Simulation-based POD study for welded pipe inspection

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Abstract

Flowlines used in the Oil and Gas industry are composed of several pipelines welded all together. The girth weld shall withstand pressure and temperature conditions during the life cycle of the flowline and thus has to be inspected for unacceptable defects during production and before installation. One reference nondestructive testing method of such girth welds is the Zonal Discrimination Method, which uses ultrasound phased array transducers. For a given weld geometry and transducer, the performance of the inspection has to be demonstrated during qualification using statistical quantification tools such as Probability of Detection (POD) and sizing accuracy curves.

So far, the qualification is based on a substantial number of experiments on representative welded mock-ups, some with machined calibration defects, and others with realistic defects induced intentionally by artificial means. Such realistic defects are very difficult to create and have to be destructively characterized to measure their real height and location. Thus, the whole procedure is costly and the number of defects is limited. In this communication, we present the results of a study performed in collaboration between CEA, Bureau Veritas and TechnipFMC. The aim is to use numerical simulations to support and complete experiments and to provide robust qualification procedures. State-of-the-art numerical tools based on CIVA 2017 are used to simulate phased array inspection on various defects located in the weld and to rank the criticality of the different variables of AUT set up and procedures and compute model-assisted POD curves.

1. Introduction

The qualification of any kind of NDT system is a costly procedure involving numerous destructive and non-destructive measurements to build POD curves. Therefore, the use of modelling for POD computation has been studied for the last few years [1-3]. It enables to overcome the limitation regarding the number of defects or samples; and it allows performing sensitivity analysis to rank the influential parameters in terms of influence on the outcome of an inspection, which can be used to increase the reliability of the system.

However, the determination of the influential parameters potential values is often still challenging. This issue is addressed in the first part of this paper, and applied to a use case of Bureau Veritas. The second part deals with the influence of irregular shape of real defects on the reliability of the inspection.

2. Metamodelling for influential parameter value determination

The use case is presented in figure 1. A carbon steel girth weld is inspected by a 7.5 MHz phased array using the zonal discrimination method (for details on this method, see [2]). The POD curves have to be determined for each zone (defined in figure 1), and are computed using Hit Miss approach [2]. We focus here on one Fill zone (noted F in figure 1). As required by [3], prior to model-assisted POD (MAPOD) that is done here with CIVA software, a careful analysis of the influential parameters was done. Regarding the transducer positioning, the range of actual values depends on the operator placing the scanner-guiding band on the pipe. The statistical distribution of these parameters are retrieved using both repeatability tests on a calibration defect and simulations of the same defect. The accuracy of the retrieved distributions grow with the number of repeatability tests. In the absence of enough experimental data, simulated repeatability tests were used. After a proper inversion procedure based on a metamodel of CIVA , it was shown that 100 repeatability measurements were enough to retrieve the statistics of the transducer position with an uncertainty of maximum 10%. The MAPOD curves (figure 2) computed with extreme values of the position distributions give a range of value for $a_{90/95}$ from 1.1 to 1.9 mm.

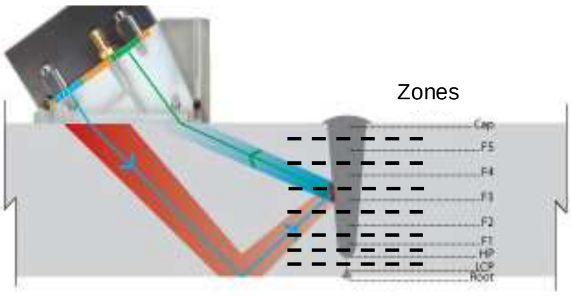

Figure 1. Inspection set-up.

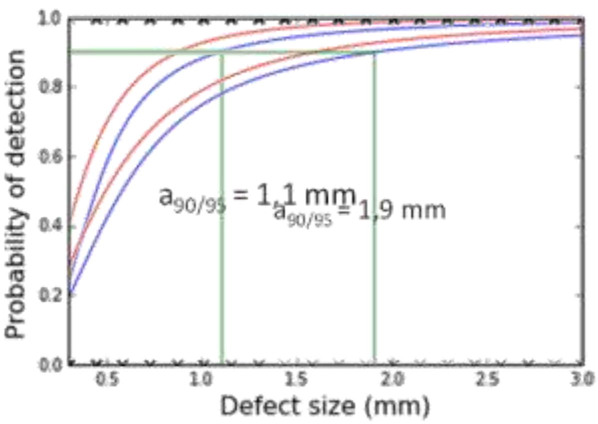

Figure 2. MAPOD curves for extreme values of distribution of transducer position.

3. Study of the influence of the complex shape of the defect

The simulation of an ultrasonic inspection is usually done for simple shape defects (e.g. rectangular notches). To take into account complex defect shapes, finite element models may be used with an increase in computation time compared to semi-analytical models. For a few years, a hybrid approach is developed in CIVA [4], and used here to assess the influence of a defect complex shape on the reliability of the inspection (using empirical knowledge of the shapes encountered in such welds). It is shown that the irregular shape leads to a reduction in the variability of the defect amplitude for big sizes (>3 mm), but with no impact on the $a_{90/95}$ due to the low detection level.

4. Conclusion

In this paper, a new methodology was proposed to determine properly influential parameters for MAPOD of pipeline girth weld inspection system. The shape of the defect was also shown to have negligible impact on the reliability compared to a planar notch. These results give tools to build sound MAPOD curves able to replace all or part of experiments in the framework of a qualification process. As a side benefit, it may also help checking the consistency of the settings used in the experimental process.

5. References

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