The Use of a Magnetic Probe coupler to aid the reliability of manual ultrasonic testing (MUT) on carbon steel components

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Abstract. The reliability of MUT is arguably sub-par. There has been very limited work on the reliability of MUT of corrosion as most of the research focused on MUT of weldments. The current body of literature showed a host of human factors that affected MUT, and a survey carried out on Non-destructive testing (NDT) personnel working in industry highlighted that two areas of concern were the task and the inspector. It is proposed that the use of a magnetic probe coupler (MPC) will aid the task and the inspector in carrying out a reliable MUT inspection. It will do this by ensuring that probe coupling is maintained to the Carbon Steel surface when working in a variety of positions while improving the tactility of scanning a component. It will greatly aid the monitoring of known areas of wall loss by ensuring that the probe is coupled consistently and accurately in the same position. The areas of wall loss can be easily marked when the technician is not manually trying to hold the probe to the test piece. The research will look to demonstrate the effectiveness of the MPC utilising it in corrosion inspections trials to validate the MPC.

Keywords: Reliability, Manual ultrasonic testing (MUT), Carbon Steel, Corrosion, Non-destructive testing (NDT).

1 Introduction

Plant operators protect their pressure systems and assets with pre planning in the design stage of the engineering of plant and equipment. Companies do not have limitless budgets so the perfect materials cannot always be selected due to costing. Therefore, carbon steel is a prime candidate to be used in pressure systems and structural steel due to its availability, pressure retaining strength and ease of workability. Corrosion rates are calculated and worked into the design and there is an expectation that the components will corrode but the necessary control measures will be in place to mitigate the risk of total failure of the system by means of careful engineering and planned inspection intervals. Regular inspection regimes are paramount for plant and structural integrity it is vitally important that the reliability of MUT is high to ensure the continued safe operation of assets.

MUT is a commonly used technique to detect and gain quantifiable data on remaining wall thicknesses however there are many variables which can be attributed to both human and physical factors, any changes in these variables can have significant effects on the data collected. There have been numerous studies on the reliability of MUT and large scale trials and projects such as the programme for inspection for steel components [1] (PISC) which took place from 1974-1991, The Netherlands instituut voor lastenchiek, Dutch institute of welding [2] (NIL) project initiated in 1986 and the programme for assessment of NDE in industry [3] (PANI) in 2009.

These have been focused on weld scanning and not on wall thickness/corrosion measurements which are one of the most common uses for MUT in the oil and gas sector. [4] In a survey conducted by HOIS offshore inspection JIP, an initiative instigated in 2016 to address human factors in oil and gas industries, found that 44% of companies and organisations hardly address human factor issues when planning and managing NDT inspection. The remainder 56% addresses some of the issues only, Nevertheless, MUT remains a cost-effective solution for companies and will continue to be used for many years to come but it is imperative that MUT reliability is improved to ensure that the results obtained are as reliable and accurate as inherently possible. The cost and ease of application of MUT for remote locations makes it particularly appealing to companies.

Human factors are an integral part of NDT and it is one of the main reasons reliability is affected during an examination or inspection [4]. There is a clear consensus that despite their obvious impact on NDT, they are often ignored. This is in part due to a lack of actual data that records human errors in an inspection. Examples of human factors which can affect an NDT are vast, some of these factors are organization, equipment, fatigue, lack of knowledge, lack of communication and complacency to name a few. In contrast to early evolution of improving the reliability of MUT, which consisted of training operators and organizational changes, the emerging line of development puts more emphasis on the use of novel ultrasonic probe design. This research aims to address the impact of human factors through a magnetic casing to control scanning speed, tactility and coupling of the probe to the test piece.

2 The Prevalence of MUT in industry

A survey of 73 NDT workers undertaken in 2021 asked practitioners in industry 13 questions on their use of MUT in industry. Two key outcomes have strongly emerged in their responses:

1.) MUT is still widely used in the oil and gas industry. 46% work in oil and gas, upstream and downstream sector and carry out MUT on a frequent basis and 53% stated that the access to the test item is deemed easy while 74% identified Carbon Steel as the most common material they test.

2.) The improvements that are needed to produce a more reliable MUT test were identified to fall in 3 clear categories based on Martin Wall reliability model [4]. These are: detailed pre site job assessments, additional training, and modern and varied equipment availability as shown in Figure 1.

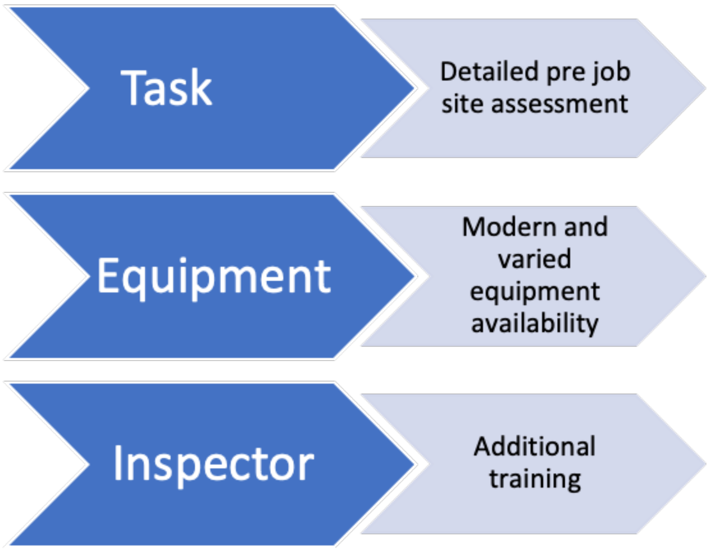

Figure 1. Improvements needed to produce a more reliable MUT as identified by survey respondents.

2.1 Magnetic probe coupler

A typical compression twin crystal probe and A scan display on an internally corroded component under test is illustrated in Figure 2. The probe used in corrosion inspection has a diameter of 10mm.

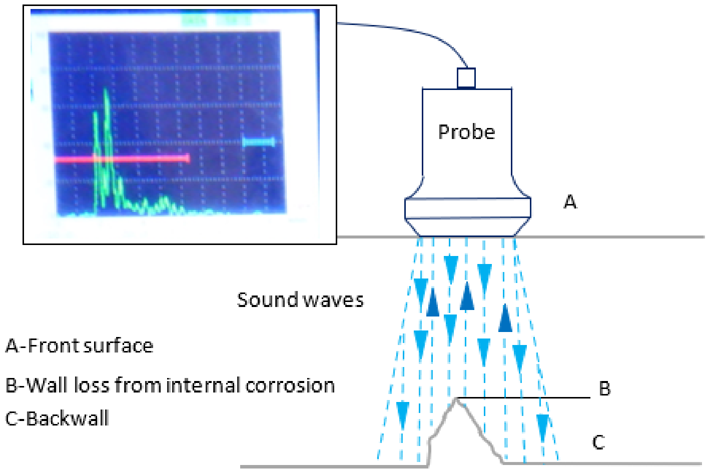

Figure 2. Internally corroded component under test and A scan display

The housing of a typical probe is either plastic or metallic with a Perspex shoe which wears over time. The probe is coupled to the test surface by the user who then manually moves the probe over typically curved test surface trying to apply a constant pressure as demonstrated in Figure 3.

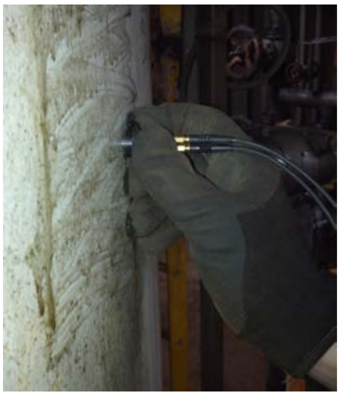

Figure 3. Standard twin crystal normal compression probe at 5 MHz coupled manually to Carbon Steel component.

The probe is typically small and lightweight and can be easily scanned over pipe size diameter greater than 2”. However, it may be difficult to maintain a constant scanning speed or constant pressure and therefore requires frequent manipulation.

Besides, the tactile sensation is diminished due to wearing of personal protection equipment (PPE) gloves. Hence marking low readings on components in exact locations becomes unreliable due to poor probe contact.

A magnetic probe coupler prototype was developed which couples to the Carbon Steel test surface using magnets countersunk into the face of the coupler. The MPC was constructed out of wood. The magnets ensure consistent coupling and pressure application while also giving the user several other benefits when moving the probe across the test surface such as controlled speed, a positive tactile response, and the ability to manipulate the flaw detector settings such as moving gates, adjusting sound decibel, and easily marking defects on the component. This design ensures known quantifiable parameters that can be repeated by the next inspector which will lead to a more reliable and consistent MUT inspection. Figure 4 shows the first handmade prototype design and Figure 5 shows the initial design for proof of concept.

Figure 4. Magnetic probe coupler prototype coupled to Carbon Steel component.

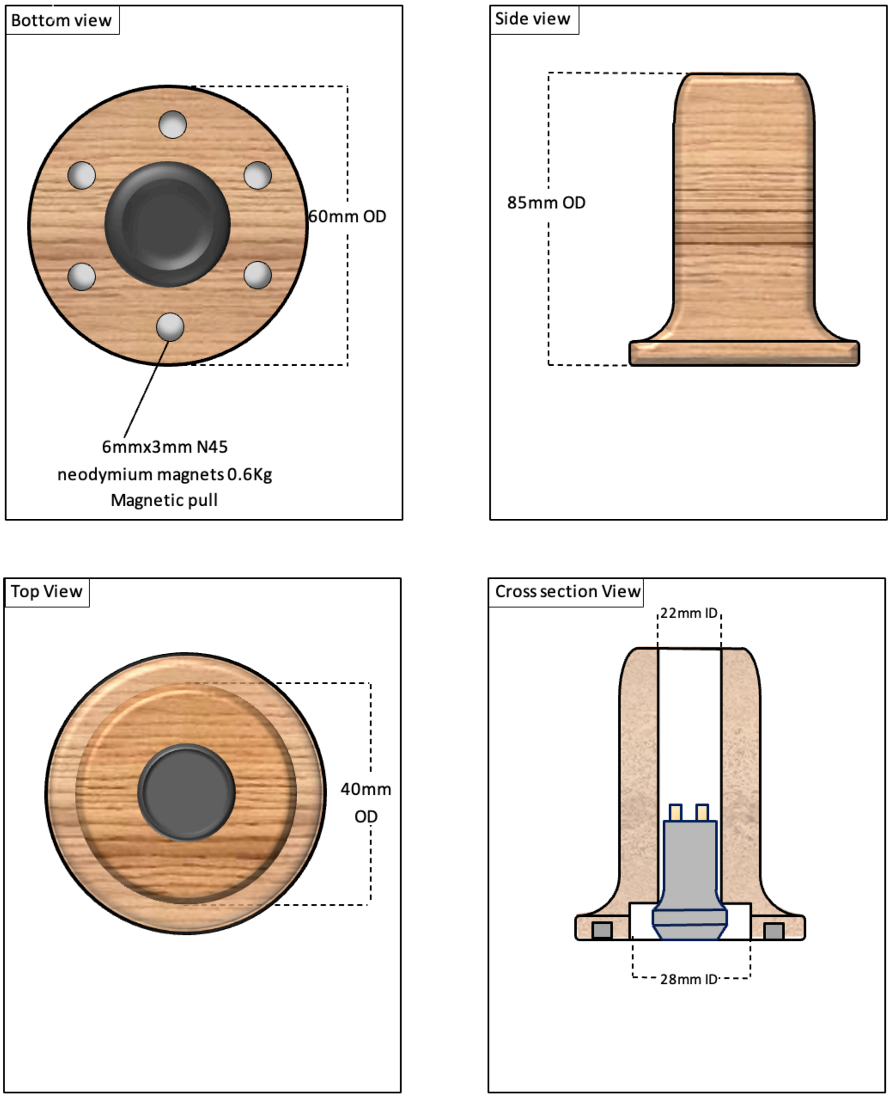

Figure 5. Magnetic probe coupler design for proof-of-concept drawing

2.2 Future work

The future MPC will be 3d printed to easily cater for all probe manufacturers designs and the differing curvatures of pipework. The MPC will be used in MUT reliability trials on Carbon Steel pipes seeded with internal corrosion like defects. The results from trials used with the magnetic probe coupler and a probe used without a coupler will be compared in terms of defects detected, the sizing of the defects and feedback will be gained from the participants to gain valuable information to further improve the design and application. There are further design changes proposed for the probe coupler to improve the ergonomics. An additional modification could include a couplant delivery system which would use a basic pressurized sprayer modified with an outlet hose connected to the probe coupler. A prototype is being designed with haptic feedback capabilities, the coupler will provide haptic feedback to the user through positive vibrations through the body, these would occur when a low reading alarm is triggered on the ultrasonic set. This alarm function is already incorporated into many ultrasonic sets, and this could be configured into the probe design.

3 Conclusion

MUT of corrosion is widely adopted and used daily in a wide variety of industries. The prototype was made to check that the perceived benefits expected from the design would be achievable when using it during a MUT inspection on an offshore oil and gas platform it was successful on larger diameter pipework but less so on smaller diameter due to the curvature of the pipework at the <12” diameter. From this site trial it could be seen the MPC in its current form would be particularly advantageous when scanning vessels and tanks. 5 technicians who used the MPC commented on the positive tactility, the ease of stop starting a scan in the same location along with marking up potential defective areas and the simplicity of coupling to the test piece. The industry standard normal compression ultrasonic probe is unsophisticated and readily available with almost no change to the design for decades. One of the goals of the MPC is to decrease human factors errors, it is designed to augment the existing probe, while retaining the virtues of simplicity, low cost, and dexterous movements. This allows it to be deployed across industry to aid the inspector carrying out the task and to ensure that it satisfies the inspectors need to use modern and varied equipment which ultimately will improve the reliability of MUT. The trials that are to be carried out will aim to give quantifiable data and demonstrate the effectiveness of the device.

References

1. Programme for inspection for steel components, (PISC) (1974-1991)
2. The Netherlands instituut voor lastenchiek, Dutch institute of welding, (NIL) project (1986)
3. Programme for assessment of NDE in industry (PANI) (2009)
4. Wall, M: Human factors guidance to improve reliability of non-destructive testing in the offshore oil and gas industry.