Goal: Make the user aware when the magnet is activated

Participants: Øyvind

Responsible: Øyvind

8. Check reliability for using laser

Description: Decide if the lasers are suitable for quality control

Goal: Develop a system/mechanism for quality control

Participants: Benjamin and Steffen

Responsible: Benjamin

9. Tool 3

Description: Finish turning tool for the pneumatic gripper and construct jig/holder

Goal: Use the gripper to turn disks

Participants: Benjamin and Steffen

Responsible: Steffen

10. Visualization

Description: Keep working on visualization and server/client communication with python and Blender

Goal: Give the user/observer an overview of the process

Participants: Øyvind

Responsible: Øyvind

11. CAD drawings of robots

Description: Try to get a hold of 3D models of the robots.

Goal: To get 3D models so we won't have to draw them ourselves.

Participants: Steffen and Øyvind

Responsible: Øyvind

1.

Actual finished activities this period.

Planned:

1. Job creation for disks

Notes: **Completed.**

2. Job creation for bearings

Notes: **Completed.**

3. Job creation for piston

Notes: **Progressing.** Not yet lowered the piston completely

4. Bearing-processing
Notes: **Completed.**
5. Pneumatic gripper-modification
Notes: **Completed.**
6. Esthetics
Notes: **Progressing.** The pneumatic tool has not yet been painted. Not yet completed due to broken work-station.
7. Warning LED
Notes: **Completed.**
8. Check reliability for using laser
Notes: **Completed.** Laser is used to see if parts are there when assembled
9. Tool 3
Notes: **Completed**
10. Visualization
Notes: **Progressing.** 3D models are completed. Animation will be saved as a movie file and played/paused via Java, not live via Blender/Python. Waiting for assembly to be optimized before animating process.
11. CAD drawings of robots
Notes: **Completed.** A contact at Motoman supplied a STL. This STL file was processed and the individual parts were extracted via Blender.

Not-planned

12. Job creation for turning the disks
Notes: The disks have to be turned for the piston to be lowered. **Progressing**
13. Job creation for lowering the piston
Notes: **Progressing**
14. Media player in java
Notes: **Progressing.** Be able to play the animation and listen for start/stop signals using Jamod
15. Replaced air-valve
Notes: **Completed.** During easter, an electric air-valve was malfunctioning.

Deviation

See “notes” under the activities.

Description of changes which changes the projects contents or procedure.

- Using laser to determine if parts are in place on the grippers, not flat on them.
- The animation will not be live, but played so that it seems like it is real time.

Experience from this period

- Laser is not very reliable on shiny objects, even with the use of median filters.

Focus next period

1. Optimization of jobs regarding speed and quality.
Responsible: Steffen
2. Lowering the piston into place
Responsible: Benjamin
3. GUI and CodeSys
Responsible: Benjamin
4. Visualization and playback timing
Responsible: Øyvind

Planned activities next period

1. Optimization
Description: Make the robots work as fast as possible, while still keeping the assembly success rate at 100%.
Goal: Have the lowest time possible for assembly.
Participants: Benjamin and Steffen
Responsible: Steffen
2. Lower the piston
Description: Lower the piston using logic in Codesys by the help of the laser.
Goal: Lower the piston so that the assembly is complete
Participants: Benjamin and Steffen
Responsible: Benjamin
3. GUI
Description: Polish the GUI so it looks good
Goal: Make an easy and reliable GUI
Participants: Benjamin
Responsible: Benjamin
4. CodeSys coding
Description: Finish the coding in CodeSys. Comments and readability.
Goal: Easy to read and further develop code
Participants: Benjamin
Responsible: Benjamin
5. Visualization
Description: Complete the movements and dependability in Blender

Goal: Complete movements in Blender

Participants: Øyvind

Responsible: Øyvind

6. Playback timing

Description: Code a java program for playing and stopping multimedia. Implement Jamod to know when to play/stop.

Goal: Be able to play the visualization in seemingly real time with the assembly

Participants: Øyvind

Responsible: Øyvind

Div.

- The group is pleased with their progress and are eager to finish the work by the end of the next period.
- The group has decided to finish the practical parts of the project by April. The project report and presentations will be finished in May.

Need/wish for council, teaching, etc.

Approval, group leader

Benjamin

Approval of other members

Steffen, Øyvind

Appendix G

Progress report 5

ID303612 Bachelor	Project Automated small scale assembly.	Meetings this period Internally: 3 Council: 0 Management: 1	Firm Rolls Royce - Marine	Page 1 of 2
Type Progress report	Period Week 16-19	Working hours this period: 160	Project group Benjamin Skinnes, Steffen Sunde og Øyvind Strømsheim	Date 11.05.15

Focus for this period.

Optimization of jobs
Lowering the piston
GUI and control
Visualization and playback timing

Planned activities this period

1. Optimization
Description: Make the robots work as fast as possible, while still keeping the assembly success rate at 100%.
Goal: Have the lowest time possible for assembly.
Participants: Benjamin and Steffen
Responsible: Steffen
2. Lower the piston
Description: Lower the piston using logic in Codesys by the help of the laser.
Goal: Lower the piston so that the assembly is complete
Participants: Benjamin and Steffen
Responsible: Benjamin
3. GUI
Description: Polish the GUI so it looks good
Goal: Make an easy and reliable GUI
Participants: Benjamin
Responsible: Benjamin
4. CodeSys coding
Description: Finish the coding in CodeSys. Comments and readability.
Goal: Easy to read and further develop code
Participants: Benjamin
Responsible: Benjamin
5. Visualization
Description: Complete the movements and dependability in Blender
Goal: Complete movements in Blender
Participants: Øyvind
Responsible: Øyvind
6. Playback timing
Description: Code a java program for playing and stopping multimedia. Implement Jamod to know when to play/stop.
Goal: Be able to play the visualization in seemingly real time with the assembly
Participants: Øyvind

Responsible: Øyvind	
Actual finished activities this period.	
Planned:	
1. Optimization of jobs regarding speed and quality. Notes: Completed.	
2. Lowering the piston into place Notes: Completed.	
3. GUI and CodeSys Notes: Completed.	
4. Visualization and playback timing Notes: Completed.	
Not-planned	
5. Mount a pressure-regulator-valve (pressostat) Notes: Completed	
Deviation	
See “notes” under the activities.	
Description of changes which changes the projects contents or procedure.	
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Experience from this period	
<ul style="list-style-type: none"> • Laser is not very reliable on shiny objects, even with the use of median filters. 	
Focus next period	
Finish the report	
Planned activities next period	
Writing the report	
Div.	
<ul style="list-style-type: none"> • The group is very pleased with the final result. 	
Need/wish for council, teaching, etc.	
Approval, group leader	Approval of other members
Benjamin	Steffen, Øyvind