Conclusions of the 5th European-American Workshop on Reliability of NDE

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1. Introduction

The insights from the first four workshops from the series of European-American Workshops on NDE reliability can be summarized as follows. The main achievement from the first workshop 1997 in Berlin – in a time of debating whether testing according to standards, i.e. well defined parameters or qualification by blind trials would yield the right quality - was the conceptual model [1] (later referred to as Modular Reliability Model [2]) in terms of the reliability formula. According to this model, the total reliability of an NDE system is composed of the intrinsic capability, IC (physical principle behind the defect indication and its technical realization as an upper bound), the application factors, AP (realistic circumstances such as the UT coupling, limited access, noise of the surrounding, etc.) and the human factors, HF, present in each application. While imperfect – e.g. the mutual interactions between the factors were not considered – the conceptual model helped to properly define the potential for performance optimization, and worked as an assessment tool for the adequacy of open and blind trials. The main benefit from the Second European American Workshop on NDE Reliability, September 1999, Boulder, Colorado, USA [3], was the clear definition of i) the NDE system as the procedure, equipment and personnel, that are used in performing an NDE inspection and ii) the NDE reliability as the degree that an NDT system is capable of achieving its purpose regarding detection, characterization and false calls. The main conclusion from 2002 from the third European American Workshop [4] was: We need to quantify the risk in NDE and demining! The fourth European-American Workshop in 2009 in Berlin again showed the progress in attempts to consider the reliability of NDE on a system level with the goal for integrated solutions in the industrial applications. The limitations of the original empirical methods were shown resorting to advanced and model assisted methods. Also, for the first time an extra human factors session was launched resulting in the recognition that human factors are present in all stages of an NDT activity. Potential for improvement is seen in the training, procedure, calibration, inspection and data evaluation.

In the year 2013, the overall question to be answered remained: What is influencing the performance of NDE and how can we measure and optimize what we want to know with minimum effort? The focus of the current workshop was: What is the "*delta*" to the everyday field conditions? What do we need to overcome?

Already in the 37 oral presentations and 25 posters different general strategies and specific solutions from the scientific and industrial point of view were presented. However, the highlight of the year's 2013 event was the "Open Space Technology" (OST) workshop. The "Open Space" – format was selected to replace the "break-out-sessions"- format from

the former workshops, in which a specific goal for each working group was defined beforehand. The underlying principle of an OST workshop, developed by Harrison Owen in the sixties, and ideal for large groups, is to allow the people to work on a topic that interests them [5, 6]. It works on a principle that offers participants complete freedom in the choice of the topic, the duration, the participants and the flow of the discussion; and resides on a "law of two feet", which allows the participants to move from one discussion point to another and to leave the discussion, if it no longer pleases them.

In the preparation of the Open Space Technology discussion to be held on the last day of the Workshop, every participant had the possibility to place questions or urgent issues on a wall of ideas. This was frequently used and on the morning of the discussion the board was full.

Figure 1 The wall of ideas

Figure 2 The Open Space Technology session in action

In the open forum 6 groups of interest were formed based on the questions on the wall. The groups separated and, under the lead of an expert, i.e. the group leader, the different issues have been discussed. At the end of the day the groups recollected and presented the content and the result of their work. Every group leader wrote a summary of the discussion, which is available in the Workshop Proceedings under the title "Summary of the Open Space Technology Discussions". Here is a short summary of the most important discussion conclusions.

2. Summary of the most important conclusions from the discussion groups

Group A: "New Reliability Methods: Multiparameter POD, MAPOD, Bayesian"

The focus of this group discussion was how to combine the data from different sources properly, weighted for quality or importance, for instance using the Bayesian update method.

"This leads to a few key choices for the engineer or scientist responsible:

1. What data shall serve as the prior?
2. How will the new data be weighted?
3. Will the new data be checked for consistency with the original assumptions?

A key outcome of the discussion was the suggestion that an application guide including worked problems would be a great benefit. This is a potential subject for

the next Workshop to undertake." (Quotation from the Group A summary report by David Forsyth & Pierre Calmon)

Group B: Reliability of Structural Health Monitoring

"The main discussion areas were

- the ways in which structural health monitoring (SHM) is different from conventional nondestructive evaluation (NDE)
- reliability issues of SHM systems
- issues concerning determination of reliability of SHM" (Quotation from the Group B summary report by Jay Fisher)

Group CDE (union of Applications in Industry, Human Factors, Integrated solution and "Delta" topics)

This most complex field of reliability and human factors application in industry treated a number of different questions:

1. What POD is good enough? "The necessary POD should be decided jointly between the structural integrity and NDT groups - this was the general consensus of the group. A higher POD value brings higher cost in demonstration and implementation." (Quoted from summary report by Luke Carter)
2. Definition of requirements of NDE Reliability by customer versus provider: "The group discussed the question of the definition of requirements on NDE from the customer (end user) point of view in contrast to the requirements seen from the NDE research and provider point of view. A gap was discovered between both positions and means to overcome discussed. Bridging gap between both positions could be found in an agreement on reasonable targets. This requires in its turn an adequate information management between both parties." (Quoted from CDE summary report by Christina Müller)
3. Human factors: "It appears that there is a lot of interest in the influence of human factors on the reliability of NDE, at least from the research community. However, there is a gap in the communication between the utilities and the service providers, causing problems in the transfer of knowledge and, hence, posing a difficulty to implement the findings in the field. The following conclusions for future work were drawn: A broad discussion and raising of awareness is needed between the customer and the NDT service providers. Considering that the customer is no NDT expert, it is up to the NDT community to spread the word. However, the customer should take over the responsibility and consider the benefits and the costs of considering NDE reliability and human factors." (Quoted from CDE summary report by Marija Bertovic & Luke Carter)
4. How do we keep an inspector vigilant, even when they never see a flaw? "Re-qualification to refresh operator knowledge and skills for detection and characterisation, recording geometric indications to keep operators occupied during their task, yearly practice on test components with realistic defects, engagement with staff in non-outage time (developing procedures, performing open trials) were some of the suggested solutions for the vigilance problem." (Quoted from CDE summary report by Marija Bertovic & Luke Carter)

5. What advantages and disadvantages regarding the reliability can be foreseen in automated, mechanized vs. manual inspection? “In general it was concluded that the reliability is higher in mechanized inspection compared to manual inspection, but it was stated that “the mechanical system is not always as good as the best manual inspector but at least better than the average manual inspector. In general it needs to be spread out that there still are needs to investigate the reliability of more or less automated inspection systems. Especially as it has been concluded that the errors that might occur often are different from errors in manual inspection. One of the most important tasks in mechanized inspection is the evaluation of data and as it often includes interpretation of complex signals and/or images, there is a need for high quality procedures.” (Quoted from CDE summary report by Ulf Ronneteg)

Group F: Basic Concepts of Reliability of NDE

> “ ... even if the NDE reliability has gone a long way, there is still a need to discuss the fundamental principles that form the basis for all advanced concepts. The topics discussed ranged from confidence bands, applicability of POD to different kind of defects and sensors, the role of thresholds up to the connection of POD to risk analysis. From the wide spectrum of questions one can conclude that there is a need for learning materials in form of the text book and possibly organization of courses and tutorials on the topic of reliability of NDE.“ (Quotation from the Group B summary report by Mato Pavlovic & Ward Rummel)

3. What can be concluded in total from the presentations and the Open Space Technology workshop?

Reliability of NDT is an active scientific field, which is interesting for many users of NDT, as shown by a large number of participants, even on the 5th workshop of this kind.

The newcomers were interested to learn more about the basic ideas of reliability in NDT. This raised the question of why there is not enough learning material and sample data on the market.

The “insiders” of reliability of NDE were in the process to search for the “*Delta*” between the output of our current reliability models and the actual reliability in the field.

In this context, human factors seem to be a field where further knowledge is needed. The transfer of knowledge about the optimal working conditions for operators and the optimal organizational environment from theory into praxis, to guarantee an adequate information process (which means the flow of information followed by mutual feedback and common understanding) for all involved parties, seems to be a key point.

It also became apparent that the information exchange about the target of testing and the reliability from the NDE and structural integrity point of view is necessary between the end user and the NDE service provider.

The use of mechanized or automated NDT-systems does not completely remove human influence. Even though by introducing mechanized/automated NDT many of the errors, which occur during the manual NDT, can be avoided, new errors can arise. Therefore, even here the influencing factors and processes (especially in the case of evaluation of data) must be taken in to account.

A lot of progress has been made during the last years in using different mathematical models for the handling of POD-data and making the POD affordable or even

possible. Still, there is much more knowledge necessary about the validity of these models and their correct use. To overcome the high costs of a statistically sufficient number of artificial and natural specimen modelling is more and more used. Further investigation is required to improve the validity of these models.

The final topic discussed was if the reliability approach for the traditional NDT can be directly transferred to Structural Health Monitoring. It was concluded that a direct transfer is not possible since both systems work under very different conditions and approaches. There is a need to understand the difference and to develop own models for SHM reliability.

The huge amount of open questions concerning reliability of NDE on the one hand, and the limited resources for research and development in this field on the other hand, motivated the participants of the workshop to gain the advantage of mutual support and information from the series of "European-American Workshops on Reliability of NDE" and to meet already after two years again in connection with the QNDE 2015 in the US. Before the accomplishment of this article it was agreed that a special session on reliability will already be organized during the QNDE 2014 devoted to the advanced methods (Group A).

4. References

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