POD Evaluation Using Simulation: Progress and Perspectives regarding Human Factor

Nicolas DOMINGUEZ 1, Damien RODAT 1, Frank GUIBERT 1, Aurélien RAUTUREAU 2, Pierre CALMON 3
1 Airbus Group Innovations, Toulouse, France
2 Airbus Operations, Toulouse, France
3 CEA Tech, Institut LIST, Gif sur Yvette, France

Contact e-mail: nicolas.dominguez@airbus.com

Abstract. NDT performances evaluation in the aeronautic industry is made by estimating Probability of Detection (POD). It is a statistical estimation of the capability of a given NDT procedure to detect defects as a function of their size. Production of experimental data to feed the statistical estimation turns out to be highly expensive, and the obtained results often subject to discussions regarding their representativity of the real environment. In the last decade MAPOD and simulation-based POD approaches have emerged and been used for concept demonstration as a solution to decrease the cost of evaluating POD. Software tools mixing NDT simulation and statistics are now available to support these studies and are used in industrial laboratories. This paper reviews some examples of POD evaluation using simulation, draws today’s limitations and proposes new perspectives, in particular regarding the accountancy for human factors in real environments, targeting a future wider application of the simulation POD approach for industrial purposes.

Introduction

NDT reliability is a key aspect in ensuring safety of structural components in the aeronautic industry. Quantitative assessment of NDT reliability linked to damage tolerance approaches in aeronautics is performed by estimating Probability of Detection (POD) curves, which is an input for the design of the structure and its maintenance plan definition.

![Damage tolerance approach – concept illustration with POD input](http://ndt.net/?id=19531)
The POD is the probability of detecting a flaw as a function of its size. POD is a powerful concept since it integrates sources of variability of the NDT process in a quantitative assessment. However a POD campaign requires production of a lot of data [1], which appears to be very expensive. To get rid of this cost issue recent research efforts aim at replacing experimental data with simulation data. The concept of Model Assisted POD has been introduced first in the US in 2004 through the constitution of the MAPOD working group [1,2]. The work of this group led in particular to an update of the MIL-HBDK 1823[3] containing recommendations for the use of the MAPOD approach. On the European side, a French national funded project called SISTAE started in 2006 on this subject and has been followed by a European project called PICASSO. These projects allowed developing software tools mixing NDT simulation and statistics and demonstrating some successful validation cases [4,5,6].

However the simulation-supported POD approach does not take into account human factors in a broad sense – no cognitive aspect, no notion of difficult to access. This paper presents a concept of operational NDT simulator [9] that enables playing inspection scenarios in real NDT configurations but with synthetic data displayed to the operators. With such simulator human factors are considered de facto since the procedure is played by the operator just like in the reality.

1. Experimental and Simulated POD

1.1 Baseline principles

The basic idea of the experimental POD approach is to estimate a statistics of the detection capability – as a function of the defect size – from several realizations of the NDT procedure. It is understood that the NDT procedure under evaluation is subject to variability, which is de facto integrated in the gathered data since the experiments allows to experience this variability. In this approach it is not of primary importance to identify the exact sources of variability to be able to make a reliable estimation of the POD of the procedure. However it is generally admitted that the variability may come from: the inspected structure, the defect, the procedure, the device, the human.

The simulation assisted POD approach uses the principle of uncertainty propagation to represent the variability on the output from the description of uncertainties in input (Figure 2).

![Fig 2. Uncertainty propagation principle for POD using simulation](image-url)
In this approach the knowledge of the sources of variability matters, and is key for the success of the evaluation process. Figure 3 shows a view of the CIVA software panel which exhibits the list of the variable parameters selected for a given case. Amongst them is distinguished the so-called characteristic parameter which characterizes the defect for this POD study. In other words, it is the parameter that will be plotted in abscissa of the POD curve. The other variable parameters are considered as aleatory. One probability density function (p.d.f.) is assigned to each of them – instead of a scalar value in classical simulation. The design of (numerical) experiments, is achieved by sampling these aleatory parameters according to the defined p.d.f.

![Variable parameters description in CIVA software](image)

Fig 3. Variable parameters description in CIVA software

1.2 An example of application of simulated POD

The practice of simulation assisted POD is growing progressively in Airbus Group with the maturity of the software tools. Several uses cases have been undergone with good success, and already reported in previous communications [4,5,6,7,8]. For the sake of concision we briefly report here only one of these cases demonstrated during the SISTAE project. This case was very interesting because associated to a full set of experimental data. It consists of a High Frequency Eddy Currents inspection which is performed as a maintenance operation on aircrafts. It is applied manually by certified operators. The details of this case are reported in the 2010 QNDE proceedings [4]. The case is briefly described on Figure 4 and the results on Figure 5.
2. Perspectives regarding human factors

2.1 Feedback on simulated-POD

The experience acquired with the realization of simulation-supported cases in Airbus Group gave us the opportunity to have users and customers feedbacks, which are important in view of further improvements. The main points of this feedback are the following:

- It is in general difficult to explicit the p.d.f. of aleatory parameters. This step of the process is strongly based on the engineering judgment. Then what if inputted p.d.f. are “wrong” or not well known?
- What about “confidence” in a POD using simulation? Here the confidence has to be understood in a common sense: “Can I trust the result”? Besides the question of “simulation fidelity”, this question is often strongly related to the fact that NDT operations in-service are made by humans.
- How to consider human factors?
2.2 A concept of operational NDT Simulator for POD and training

Following these feedbacks and to address human factors in such studies, we have imagined a concept of “operational NDT simulator” [9] that combines real operations with real parts and environment, performed by real humans, but using synthesized data. This concept enables to play infinity of defect scenarios with a single representative mock-up. It can be seen as a serious game for NDT operations. The principle of the concept is depicted on fig. 6.

The NDT scene is instrumented to provide information such as the location of the probe. From this information the NDT response is synthesized and can be displayed on any terminal: PC, tablet, smartphone, or even on a real testing device. Synthesized data may be, simulated, measured experimentally, or made of a mix of simulations and experiments to make it very realistic. The operator then makes his diagnosis from the data which have been displayed to the screen.

The advantage of this concept is in particular for the accountancy of human factors. In this approach, the human is involved for real, which eliminates the need to simulate its behavior. He really moves the probe; he really reads the screen and really makes the diagnosis. The only “non-real” aspect is the data which is synthesized. Therefore this point is key for the realization of a realistic operational simulator. This type of operational simulator is of course relevant for POD studies, but could also be very valuable for operators training in real conditions.

2.3 A first example of operational NDT Simulator

Here we present results of a first implementation of an operational NDT simulator on a simple case. The considered case is the one of phased array ultrasonic testing of reference blocks of composite material (CFRP), widely used in the aeronautic industry. These reference blocks have several thicknesses and flat bottom holes (FBH). This case is simple in terms of geometry but can be considered as complex in terms of signal synthesis. Indeed ultrasonic signals in composites contain noise related to the lay-up of the material which is particularly difficult to represent with a good realism.

A first element of the operational simulator has been developed to enable live tracking of the probe position. Figure 7 shows pictures of the tracking device which has been synchronized with our phased array acquisition device (Smart NDT Tool®).
A second element of the simulator is the signal synthesis. The signal synthesis is particular to the considered application. In this case we want to simulate the responses of FBH in a reference block. The input are: FBH diameter and location, probe position and part thickness. The simulator outputs are signals, A-scans or B-scans. Signals must be as realistic as possible and delivered as quickly as when a real acquisition system is used to (30 Hz). If a 64 linear probe is used, the computation of one A-scan has to take less than 0.5 ms to be able to display the B-scan at 30 Hz.

With the objective of providing realistic signals, including noise from the material, we have developed a model that learns from data acquired on the real reference block. The model has been learnt from a set of FBH hole diameters and part thicknesses.

Once built, the model can provide the response for any FBH hole diameter or material thickness in the range of the model. Fig. 8 illustrates the reliability of the model by showing a comparison between real and synthesized signals (B-scans) on two learning points (FBH 9 mm and 12 mm). Fig. 9 shows an example of synthesized signals for two FBH of diameter 7.5 mm and 14 mm which don’t correspond to learning point. The underlying model will be presented in more details in a future specific communication.
From these two elements (probe tracking and signal synthesis) we are now able to propose the scanning of a virtual reference block with infinite possibility of FBH scenarios. This first simulator will be presented at the WCNDT conference.

Conclusion

After recalling recent works on POD using simulation we have presented an original approach to deal with human factors. It consists of an “operational NDT simulator” [9] that combines real operations with real parts and environment, realized by real humans, but using synthesized data. This concept enables to play infinity of defect scenarios with a single representative mock-up. A first example of such simulator has been illustrated on the case of Flat Bottom Holes in a composite material part.

References