

Designing a Testing Jig for Ultrasonic Testing on Pipe Flanges

Major Project

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Declaration of Authenticity

This dissertation is the result of the author's own personal research. It has been written by the author and has not been previously submitted for examination which has led to the award of a degree.

Signed:

Date:

Acknowledgements

I'd like to begin by thanking Richard Morgan for his assistance and guidance for the duration of this project. Richard's help with methods of completing a project and his guidance with manufacturing methods and materials was an invaluable resource, and his role as my project supervisor helped to keep the project on track and help maintain the progress throughout the length of the project when I needed guidance most.

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I'd also like to thank Liam Penaluna at Oceaneering, as this project was being completed in partnership with Oceaneering then there was a few visits and consultations with Liam which helped guide me on the testing methods and explain exactly what was needed to come up with a PDS and a final design which was suitable for both the purpose of the project and the company.

Finally, I'd like to thank my family and friends for the constant support over the length of the course. The support they have given me has been vital to help me complete the course.

Abstract

The purpose of the following report is to focus on the creating of a design that would be able to support a phased array probe that can carry out tests on pipe flanges in a range of environments meeting the criteria of a PDS. The part will then have considerations that need to be met and using engineering techniques such as design methodology, design for manufacture, design for assembly and linkage analysis then a final design can be created which would then be able to be produced.

The data and information is collected from sources, lecturers and the company which this project is for and then the information is used to create a design from scratch which will benefit the company.

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1.0 Introduction

The use of ultrasonic testing in pipes is a highly valued testing method for companies. For ultrasonic testing to take place, there need to be testing rigs created which allow the testing to be completed. The purpose of my project was to create a testing jig which allowed the testing of the tapered part of pipe flanges which can be seen further into this report.

The company which this project is being completed for are called Oceaneering. This is a worldwide company based in Swansea which specialise in non-destructive testing of pipes, pipe welds and pipe flanges. They wanted to create their own design and method of testing the tapered part of pipe flanges instead of relying on other company's components and their current method of testing which is handheld testing.

Their current method of testing is not ideal as it does not always give accurate results and the testing method is not suitable for locating and measuring the deterioration of pipes and how the standard of the pipes is changing. By creating a jig which is able to carry out the testing, this will standardise the components and enable the tester to carry out more accurate testing and be able to log results better which will have a positive affect for the company.

The purpose of this project from my point of view is to design, evaluate and create a working model which would be suitable for the company to use to carry out their testing. This includes using project planning, design of component, investigating different design methodologies, investigating different linkage systems, testing and evaluating designs to improve them. The purpose of this project from Oceaneering's point of view is to create a standardised testing jig which includes an encoded wheel that can carry out accurate testing which gives results to a specific location within the pipe flange. By encoding the device, the location of any cracks that have been detected on the pipe can be more accurately followed and by seeing the speed of deterioration of the pipe cracks then the company would be able to predict how the crack will get worse therefore having to test less regularly which saves the company money. The testing method would also mean that parts could be changed only when they need to be which will save time in breakdowns. There are a number of deaths in America each year from pipe flanges exploding and killing people near to it, this more accurate testing method will hopefully decrease this stat.

2.0 Ultrasonic testing

2.1 What is being tested?

Oceaneering test the pipes for any cracks or if the pipe is worn throughout the whole pipe and joins and flanges, the pipe is tested everywhere, in the position where it is. Therefore the pipe will not be disassembled to be taken somewhere for testing it will be done wherever it is. There are many different methods of applying the testing method, which is phased array ultrasonic testing, but unfortunately the tapered area on the flange of the pipe has no current method of testing, which is the purpose of this project to design a jig to allow this method of testing to be applicable. You can see the area as shown in appendix 1.

2.2 Why is it being tested?

The reason for this part of the component being tested is because there are many incidents each year where pipes explode and one of the more common areas of pipe explosions are on the flanges of the pipes. The corruptions, metal fatigue and poor maintenance of these pipes are what cause life threatening explosions which can easily be prevented (McCord, 2018). From completing research it is found that the explosions that can be caused can cause enormous damage and can even take lives, therefore the accurate testing of these components is key to preventing this happening. The new way of testing which is being designed would incorporate the use of an encoder wheel which would give more accurate results and the location of the cracks and how they progress over time. This would allow the testers to give more informative results and allow them to have more information in changing pipe flanges when they need to be changed to prevent explosions or corrosion getting to a bad enough state that it could cause danger. The current testing method is not ideal but still stops corrosion getting too bad but the tests need to be carried out more regularly because there are ways for it to be improved, the new method would allow more accurate testing, but not as often which would save the company money.

2.3 Why use this method of testing?

Ultrasonic testing is the method that is used because firstly and most importantly, it is a non-destructive testing method. Phased array ultrasonic testing can be used for medical purposes or can be used in industrial purposed for non destructive testing on pipes and welds which is ideal for the situation here.

To carry out phased array ultrasonic testing, there must be contact between the probe and the testing surface. The probe must then stay in contact while moving around the pipe taper consistently with the same speed, pressure and stay in constant contact allowing the software to give accurate readings of what it sees when passing around the pipe. The encoder wheel is there to show accurately exactly where the cracks are and the detection of the deterioration can be seen and how it progresses can be logged more accurately.

When the probe is in contact with the pipe, there needs to be a fluid between the probe and the pipe, most commonly used is water. Water pipes to allow this water must be incorporated into the design. There are multiple small elements in the probe which sends a wave of beams through the material and measures how far the beam travels showing the thickness of the pipe. This would allow the tester to see the depth of the pipe and show if there has been any wear or corrosion on the pipe and how this has affected the pipe. As previously mentioned the current testing method is just done by hand which doesn't allow the tester to accurately see where the cracks are and how long they are or how deep. So with the encoded method we can accurately see where the start, where they end and how deep they are. (Olympus, 2018). From conducting research on this website, it was found that the most suitable way to complete the testing, was using the advanced non destructing testing technique of phased array ultrasonic testing.

The advantages of using NDT (non-destructive testing) are:

- Recordable and repeatable
- Relatively low cost (Probes are expensive but are long term)
- Produces easy to read data
- Can be carried out by different people due to recordable data.

The Disadvantages of using NDT are:

- High level of training needed for testing
- Some probes can have high costs
- Must be used regularly to justify the cost.

(Ashtead, 2018)

An alternative to phased array ultrasonic testing is radiographic testing. This would not be a suitable replacement for UT as this was the method that was used to replace radiographic testing. The reason it was replaced was the chemicals used and the area that was being tested had to be controlled, there was too many health and safety problems and dangers with radiographic testing and the transportation of the equipment to carry out the testing would not be suitable for this which is why phased array ultrasonic testing is the best method for this problem.

3.0 Initial design

3.1 Design Methodology

When creating a design for the jig that needs to be made. There is a method that should be followed when making initial ideas and initial designs for the parts needed. Some examples of these are:

- Design to value (more suitable for products that are to be marketed)
- Inclusive design (used more for environments, suit relevant to this purpose)
- Total Design (the design methodology that will be used).

Total design is the design methodology that is found most relevant to this cause to give the best chance of a good design and successful product. There is a book by Stuart Pugh which is called 'Total Design – Integrated Methods for Successful Product Engineering. From this book there was a design method which was called total design; this structure can be seen from the graphic below.



As this image is slightly hard to read, it shows the following points in this order:

- Market
- Specifications
- Concept Design
- Detail Design
- Manufacture
- Sell

As can be seen from this report, this is the design methodology that was followed up until the selling point as this would be a specific design for a specific company. This product could go on to further be sold to more customers, but this was not part of my project for this company as it was to design some working method for them.

3.2 Chain – Linkage design and analysis

The chain was designed to be able to clamp around a series of different diameter pipes. The pipes that are tested range from diameter sizes of three inches to 30 inches (see PDS Appendix 2). The components that are needed in order to build the chain are as follows:

- Chain block (appendix 3)
- Connecting bush (appendix 4)
- Connecting pin (appendix 5)
- Tension block (appendix 6)
- Chain block with arm holder (appendix 7)
- Bearings and circlips.

These five components make up the assembly for the chain block as shown in appendix 8. This assembly is key to the design and function of the complete assembly as this will be the major support area of the probe holder. Each of the components are vital to the function of the chain.

3.2.1 Chain block

The chain block is designed to be interlinking with the next block along the chain, this allows for movement between the links and allows for different sized diameters to be taking into consideration by adding or removing another block. For prototyping sake, only a few would be created just to prove that the design works. To come up with a plausible design that would work, then research had to be completed into the linkage design and analyse different methods of linkage to see which one would be most suitable. From completing research into mechanical linkage systems, there are systems that involve bearings, gears, sprockets and chains. The system which will be used here is a chain which is connecting with bushes and pins. The linkage would also be finished with the design of a tensioning block.

3.2.2 Connecting bush

The connecting bush is one of the two main components responsible for linking the chains together, that and the connecting pin. As this bush would be involved with moving parts but would not allow for there to be any play, then there has to be further research into different types of fits, such as push fits, interference fits, bearing fits etc. This research can be found under the section '?? Types of fits'. The material is also a main concern for the bush as we would want parts that would not wear, would not cost too much, would be easily accessible and were able to be machined to the standard of the fit without being damaged which would cause wear. Typically, from the previous research and knowledge I have from completing an apprenticeship, the best material that is used for making a bush with moving parts is brass. The material is soft enough not to damage the pin or the chain block, and is perfectly suitable for moving parts.

3.2.3 Connecting pin

As the second part of the connecting link, the pin is also essential to the function of the chain assembly. Not only is the pin responsible for holding the two chain parts together, but as can be seen from the assembly, the bearings also sit on the connecting pin with the circlips holding the bearings on. The material being used for the pins is also a key consideration that has to be made. As previously said, the fit of the pin means that a material that has to be used is one that can be machined to the suitable standard needed, which can be found in the type of fits section.

The initial consideration for the material needed for the connecting pin would be to use silver steel which has typically just over 1% carbon in it meaning it can be hardened and tempered which will be useful for the function of the pin. The reason for hardening this pin would be because the stress forces that will be on the chain assembly will be focused mainly on the pin in different directions. The tension block will tighten up, applying forces the joining pins and bushes. Analysis can be completed on this to see how much stress will be applied to allow the chain to grip the chain sufficiently. Due to there being different amounts of arms and different diameter pipes, the forces would vary on the pins and bushes as there will sometimes be more and sometimes be less depending on the diameter.

3.2.4 Tension Block

The tension block that is seen in appendix 6, this shows the full assembly of two blocks that join onto the regular chain blocks and are connected by a bolt that goes through the centre of each which can be turned to tension the chain. The reason for this design is so there can be a various amount of diameters than can be used using the same amount of chain links. The tensioning arm would then take up any slack that is in the chain as it stands. More considerations had to be made for the material for these components as it couldn't be too soft as the threads would strip when tensioning. But at the same time to satisfy the PDS, the material being used would have to be suitable to use in a range of environments. Further research and decision would be made in the final design section.

3.2.5 Chain block with arm holder

The chain block with the arm holder is not really any different from the regular chain block, but with the exception of two slots which are there to hold the arms of the probe holder assembly, and two holes which have holes which support pins for the location of the arms. Besides these minor differences the rest of the chain block is the same in the sense of material, geometry and function.

3.2.6 Bearings and clips

The bearings that are being used are where the chain is going to make contact with the pipe, these bearings sit on either end of the connecting pins. As I have previously mentioned the pins must be machined to a standard that is a bearing fit for the bearing to sit on the pin and not move but still be able to rotate freely acting as a wheel on the pin. The British standard for limits and fits can be found as either

BS8888 or BS 1916-1 (One standard was given by a lecturer the other from online research). The bearings that would be used would be ball bearings that would have shields covering the balls which would stop them getting clogged up with any debris or sand or anything that the environment could have to hinder the operation of the bearing.

The clips that could be used for the pins to hold the bearings in place are:

- Split pins
- Circlips
- Nuts with washers
- 'R' pins

Each of these would be suitable options, but in the interest of not having to complicate the shaft by adding a thread either end, or by drilling holes in the shaft (which would be extended time to the machining time of the shaft), the most suitable option would be circlips, as the shaft would be able to be machined on a lathe in one operation then rather than taking it out and adding time to the machining.

As the bearings should not be under too much loading, the movement along the shaft should be minimal once the bearing has been fitted, therefore the loading on the circlips should also be minimal.

3.2.7 Supporting arm

The supporting arms that are being used are two 10mmx10mm square rods that extend all the way from the chain block to the probe holder assembly; they are essentially the main connecting rods from the top part of the assembly to the bottom part of the assembly. As part of the PDS, the supporting arms must be adjustable in height, therefore as can be seen from the drawing, appendix 9, you can see that there are a series of location holes towards the top of the arms allowing for variant heights to be achieved depending on the design of the pipe being tested.

3.3 Probe Holder

As can be seen from the drawing, this is a complex part of the design, the design consists of:

- Holder base (Appendix 10)
- Support arm pins (2x blank pins that pass through arms into plate)
- Probe holder plate (appendix 11)
- Tensioning plate (appendix 12)
- Springs

These components are what are essential to the assembly and function of the probe holder assembly. Each of these parts are discussed in more detail further into this report.

3.3.1 Holder Base

As seen from appendix.., the base of the probe holder is the bulk of the design, this is the connecting part between the connecting arms and the probe holding plates. The design of this allows the plates to locate in five different holes, which will allow for varying tapers on the pipe. The first plate will locate in the holes and the second plate will be spring loaded from there to make fine adjustments for the angle and the pressure supporting the probe. The base is held in place by two pins at the back of the base which pass through the connecting arms which locate the base in place. The design has been made in this way so the plates can rotate around it with no fouling and rotated around the pin and bush which passes through the base and two plates.

3.3.2 Support arm pins

There are four holes in the back of the base that can support pins that locate in the connecting arms, these pins have different locations to allow the change in height of the base which allows incremental changes in height to allocate for many different designs. The two pins are to be machined, like previous pins mentioned, to a standard that allows for the fits so there is no play or movement.

3.3.3 Probe holder plate

There are two plates which make up the design of the probe holder assembly; one plate (probe holder plate) is the plate that actually holds the bracket which supports the probe holder. This is the outer plate of the two that can be seen in appendix 11. This plate consists of location holes for the bracket and location holes for the springs which will be placed between the two plates. The spring stiffness will be calculated further into the report but due to the difference in how much of the gap between the plates will be taken up, a further design development may need to be made for the final design.

3.3.4 Tensioning plate

The other of the two plates that are part of the assembly, which is the tensioning plate, is one of the most important parts of the entire assembly. The plate here is what will apply the force onto the probe holding plate. This will be done by the tensioning plate being held in place by a pin which locates in the holes which are described in the probe holder base. These five holes, as can be seen from the drawing, are all located in the bottom left of the base evenly spaced 18° apart. A pin would then locate the plate in whichever of the five holes was most suitable and then the springs between the plates would allow for the minor, incremental difference that is needed to let the plate sit on the tapered part of the pipe.

3.3.5 Springs

There are a few options that can be considered for the springs, there are:

- Use one type of spring that all have the same spring stiffness.

- Have a few sets of springs that can be changed depending on each task.
- Have one set of springs that have bolts running through the centre of them passing through each plate which can alter the tension for each separate task.

Where each of these options are sensible and plausible ideas, each have their advantages and disadvantages. For example a few advantages of using the first point would be, there would be no chance of user error as they would only work one way, there would be plenty of easily accessible spares and there would be one standardised way. Whereas a few disadvantages of using this method would be the force would be changing between the two plates meaning that if the plates were closer together then the force that would be applied to the bottom plate would be much greater as the spring would be under more tension, whereas if the plates were far apart then the tension would be lower meaning the force applied would be lower. If the forces are too high then the probe may not run smoothly on the surface, if the forces are too low then the probe may not get an accurate enough reading, therefore this plan would not be a good idea.

The next point which would consist of having more than one set of springs would be a suitable idea to replace the previous points bad points because it would allow for the different spaces between each of the plates by changing the springs which will have different stiffness's which would take up the problem of too much or too little force. This is basically the main advantage of using this method but by having different sets this makes more disadvantages. For example the design efficiency would be worse and in terms of design for assembly and design for manufacture it would also be a worse choice. If there were more springs then there are more chances of human error and more chance there would problems with the assembly which will make more problems than it would solve.

The final design solution would be use one set of springs but the springs would be tensioned by running a bolt through the centre of the spring, with one plate being tapped with a thread and the other end being a clearance hole and then the plate can be tensioned using the springs. This would negate both the disadvantages of the previous two points, even though there are still more parts, the way that the assembly is assembled could still not be done incorrectly because the parts are only able to be put together one way. With the gap between the plates being able to be changed this would allow for the forces to be set using the springs and allowing for there to be the perfect amount of force needed to complete the testing.

3.4 Design for Manufacture considerations

When considering the design for manufacture we must considering the parts of the design that are able to manufactured in the method we choose, for example if we are going to machine something, we must consider how it will be held, what tools could be used, what design considerations there must be to allow the component to be made. For example in the chain link which holds the arms, there are square holes

that are there to hold the arms. Obviously on a milling machine there is no way to machine a square hole, which opens up the option to different manufacturing methods. The ways each of the components will be made will be discussed further into the report once the final designs have been decided. (NBPlastics, 2014)

As well as considering these, the following points can also be considered:

- Standardised parts
- Minimise amount of parts
- Assembly only go together one way
- List acceptable surface finishes
- Minimise machining operations

Each of these parts have been considered in the initial designs.

The standardised parts of pins, bushes, bearings, clips, springs are all examples of standard parts which will not be tampered with or changed or machined in any way before going into the assembly. This will mean that if any parts need to be replaced or need to be found, they should all be pretty well known and due to them being standard parts it will minimise the time to get them.

Minimising the amount of parts on an assembly such as this can be quite difficult as each part is essential to the function of the full assembly. This part has been considered but not always can every part be achieved in order to have a fully functioning product.

Making the assembly only able to go together one way was relatively simple, the parts consist of many symmetrical parts and all the pins are different sizes meaning they will not fit into other holes where they are not made for. Also the chain blocks are symmetrical so they can only go together one way. The people assembling and using this product would be trained people in their field so they should have good knowledge of how the parts go together and how they work.

The list of surface finishes and fits for the parts has a section of its own further into this document, see section '4.0 Types of fits'.

Minimising machining operations can be tricky because some of the parts are quite complex and need more than one machining method on them. The standardised parts are not to be machined as these will be brought in specifically for the job. The parts that are being printed, machined, cast or abrasive water jet cut are the parts that are more complicated for machining.

4.0 Types of fits

4.1 Theory

From BS8888 (British standard for geometric product specifications and geometric tolerance specification and engineering drawings), there are a list of British standards that are to be met when making parts for surface finishes, types of fit, size tolerances and everything else you need to know when creating parts that are interfering with each other in some way. The reason for having tolerances and maximum and minimum values are so parts are not too tight when mating or too loose so they do not fulfil their functions. There is a major list of variables that are covered by this British standard, but for this case, the focus will be on limits and fits.

The majority of the limits and fits for this assembly are for shafts and holes. There are two systems which can be used to calculate these and they are:

- The hole basis system
- The shaft basis system.

The hole basis system is where there is a constant size hole and the shaft size changes to suit the hole. So in this case where the shaft would go through the chain links and into the bearings, this shaft will change size to suit the bearings and the bushes.

The shaft basis system is the opposite, where the shaft size does not change and the bearings and bushes hole diameters would change to suit the shaft.

The system that will be used for this scenario would be the 'hole basis system' as this is easier to use and the shafts are easier to change than the bearing sizes and the bush sizes, drills and reamers are easier to keep to standard rather than changing the hole size.

The different fits that can be used are:

- Clearance fit
- Interference fit
- Transition fit

There will be some clearance fits in this proposed design, for example where the bolts go through the springs for the tension, the holes where the head of the bolt will be would be clearance holes as we do not want an interference fit or a transition fit on the bolt as we want it to rotate freely. Also where the tension block for the chain is, the same principle applies for the tensioning bolt.

The majority of the fits will be interference fits, where any pin or shaft is involved, there will be interference fits to make sure the parts do not move in any way they are not supposed to.

The holes and shafts are set into two groups and then depending on the finish needed and the size of the shaft or hole, they are split into even more groups. For example a 40mm shaft would be put in the 30-50mm section and if it needed to be an interference fit it would be in a different section to the clearance fit. This can be seen in the table below.

https://www.engineersedge.com/international_tol.htm

Basic size mm		Standard tolerance grades																	
		IT1 ²⁾	IT2 ²⁾	IT3 ²⁾	IT4 ²⁾	IT5 ²⁾	IT6	IT7	IT8	IT9	IT10	IT11	IT12	IT13	IT14 ³⁾	IT15 ³⁾	IT16 ³⁾	IT17 ³⁾	IT18 ³⁾
Above	Up to and including	Tolerances																	
		μm												mm					
—	3 ³⁾	0,8	1,2	2	3	4	6	10	14	25	40	60	0,1	0,14	0,25	0,4	0,6	1	1,4
3	6	1	1,5	2,5	4	5	8	12	18	30	48	75	0,12	0,18	0,3	0,48	0,75	1,2	1,8
6	10	1	1,5	2,5	4	6	9	15	22	36	58	90	0,15	0,22	0,36	0,58	0,9	1,5	2,2
10	18	1,2	2	3	5	8	11	18	27	43	70	110	0,18	0,27	0,43	0,7	1,1	1,8	2,7
18	30	1,5	2,5	4	6	9	13	21	33	52	84	130	0,21	0,33	0,52	0,84	1,3	2,1	3,3
30	50	1,5	2,5	4	7	11	16	25	39	62	100	160	0,25	0,39	0,62	1	1,6	2,5	3,9
50	80	2	3	5	8	13	19	30	46	74	120	190	0,3	0,46	0,74	1,2	1,9	3	4,6
80	120	2,5	4	6	10	15	22	35	54	87	140	220	0,35	0,54	0,87	1,4	2,2	3,5	5,4
120	180	3,5	5	8	12	18	25	40	63	100	160	250	0,4	0,63	1	1,6	2,5	4	6,3
180	250	4,5	7	10	14	20	29	46	72	115	185	290	0,46	0,72	1,15	1,85	2,9	4,6	7,2
250	315	6	8	12	16	23	32	52	81	130	210	320	0,52	0,81	1,3	2,1	3,2	5,2	8,1
315	400	7	9	13	18	25	36	57	89	140	230	360	0,57	0,89	1,4	2,3	3,6	5,7	8,9
400	500	8	10	15	20	27	40	63	97	155	250	400	0,63	0,97	1,55	2,5	4	6,3	9,7
500	630 ²⁾	9	11	16	22	32	44	70	110	175	280	440	0,7	1,1	1,75	2,8	4,4	7	11
630	800 ²⁾	10	13	18	25	36	50	80	125	200	320	500	0,8	1,25	2	3,2	5	8	12,5
800	1000 ²⁾	11	15	21	28	40	56	90	140	230	360	560	0,9	1,4	2,3	3,6	5,6	9	14
1000	1250 ²⁾	13	18	24	33	47	66	105	165	260	420	660	1,05	1,65	2,6	4,2	6,6	10,5	16,5
1250	1600 ²⁾	15	21	29	39	55	78	125	195	310	500	780	1,25	1,95	3,1	5	7,8	12,5	19,5
1600	2000 ²⁾	18	25	35	46	65	92	150	230	370	600	920	1,5	2,3	3,7	6	9,2	15	23
2000	2500 ²⁾	22	30	41	55	78	110	175	280	440	700	1100	1,75	2,8	4,4	7	11	17,5	28
2500	3150 ²⁾	26	36	50	68	96	135	210	330	540	860	1350	2,1	3,3	5,4	8,6	13,5	21	33

The lists going down the left show the size of the components that needs to be calculated. For the second axis to work out which 'IT' number is needed to complete the calculations, the 'class of work' table needs to be referred to as shown below.

IT	Class of work
16	Sand casting
15	Stamping
14	Die casting, plastic moulding
13	Presswork, and extrusion
12	Light presswork, tube drawing
11	Drilling, rough turning, boring
10	Milling, slotting, planing, rolling
9	Low grade capstan & automatic lathe work
8	Centre lathe, capstan & automatic
7	High quality turning, broaching, honing
6	Grinding, fine honing
5	Machine lapping, fine grinding
4	Gauge making, precision lapping
3	High quality gap gauges
2	High quality plug gauges
1	Slip gauges, reference gauges

From these sets of information, the calculations needed to work out what we need to do for each component are able to be calculated.

4.2 Calculations

Here is a table of all the components that need to be considered for calculations and their diameter size and what type of fit is needed.

Component	Dimensions	Type of fit
Chain link pin	9mm diameter	interference
Bearings	9mm ID – 26mm OD	Interference
Chain Bush	9mm ID – 12mm OD	Interference
Connecting arm in chain	10mmx10mm square	Interference
Connecting arm pins	8mm diameter	Interference
Probe Holder base shaft	15mm diameter	Interference
Probe Holder plate	15mm hole diameter	Interference
Probe holder tensioning plate	15mm hole diameter	Interference
Locating pin for plate	7mm diameter	interference

Bearings from <https://uk.rs-online.com/web/p/ball-bearings/6671217/>

As we are using the hole basis system, the holes will be kept at a constant size as they will be milled or reamed, therefore they will be very accurate. Therefore to calculate the fits the shaft would have to suit the holes. As an example, the calculations made for the 9mm chain pin which will be passing through the chain bush would be shown in the table below.

Component	Upper limit	Lower limit	Tolerance
Chain bush hole	9.015mm	9.000mm	0.015mm
Chain link pin	9.024mm	9.015mm	0.009mm

As can be seen from this example, the tolerances are extremely low for interference fits. This is so low that the accuracy is vital to the function of the assembly. From referring to the tables previously shown then it can be seen that the hole would have to be made to the standard of IT6 or IT7 which would require machining methods such as high quality turning, grinding, broaching or honing which has been considered in the design process and when considering machining methods for the final design.

5.0 Manufacturing methods

5.1 Water Jet Cutting

As the design shows, there are many components of this assembly can be created using water jet cutting. From the list of parts previously stated, the parts that will not need to be manufactured using water jet cutting are the bearings, the bushes, the pins, the arms holding the probe holder, and the base of the probe holder components. The parts that can be produced using water jet cutting are the chain, the tensioning components, and the blank shapes of the probe holding components. As water jet cutting can only be completed on one plane at a time, this means that only profiling can be completed meaning that there must be machining post production of these components to complete them.

The process of water jet cutting involves using high pressured water with an abrasive element added which allows the cutting of metals, glass and tough materials rather than just plastics where normal water jet cutting can be used for. This process which includes the abrasive element can also be known as abrasive water jet cutting. It involves using water which is under an enormous pressure of between 40,000 and 60,000 psi. The component is then designed using CAD software which then links up with the water jet cutting allowing the cut to be made. This would be suitable for machining parts such as the components which have been shown previously in this document, the material range for water jet cutting gives a series of choices for the production of the parts.

Advantages of water jet cutting include the cost, even though the machinery itself is expensive, for the purpose of this task then there would be no need to purchase a complete machine but rather find a company who specialises in water jet cutting and use them for the production of the components needed. Another advantage would be that the drawings can be made on CAD firstly and then the drawings can be used to create the product. Another advantage would be the speed it takes to create a component, for this particular design the production time would be shorter compared to other production methods such as casting, machining completely or making from a series of smaller components and putting them together. This was the best method chosen to create the profile shapes. An obvious disadvantage in water jet cutting is the fact it can only profile parts, using this method cannot completely manufacture the product without post production machining taking place which can be an issue for time efficiency and cost efficiency.

5.2 3D Printing

3D printing is a method that can be used for the production of all the components for prototyping or for final production but the material range is much smaller. There is not just one way of 3D printing there are a wide range of different methods than can be used to complete these tasks. These different methods can be methods such as:

- Stereolithography (SLA)
- Fused Deposition Modelling (FDM)
- Selective Laser Sintering (SLS)
- Selective Laser Melting (SLM)

These methods can use different materials but more regularly are used for plastics, but there are methods that can be used for aluminium which is the current idea of which material that would like to be used. One of these methods is direct metal laser sintering (DMLS). As opposed to the previous process, water jet cutting, this method of 3D printing would be able to complete the components without any machining needed for after the completion of printing.

The process of direct metal laser sintering is an additive manufacturing method, this is also different to both machining and water jet cutting as these both remove material from the work piece, whereas using 3D printing methods these are additive processes which reduce waste and are therefore better for efficiency and for the environment (only the waste not necessarily the process itself). DMLS also uses CAD drawings to produce the parts where the component is designed using CAD and then the product is made from that drawing. The process is better and used mostly for prototyping parts. The part is produced in layers where the component is built up layer by layer until it is completed. A powder base is used and then the software breaks the component down into multiple 2D layers, this information is then used by the software to show which parts are to be sintered and therefore creating the shape of the component, after each layer is completed, the software moves onto the next layer from the bottom up, each part is made from the bottom then upwards towards the top layer.

Whereas this method of producing parts is obviously very useful in some aspects, the more common use of this method is for making parts such as small gears, dental components, surgical implants and aerospace parts. For the purpose of this manufacturing I don't believe that this would be a suitable method for creating the components.

5.3 Machining

One of the most common ways of making parts for this purpose would be machining. This would be using a list of different machines which would be responsible for machining the different components of the assembly. The machines that would be used are:

- Milling machines
- Lathe
- Surface grinder
- Cylindrical grinder

Each component of the assembly could be made through machining, although this could take a lot of time and depending on whether or not the product is made using manual machining or using CNC machining then this could also take even more time and depending on the machine operator then the accuracy of the product could vary. But on the contrary, depending on the machine operator then the components could be made very accurately and better than either of the other two methods.

Because of the accuracy of some of the parts needed and the fits that will be needed for the bearings, pins, shafts and bushes, machining would be a highly recommended method because of the machining that would be needed such as reaming for the components with holes and surface grinding for the cylindrical parts that will fit into the holes.

The best way to make these parts would be to use a mixture of different manufacturing methods, this would use the advantages of each method and combine them to create an overall assembly that will meet the criteria of the PDS while being the best effective in terms of cost, time and practicality.

6.0 Final Design

When considering the final design, the majority of the design is staying the same as the initial idea as it was found from discussing with the project supervisor and the employees at Oceaneering that this would be a suitable method for making the project a success. There was enough design considerations, production method considerations, environmental considerations and other considerations that have been discussed up until this point to stick with the same drawings and design that was made initially. For the project to be a success though there must be materials decided that will be suitable for the job.

6.1 Materials

By taking a look at the PDS, there are design specifications which must be considered before deciding on the final materials. For example, the component must be lightweight, not bend or deform under load and must not wear or rust under the working environment. Breaking the assembly down into three parts of:

- Chain
- Connecting Arms
- Probe Holder

From this we can see that everything above the connecting arms is the chain and everything below the connecting arms classes as the probe holder. From the components in the chain part, which will be the chain blocks, connecting pins, bushes, bearings, circlips and tensioning block, the majority of these are standardised parts such as pins, circlips and bearings. The materials of these cannot be changed, the pins would be made from silver steel, circlips to made from carbon spring steel and the bearings to be made from stainless steel. To reduce the weight

as much as possible for the other components, a lightweight material such as aluminium would be used. This would help each of the criteria as it is lightweight, it will not rust as quick as mild steel in the environment it's being used (sea or desert), it can easily be machined and with a tensile strength of 90Mpa it would be able to support the loads that will be applied to it.

The connecting arms would be produced using key steel, the reason for this is because it comes in the standard shape required of 10x10mm. Obviously different sizes are available but for this case we would require 10x10. Another advantage of using key steel is because it has similar properties to mild steel but just slightly tougher, this would be perfect because it is passing through rectangular holes and it would result in no wear on the connecting arms, it is still relatively easy to machine so machining the holes into the key steel would be no issue.

The probe holder assembly will be similar to the chain in the sense that the majority of the components would be made from aluminium, the only one that wouldn't be is the pin that will be made from silver steel, like the other pins. The reason for using aluminium again is the same as the previous reasons, for weight limitations, ease of machining, cost, how easily accessible it is and corrosion resistance.

6.2 Production Methods

As there are so many components in the assembly, there are a list of processes that have to be considered. Some of these are:

- Milling
- Turning on a lathe
- Abrasive water jet cutting
- Drilling, reaming and broaching
- Casting
- 3D printing

The considerations that need to be made are how quickly we need the parts made, how accurately we need the parts to be, minimise the amount of processes, the type of material being used, the cost of the method, additive or subtractive machining (to consider the wastage) and how many of them are being made (mass production or single one off parts).

As previously mentioned, there are many parts which are standardised parts which therefore would have no considerations for the method of manufacture. For the chain blocks, the manufacturing method would be abrasive water jet cutting for the reasons mentioned in the previous section of 5.0 manufacturing methods.

There are many components that will need more than one machining method on them. These would be:

- Probe holder base (abrasive water jet cutting and milling)

- Chain block (abrasive water jet cutting and milling)
- Chain block supporting the connecting arms (abrasive water jet cutting and milling)
- The probe holder plates (abrasive water jet cutting and milling)

The probe holder base would be machined in 2 parts, initially abrasive water jet cutting would be used to get the shape of the part, then the holes which are blind holes would be milled in using slot cutters as the holes are blind and the accuracy of this would be suffice for the pins being inserted. The chain blocks would also have abrasive water jet cutting to get the blank fork-like shape, and then the holes would be milled or drilled into them. Both these methods would be suitable for the type of fits that would be needed as seen from type of fits section. The chain block with the holes for the connecting arms would be made the same way as the chain but with the added holes for the arms to run through. The probe holder plates would also be initially abrasive water jet cut as it would be only this method or casting to get the round ends on the plate with the flat plate connected to it. The reason that casting would not be used is because the majority of the assembly would be made with water jet cutting then to keep the production methods constant.

The components that would only require only one method of machining are:

- Connecting arms (milled or drilled)
- Bushes (turned)
- Chain connecting pins (turned to make groove for circlips)

The connecting arms would be machined from key steel as previously mentioned and the holes can either be milled out or drilled and reamed for accuracy and to allow the interference fit for the pins. The bushes would be turned on a lathe and would be drilled and reamed, again, to allow for the tolerances and the interference fit. The pins would be a standardised part so the shaft would not have to be machined it would be ordered that size and then the grooves for the circlips would be machined in using a lathe. To get the accurate measurements for the circlips to do its job, there were drawings found here:

<https://www.trfastenings.com/products/Catalogue/Washers-Circlips-Seals-Rings/Circlips/External-Circlips/TR00020251-000>

6.3 Costs

The costs of the assembly would have to consider all the materials, the machinery and the standardised parts. After sending e-mails and phoning companies they were not very forthcoming with information of costs for materials for the amount of stock that would be needed, so the only prices that could be found were for the bearings, key steel, pins and circlips.

The following table lists the costs of the parts.

Part	Cost	How many needed	Where it was found
Bearings	£2.35	16 (depends on how many chains)	https://uk.rs-online.com/web/p/ball-bearings/1440847/
Key steel	£4.18	2	https://simplybearings.co.uk/shop/p530010/Bright-Drawn-Keysteel-10x10mm/product_info.html
Pins	£5.99	2	https://www.ebay.co.uk/itm/SILVER-STEEL-GROUND-SHAFT-ROD-ROUND-2MM-3MM-4MM-5MM-6MM-7MM-8MM-9MM-10MM-12MM-20-/271277844956
Circlips	£2.95	16 (depends on how many chains)	https://simplybearings.co.uk/shop/p82827/External-Circlip-9mm-Diameter-Un-Sprung-Dia-8.4mm/product_info.html
Brass	£26.39	2	https://uk.rs-online.com/web/p/brass-rods-bars/0682646/

7.0 Analysis

The majority of the analysis has been covered throughout the report already, but this section is basically to sum up and conclude on each of the findings. As the product had not been created, then most of this analysis is purely theoretical and further work which could be completed is discussed further.

7.1 Forces on Chain

The forces on the chain are created from the tensioning block. The forces need to be great enough to stop the chain from slipping down the length of the pipe. The forces must be enough so the bearings grip the pipe which is why there was an adjustable tensioning block so the forces can be set by the user to fulfil the needs of each pipe. Practical analysis can be completed on this once the product has been manufactured.

7.2 Forces on Probe

Similarly to the chain, the forces on the probe need to be large enough so the probe has a firm force on the pipe taper and also cannot be weak enough so the probe does not get an accurate enough reading. This is why the design incorporates an adjustable method of springs that can be altered to suit each different test. Similarly to previous, further analysis could be completed on this when the product is made which would be a trial for each case to suit which one is best for each different probe and pipe.

7.3 Linkage System

As previously covered, the linkage system is a chain which is connected by bushes and pipes. The amount of research that had to be completed to analyse the different types of chains and methods for creating a suitable linkage system was vast, the materials, range of motion, types of fits, method of clamping and forces analysis had to all be considered to find out which system would be most suitable.

7.4 Fits and Tolerances

The bulk of the analysis completed was done on the chain and linkage system, the parts that are responsible for creating this assembly all have to be machined and produced to a high standard and accuracy to meet the tolerances that are needed for a working system. The hole basis system that was used is a system that is widely used and is proven to work system which is why it was also used in this case. The notes and research completed for finding out manufacturing methods and how accurately the products needed to be made are the main focus points for ensuring the function of the chain and eventually the probe assembly.

8.0 Design Evaluation

The following section is dedicated to breaking down the assembly into a few parts and then evaluating each part of the design and finding the positives and negatives of it. These parts will be broken into the chain, connecting arms, probe holder and full assembly.

8.1 Chain

The chain design has incorporated all the conditions that were needed to satisfy the PDS. The design is lightweight, has adjustable tensioning, can have more links added to it for larger diameters, can be made using common manufacturing types, easily accessible materials and most of all it is fit for purpose. If there are any changes that could be made to the chain, these would be to maybe include specifically designed wheels instead of using bearings. This would allow for a change in material for the outer race which could require less force if it was to be used from a material with a better grip such as rubber instead of being steel. Although this would add more parts to the assembly, which could also be detrimental as this would be more complicated for assembly and the design for manufacture, design efficiency and assembly efficiency would be affected.

8.2 Connecting Arms

The design of the connecting arms was pretty much not able to be altered that much as it was only one design which would be suitable to use. The only way they could be changed is changing the material or by using a cylindrical shaft instead of using square key steel. The reason that square was the better option was because there is more material for the pins to be held in place and the base plate would sit square against the probe holder base which is why this was chosen. Another reason this design was chosen was to include the encoding wheel and bracket, unfortunately this has not been included in the drawings as the encoding wheel and bracket had not been chosen, but the holes for the bracket have been included in the arms so this would allow for the bracket to be located there once this had been decided.

8.3 Probe Holder

There are a list of components that are part of the probe holder and each of these were designed carefully considering the requirements of the probe testing. As this needed to be designed for the probe which was used for ultrasonic testing, we constantly had to consider these methods at all times. The parts to be considered were the plates, base, probe extension arm and the probe itself, which for the purpose of the design was a 5L32 probe from Olympus. (Olympus, Olympus Probes, 2018). The plate and spring tensioning I think is a key part of the design as it allows for adjustable forces to be applied which will allow for the probe to be firmly pressed and stop there being any skewness on the probe which will allow for a clear and accurate representation of what the corrosion looks like on the inside. The extension arm on the plates shows that there can be different size probes suitable to fit the assembly there would just have to be a change to the probe extension arm. The

disadvantages of this design are the amount of parts that are there, the amount of block material that is there and the fact that when producing these there are a lot of subtractive machining methods which will lead to waste which could be avoided if there was more time to work on the design.

8.4 Full Assembly

The overall design would be a successful design and would suitably be able to hold the probe and fulfil its task which was to measure the corrosion on the inside of a pipe taper which is attached to the flange. The design incorporates everything that is needed and from discussing with my project supervisor and employees at Oceaneering this would be a good method and if it were to be produced would be a success. The criteria that is listed in the PDS, which was agreed to before the design process began, has been met and for this reason, the design would be a success.

The full assembly can be seen in appendix 13.

9.0 Further Work

9.1 practical analysis

Once the product has been produced, then there can be practical analysis completed on the probe and probe assembly to show which way is best to test the pipes. This would be useful because once the forces can be practically proven rather than just theoretical calculations then either design changes or a manual showing which way to test each test could be produced to further the audience of customers that could use the probe assembly.

9.2 Encoder wheel inclusion

A key feature which would be a further design consideration would be the inclusion of the encoder wheel. In the current final design there are location holes and room for a bracket which would show where the encoder wheel would go, but as I didn't haven't enough information on which type of encoder wheel they were going to be using for this specific task, then a bracket could not be designed. This is the reason that there is a place for which the bracket could go, but the bracket and wheel have not been modelled. (There is an example drawing that has been made but I have not included in this document, it will be included in the presentation).

9.3 Production

The most obvious path to take for further work would be the production of the final design. The reason this has not been completed was there was not enough machinery accessible to me at the time I needed it through no fault of anyone's other than the sheer mass of final year projects that were being completed and needed to be done. If there was more time or less demand for the machines or there was money available to complete the project from outside of university then the products could have been produced and would be able to then further tested and used in production.

9.4 Further considerations

If the previous three points were completed then there could be further considerations made which could also improve the whole project, these can include completing practical analysis and changing design if needed, the use of an encoder wheel would be enable accurate testing and increase further profits for the company, by producing the complete assembly then any more design improvements could be considered.

10.0 Conclusion

The aims of this project were to get a better understanding of how phased array testing works and how I can make a jig that would be able to support that testing method and be able to apply it to the pipe and different types of pipes with different circumferences and angles.

The initial design that was created was a suitable method using a range of different engineering techniques and methods which allowed the design to be a working method. The initial design was then improved further when there were more considerations for materials, environment, cost, weight and more PDS criteria. From this we were able to create a final design which was also a suitable method for completing the testing.

From using different techniques and analysis such as design methodology, design for manufacture, limits and fits and linkage analysis, the final design was able to be perfected and using these techniques then a final design was able to be made.

The project can be considered a success as a design which was agreed by all parties would be a suitable design for the project given has been met and by using further considerations like production and practical analysis this can be very beneficial for a company such as Oceaneering.

11.0 Bibliography

Ashtead. (2018, 4 16). *Ashtead Technology*. Retrieved from <http://www.ashtead-technology.com/news-events/the-advantages-and-disadvantages-of-advanced-ndt/> :
<http://www.ashtead-technology.com/news-events/the-advantages-and-disadvantages-of-advanced-ndt/>

McCord, M. W. (2018, April 16). *Frac Dallas Pipelines*. Retrieved from
<http://fracdallas.org/docs/pipelines.html>: <http://fracdallas.org/docs/pipelines.html>

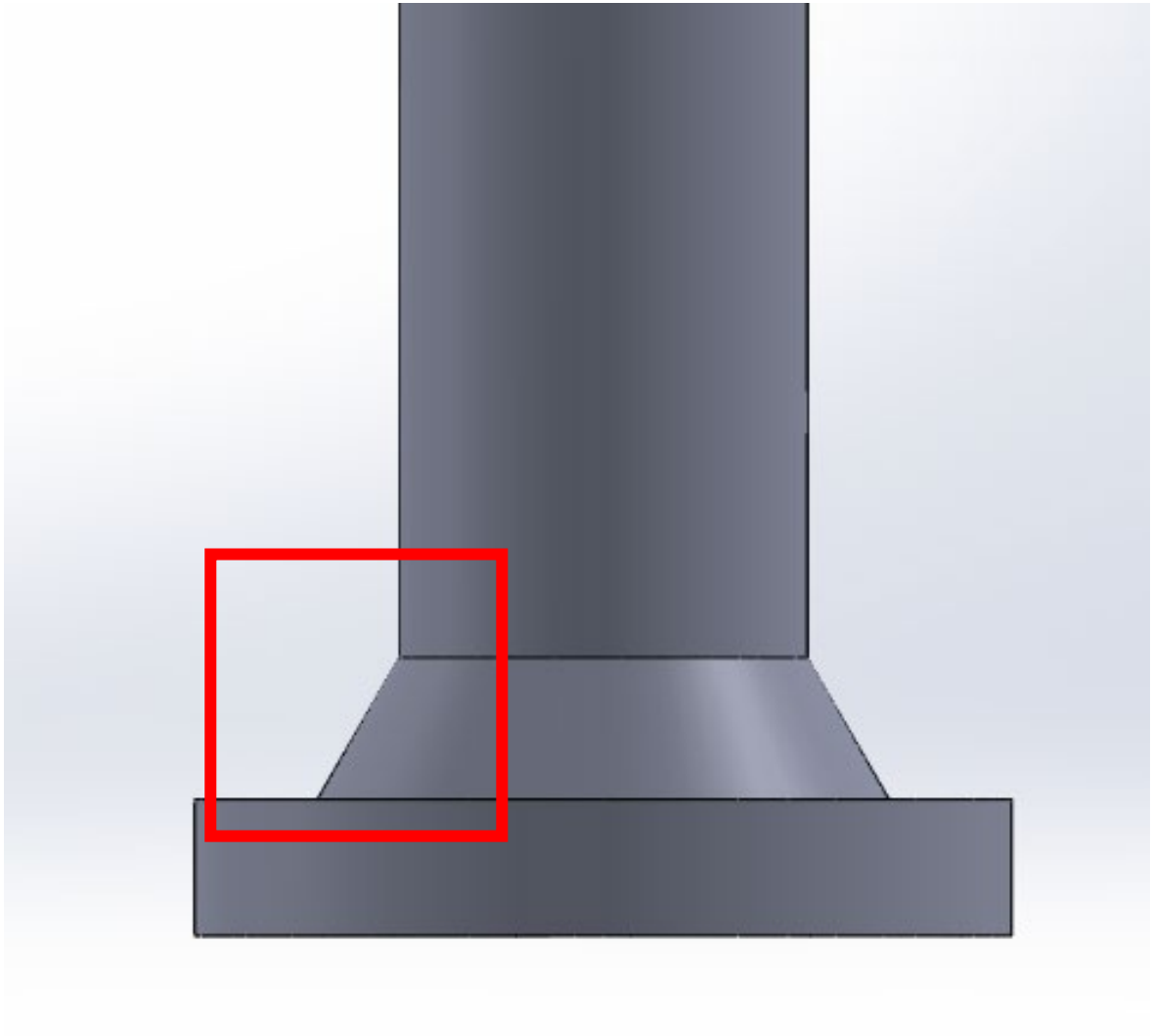
NBPlastics. (2014). *New Berlin Plastics*. Retrieved 2018, from <http://nbplastics.com/10-principles-considerations-design-manufacturing-dfm/>: <http://nbplastics.com/10-principles-considerations-design-manufacturing-dfm/>

Olympus. (2018, April 16). *Olympus Corporation*. Retrieved from <https://www.olympus-ims.com/en/ndt-tutorials/phased-array/>: <https://www.olympus-ims.com/en/ndt-tutorials/phased-array/>

Olympus. (2018). *Olympus Probes*. Retrieved from <https://www.olympus-ims.com/en/probes/pa/>:
<https://www.olympus-ims.com/en/probes/pa/>

12.0 Appendices

Appendix 1.



Appendix 2.

Product Design Specification

Design Specification for a Multifunctional Jig to complete ultrasonic testing on pipe joints and flanges.

The following Project Design Specification shows what the specific limitations and variables would be applicable for the testing jig which will be used on the different varieties of pipe size, dimensions, angles and thicknesses. This is to be agreed by both myself and Oceaneering prior to any design or prototypes of the jig to be made.

Ultrasonic Testing Jig

Design Brief

The problem in which I have been given is to create a structure that allows phased array ultrasonic testing to be completed on pipes and pipe welds where the flange has tapered sections. The jig should be able to work on a variety of diameters, angles, thicknesses and materials. This creates a series of problems which will have to be considered when making a PDS and the following document is going to outline the issues that need to be considered.

Performance

- 1.1 Must enable the testing method to be carried out with no issues.
- 1.2 Must be able to be adjustable to function with different sized tapers and diameters. (May be impossible and therefore group different sizes together e.g. 10mm-50mm jig, 50mm-100mm jig, 100-200mm jig, etc.)
- 1.3 Be able to be used infinitely without the mainframe deforming or malfunctioning. (parts such as bearings and bushes would be able to be changed).
- 1.4 Be able to be transported easily to be used in a variety of places. The dismantling and reconstruction of the testing probe holder must be easy for the user, depending on competence).
- 1.5 Parts must be readily accessible in case of any problems that could occur during the process. (Use as many standard parts as possible.)
- 1.6 The design must ensure that the probe is parallel to the taper and must maintain contact on the pipe at all times.
- 1.7 Needs holes incorporated into the design for water hoses for the testing method.

2.0 Environment

2.1 Must be functional in a variety of temperatures depending on the location in which the testing jig will be used. As it will be portable this would have to be functioning in temperatures ranging from different countries where Oceaneering is located. Depending on fluid and material of the pipe, the temperatures where this must be functional is 0-300°C.

2.2 Must only be used in a clean working environment as there are moving parts and sensitive testing equipment there must be no interference from anything else. Also for the encoder wheel which measures distance around the diameter this must be very accurate for good results. (Free of dirt, debris and only run on a clean surface).

3.0 Target Costs

3.1 The product should not exceed a £1000 cost to resolve issue. This includes research, materials, production, testing and any amendments made after testing. This does not include the cost of the testing equipment and the software as my project is only to design and produce the testing jig. As the testing equipment being used is expensive, if unavoidable costs are incurred on the way, then this would be acceptable.

3.2 Project must be completed in timeslot given for both an academic and a practical use, academically for my final year project and practically for Oceaneering to start using and save money on alternative testing methods.

4.0 Quantity

4.1 One prototype to be made to make ensure the jig works.

4.2 Initially, two final products to be produced. These can then be compared to each other to validate the results.

4.3 If the final product is successful and the demand for more of these is necessary, the more must be able to be produced for demand.

5.0 Maintenance

5.1 Initial maintenance plan to be created. As there are moving parts this would involve lubrication and spare parts e.g. bearings, chain links, chain, encoder wheels.

5.2 Manual lubrication would be suitable for this form of maintenance. (Oil or grease as long as it does not interfere with the testing of the product. i.e. the surface of the material and the surface of the testing probe).

5.3 Spare parts should be readily accessible and if these parts are not stock items and are machined then more than one of each should be made per unit.

5.4 After many uses, the parts may show wear on certain areas of the pipes or the testing equipment itself, in this case a plan could be created to insert wear plates where there are areas of stress or friction.

6.0 Size and Weight Restrictions

6.1 Weight should be as lightweight as possible, the material being used will determine this and aluminium would be the best choice, suggested to stay away from carbon steel.

6.2 The size of this product would vary depending on whether it is designed for groups of dimensions (as mentioned in section 1.2) or if the design will be one size fits all.

6.3.1 In the case that it's grouped dimensions then the size would vary depending on the product.

6.3.2 In the case that it's one solid dimension then the size of the product would be used up to 24" diameter pipe, so the design should incorporate this dimension.

6.4 The size of the jig must ensure that there is contact between the probe and pipe at all times.

7.0 Manufacturing Processes

7.1 For the prototype, a 3D printing process can be used where applicable and off the shelf parts for the other components.

7.2 For the final product, Oceaneering use a lot of aluminium which can be easily machined in either their workshops or machining shops on campus. (Milling, turning and grinding).

7.3 For design efficiency, bolts, nuts, pins and clips are going to be kept to a minimum, but where needed these will be standard sizes and parts easily accessible.

8.0 Quality and Reliability

8.1 This process should not fail in its lifetime, once made it should break if maintenance plan (as explained in section 5.1 is adhered to)

8.2 Obviously some parts may experience problems which we do not foresee, therefore contingency plans will be put in place for any issues (such as explained in section 5.4).

9.0 Processes

9.1 All components to be of metric form and comply with BS8888 for limits and fits.

9.2 For the assembly of the jig, there should be as little parts as possible, this will increase the design efficiency.

9.3 For the assembly, there should be only one way the assembly can be put together minimising the chance for anybody using the equipment to misuse it or assemble it wrong.

10.0 Safety

10.1 All moving parts should not be able to move if there is any deformations on the pipe.

10.2 Depending on who is using the equipment, they should be trained to a competent standard.

10.3 If the person using the holding equipment is not competent, they should follow an instructions manual for assembly and use of the equipment.

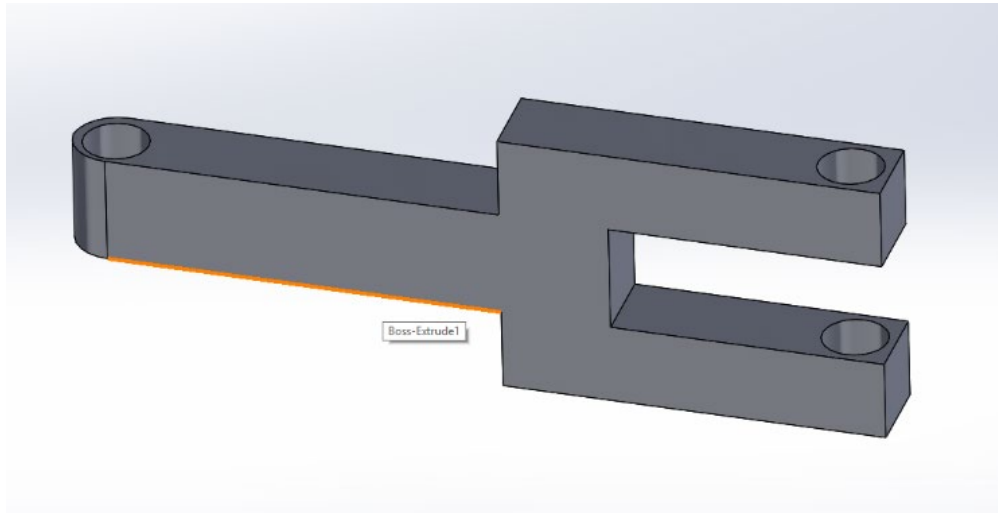
11.0 Testing

11.1 Testing is to be carried out on 3 example pipe flanges of different sizes which have been previously tested to compare results.

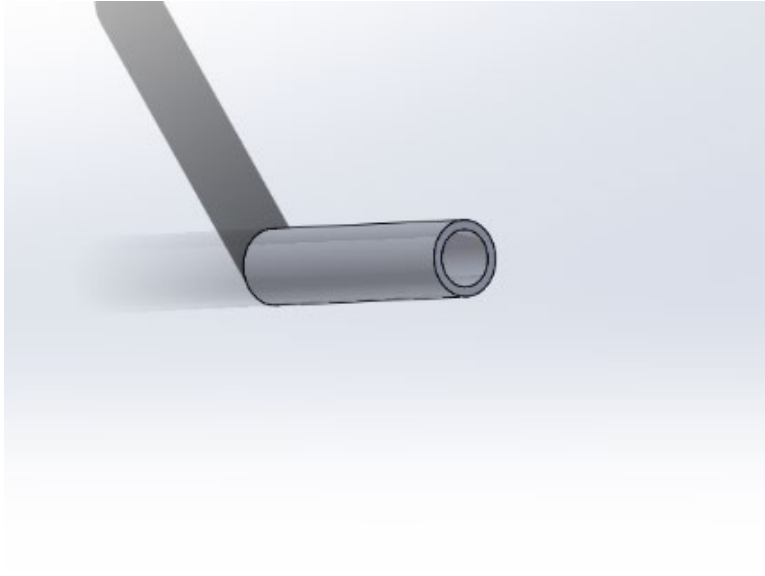
11.2 Tests completed on parts which are known to be deformed and see if equipment is functioning.

11.3 Moving parts and components such as: bearings, pins and bushes should be tested prior to completing the material testing to check for wear or deformation.

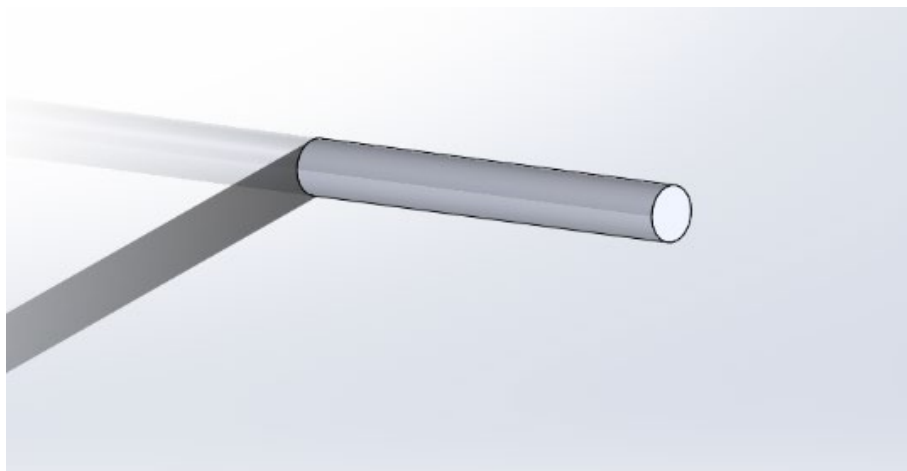
Appendix 3.



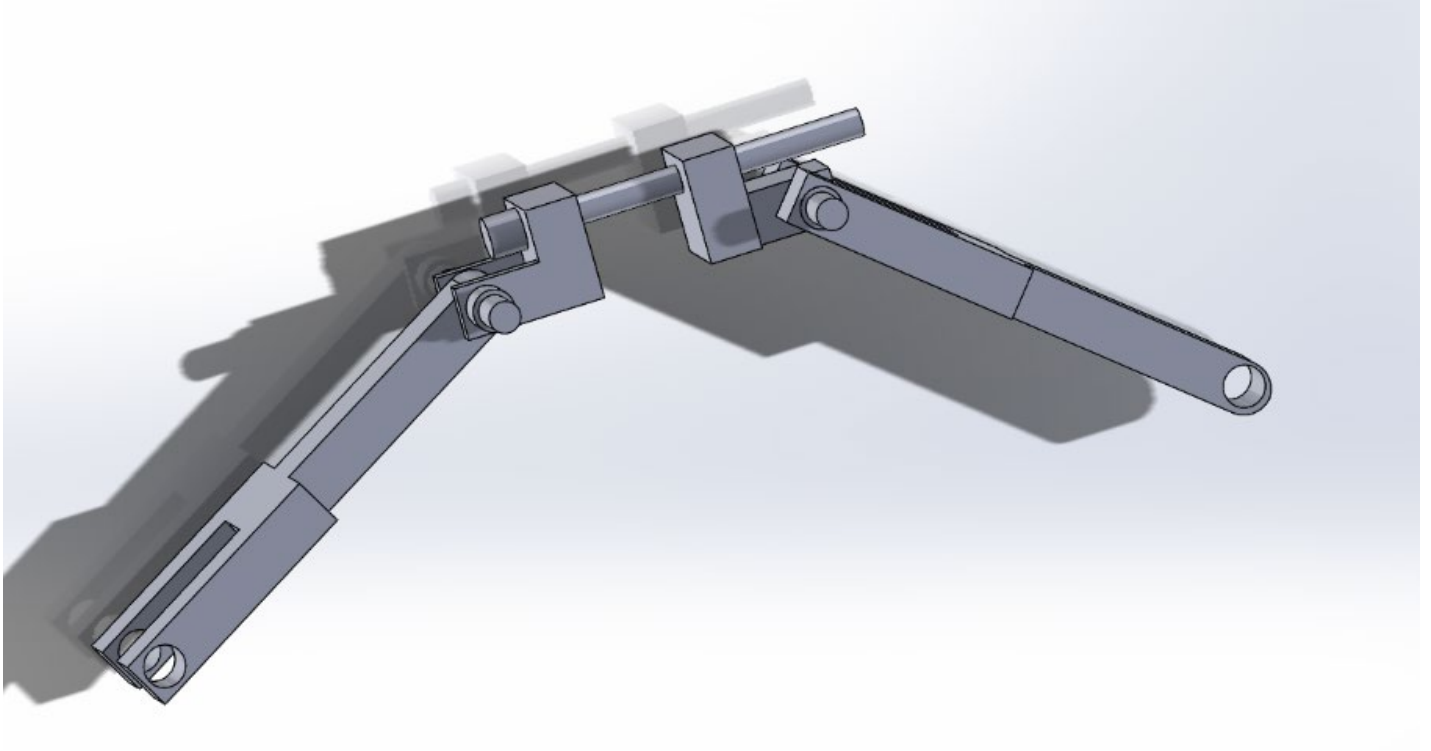
Appendix 4.



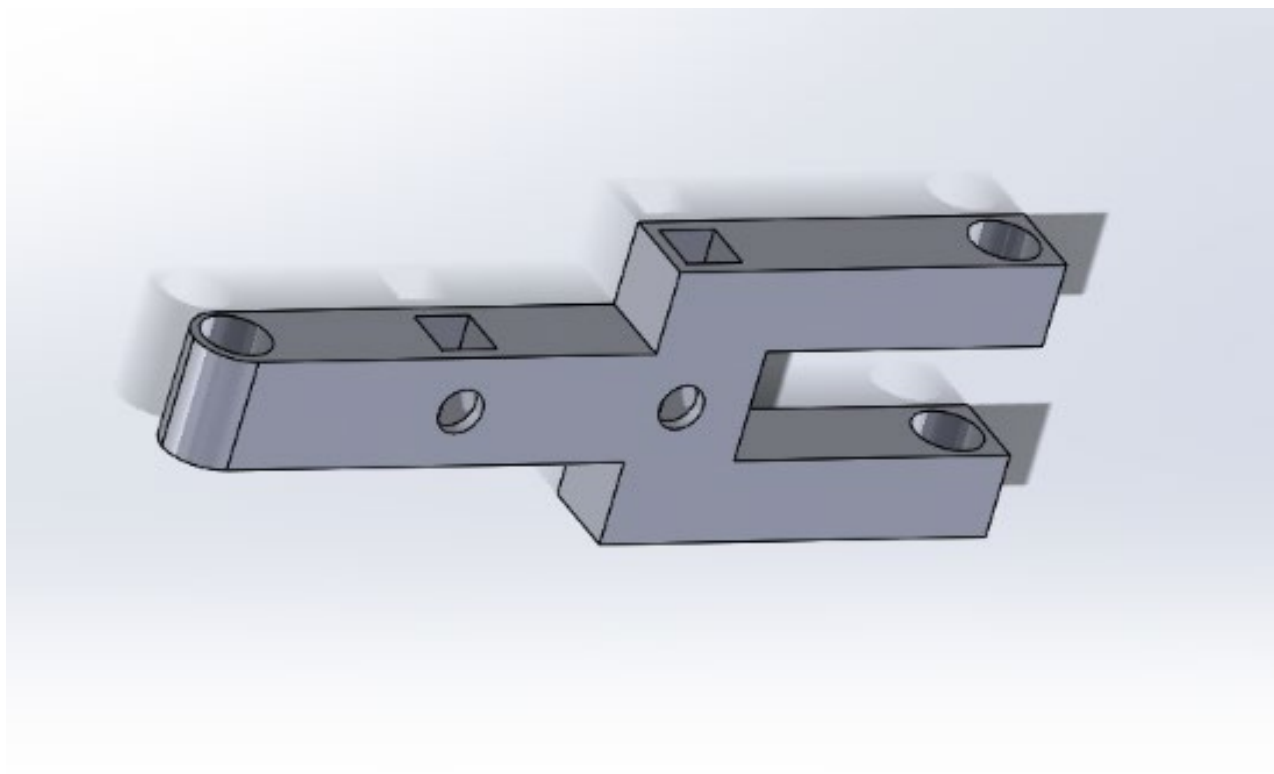
Appendix 5.



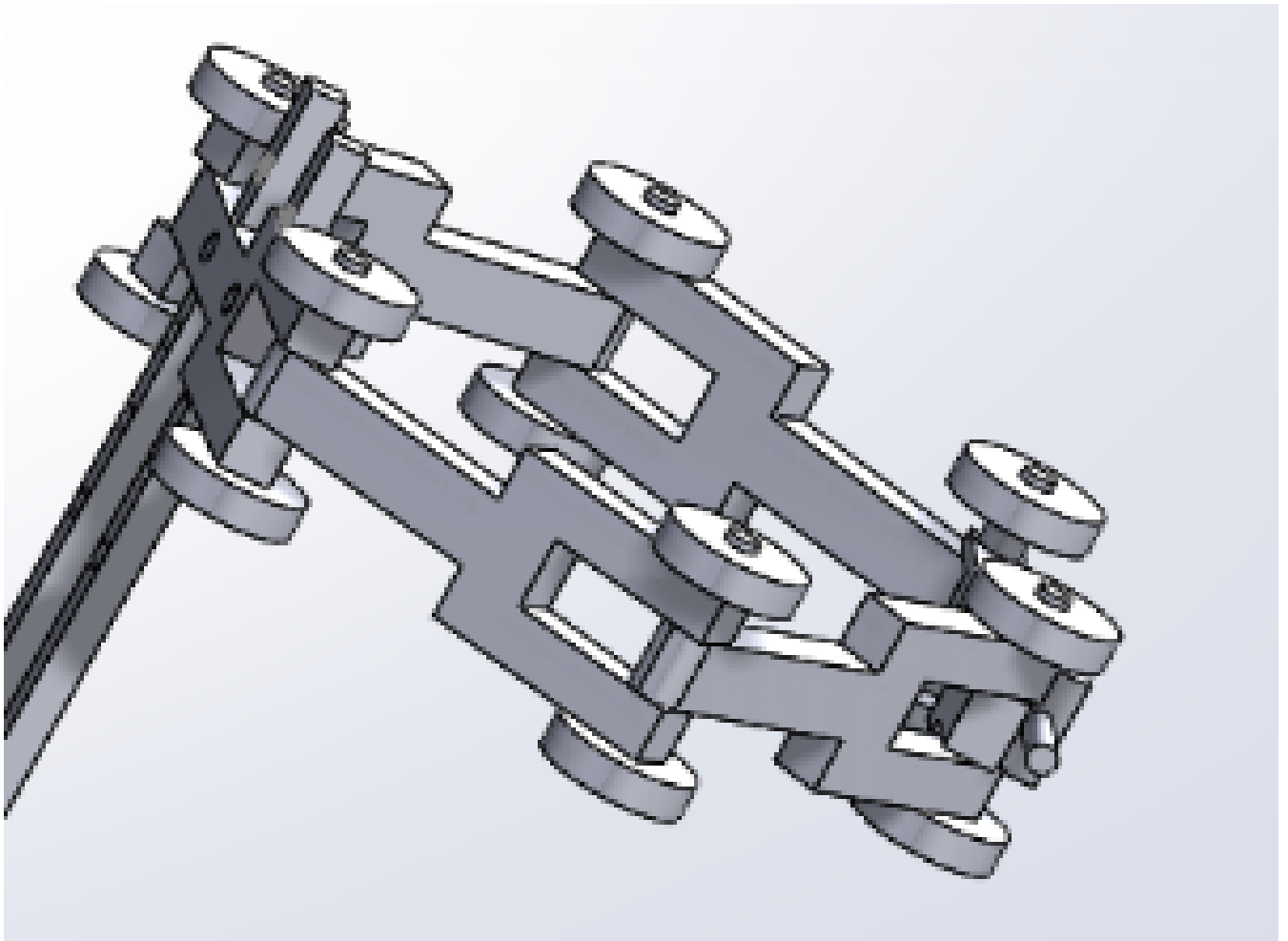
Appendix 6.



Appendix 7.



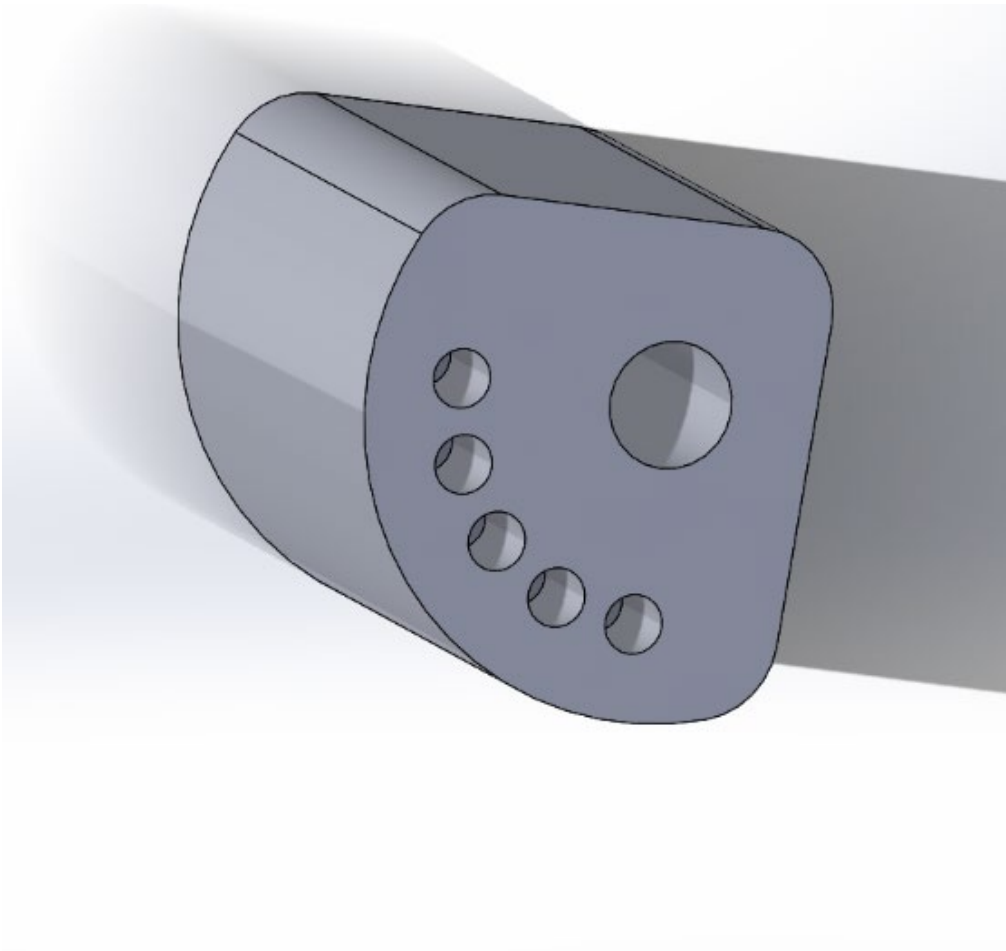
Appendix 8.



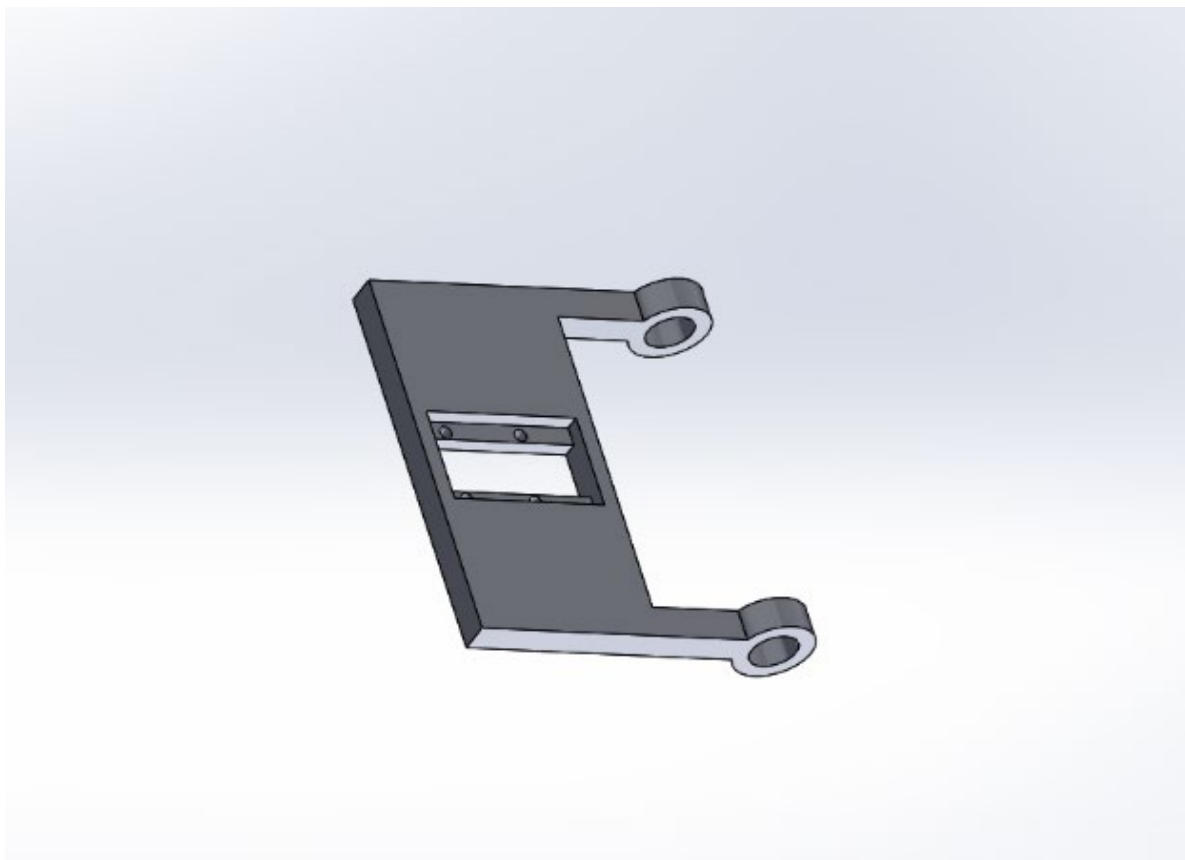
Appendix 9.



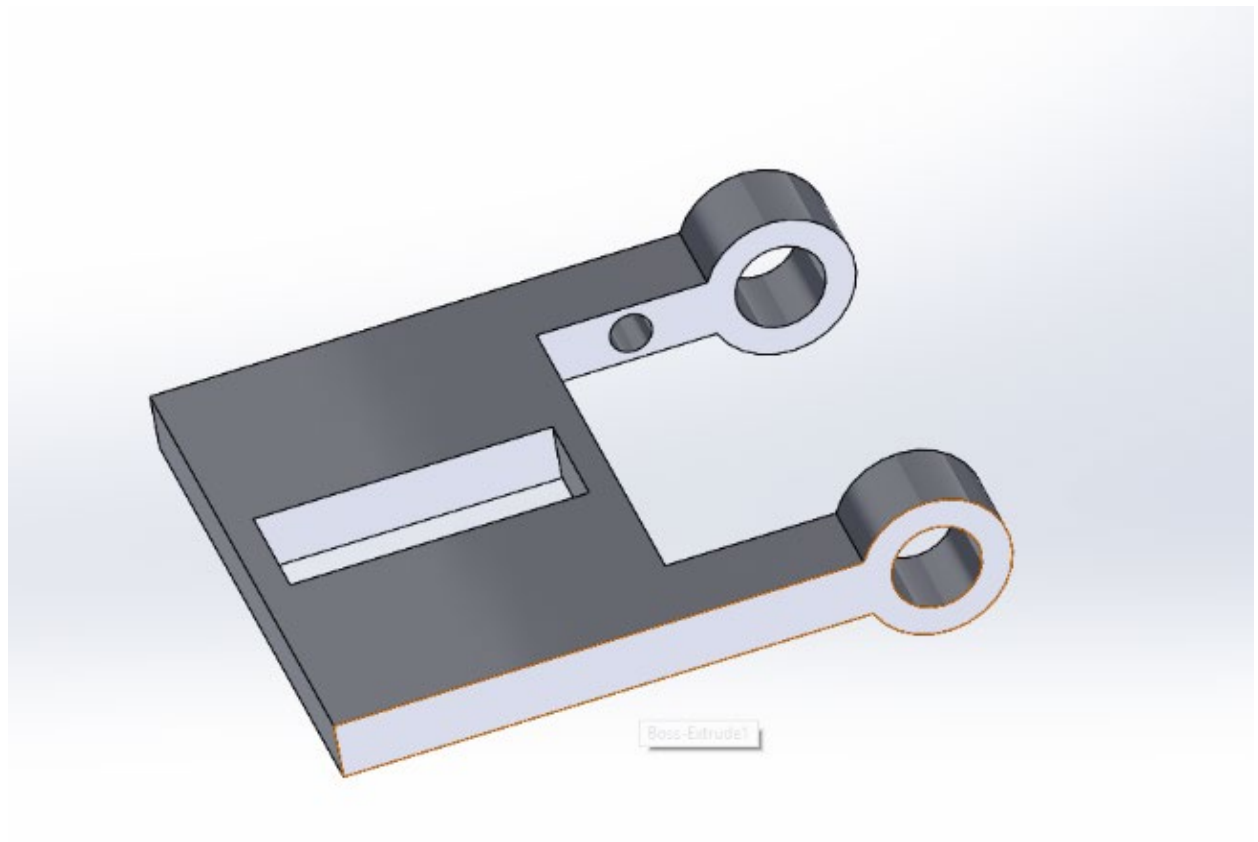
Appendix 10.



Appendix 11.



Appendix 12



Appendix 13

