Robotic Ultrasonic Thickness Measurement for Turbine Airfoils

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Abstract

Aero engine MRO industry mostly depends on manual method to perform wall thickness measurement on Turbine Airfoils because of its non-uniform surface condition due to engine run & repair processes. NDT Automations in aerospace industry are becoming more and more necessity in terms of achieving reliable and repeatable results, which are not conceivable by manual method. This paper by Pratt & Whitney dictates ultrasonic thickness measurement on Turbine airfoils using robot. We have partnered with system integrator (MNDT-USA) to custom design and develop the robot to perform ultrasonic thickness measurement. It was started with prototype and developed for V2500 2nd stage high pressure turbine blade. After the successful results, the system has been further developed with signal normalization feature in order to accurately measure the thickness on non-uniform surface and make the disposition based on preloaded acceptance value. This smart system, inbuilt with periodical calibration feature to ensure the measured thickness values are accurate. It can be set how frequent this verification is needed. Apart from providing this quality features, this system is also capable of producing output which is equivalent to 5 inspectors output. It can be adapted to similar kind of inspection tasks.

Keywords: Non-destructive testing, Robot, Ultrasonic Thickness Measurement.

1. Introduction

The custom made Robotic Ultrasonic Thickness measurement system was integrated by Marietta NDT - USA. The system is capable of capturing the ultrasonic data in static mode of operation. The test data is presented in real time via tabulated and graphical displays. The system described in this document is designed for high production applications and utilizes a multi-part load mechanism that employs a series of specifically designed trays to hold the test parts during the inspection process. As illustrated in Fig 1, the parts handling and manipulation is achieved by use of a robust industrial robot with vision-controlled part detection capability which is mounted

together with a specifically designed lighting system within a protected retaining enclosure. The trays are manually conveyed into and out of the system via an easy movement slide mechanisms. The robot is programmed to pick, place and manipulate the components in the following sequence:

- Pick component from the loading tray
- Convey the component to the ultrasonic transducer and manipulate it in a pre-programmed manner so all the data is captured.
- On completion of the inspection program, the components that meet the acceptance criteria are placed in the accept tray marked blue.
- Components that do not meet the acceptance criteria are placed in the reject tray marked red
- In the event the inspection data cannot be captured in a format that meets predetermined ultrasonic data parameters, the system indicates a "No Test" condition exists. In these events the components are placed in the "No Test" tray marked Yellow.
- This test component's load and unload method is illustrated in Fig 2.
- Part numbers and serial numbers, when present, are recorded along with the test data and prominently displayed within the test report.
- Upon completion of the total inspection sequences, all trays are conveyed out of the retaining assembly and the inspection sequence is repeated.

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Figure 1
Robotic UT Machine
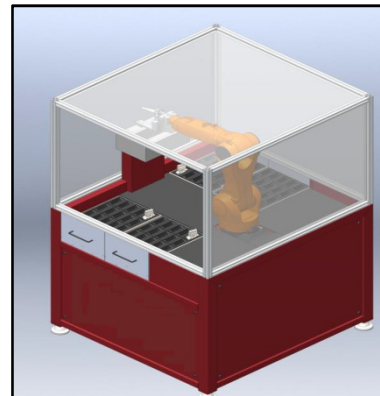
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Figure 2
Robotic UT Machine - Trays

2.   Major System Components

- Robot, Gripper tooling
- Vision-controlled component recognition
- End of arm gripper exchange mechanism.
- Advanced High-Tech ultrasonic instrumentation
- High frequency UT immersion transducer mounted in a specially designed "bubbler" UT coupling assembly
- Load, offload, and reject component capability
- System controller and integrated workstation

3. System Operational Principles

The major functions for point to point measurement are as follows; including the "Auto Pulse Correct" feature.

3.1 Prior to commencement of operation, the system is a calibrated using a conventional ultrasonic step wedge technique.

3.2 The part number of the component to be inspected is identified either by the part and serial number being keyed-in by the operator.

3.3 The test components are loaded in the tray and pushed into the machine

3.4 The robot picks up the test parts from the loading tray.

3.5 The test component is conveyed by the robot in a preprogrammed manner to the ultrasonic transducer assembly and positioned immediately over the transducer's water couplant stream. The ultrasonic readings are obtained at predetermined positions.

3.6 To accommodate the potential of the received ultrasonic pulse being distorted due to irregular internal conditions within the component being tested, the "Auto Pulse Correct" feature monitors the measurement process. This feature ensures the ultrasonic signal received conforms to characteristics that will produce an accurate ultrasonic measurement.

3.7 In the event the "Auto Pulse Correct" feature determines the ultrasonic pulse initially received does not meet specified conditions, the system is programmed to apply A-scan waveform analysis techniques. These techniques monitor the waveform amplitude and or statistically analyses waveform characteristics. Upon confirmation the received A-scan waveform meets specified characteristics, the ultrasonic measurement is recorded. If it is not possible to obtain an ultrasonic signal that meets specific characteristics, a "No Read" result is recorded.

3.8 The test data is downloaded to the Test Results Display module in a sequential manner.

3.9 In the event the test data shows that the test component is within specification, it is placed in the appropriate tray.

3.10 In the event the test data indicates the test component does not conform to specifications, it is placed into the reject tray.

4. Ultrasonic Calibration

4.1 Prior to operation on production test parts, the UT system is calibrated using conventional step wedge calibration technique.

4.2 Dedicated gripper tool has been used to hold 7 Step wedges for different materials.

4.3 Appropriate step wedge that matches the material characteristics of the component to be inspected is selected prior to carrying out the calibration process.

4.4 The system has the capability to measure using either the "Interface to First Returned Echo" or "Multiple Echo" ultrasonic techniques.

4.5 The system is programmed to utilize the same ultrasonic measuring technique for the step wedge calibration procedure as would be used to carry out the actual test measurement.

4.6 The calibration procedure utilizes the robot to present a step wedge to the ultrasonic transducer and the complete procedure, including selection of the appropriate step wedge, is carried out in a preprogrammed manner.

4.7 In production, the calibration procedure can be applied when required, e.g. before and after every productions runs.

5.   Positional Off-set Calibration/Test Component Recognition

5.1 Vision control system has been in place in order to overcome the potential of variance in positional repeatability from one component being tested to another and or over the batch of components being tested.

5.2 This vision control system captures the dimension of unique location which is constant, As illustrated in Fig. 3 and compare with master dimension, which has been input through program earlier. If the captured dimension and master dimension matches, then the program will trigger to execute, else it will stop the process and give error notification.

5.3 The above mentioned verification step applicable for each and every product.
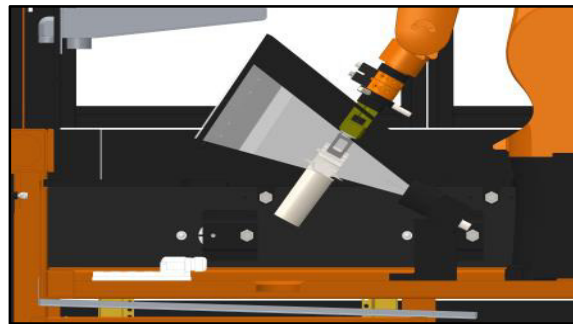
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Figure 3
Vision Control - Scanning

6.   Tray Design, Parts Loading & Unloading

6.1 Before loading any of the blades onto the loading tray, the operator should pay attention to the embossed symbols imprinted on loading tray for guidance on blade placement. All blades should be placed concave side facing left as illustrated in Fig. 4
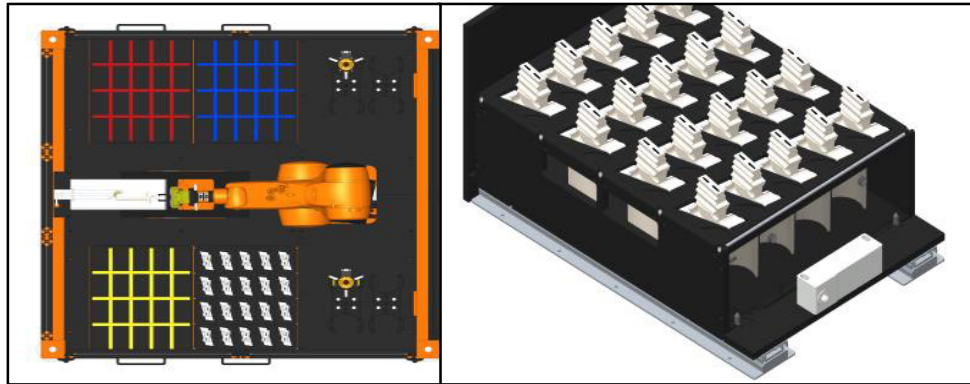
6.2 Loading tray and Unloading trays differentiated by color codes
Blue=Accept; Red=Reject; Yellow=Unknown (Inaccurate reading or incorrect thickness)
Black=Load Trays

6.3 The tray loading and positioning illustrated in Fig. 5
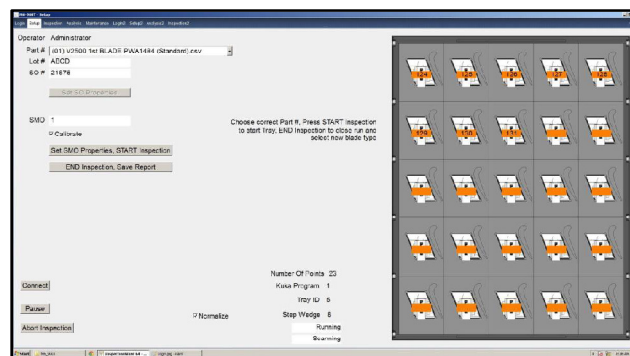

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Figure 4
Loading Tray

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Figure 5
Tray Arrangements

7.   Ultrasonic Thickness Measurement – Operation

7.1 Upon completion of loading the parts, manually select the program from drop down list.

7.2 Input the serial number of each part in order to achieve 1 to 1 tractability as illustrated in Fig. 6 and press "Start Inspection".

7.3 Robot will pick up the 1st part and perform vision offset verification. Then based on preloaded program, it will carry out thickness measurement.

7.4 Normalization features reflect as same as human hand manipulation during ultrasonic thickness measurement. Due to this feature every point it captures 50 data points (Thickness Readings).As a user we can set ,out of 50 data points, how many matches of data points reading need to capture as valid reading.

7.5 As a result of our studies it proves 3 data points matches will give accurate readings.

7.6 The system is programmed to analyze each and every signal and compare the distance between 1st back wall echo to 2nd back wall echo and 2nd back wall echo to 3rd back wall echo. If both reading matches, it takes as correct signal.

7.7 As a result from the above 2 set criteria, system captures the accurate reading and makes the disposition based on preloaded acceptance value program.
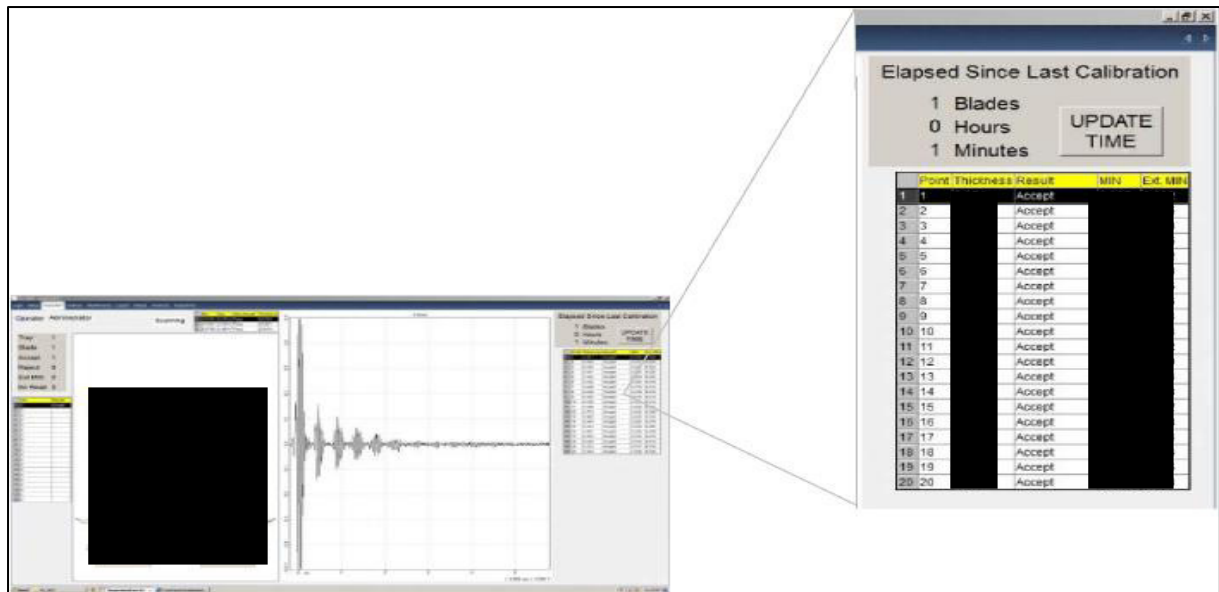

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Figure 6Data Input Screen

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8.   **Presentation of Ultrasonic Test Results for Point to Point Measurements**

8.1 All ultrasonic test data and position of measuring points is recorded and displayed on a high resolution monitor in a tabulated and graphical format. This easy to read data is updated in real time as the component under test is being inspected. In addition, the identification numbers of the part under test is recorded and displayed together with the relevant test data.

8.2 If required, the A-scan waveform that captured the recorded thickness measurement can be stored for reference and analysis.

8.3 The system has the capability to format the test data in a flexible manner. Therefore, the inspection reports can be formatted to meet the customer's requirements. Example: Export to spread sheet. The Examples of the test data results are illustrated in Fig. 7.

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Figure 7
Test Data (Results)

9.   **The benefits**

9.1 Improved measuring accuracy- (better than ± 0.001 inches (0.025 mm) and repeatability of inspection results (Thickness Range: 0.015" to 0.080")

9.2 Improved reliability of inspection results - confidence measurements are taken at the correct position and recorded accordingly

9.3 Easy to understand graphical displays of inspection results and consequently improves the pass or fail process and reporting

9.4 Substantial increase in overall inspection speed