

Automatic Analysis of UT Inspections in Aircraft Structures (MIDAS-AUTODET Software)

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Abstract - NDT data analysis is a crucial activity in quality control and maintenance of industrial parts, in particular, of aircraft structures. This paper presents MIDAS-AUTODET, an advanced Software for automatic UT data evaluation under customisable criteria that can be easily defined and programmed by the expert to comply with different customer's quality procedures. Ultrasonic records (mainly C-scan images) can be combined to perform defect extraction, defect grouping applying different clustering techniques, as well as defect sizing and characterisation.

MIDAS-AUTODET is an optional module integrated into MIDAS Data Analysis Software, developed entirely by Tecnatom in a 3D environment. 3D UT data representation is available (as well as information on trajectories and component geometry).

This Software can deal with conventional UT records generated by MIDAS Multichannel UT Data Acquisition systems (also developed by Tecnatom1) as well as with MIDAS-Multi 2000 phased-array systems when phased-array inspection is required. Recent experiences show that the combined analysis of such inspections using the Software described in this paper is feasible.

Taking into account that several areas (and therefore, associated defect assessment criteria) can be distinguished in each component, additional tools have been developed to obtain a description of the part under inspection using experimental data. So, areas with different thickness, different class, structural elements such as stiffeners, exclusion areas, etc. are identified and this information combined later on with the UT records.

The Software will allow an important reduction of evaluation time, improving quality and therefore reliability, simplifying an activity that takes several hours to skilled workers and that, now, could be carried out by personnel with a lower qualification and then, confirmed and approved by an expert afterwards.

Introduction

Automatic ultrasonic inspection techniques are the most extended non-destructive (NDT) methods available for operators to determine the structural integrity of aircraft components, mainly at manufacturing level. The records produced in the data acquisition process must be analysed to detect any kind of defect or indication that could suppose any risk in the aircraft lifetime. That means sometimes several hours per component, as well as the experience of expert and skilled operators for defect detection, characterisation and sizing. Data analysis is based mainly in C-scan images (amplitude C-scan, time-of-flight or thickness C-scan, ...) that are reconstructed in very specific conditions (maximum echo, first echo recorded in the acquisition gate, ...). Moreover, it requires highly trained operators to accurately classify the observed image features as component defects or image

artefacts inherent to each particular inspection method. Most of the times, the operator has to combine information from different images with the raw data (radiofrequency signals, time-amplitude couples, etc.) to confirm defect characteristics (depth, defect type, ...).

Consequently, the use of several images as independent and separate processes for the detection of different types of defects, increases significantly the overall manufacturing cost due to the requirement of a significant amount of inspection time (especially in the case of inspecting large primary structures) and needs highly trained staff.

If huge amounts of data are produced by the conventional ultrasonic systems in automatic inspections, evaluation process becomes more critical and time consuming when phased-array techniques are applied.

The aim of this paper is to present MIDAS-AUTODET Software, that consist on a module integrated in MIDAS Evaluation Software. The main objective of MIDAS-AUTODET Software is to provide, in a very simple and fast way, the list of potential indications, their precise location and estimated size, by combining as many defect detection criteria as desired by the expert to get a complete assessment of the testpiece under analysis. The process will be repetitive in all the components produced in the same conditions, applying objectively the defect assessment criteria selected.

One of the main features of MIDAS-AUTODET is its flexibility and friendliness to deal with the ultrasonic information, merging it with the component geometry description and manufacturing specifications.

The Software can be used not only for automatic defect search but also assisting operators in manual data evaluation and defect sizing. In particular in technique qualification processes, where reference mock-ups with many artificial and reference defects are inspected and must be very accurately located and sized, this Software has demonstrated that evaluation time can be drastically reduced.

During the specification of such Software, Tecnom has contacted different aircraft manufacturers to know from them the necessities and main end-user requirements as potential future customers. One possible method to reduce inspection time while maintaining full defect detection capability and all of them (Airbus, Boeing, ...) coincided in this approach, is to get, as quick as possible, an "overview" of the component, identifying very reliably which areas are free of defects (so analysis is not needed) and where expert operator should pay special attention and carry out a more detailed data analysis.

There is also unanimity regarding "*False Calls*" because, in very critical components as these are, it is better to identify as defect an indication that it is rejected later than to miss a real defect.

However, as an aircraft component is likely to consist of different material structures, the generic data processing for defect visibility in one part of the aircraft component is likely to be accompanied by deterioration of the defect/structure visibility in another part of the aircraft component. For this reason, additional information on component CAD model is required. Based on the structural and material information available in the CAD data, the Software proposes to divide the NDT images into several regions having the same material structure thereby enabling the defect recognition to be performed with its fusion parameters optimised according to the unique characteristic patterns in each decomposed region. The effectiveness of the proposed method for reliable defect interpretation and component sentencing has been demonstrated first in reference mock-ups with areas of different thickness and configuration (laminates, hat stringers, etc.).

Scope

The scope of MIDAS-AUTODET Software is described as follows:

- It processes ultrasonic data files produced with MIDAS data acquisition system (multichannel system developed by Tecnatom) or with MIDAS-Multi2000 phased-array system.
 - It is integrated into *MIDAS Evaluation Software*. Therefore, the operator can make use of all the capabilities developed in such a Software for data reconstruction, processing and visualisation (2D-3D environment, measurements, special tools for aeronautic applications, etc.).
 - It provides a list of defects and their characteristics (position, size, area, etc.). This list is stored with the raw data and exported to applications such as Excel for further processing and reporting.
 - It is focussed on **composite materials**: Nowadays, composite materials are extending their application in aircraft structures and other fields (construction, ship building, etc.). More complex and large structures are manufactured and therefore, aircraft industry demands more reliable quality control techniques and procedures for these components.
 - Target defects in this material go from delaminations to porosity assessment, disbonds, etc.
 - Special tools and assessment criteria are developed for different types of structures: laminates, stringers, radius, etc.).
- Next chapter shows the main characteristics of the Software, illustrated with several examples.

Automatic analysis of UT inspections: Software Description

Tecnatom is a company that began the design and manufacture of ultrasonic (UT) and eddy current data acquisition and evaluation systems almost 20 years ago. Having as predecessors UT systems with lower capabilities (UPRES, SUMIAD, etc.), Tecnatom developed MIDAS system around ten years ago (see figure 1).

MIDAS data acquisition architecture was designed to deal with different electronics, adapted to customer requirements in terms of price and performance. Moreover and very recently, MIDAS has been integrated with phased-array Hardware **Multi-2000/MultiX**, from M2M, France (see figure 2). So, in a transparent way, UT operators can deal with different systems through a unique user interface: **MIDAS Evaluation Software**.

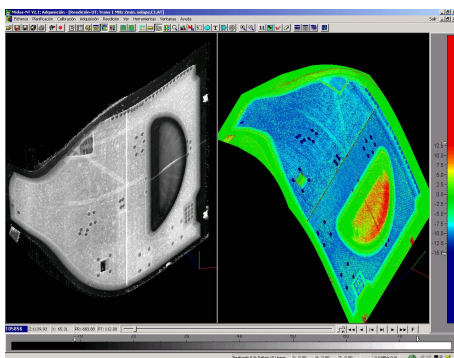


Fig. 1. Inspection of landing gear door with MIDAS system.

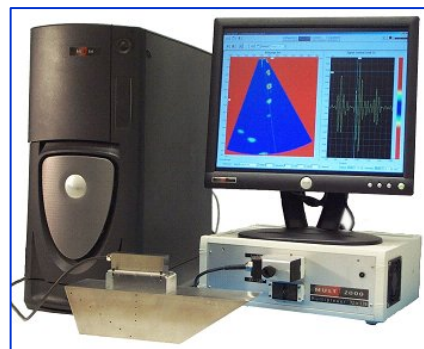


Fig. 2. Multi-2000 phased array system

As requested by some customers, Tecnatom started one year ago the development of **MIDAS-AUTODET** Software, integrated into MIDAS and capable of processing MIDAS files, extracting potential indications (defects).

The Software has been specialised in composite structures, because inspection procedure, data evaluation, target defects, etc., present some particularities that require specific Software tools, different than corrosion analysis, cracking assessment, etc., typical in metallic components.

Depending on the structure under examination, the techniques applied can be pulse-echo (for thickness measurement in laminates), full transmission (for sandwich structures), reflecting plate, etc. Two types of images/records use to be analysed: The C-scan of amplitude (or attenuation in transmission techniques) and the C-scan reconstructed with Time-of-flight (thickness) information.

The process to follow for automatic data analysis of UT inspections is summarised in figure 3.

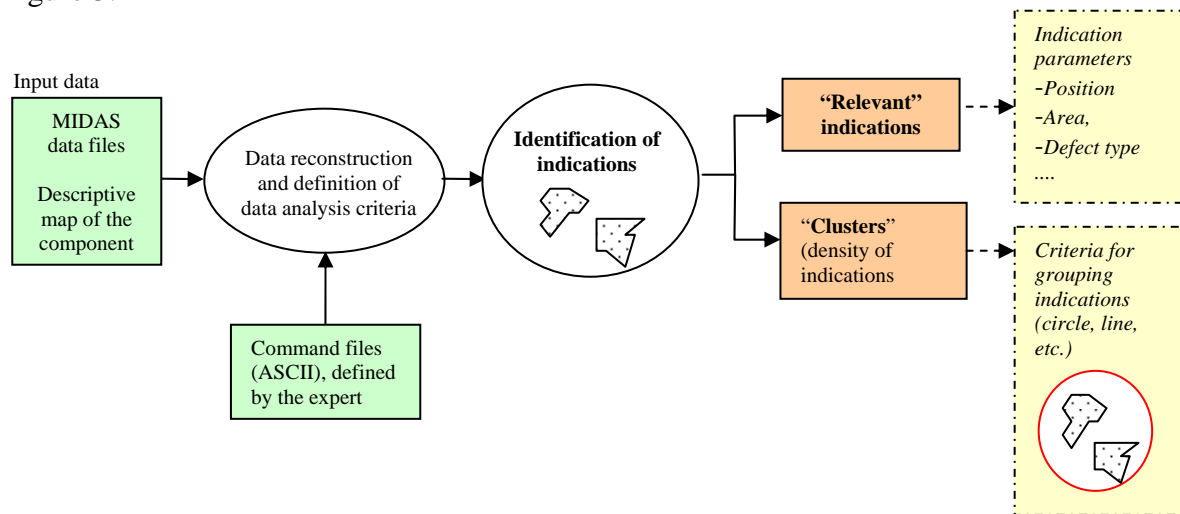


Fig. 3. Automatic analysis process

Input data

Two types of data are required:

- raw UT data (MIDAS files)
- descriptive map of the component, containing the real geometry and the different structures that are part of it. Some of the defect detection criteria are based on structure thickness. For this reason, this is an important parameter that must be known to provide a reliable defect detection and characterisation.

Data reconstruction & Command files

This is the main step before starting data analysis. Depending on the acquisition parameters, volume of interest, technique used, etc., data reconstruction can be based on different aspects: study of the backwall echo, research on the presence of intermediate echoes, lack of UT signal, ... It is the expert who decides on it and will demonstrate that this approach is valid to reliably identify all or part of the defects. Figure 4 shows a partial view of the reconstructed data in a real inspection.

Trained operators, knowing the manufacturing characteristics of each component will interpret these images, identifying areas with different thickness and extracting visually on the images any difference with the “background “ (undamaged areas) that could mean a potential defect.

So, depending on the technique employed and data reconstruction performed, defect extraction criteria will be different. Using a dedicated syntax and related interpreter, the operator will define how data processing will be carried out. Several C-scans can be processed using different filters, several images will be combined by logical operators (AND, OR, SUBSTRACT,) to introduce the criteria. A dedicated editor will be available at short-term to assist to the operator in this task.

Once the command file is able, it will be executed automatically zone by zone in the whole image or in the areas selected, extracting all the defects.

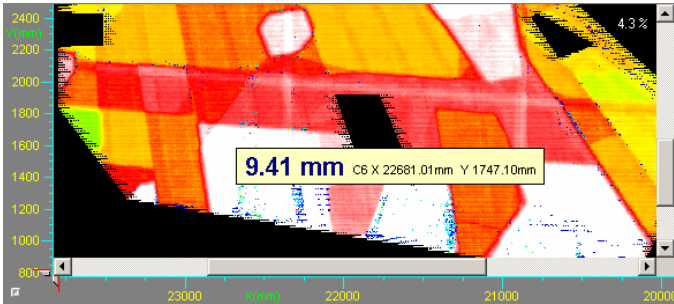


Fig. 4. UT reconstructed data (thickness C-scan)

Managing the list of defects

The list of defects and their characteristics are always associated to the criteria used by the operator. Figure 5 shows an example. The list of defects must be reviewed by the expert, in order to eliminate image artefacts, irrelevant indications (because of their size, position, etc.), etc. The Software makes possible to identify each indication in the table and on the image simultaneously. Indications can be ordered by position, size (area), etc.

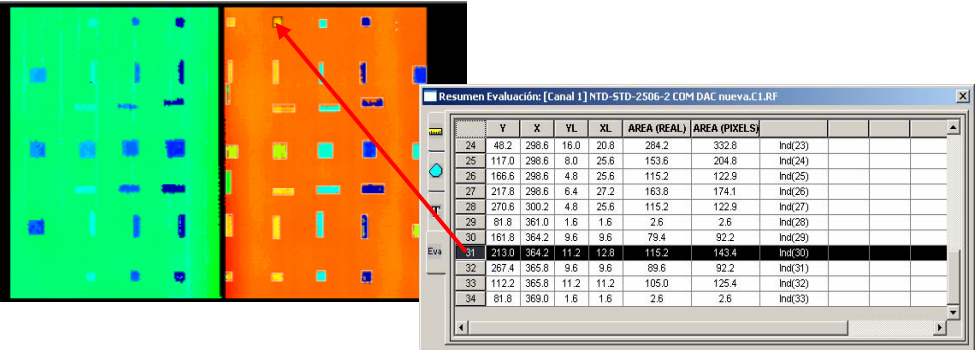


Fig. 5. List of defects

Indications are highlighted on the image, into a rectangle or polyline that delimits it.

Software can also deal with indications that become apparent as “lack of UT signal”. Hat stringer UT inspection is a typical case (defects in radius zones, defects in reverse cuts, etc.).

Density of indications.- Analysis

Depending on the type of defect and its size, some indications are considered directly reportable. However, when porosity is detected (see figure 6), standard procedures recommend to analyse the density of indications to assess damage severity. Several techniques have been implemented (circle, rectangle, line for areas close to component borders, etc.). Relevant groups of indications (called **clusters**) are included in the list of defects and described in the same way.

Once the list of indications is confirmed by the expert evaluator, this information is stored in MIDAS and could be used for defect marking later on, because information on scanning trajectory is available.

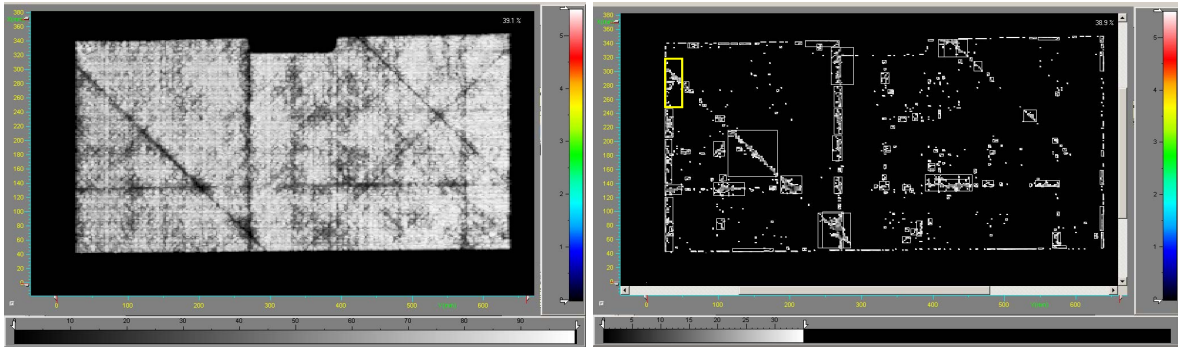


Fig. 6. Example of porosity

Automatic sizing of indications in manual evaluation: Software tools

Part of the tools developed for automatic analysis have been adapted to assist operators in manual evaluation but applying automatic defect sizing. These functions are used for technique qualification, where defect detection and sizing must be demonstrated in mock-ups with a set of artificial defects, following customer’s requirements. This process is carried out zone by zone. When “background” level for the selected parameter is required, the operator can select a set of polygonals: mean, minimum and maximum values, etc. are automatically calculated (see figure 7). Sizing criteria is sometimes based on such value.

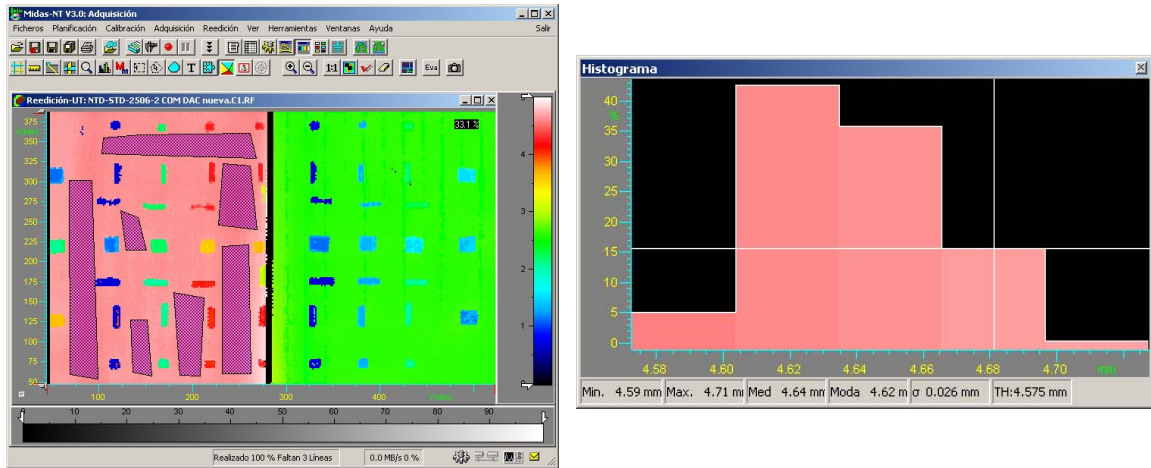


Fig. 7. Estimation of background level (clean areas) using the histogram tool

Conclusion

Although Software has not been applied yet on real full-size components, time reduction in data evaluation has been demonstrated for automatic analysis of reference samples (60%) as well as for automatic defect sizing area by area (90%), as part of the manual evaluation of the records required for UT technique qualification.

Future work

In a very short term, the Software will be validated in real components (section 47 and 48 of fuselage of Boeing 7E7 aircraft, Airbus components, etc.) at production level.

Tecnatom will provide assistance in Software setup and training for any new application (introduction of defect assessment criteria, etc.)

Acknowledgements

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References

- [1] Tanarro, A., Ortega, J., Cabrera, E., Borrás, M., Aldea, J. "Ultrasonic inspection of aerospace parts: the challenge of working on the 3D world". Aircraft Engineering and Aerospace Technology Journal (ISSN: 0002-2667, February 2003, Volume 75, Issue 1, Pages 5.10.