INTRODUCTION

Automation of ultrasonic testing procedures is a kind of non-destructive testing procedures, which involves the use of both longitudinal and transverse high-frequency sound waves for the exploration and/or mapping of both surface and sub-surface defect or irregularities. Of course the material thickness or the material loss (corrosions/erosions) can also be observed by the concept of feedback echo of the ultrasonic wave.

Easily using the ultrasonic beam produced by the ultrasonic testing machine, we can locate down the position where the deformation occurred and hence progress a more detailed observation. This technique are widely used for the quality control inspection for the finished component such as seam weld of a steel plate, as well as for the inspection of part processed material. The technique is also used for the in-service testing of parts and assemblies as well as on-site testing for the respective structures.

Basically the objectives of this project is to perform a typical automation of ultrasonic testing procedures, which aims to:

1. Determine the location of defects in the specimen
2. Determine the size of defects in the specimen
3. Determine the acceptability of the defects (interference) in the specimen

The range of the frequency of audible sound is between 10Hz to 20KHz. The sound waves have a frequency higher than 20KHz are referred as ultrasonic or ultrasound. However the sound waves used for non-destructive testing of materials are usually having a frequency range of 0.5MHz to 20MHz. By using the equation \( V = \frac{\lambda f}{\lambda} \), which \( \lambda \) is referred to wavelength and \( f \) is referred to the frequency of the wave, it can be known that ultrasonic waves have an extremely short wavelength and strong penetrating power. For example if a defect in a material is expected equal to 0.30mm, the ultrasonic beam used in the testing procedure must have a wavelength smaller than 0.30mm.

When a normal (90°) ultrasonic beam travel through the interface of two different media, reflection and transmission occur due the acoustic impedance \( Z_1 \neq Z_2 \). Therefore, any discontinuity inside a uniform material will be detected because of the different time feedback echo of the ultrasonic waves. By using an ultrasonic flaw detector, the defect signal can be screened on a cathode ray oscilloscope so the location and the size of the defect can be observed in order to produce further analysis. Fig 1 is a typical graph obtains from a CRT using ultrasonic flaw detector.

MATERIALS and METHOD

Nowadays a combine system of CRT, Pulse generator, Signal amplifier and a Time base amplifier are used to proceed the experiment. The combine system used in this experiment is USD-15. Basically the equipments needed in the experiment were:

1. USD-15 ultrasonic flaw detector
2. 90° probe transducer
3. \( \mu \)W Calibration block
4. Lubricant gel

So at first the probe transducer was connected to the USD-15 and therefore an ultrasonic beam was produced. Then kindly put some lubricant gel on the surface of the calibration block that would be work on. Steadily and softly attached the transducer on the lubricated surface and moved it steadily and softly. Be cautious on the display screen of the USD-15, the display system was then adjusted to “A” scan display system.

| A-Scan | Display in which the received pulse amplitude is represented as a displacement along one axis (usually y-axis) while travel time of the ultrasonic pulse is represented as a displacement along the other axis (usually the x-axis) | a. Pulse echoes are reflected each time there is a discontinuity due to differences in each medium’s acoustic impedance (see illustration) b. These feedback signals are displayed as waveforms | 1. Investigate signal shifts 2. Detecting skips of back wall (echoes), water path, cavities etc 3. Evaluating material properties |
“A” scan was the most common scanning system, which provides the one-dimensional signal relationship between echo positions and the time base. Above is the brief description of “A” scan

Figure (1) shows the A-scan presentation. It can be known that A-scan system provides the defect information in a time base signal waveform format. When the transducer moved along the surface of the calibration block, high frequency ultrasonic beam would penetrate the specimen in a 90° angle to the normal and eventually hit the backwall of the block and reflected back. Whenever the sound wave hit the defect or a “hole” during path, reflection would be occurred at the interface boundary due to the different acoustic impedance in between the two mediums. So there is actually a first surface echo, backwall echo and a bundle of crack echo present on a scanning point. So actually the sound beam traveled twice of the distance of the thickness of the block. After a sharp echo was obtained, a printable result Figure (2) was made.

In order to obtain general software solution from the result, the digital X-Y axis format of the Figure (2) should be obtained. A simple Basic computer software program can convert the frequency graph to digital format base on X-Y positioning system. What have been done was the software program compared the X-Y values that obtained and from there the direction and properties of the graph can be known. Furthermore the unwanted interference value can be eliminated. Hence the general software solution for every single experiment was obtained. Once the general solution was obtained, the “real” crack and the crack properties can be known easily.

RESULTS

Figure (2) was the scanning result from USD-15 ultrasonic flaw detector. It can be seen that the amplitude from crack echo decreased discerningly and many small amplitude was presented around the main echo. The small echo was interpreted as the interference that occurred during the experiment. The decreasing crack echo was due to the sound attenuation phenomena. Sound attenuation is a phenomenon that the sound wave continuously losing energy when it’s propagating through the material. The energy loss was due to scattering microscopic interfaces and internal friction effect within the material. The higher the frequency of the sound wave, the bigger the sound attenuation
phenomena. The X-axis represents the distance from the surface of the calibration block and the Y-axis represents the amplitude of the energy of the reflected sound wave. Therefore the location of the defect can be found. Generally the height of the echo is proportional to the size of the reflection surface but the distance traveled by the signal and the attenuation effect within the materials also affects the height. The linear position of the echo is proportional to the distance traveled by the sound beam before it hit the reflection surface, assuming normal type of transducer was used. Generally a big crack echo will cause a small backwall echo and a small defect echo will have a big backwall echo as well.

Soon after the position and the size of the defect was determined, the next step was to construct a general software solution to represent the testing result. By writing a simple Basic software program, a digital format of the graph can be obtained. The USD-15 ultrasonic flaw detector can obtain 500 pairs of points from the graph. Due to the huge range of the value obtain, only 10 pairs of points was assume in this report, for example:

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Therefore the digital value show us that Y5 and Y6 were the maximum echo feedback value so it can be known that X5 X6 are the place where the maximum energy reflection occur. Next all the pairs of point were arrange in an array format in order to compare to each other using programming language. The program should compare every value to each other in order to get the position and the value of acceptable amplitude. In this case the acceptable value of possible defect was between 15 to 25. Therefore the digital value show us that Y5 and Y6 have the biggest possibility to be the defect echo feedback so it can be know that X5 X6 are the place where the defect occur. The rest of the pairs were the interference point and it is caused by the environmental factors. The software itself should eliminate the interference (below 15) and automatically chose the possible defect echo, which are Y5 and Y6. Therefore if the software can map the defect correctly, it can be used to the other experiment whichever have the same block and same probe. This is so call the general solution of the ultrasonic testing procedure.

**Discussion**

Although the interface software has been constructed, it was only limited to use in the experiment with the same kind of calibration block and same kind of the ultrasonic flaw detector. This is because the software itself cannot react to the different range of the defect echo feedback value. The problem also arises because the accuracy converting the frequency date to digital data is not precisely optimistic. In other words, there is limitation to convert as many frequency data to digital date as possible. Presently the USD-15 can convert up to 500 pairs of point, which is not enough to observe a big block with many defects. Despite of the limitation of the limitation of getting digital value, some time the interference amplitude will be easily mistaken as the defect echo value. Therefore the software can be further developed to automatically recognize the properties of the real defect echo and the software can chose the correct value although sometime the interference value is bigger than the defect echo value.

**CONCLUSION**

The automation of ultrasonic testing procedure can be summarized into a series of flow chart as below:

**Prepare the correct instrument to proceed an ultrasonic testing procedure:**
1. Ultrasonic flaw detector (USD-15)
2. Calibration block
3. Crystal probe transducer
4. Lubricant gel
Print out the “A” scan graph, which show the different amplitude at the respective point. Find out the defect echo feedback value and locate down the defect position. From the height of the amplitude estimate the size of the defect. Using the interface software convert the frequency amplitude into digital value. Convert as much pairs of points as possible.

Writing a software program which has the ability to compare every single amplitude value in order to get the correct bigger value. The program should be able to choose the correct value instead of choosing the interference amplitude.

Further improve the software in order to work with different material and various shape of the specimen. The testing procedure will become fully automatically if the software are develop to be workable under various experiment condition.

So basically the ultrasonic testing procedure has been concluded. Finding the position and the size of the defect by using the computer interface software is the final destination of this project. Evaluate the acceptance of the data obtained is the most important purpose in this project. Usually the date obtained from the ultrasonic testing in term of length of defect is well within 10%. The automation of the procedure will not affect the accuracy if the interface software is well programmed.

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