

Bobby Freer - MSC Project proposal



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1.0 Introduction

1.1 NDT & Flange Inspection

Non-destructive testing (NDT) is an ever-evolving field of engineering which essentially involves the use of scientific and practical analysis to determine information from a sample / component without damaging the specimen, unlike destructive testing which would likely damage the component to a point where it cannot be used.

A pipe flange is a disc collar that attaches sections of pipeline together giving increased support and the ability to block of the pipeline if needs be. They are typically welded to the pipe ends and connected with bolts (as the figure below shows). A gasket is then inserted between the two mating flanges to provide a tighter seal.

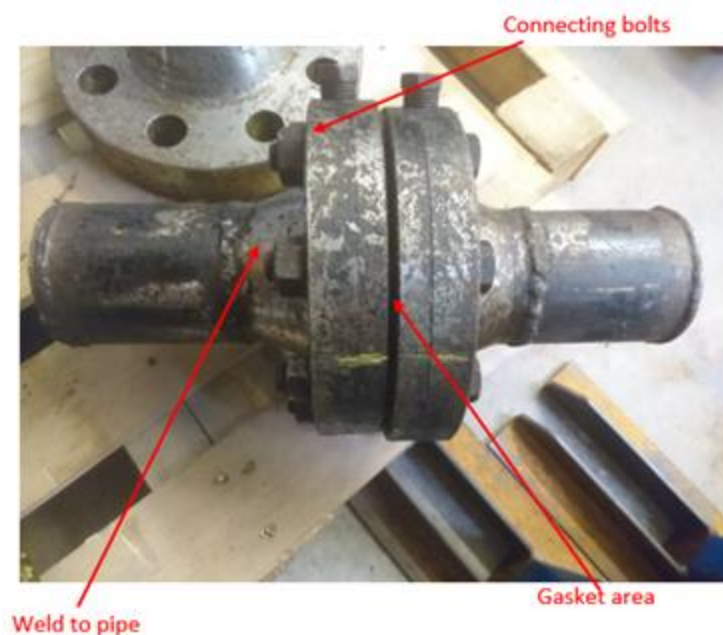


Figure 1 Pipeline Flange (Liam Pennaluna)

Current ultrasonic testing methods uses a phased array ultrasonic testing technique (PAUT). This is an angled shear wave scan Introduced to the component either through the bolting area or the flange skirt (Kenny, 2012; Kenny, 2012). The problem with the current methods is that there is an area within the flange skirt that the ultrasonic cannot inspect.

1.2 Current Limitation

Mr Liam Pennaluna, is developing a procedure for Oceaneering where he can inspect the blue area of the figure below, current procedures cannot inspect this blue section of a pipeline flange skirt (at the time of this report). In regard to the procedure he has developed my first task is to run an ultrasonic PoD (probability of detection) and PoS (probability of sizing) analysis on it for varying thicknesses and angles.

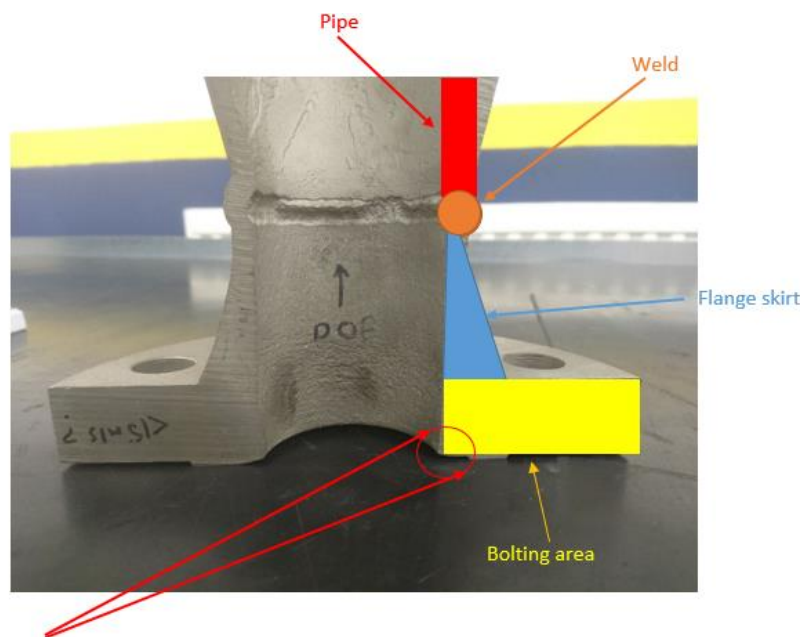


Figure 2 Uninspected area of flange (Liam Pennaluna)

Once all the data has been collected, excel spreadsheets can be created and graphical analysis will be carried out where assumptions can be made from this graphical analysis of how reliable the method is etc. Data can be collected from looking at when at certain thicknesses the system will reach 90% confidence, and how small a defect could it detect to a certain confidence limit of say 20% for example. For probability of sizing the data should be able to give indication into possible calibration issues, and consistency of the user friendliness when used at different gauges of flange.

My next task will be to investigate how resolution is affected. When the beam angle from the ultrasound is steered to achieve the angle needed to investigate this *flange skirt* inspection a high resolution is needed because better resolution means the smaller defect we can find.

Beam focusing means that rather than steering the sound into different regions the aim will actually be to converge all wave fronts to meet at a given point, this is essentially achieved by setting the elements to fire at different angles and with a time delay between as the figure below shows.

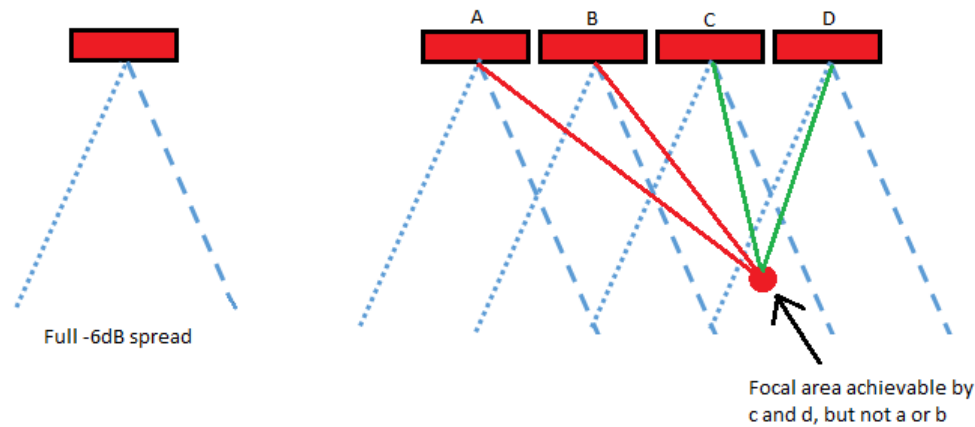


Figure 3 Phased array focusing

My aim here is to find a relationship between resolution and depth when looking at this *flange skirt*. Resolution and scan width. To create an image multiple scans must be taken at the same point, due to steering in the phased array system the image can only be built up from the center of the scan, the problem we have is that only the center of the scans will have this overlapping image

1.3 Statistical Analysis

Now in the position where the problem is understood data can be analysed statistically. NDT processes and procedures can be ineffective unless the correct method is applied to the task in hand. Statistical analysis helps to choose the optimum process and procedure for a given task by with data from experimental trials, by optimising the methods of testing with statistical analysis we will be able to get more accuracy from readings and improve the chances of an operator finding a flaw.

As NDT engineer's basic methods of statistical to analysis can be used on for data such as the mean, standard deviation and, confidence limits, these analytical methods will indicate how consistent tests may have been but to get more indication on the testing process and procedure we can use PoD (Probability of Detection) and PoS (Probability of Sizing). PoD can be defined as the probability that using a given inspection procedure/system/sensor an inspector will detect a flaw that is present in a component (B. Raj, 2007), PoS can be defined as a systems capability of defining the size of a known defect.

The ability to check how accurately an operator can define a defects dimensions, will allow for safer pipeline flange design and inspection procedures, for example if it is known from statistical analysis that a defect of say 1mm could be missed in the inspection then flange designs and component lifetimes can be evaluated according to what inspectors could be missing.

1.4 Motivation

The statistical analysis I will carry out will hope to prove how good the procedure of inspecting the pipeline flange skirt is, but the motivation for being able to develop a method of inspection for this flange skirt can be seen in the following bullet points. These following pipeline incidents occurred within the United States of America in 2016:

- On January 9, a 30-inch Atmos Energy gas transmission pipeline exploded and burned in Robertson County, Texas. 4 families nearby were evacuated.
- On January 11, butane leaking from a pipeline storage facility, in Conway, Kansas, forced a closure of a nearby highway for a time.
- On February 14, a 6-inch crude oil pipeline broke near Rozet, Wyoming, spilling about 1,500 gallons of crude oil into a creek bed.
- On February 16, an explosion and fire occurred at a gas plant in Frio County, Texas. 2 employees at the plant were injured.
- On February 24, a 10-inch propane pipeline exploded and burned, near Sulphur, Louisiana. There were no injuries. About 208,000 gallons of propane were burned. The cause was from manufacturing defects.
- On March 11, about 30,000 gallons of gasoline spilled from a leaking plug on a pipeline, at a tank farm in Sioux City, Iowa.
- On March 22, about 4,000 gallons of gasoline spilled from a 6-inch petroleum products pipeline in Harwood, North Dakota.
- On June 23, a Crimson Pipeline crude oil line leaked in Ventura County, California. Initial reports said the spill size was from 25,200 gallons to 29,000 gallons, but, later reports estimate 45,000 gallons of crude were spilled.

The incidents above have resulted in toxic chemicals being released into the environment, injuries and deaths. These are just a number of recorded cases in the America within a six-month period, it could be assumed that America would have a tighter safety procedures and standards in comparison to other parts of the world who also are dealing with the same pipeline inspection processes. These incidents display the importance of NDT. It should be notes that these incidents are not all as a result of the pipeline flange skirt failing, but if there was an appropriate NDT procedure in place for these cases.

1.5 Aims & Objectives

The overall aim of this project is to be able to give data on how well the pipeline skirt inspection procedure will perform on different sized sections of flange, this will be in terms of probability of detecting a flaw, and how well it can size this flaw, as well as in scenarios where corrosion, rust and dirt are in the pipe. The second aim is to be able to determine a relationship between depth of penetration and resolution, as if resolution decreases certain size defects could be missed.

- 1) Quantity how well the system works on different flanges with statistical analysis
- 2) Find a relationship between defect depth and resolution

To satisfy the first objective knowledge of the software used, the problem in hand and phased array systems must be understood to a sufficient level before a fair statistical analysis could be carried out.

The second objective will run from the first objective as when different size of pipeline flange are tested a relationship should start to become apparent between depth and resolution.

2.0 Informative literature

2.1 Oceaneering

Oceaneering who the project will be carried out in conjunction with is a subsea engineering and applied technology inspection company who have been operating since 1964. The branch of the company where my work will be concentrated will be the advanced NDT (Non-destructive testing) and inspection services, within the Swansea site where my statistical analysis will be carried out is primarily a training and inspection site.

Oceaneering as a company have vast experience with ultrasonic NDT (www.oceaneering.com, 2018), in particular Guided wave testing, Electro magnetic transducers and Advanced ultrasonic testing. In these specific area Oceaneering offer designated inspection services to well known brands of the oil and gas industry such as Shell.

2.2 Ultrasonic Testing Basics

Ultrasonic testing techniques are widely used for many tasks in NDT such as detecting internal surface cracks in materials and structures, as well as gathering information on material depth and continuity of the material.

The basic principle of ultrasonic testing in NDT is creating an elastic sound wave with a piezoelectric crystal transducer and then propagating this sound wave through a material or structure. Here to create this an alternating voltage will be applied to a piezoelectric crystal which will cause the crystal to expand and contract thus sending out a compression sound wave (John, 2003) The transducer (piezoelectric crystal) will also act as a receiver of the signal sent, this set up is known as 'single crystal'. A set up where two transducers are used one to emit a signal and one to receive a signal is known as a 'twin crystal' set up. Twin crystal probes are generally needed for short-range operations (B. Raj, 2007), this report will predominately be using single crystal probes.

When the wave path meets a discontinuity (i.e. a crack), part of the energy from the original wave will be reflected, back from the surface of the crack to the probe. This reflected wave signal from the crack is then transformed into an electrical signal by the transducer when it reaches back to the probe, creating what is known as an 'A- scan' to be displayed on the screen of ultrasonic testing equipment.

The process described represents a single sound wave being generated from one transducer, this project will be using a phased array system which is a multiple transducer embodied in a single unit. Phased array allows for images to be built up when the sound waves are directed at the same spot, this is achieved with a series of time delays and firing angles from the beams. Having the ability to converge the sound waves in one spot allows for a high quality of image to be built upon which is why a phased array system is being used for the project.

2.3 Statistical Analysis Methods

Some of the most important questions to be answered when looking to use NDT for a specific task are, what inspection methods are applicable? how small a flaw can they detect? And what type of process control is needed to maintain this level of performance? Statistical analysis helps to determine this (B. Raj, 2007).

Two main forms of statistical analysis will be used are probability of detection (PoD), and probability of sizing (PoS). These methods will involve taking means, standard deviations and line correlation for these analysis models.

2.3.1 PoD

PoD (probability of detection) is a method to validate testing equipment and methods in relation to a defect size. It was developed by NASA in the late 60's as there was a necessity to validate procedures and capabilities of procedures and NDT equipment. An example of this variance that caused the need for PoD is in a paper by WH Lewis (Lewis W H, 1978) it is described how he had 60 air force inspectors, use the same surface eddy-current technique to inspect 41 known cracks around countersunk fastened holes in a 1.5m length of a wing box, the results were that none of the

cracks were detected 100% of the time, and different cracks with the same size had variation in detection percentages. Case stories like in WH Lewis paper can be found commonly in NDT literature, this is why there was a need to measure the variance in NDT process capabilities. (Although the main reason for NASA in developing PoD was more to find out the largest possible defect that could be missed for various NDT methods, and use this figure in consideration for fracture mechanics and design). Now many industries have adopted PoD as their standard NDT reliability method.

PoD can be found by experimentation on the number the number of defects found in parts that contain a known number of flaws, i.e. if 100 defective parts are inspected and 95 are found to have defects we can say that the Probability of detecting a defect is 95% (B. Raj, 2007). PoD results will fall somewhere between 0 (0% chance of detecting a defect) and 1 (100% chance of not detecting a defect), i.e. if a defect is found a value of 1 is recorded and no defect records 0. By assigning POD values to a procedure, it is possible to compare the effectiveness of different inspection techniques and equipment for a certain task. Alternatively, PoD values can be used as a target for procedures to be shown to be able to achieve (www.bindt.org, 2013).

This experimental process mentioned of whether a flaw has been found in a sample with known defects, will categorise results into four possible outcomes (www.ndt.net-POD, 2006). It will essentially be described as hit and miss data.

1. An item is flawed, and the NDT method detects it (True Positive)
2. No flaw exists, and the NDT method indicates a flaw present (False Positive)
3. An item is flawed, and the NDT method does not detect it (False Negative)
4. No flaw exists, and the NDT method has no indication of a flaw (True Negative)

The tool most commonly used for PoD description is the PoD curve, as displayed in the graph on the next page taken from an NDT.net (www.ndt.net-POD, 2006). Here we can see from the graph that there is a 30% chance of detecting a flaw 1mm high, and an 80 % chance of detecting a defect 2.2mm high. The pink curve below the PoD curve displays a confidence limit.

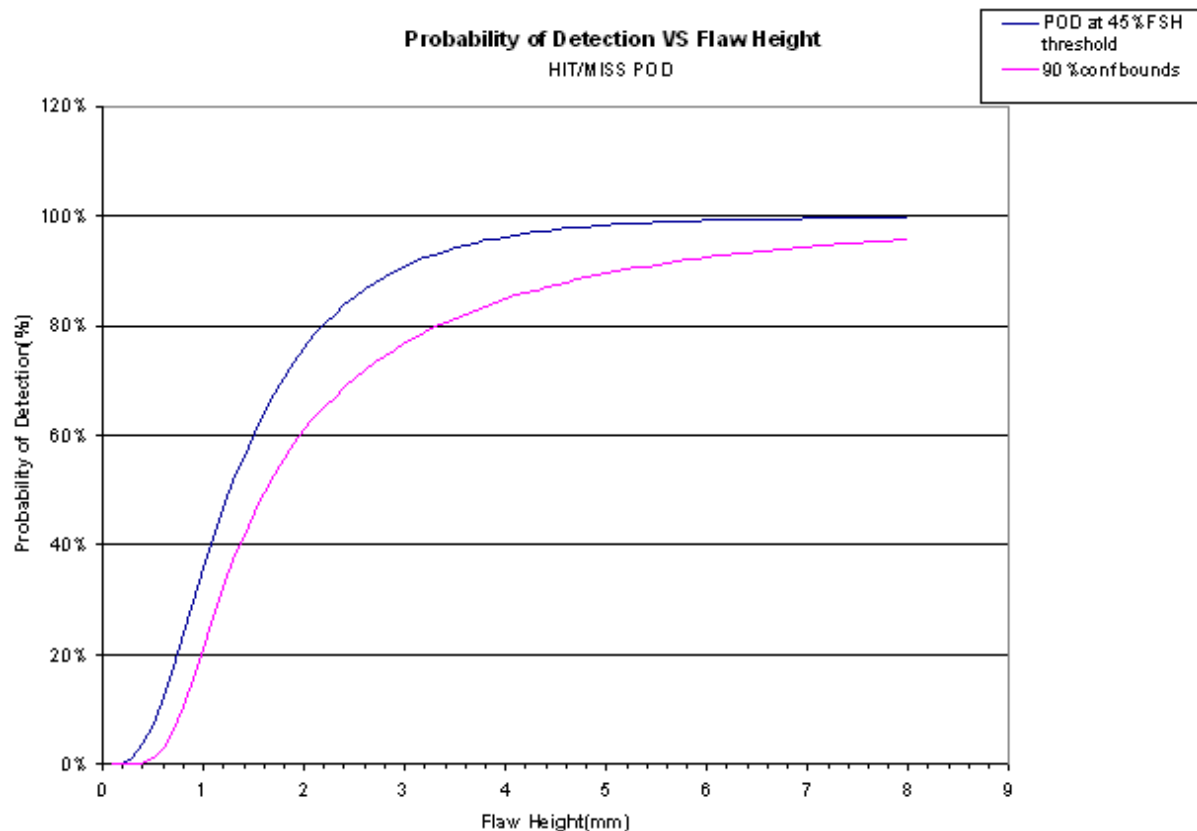


Figure 4 PoD Graph

2.3.2 PoS

Probability of Sizing refers to how accurately an operator can size a defect. Here uncertainties will exist when the operator must provide dimensions on the flaw, different operators readings will vary plus/minus the actual size of the flaw, as is typical with all operator measurement. For example, if a group of 20 people were to use measure a block with a vernier calliper for *Length, Height, Width* results would differ due to how much pressure they apply to the calliper jaws, where they take the measurement from, skill level and if it is a mechanical, not a digital vernier gauge possible rounding errors (www.ndt.net-POD, 2006).

When an NDT operator is asked to make a judgment about the size of the flaw the result is then compared to an allowable dimension chart, operator under-sizing could ignore a potential failure and oversizing could cause concern to a within tolerance component. The graph below has an Ideal Sizing line, this would have been calculated through destructive testing where the recordings can now be compared to what is an allowable deviation. In the case of where a known defect sample is being used we can create a True Size line and compare the operator's readings to this True Size, this will give assessment on how well the equipment can be used by the operator.

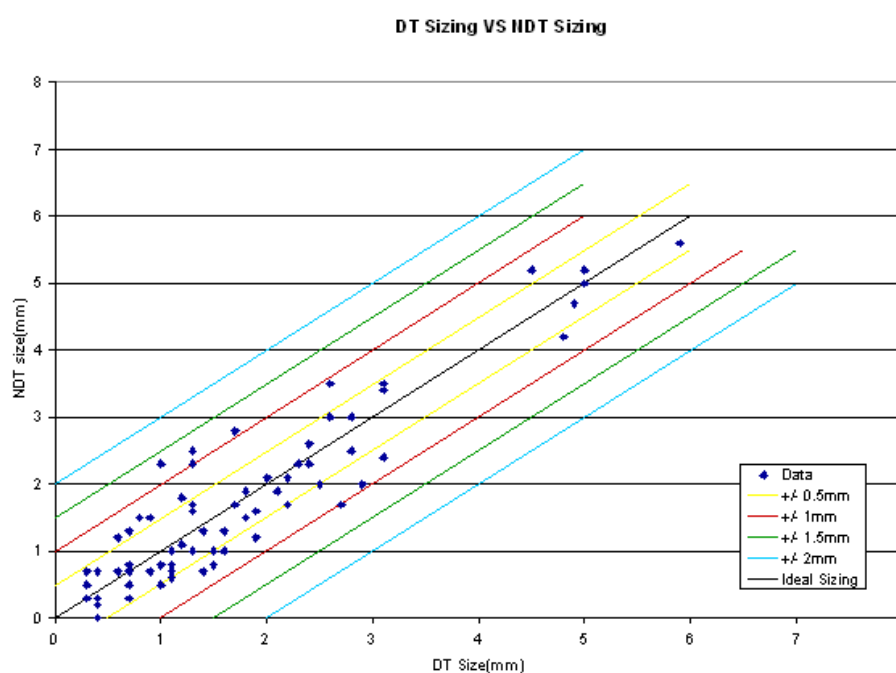


Figure 5 PoS Graph

These graphs are created by comparing the true size against the operators estimated readings. From these values the operators error can be calculated using the following;

$$\text{Operator Error} = \text{Operator Measurement} - \text{True Size}$$

This value is used to calculate the standard deviation of the operator's errors allowing for the 95% confidence limits to be determined.

3.0 Research & Development Methods

For the research a further literature review around the study of ultrasonic phased array imaging will be carried out along with some relevant case studies experiments of similar problems involving resolution and depth. This will give further understanding of the problem and allow the statistical data to be approached in a more methodical way.

3.1 Risks & Limitations

Limitations have already been encountered, after I had found six samples which I wanted to test and marked with a name on and put them to one side the samples were then needed to be sent out to Norway, which was unplanned for, essentially leaving me back to find another six samples. So essentially there will need to be greater communication between myself and the company to the samples I will need to the ultrasonic testing data.

Other possible limitations will be;

- Learning new software within a time frame
- Being able to record consistent data with vast UT experience
- Being able to make correlations for resolution if data is not recorded correctly

3.2 Data Evaluation

As mentioned to be able to evaluate the data, the problem and background theory must be understood first. The aim is to be able to record the data after the literature review and similar case studies have being investigated in order to know the problem further and be able to approach the practical side of the project with more knowledge rather than just recording large sets of data with no direction.

The statistical methods will allow for the evaluation of the data and will soon highlight if there is a problem with it, as with most statistics the more sets of data that can be recorded the better the

results will be, but a decision will be made on how many sets of data to take after time scales of how long it takes to record one set is finalised.

4.0 Resources & Planning

Although it is still early in the project a degree of planning for the coming months has been taken into account, this is hoped to be a first draft guideline of the tasks to come, but it would be expected that after further reading around the subject area that more tasks needed to be completed will be apparent.

4.1 Resources Required

Hardware

- Phased array 32 element ultrasonic
- Test samples
- Vernier calliper
- Micrometre

Software

- Civa ultrasonic software
- Microsoft package

Gantt Chart

Task	March	April	May	June	July	August	Septmeber
Lit Review							
Similar Projects							
Data Collection							
PoD Analysis							
PoS Analysis							
Resoltuion Investigation							

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