Automatic analysis and weld indications classification on TFM acquisitions

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Abstract

Ocean Breeze Energy GmbH & Co. KG is owner and operator of the windfarm, BARD Offshore 1 (BO1), approx. 100 km off the German North Sea Coast. This windfarm is made up of 80 wind energy generators from the 5 megawatt class, which reaches a rated power capacity of 400 megawatts. NDT inspections were performed and shall be performed on cross welded beams of the BARD1 Offshore wind park. These inspections are achieved with the Total Focusing Method ultrasonic measurement (TFM) using a Gekko system (developed by M2M Company). Consequently, an amount of acquisition files representing approximately 7 Km of measurements must be analyzed in a very short time, which is quite challenging. In this framework, specific improvements in the CIVA Analysis software were performed in order to automate this work as much as possible to classify the indications in weld seams and auto-generate a table of indications t presenting all the relevant information according to the inspection procedure. This article aims at presenting the specific developments that were achieved on CIVA UT Analysis software and the results of the automatic analysis and weld indications classification.

1. Introduction

Ocean Breeze Energy GmbH & Co. KG (1) is owner and operator of the windfarm, BARD Offshore 1 (BO1), approx. 100 km off the German North Sea Coast. This windfarm is made of 80 wind energy generators from the 5 megawatt class, which reaches a rated power capacity of 400 megawatts. FIGURE 1 shows the tri-pile support structure used in the Bard offshore 1 wind farm.
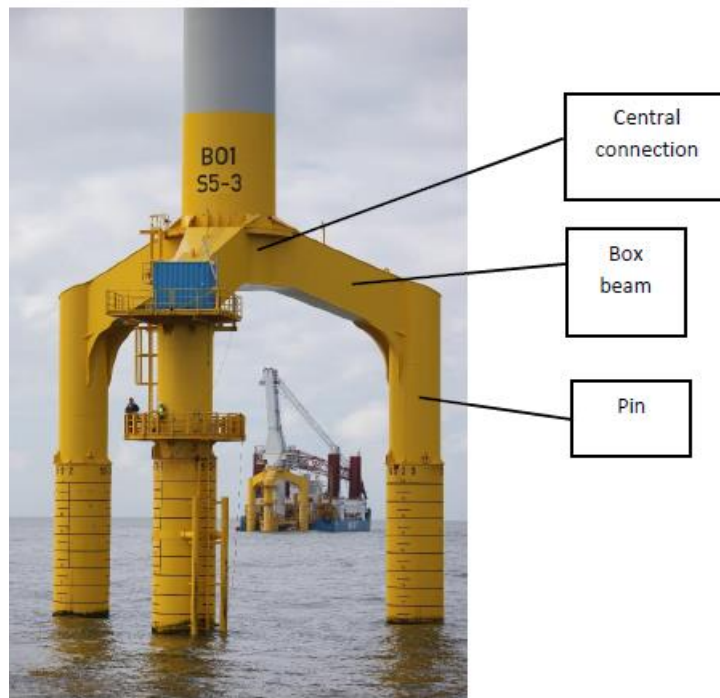
FIGURE 1: Support structure example

The three piles are linked to the tower bottom with a support cross. The latter is built with three pins, three box beams and a central connection. Pins, box beams and central connection are welded structures. The structure presents mostly fillet welds in T-connections and butt welds. It is supposed that most of the flaws are located in the weld root at the interface between the two plates. This can only be proven through a non-destructive inspection.

NDT inspections were performed and shall be performed on cross welded beams of the BARD1 Offshore wind park. These inspections are achieved with the Total Focusing Method ultrasonic measurement (TFM) using a Gekko system (developed by M2M Company). Consequently, an amount of acquisition files representing approximately 7 Km of measurements must be analyzed in a very short time, which is quite challenging. In order to optimize the analysis of a large amount of TFM acquisition data, specific developments in the CIVA Analysis software were achieved to obtain an automatic detection and geometrical classification of the flaws in weld seams.

2. CIVA platform

2.1 CIVA platform overview

Simulation and analysis tools gathered in the CIVA platform (2) dedicated to the modelling of NDT techniques are now extensively used in different industrial sectors. This software platform is developed by the CEA LIST (3) but also benefits from the contribution of numerous partners from industry and universities thus capitalizing on new developments for the modelling of various NDT techniques in a single environment. The various modules of CIVA provide access to different NDT

techniques. Ultrasonic Testing (UT), Guided Waves Testing (GWT), Eddy Current Testing (ET), Radiographic Testing (RT) & Radiographic Computed Tomography (CT) are simulation modules, while CIVA UT Analysis is an analysis module for UT data compatible with different data formats. All these modules are available in the same environment, bringing to the users a unique NDT oriented Graphical User Interface and some dedicated tools, which make its use quite easy. The simulation can constitute a real benefit to optimize performances and cost efficiency in a NDT process.

2.2 CIVA UT analysis

2.2.1 From Simulation to analysis
CIVA is a well-known versatile software for the modelling of NDT process. But this platform now also includes an analysis module for UT acquisition data. It can process M2M and OLYMPUS data files and a plug-in is also provided to allow users to develop connections with other UT acquisition data format. The main objectives of this analysis software are to display acquisition data in an easy and understandable way, to extract advanced information in an efficient manner to prepare examination reports and to avoid repeatable and time-consuming operations thanks to customization and templates, while keeping traceability for the work that has been done. In addition to these essential tools for the analysis work, this module benefits from the long experience capitalized in CIVA in modelling innovative UT inspection methods in order to provide the users with advanced and easy to use tools (Segmentation, Simulation on Acquisition, Signal processing, Total Focusing Method).

2.2.2 Main tools
Data is displayed as classical UT data (A-Scan, echodynamic curves) or more advanced images (B-Scan, C-Scan, S-Scan, E-Scan, etc.). Images in the specimen frame can also be displayed (front, top, side sections or full views) and the data can be exported in the 3D view with the specimen as 2D images or directly as 3D with the one-click 3D view. One can customize his or her own analysis procedure by adjusting the color map, the layouts, adding acquisition gates and synchronizing one gate to a second one…

The software proposes different tools to quickly extract the relevant information about the indications such as their sizing at –XdB or segmentation algorithms. The information can then be included in an indication table (amplitude, position, size) and then extracted in a final report.

To avoid repetitive tasks, save time and ease the analysis procedure a first step in the automation was achieved and integrated in CIVA for a couple of years now. This action is realized by defining a so-called template by recording some of the repetitive actions that must be performed automatically (add a gate, synchronize it, open a new tab, make a limitation in it, define analysis operators and zone of analysis, etc.). These operations will be automatically applied to other similar files while recalling the template. This can also be run in a batch mode over a set of files.

3. Advanced analysis process and automation

This automated algorithm uses several standard CIVA tools (as segmentation, table of indications, report, and automation of process). Specific parameters and the detection of the permanent echoes have been integrated as a plug-in dedicated to Ocean Breeze.

3.1 Data

As mentioned previously, OCEAN BREEZE acquired a huge amount of data thanks to the Total Focusing Method ultrasonic measurement (TFM) using Gekko system on T-welds where the probe is positioned on the "T connection". The FIGURE 2 displays the configuration and raw TFM result in CIVA.
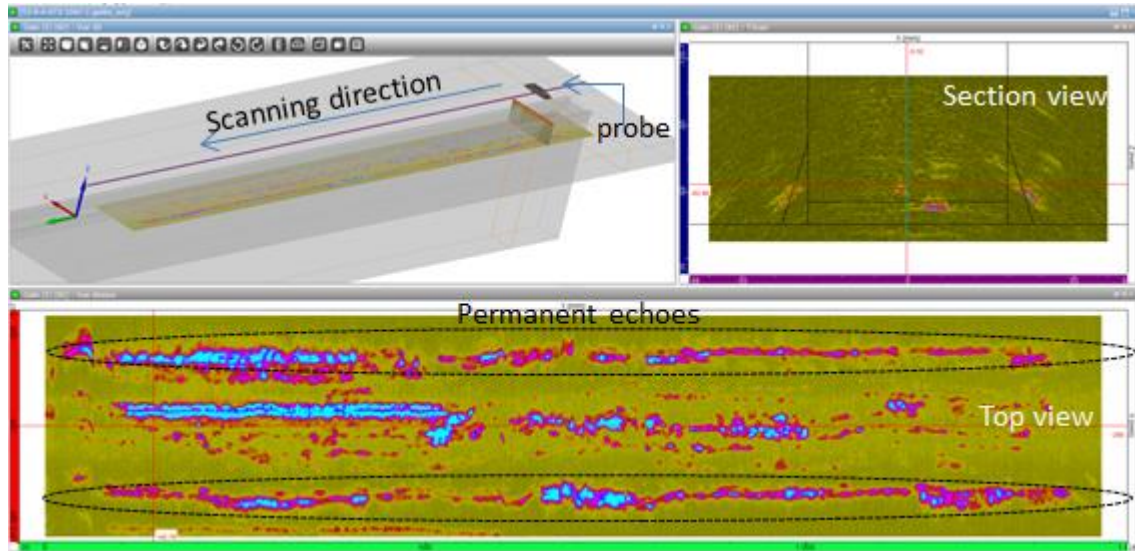

FIGURE 2: Reconstructed TFM data in CIVA

The work to be done in order to meet the requirements was quite challenging and dealt with:

- The automatic detection of indications in the whole DATA set above a given threshold, using the CIVA segmentation algorithm.

- Automatic detection of the permanent echoes generated from the weld beads

- A geometrical classification of the indications following the procedure defined by Ocean Breeze.

- Grouping the indications according to given rules in the 3D dimensions.

- Extraction of a report where each indication (as well as grouped indications) is represented by an ellipsoid. The ellipsoid is defined by the three axis length and their respective orientations.

- Automation of the whole procedure.

3.2 Segmentation

The goal of the segmentation algorithm is to group signals (echoes) that come from the same defect and to easily establish an examination report by applying filters with criteria. This grouping is based on an algorithm that ensures a more efficient association than a geometrical one by combining spatial and temporal criteria.

Segmentation is a process that uses UT data to compute segments that represent the various echoes. Segmentation can be 2D (applied to a single scan line) or 3D (applied to several consecutive scan lines). Based on a given threshold CIVA records the points (signals) that are at amplitude over this threshold. The segmentation algorithm has not been developed especially in the frame work of this project.
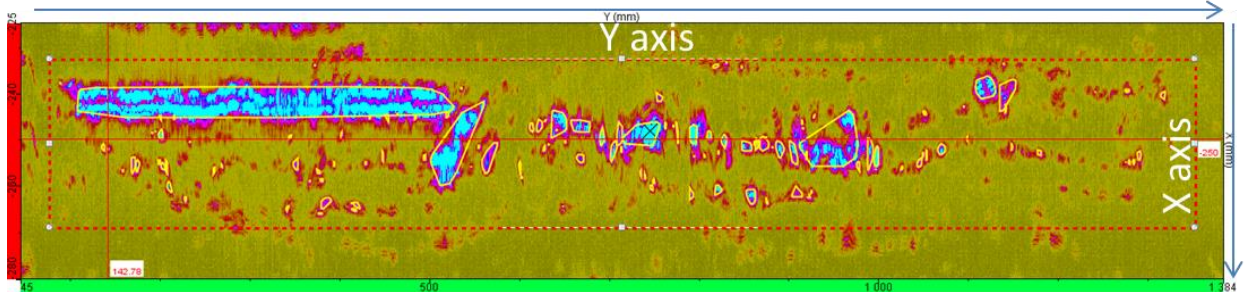

FIGURE 3: Example of segmented result

3.3 Detection of the permanent echoes

Keeping in mind that the final goal is to automate the full process and output an indications table with the relevant indications, important work has been performed to remove the permanent echoes coming from the weld. The top view of FIGURE 2 clearly highlights this problem where keeping these echoes will affect the automatic analysis by including false alarms in the final report.

Therefore additional parameters have been added in the algorithm. This parameter filters the region of interest, were the automatic analysis is applied, according to the location of the indication inside the chamfer. It considers the width of the part, i.e. the distance between the geometrical echoes of the two weld seams and also potential irregularities in the profiles of them as the permanent echoes are not always perfectly parallel to each other.

To detect the position of the chamfers, the algorithm takes as hypothesis that the acquisition system follows the weld, the weld being approximately in the centre part. As presented in the figure below, the algorithm proceeds line by line to compute the number of indications (result of the segmentation) on each line. The two maximums found (expected in the top and bottom side of the picture) correspond to the position of the chamfers. Then, starting from the maximum and going in direction of the middle, the algorithm is looking for the minimum (number of indications) in order to define the extension of the chamfer. The middle part of the image, between the two minimums is the region of interest to extract the relevant indications.
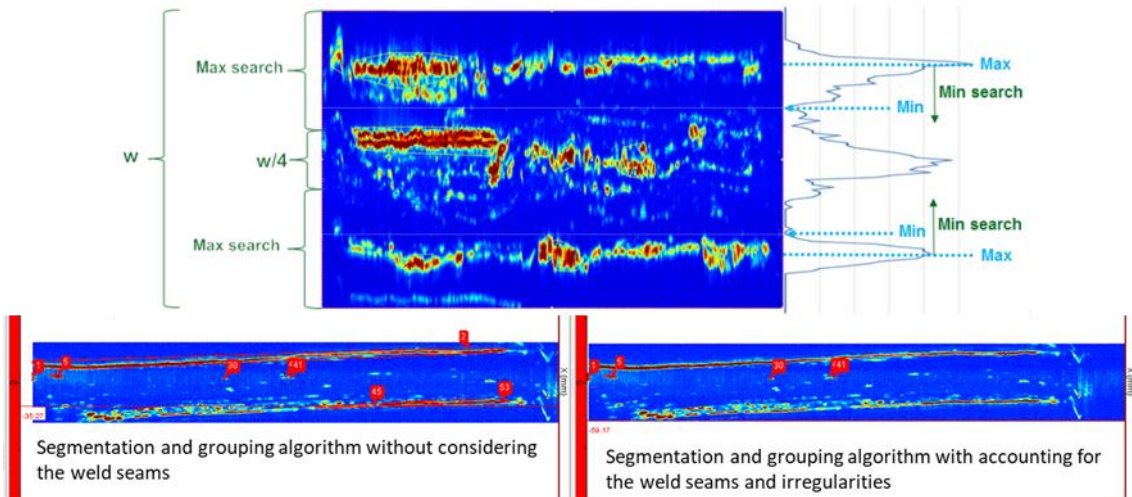
FIGURE 4: Illustration of the filtering of the permanent echoes of the bevel: on the left part the unwanted echoes are considered while in the right image they are removed from the indication table even if those echoes are not regular.

3.4 Grouping of the indications

3.4.1 FKM rule

Once the segmentation extracted all the relevant indications, grouping in the X-Y plane was developed according to FKM rules as explained below:

For evaluation, a group of indications shall be considered as a single one if :

1. The distance dx, is less than the length of the shorter indication (dx<min(2c1, 2c2))

2. The distance dy, is less than half the sum of the width of the two indications (dy<a1+a2)
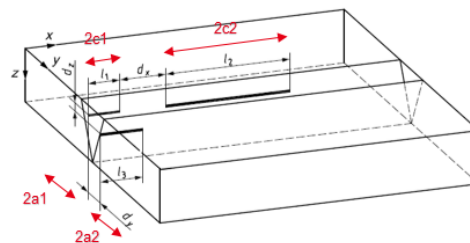

FIGURE 5: Grouping rules

For neighboring flaws closer than a given length depending on the shorter indication as explained in FIGURE 5 the specification was to automatically group these flaws together in order to display and record one single indication.

3.4.2 Region were the indications must be grouped

However this rule should not be applied for the whole inspected part but in a given depth according to the specification and based on the thickness of the part. In this given region the grouping rules has to be applied, outside this region every indication is considered as individual and reported in the indication table. This discrimination led to the need of developing a robust algorithm able to consider the different regions of interest and analyse the indication individually or not.

3.4.3 Consolidation

The last step of the merge of the indication was to integrate it into the indication table or not according to a last rule. Grouped flaws having a length smaller than a given size have to be rejected and therefore not registered in the indication table and database.

3.5 Indications characterization

In the indications table, for each indication, parameters such as the size along the axis of the acquisition, the position, the maximum of amplitude … are available. To enhance the characterization of each indication, the minimum volume enclosing ellipsoid has been computed using moments based method. The orientation and the size of the axis of the ellipsoids give precious information to the user to evaluate the flaws.

3.6 Automation and extraction

The last stage was to automate the full process in order to re-apply the algorithm to other acquisition files, removing manual, superfluous and repetitive analysis.

The first step of the automation was to store and reapply all steps of the analysis which consists of checking and setting the positioning values for reconstruction, check that the region of interest defining the all data set for the analyze fully considers the whole scan, defining layouts and views, applying the grouping requirements, adjusting color maps, operator's preferences (such as the segmentation)…and pushing the indications in the indication table. All these actions can be recorded using the "Template" tool. Applying a template will automatically re-apply these actions on similar files by opening them in CIVA and calling up this template.

The last step consisted in pushing forward the automation in order to free OCEAN BREEZE from loading the files in CIVA. This advanced development allows loading and processing the acquisition files through a batch without the need to open CIVA.

By calling the acquired file to be analyzed for a given template, the function initiates computation sequences, without use of the Civa graphical user interface.

Therefore a huge number of files can be analyzed in a very short time by calling the predefined and requested template in an optimize time. Once the batch is achieved, the folder containing a given acquisition file contains this acquisition file that has been automatically analyzed and a CVS report is created including all the indications, and the detailed information on these indications (grouped or isolated, size, position…).

This report also includes the extraction of the equivalent ellipses for the groups. From these ellipses it is possible to extract angles of the orientation of the ellipses and their dimensions.

Practically, the post processing work for the whole park was reduced from month to days. The automatic processing part happens in hours.

The FIGURE 6 illustrates the work done by the template. This template includes in one global operation the:

- Arrangement of the images defined by the user,

- The definition of the region of interest and thus the scanning dimension,

- The detection of the indication above a given threshold,

- The grouping of the indication according to specific rules and for a given depth,

- The extraction of the permanent weld seams echoes,

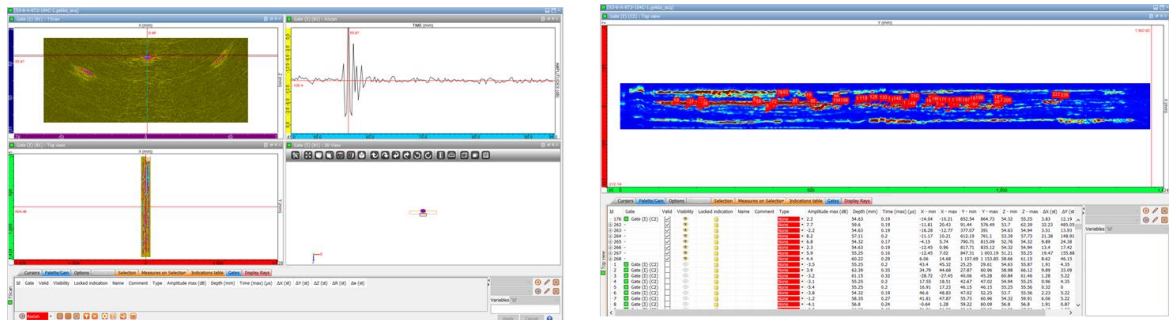- The extraction of the indications in the indication table.

FIGURE 6: left: raw acquisition not analysed right: same acquisition automatically analysed thanks to the template tool

4. Conclusions

Based on the existing analysis module available on the CIVA UT software, specific developments were achieved by the CEA through a dedicated Plug-In to fulfill OCEAN BREEZE requirements. The goal was to optimize the analysis of a large amount of TFM acquisition data by obtaining an automatic detection and geometrical classification of the flaws in weld seams.

To validate this process, manual analysis were achieved on a large amount of acquired data and compared with the automatic analysis performed by CIVA leading to a very close correlation on the number of indications, dimensions and if these indications had to be grouped or not. Even on non-linear scanning, leading to potential integration of unwanted indications coming from the permanent echoes, the results were conclusive. Nowadays OCEAN BREEZE has fully automated the analysed procedure of their TFM acquisition files in CIVA drastically reducing the time for analysing every file (20s / one day) condition of analysing and confidence on the results leading to a better knowledge of their inner structure and repairing what is really necessary.

This project makes CIVA even more powerful in the field of advanced, detailed and relevant analysis procedure enabling the user to go from their raw acquisition to the final report by automating the complete analysis process including the table of indications that can be generated without any user action.

5. References

1. OCEAN BREEZE website http://www.oceanbreeze.de/en
2. EXTENDE website http://www.extende.com
3. CIVA website http://www-civa.cea.fr