Lab 9 Introduction to Nondestructive Evaluation

Objective

To gain hand-on experience on representative nondestructive evaluation techniques and to verify corresponding theories learned in lectures with experimental results.

Introduction

The field of nondestructive evaluation (NDE) has evolved to become an integral part of aviation industry in recent years. This is largely driven by increasingly tightened safety requirements, as aircraft/aerospace structures are getting more and more complicated. It is important for you, the next generation of aerospace engineers, to get a good early exposure to NDE with sufficient understanding and experience. For this reason, starting Spring 2017 we introduced this new NDE lab unit as part of AerE 322 curriculum. In Week 11&12 lecture, you have learned the basics of three representative NDE techniques namely, tap testing, ultrasonic testing and eddy current testing. This lab will allow you practicing all those knowledge and further gaining hand-on experience. So shall we head down to the lab and continue the quest?!

References

[1] Week 11&12 lecture notes
[2] Center for NDE, ISU https://www.cnde.iastate.edu/research/
[3] NDT Resource Center https://www.nde-ed.org/

Work to be done

1. Prelab

Review Week 11&12 lecture materials and this lab manual thoroughly to complete the separate Prelab due to Canvas as usual.

2. In lab

As always, wear safety goggle during the lab. The three representative testing stations for tap testing, eddy current, and ultrasonic immersion plus a fourth ultrasonic simulator should have been set up on four benchtops. The ultrasonic simulator is also accessible from the desktop PCs associated with all three Instron load stations. Each group will then rotate to run the experiments, which will take 20-40 minutes each. The entire lab work is estimated to take up two full weeks of lab sessions. *Each group also needs to bring in a USB flash drive or the like to store the experimental data. You can also upload the data directly to a cloud storage of your own.*

2.1 Tap Testing

Startup

Fig. 1 shows the setup of the computer-aided tap tester (CATT) system in which the hand tap cable connects to the electronics box and in turn the electronics box connects to the system laptop through a USB port. Double click on the *cattv5_3* icon on Windows desktop to bring out the main screen of the tap test software (Fig. 2). Under the *Display Tap Values* panel on the far right, check the *NewBox* checkbox. Hold the tap head on the metal part in upright position and try a few gentle taps on the bench surface, just like you would normally tap with your own finger tips. Please note that tapping with excessive force will damage the tap head and specimen! If the contact time falls in the range of 200-500 microseconds (as seen on the software screen), the tap system should be working fine and ready for test run.

System operation

Under the *CATT Scan – Choose Scan Parameter* panel, make sure the *Basic Setup* tab is selected and visible (all other tabs are left along in this lab). If not already checked, click on the *Hand Tap* radio button, set *unit* in inch and *Scan Increment* at 0.25. Depending on the size of tap area (see next section of *Sample testing*), enter the proper column number of cells in *Cells Wide* and row number of cells in *Cells High*. The default orientation of the tap area starts with top left corner at the first cell and proceed to the lower right corner of the last cell, one row at a time. Once the dimensions of tap area are set, click the *Run Test* button to bring out the *Scan Area* screen. You can then start tapping on the plastic grid template (again see *Sample testing* section) and the measurements will fill the cells on the screen accordingly (Fig. 3). The software will keep track of tap counts and automatically move to the next row when reaching the end of a row. If the users make mistake such as missing a cell, the software would allow moving back to the previous row and re-tapping that row again.

Sample testing

The specimen you and your teammates will be testing is a 10.5” by 12” honeycomb plate marked with many defect areas grouped on the right- and left-sides of the plate (Fig. 4). These defect areas consist of four types of simulated defects up to three different sizes. This honeycomb panel has a three-layer structure: top skin – honeycomb core – bottom skin. As indicated, the defects in left-side group are made using .187 honeycomb core size and the defects on right side using .25 size. Also shown on the top left area of fig. 4 is a thin transparent plastic grid of 0.25” spacing, which is to be used as a tapping template. Your task is to tap test each of the four areas enclosed with blue dashed lines (as shown on Fig. 4) through the plastic grid template. Please note that these blue dashed lines are only drawn in Fig. 4 for identification purpose and were not actually marked on the honeycomb plate. Please take extra care to peel off the tapes on the edges of the thin plastic template when you reposition it on the honeycomb plate. To reduce error and fatigue due to long tapping, members in your group may want to take turn to perform the tapping work. Be sure to have another member monitor the tapping process to ensure accuracy. If a tapping error is made, as mentioned above you can move back up a row and restart from there.

Data processing and storage

Once you have finished tapping all defect areas, have fixed all tapping errors and are happy with the results as displayed, plug in your own USB flash drive to the laptop and save the data in it. Be sure NOT to include file extension in the file name, since each data file will be given the default extension “catt”. After you have done saving the data, the main software screen will return. Under the *Test Options* menu, you may want to select *Open and Process Existing Data* to process the data using a few functions provided by the software. These functions are shown on the bottom row and right edge of the screen, including viewing the raw data in grid, contour or 3D and performing threshold, etc. These processed results can also be saved as images in the same folder. Be sure to take sufficient photos throughout the testing process as well.

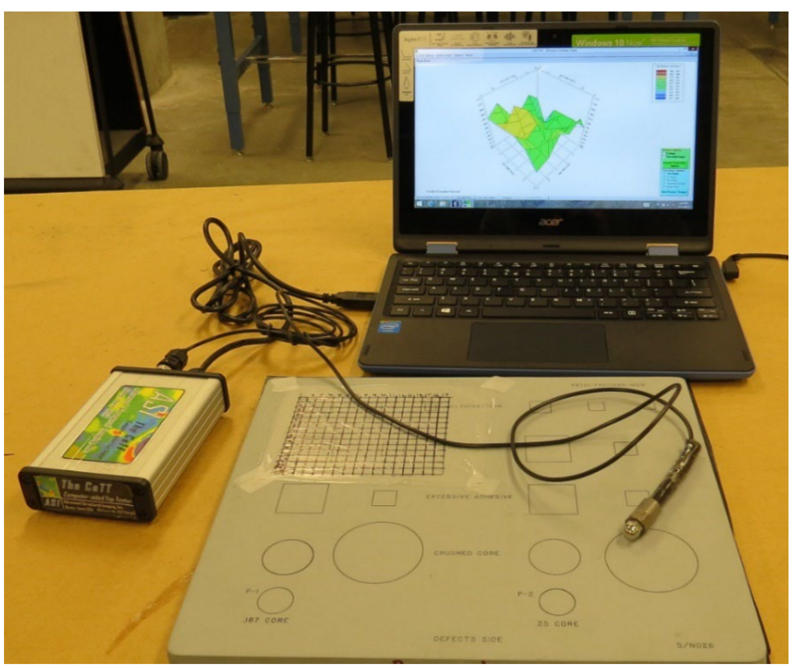

Figure 1. The computer-aided tap tester (CATT) with the specimen

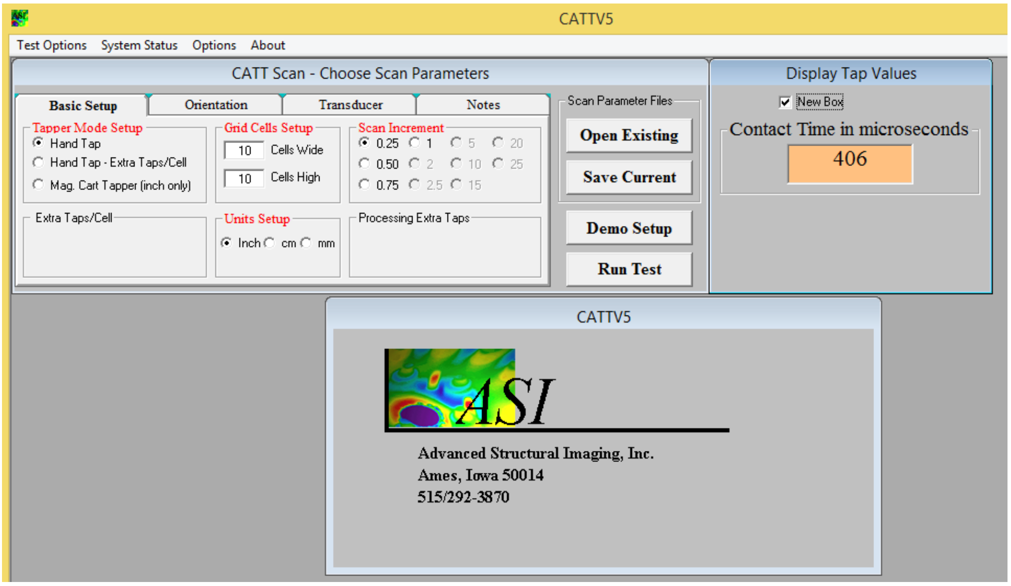

Figure 2. Main screen of tap testing software CATTV5

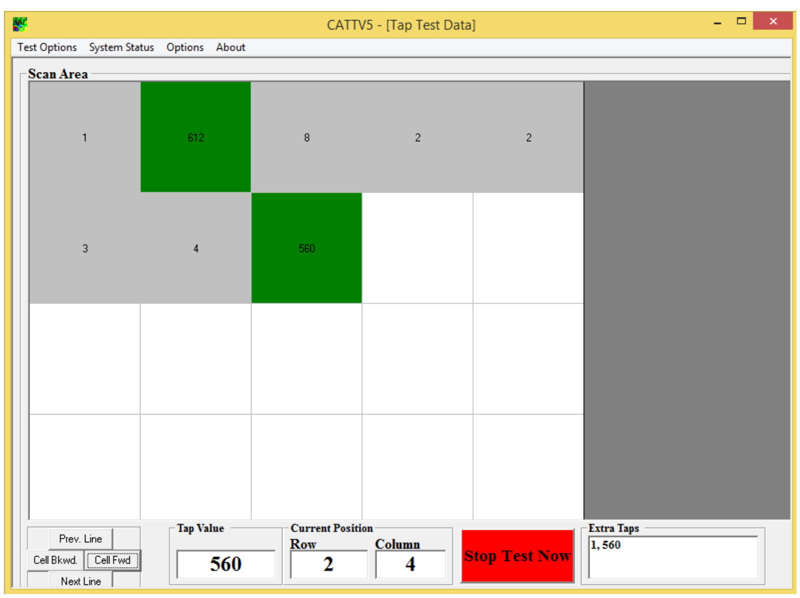

Figure 3. The area under testing is being filled with data.

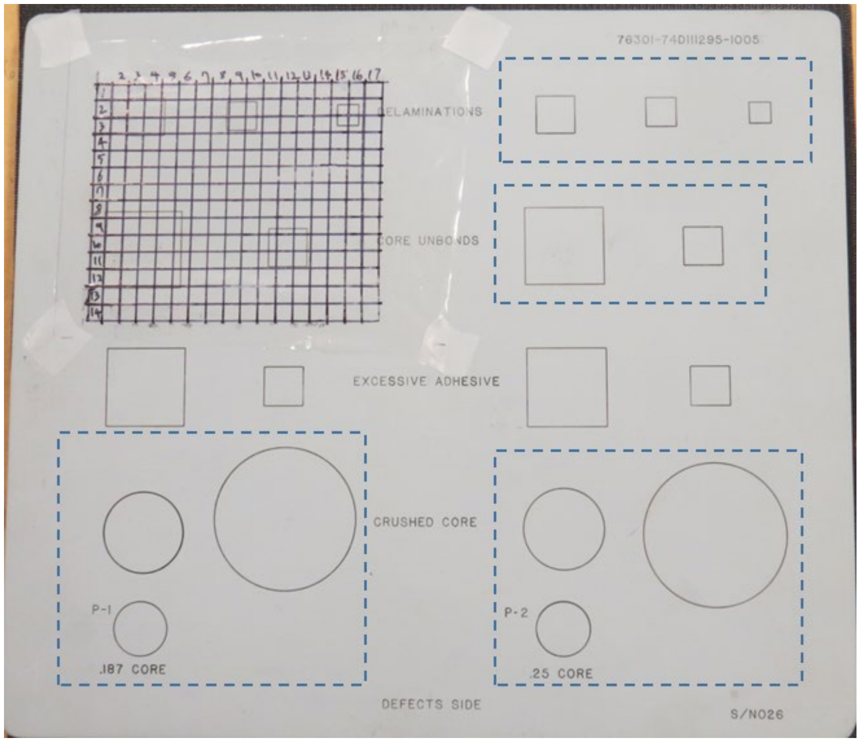

Figure 4. The honeycomb plate to be tap tested (indicated by the four blue dashed lines which were not actually printed on the plate)

2.2 Eddy current (EC) testing

Startup

If not already connected, plug the main cable of EddyCation interface box into a USB port of the system laptop and connect the probe cable to the absolute probe (labelled with a blue dot on top). Fig. 5 shows the complete compact EC test system. If the EddyCation software was not already running, double click on the HF icon on the laptop screen to start. Select English and click on On/Off button on the initial graphical user interface (GUI). If a German dialog pops out, click on the upper radio button and click ok button on right (Fig. 6a). Otherwise, a blank impedance plane panel will show up (Fig. 6b). The eddy current system is now ready to run.

Settings

On the top of the main GUI window, the *File* menu allows the users to save the current settings as files and the test results (from the impedance plane) as images to a flash drive or to the system laptop temporarily (As you should already know, this lab laptop is configured to clean up all user data after every shutdown). The *Copy* menu has similar functionality by saving the data to the temporary storage in Windows clipboard. Pull down the *XY-Plane* menu, select *Centered* and you should see the heading of the impedance plane panel reflects this setting. Below the main menu, make sure the *Basic* tab is selected and visible. In the *Basic* tab, there are vertical sliders named *Freq*, *Gain*, *Phase* and *Filter*. Slider *Freq* controls the frequency setting ranging from 0.5KHz to 5 MHz, *Gain* in dB controls the amplification of EC signal strength, *Phase* in deg. controls the angle of EC signal trace, and *Filter* controls the frequency bandwidth in terms of low-pass (LP) or high-pass (HP) filters. We will set LP at 50 or below and HP at 0 Hz (off). Under the *Pen* panel, you can dynamically change the color of the signal trace curve using the four preset colors any time during a test run. Under *Recorder*, *R* starts recording of signal trace, *P* reproduces the signal traces, *S* stops the recording and *C* deletes the recorded traces. One important function is *Balance* which re-compensates EC signal and bring the trace point to the origin of the impedance plane. During the test, you will need to balance the signal constantly, especially when the *gain* setting is high and the signal trace becomes sensitive or unstable. In the *Professional* tab, the rightmost column contains additional display settings such as the plotting style for the grid pattern and signal trace point on the impedance plane panel. You may want to select the smaller points for clarity.

Surface crack detection (slots facing upward)

This test is conducted on a narrow and thin Aluminum plate labelled BK1 on one end. This plate has four thin slots cut into the plate at depths 2, 1.5, 1 and 0.5 mm (please note that, as of Spring semester 2020, this sample was damaged with the end containing 0.5mm slot broken off). These slots are tested facing up to simulate surface breaking cracks. In order to maintain a stable signal trace, it is recommended to keep the frequency below 10KHz, gain below 45 dB and LP at 15. You will need to play with the frequency and gain settings for a minute or two, in order to find the best combination. The balance is to be set on a slot-free area (ideally the opposite end to the one with BK1 engraved on). Before testing the slots, a “lift-off” calibration needs to be carried out first. This is done by lifting the probe straight up from the specimen and back down while adjusting the phase angle until the lift-off trace is aligned with the left branch of the resistance axis, i.e. the left side of the horizontal axis. After the lift-off is completed and the signal trace point is brought to the origin by balance, one can turn on the recording and start scanning the specimen. The scan is done by sliding the probe from the left end (where the balance is performed) towards the engraved right end. The probe should be firmly pressed down onto the specimen but still allow smooth sliding on the surface. The sliding should be kept as stable and straight as possible. You can paused in-between the slots to change the color so that each crack trace is plotted with its own color. When the engraved end is reached, turn off recording by pressing the P button to reproduce the recorded traces only. You may need to practice the scan run several times before a good set of traces can be obtained (Fig. 7). Remember to take a note which trace was produced by which slot. You may also need to adjust the strength of the traces by changing the gain setting so that the longest trace (from which slot?) is displayed on the impedance plane to the maximum extent possible without "saturation", i.e. not going out of screen boundary. Once you obtain the best trace sets, you can save the impedance plane images from either *File* menu or from the print screen command and then save, e.g. to a MS PowerPoint file. Just like in tap testing, save the images in your own USB drive, or upload to a cloud storage.

Hidden crack detection (slots facing downward)

In this test, hidden cracks are simulated by turning the slots of the BK1 specimen downward. As you experiment the scan, you will find that the cracks now are lot more difficult to detect (Why?) You will need to adjust the frequency significantly to be able to do so (which direction you need to adjust it, higher or lower frequency?) Likewise, you need to increase the gain setting to be able to see the signal traces, but not too much to lose the signal stability. After you settling with a new set of parameters, perform the same lift-off and balance calibrations. Then you can scan the whole specimen as in the surface crack test. How many cracks can you detect eventually? Save your image results and again record the trace-slot correspondence.

Thickness measurement

This test is performed on the BK2 specimen. As you can see, both BK1 and BK2 are made of the same kind of Aluminum material and have the same dimensions. The difference is that BK2 has four wide slots machined out the plate and the thickness in those four areas reduces to 2, 1.6, 1.2 and 0.8mm, respectively. Both the scan and balance are to be carried out on the side of smooth surface, i.e. opposite side to the four cut-off slots. The balance needs to be done on areas having the original thickness. What frequency and gain settings should you use? This may require a few iterations before you find the proper settings. Remember to save the trace sets and record the correspondence between traces and slot/thickness.

Metal sorting

The EC system also come with a set of metal disks of different materials. Since absolute probe is sensitive to electrical conductivity and magnetic permeability of materials, which makes it very useful for sorting out materials. This test demonstrates EC's sorting capability. Note that the balance is done in the air this time. Then you can "hop" up and down from disk to disk to quickly sort them out, as different trace is generated for each disk. Can you spot the Aluminum disk by comparing its trace with that of the BK1 or BK2 specimen? Again save the trace set and record disk-trace correspondence.

Be sure to take sufficient photos throughout all four testing processes as well.

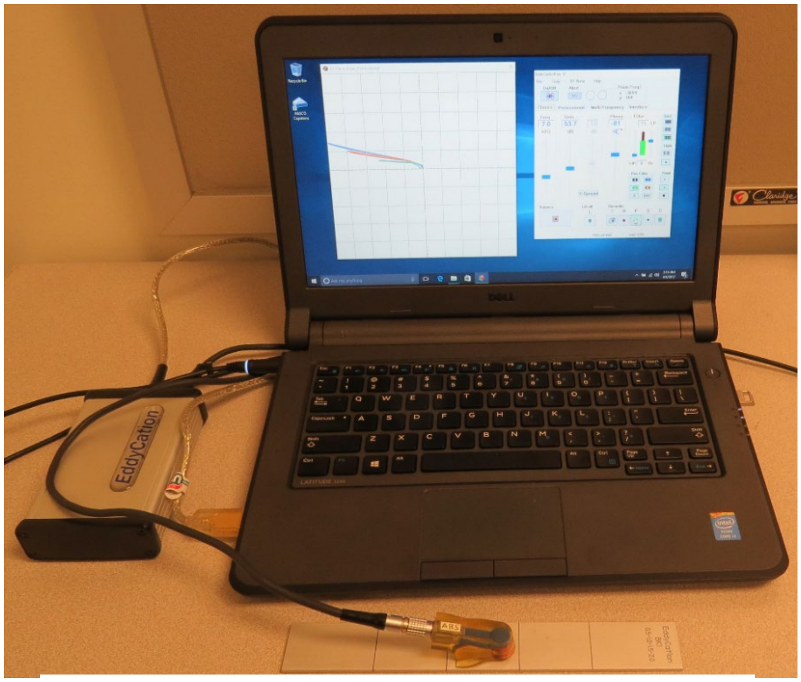

Figure 5. The compact eddy current test system.

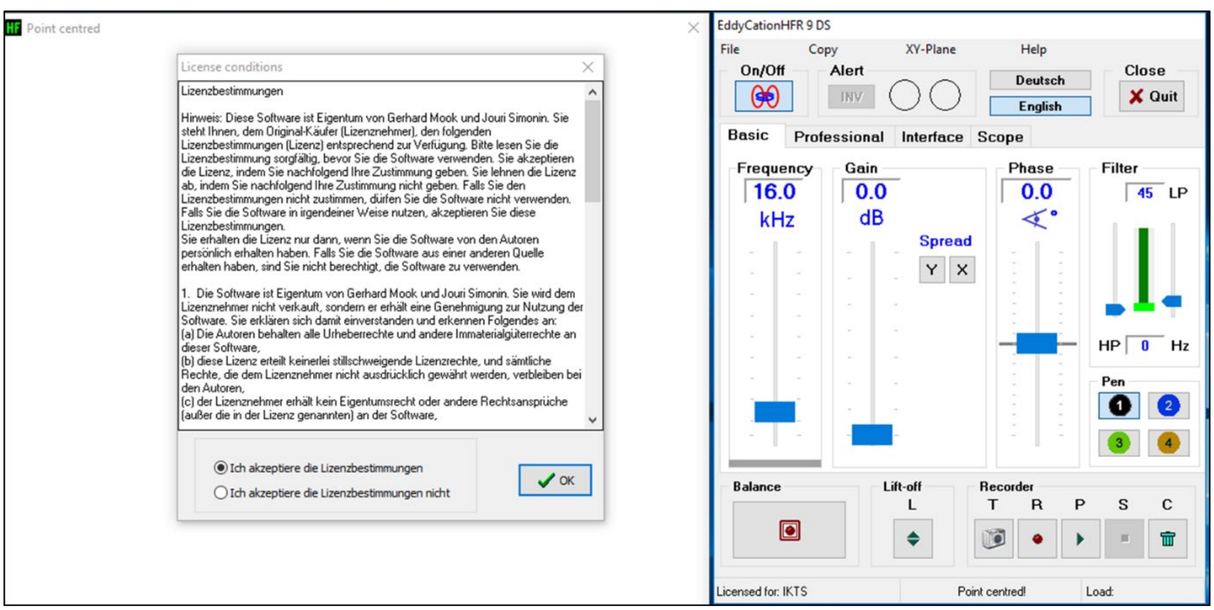

Figure 6a. The initial screen of the eddy current software (right) and license dialog (left).

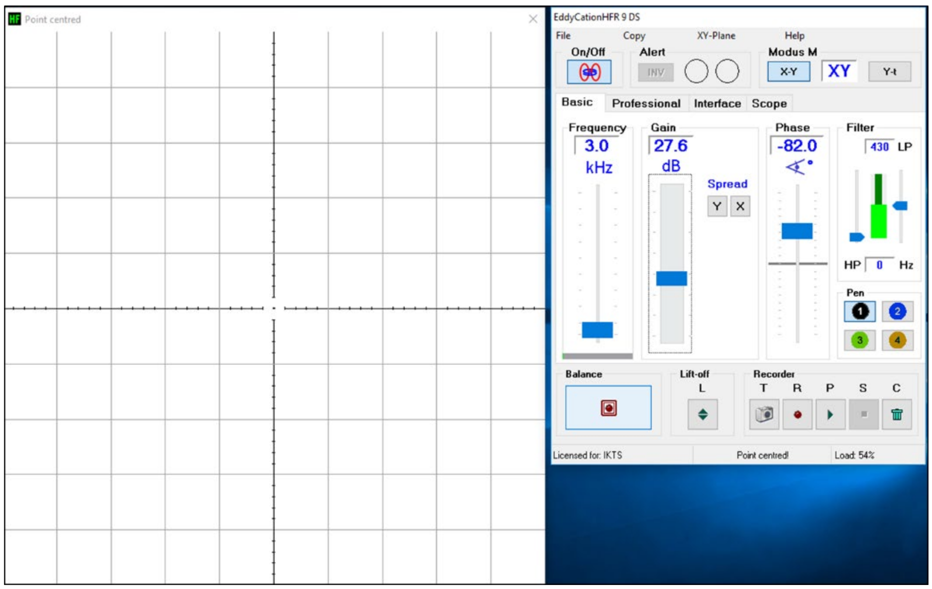

Figure 6b. The initial screen of the eddy current software (right) and blank impedance plane (left) after the license dialog is dismissed

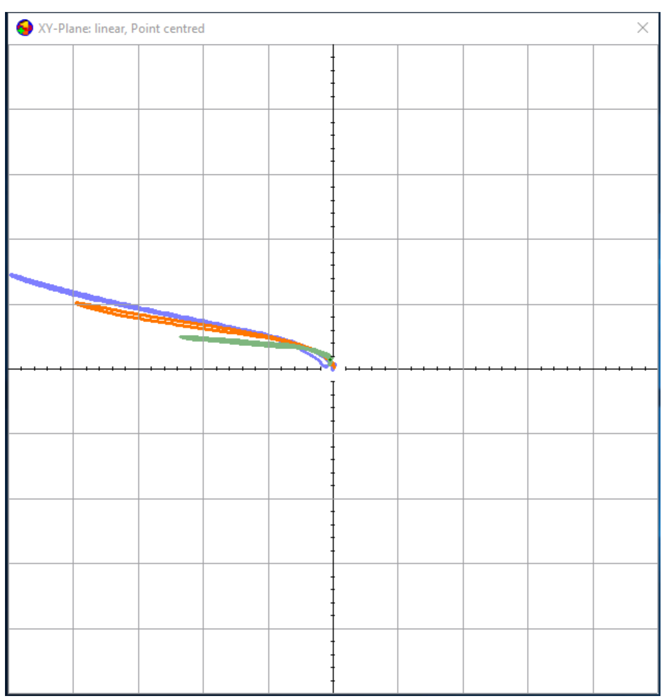

Figure 7. The impedance plane results showing the detection of four surface cracks.

2.3 Ultrasonic (UT) immersion testing

Setup

Fig. 8 displays a conventional UT immersion system that we use in this lab. It consists of a water tank, a pulser/receiver, an oscilloscope and a transducer. As we learned from the lecture, the pulser/receiver generates transient electric pulse which in turn is converted in the transducer to a UT pulse, i.e. a mechanical pulse in the frequency range of ultrasound. The water serves as the coupling medium to allow the UT pulse generated at transducer face to propagate through the water and to transmit into the metal disk specimen placed at bottom of the water tank. The vertical rod called search tube descends the transducer down into the water tank. The search tube is attached to a scan rig mounted on the top of the water tank. The scan rig allows basic manual X-Y translation of the search tube (and hence the transducer) to interrogate different locations of the specimen.

Scope settings

The oscilloscope shows the many waveform traces (i.e. A-scans that you learned from the lecture) that are reflected back from the various interfaces the incident UT pulse interacts with (Figs. 9 and 10). To see details of these A-scans, you need to operate a few controlling knobs and buttons on the control panel to scale and/or translate the A-scan display in both vertical amplitude and horizontal time axes. For vertical amplitude axis, the two main dials are located in the middle of control panel above *CH2* cable connector. The smaller knob (above the blue *CH2 MENU* button and under the *VERTICAL POSITION* label) translates the vertical position of the display while the bigger *VOLTS/DIV* knob controls the vertical amplitude scale. Similarly, the two knobs to the right of amplitude knobs control the horizontal time axis: the smaller knob moves the display window left or right to a different time frame and the bigger *SEC/DIV* knob changes the time scale. The scope is also equipped with a pair of cursors to allow precise measurements made between two time instances or two amplitude levels. This function can be activated by pressing the *cursor* push button (right above the smaller vertical position knob) to turn on the five readout areas shown on the right edge of the display. Each of these five readouts has a corresponding push button to the right. The top button toggles between time and amplitude axes, and the two bottom ones toggle between cursors 1 and 2. To change the cursor position, turn the knob above *SAVE-PRINT* push button. For recording experimental results, you can save the A-scan on display as an Excel data file to a USB flash drive. The USB plugin is located below the display window. However, due to technical issue you have to use the specific USB drive attached to the scope. You certainly can transfer from this drive to other device of your own later. The scope will take a little time to recognize this USB drive after it is plugged in. You then push the SAVE-PRINT button to save the A-scan currently on display. Again the scope will take a little time to do so. When this is done, the name of the file will be shown on the bottom of the display window. For complete scope usage, consult with the user manual “Tek TDS200 manual.pdf” which can be found in class web site on Notes and Assignments page under Misc Documents column.

Flaw detection and sizing

The task in this lab unit is to use this UT immersion system to detect a small flaw located very close to the bottom surface of the metal disk. To achieve this goal, we advise you to adopt a strategy of "sequential search"; that is, finding a series of intermediate targets or signals, one leading to the next, and finally to the flaw signal of interest. You should start out locating the UT signal just leaving the transducer face, followed by the front surface and back surface echoes of the disk specimen, and finally the flaw signal.

The transducer used here is a spherically focused type with 8" focal length. As we briefly covered this in the lecture (pages 18-21 of lecture notes), you can conceive the UT energy being converged, through this focused transducer, right at the bottom of the metal disk like a sharp laser beam. This focusing effect allows us to detect small flaws. In order to obtain a sharp focus for this specific transducer, however, the water path between the transducer and the front surface of disk specimen has to be kept around 4.5" (verify this by performing the calculations similar to that on page 21 of lecture notes) (Fig. 10). This 4.5" water path can be ensured ultrasonically as follows. Recalling from p. 22 of lecture notes, we have $D=0.5\times V\times\Delta t$ in which D is the distance that UT pulse travels between two points (in our case between transducer and disk front surface), Δt is the time-of-flight, i.e. the round trip time-of-flight, and V is the UT speed in water. UT speed in room temperature water is known to be around 0.148 cm/ μs (1 μs = 1 microsecond=10^{-6} second), so all you need is time-of-flight measurement. To get this, you first determine the initial pulse (at the transducer face) from the scope. This is the pulse with a downward arrow pointing to it (Fig. 10). Also recalling from page 16 of lecture notes, the first pulse after that would be the front surface echo from the disk specimen. From the scope you can conveniently measure time difference between any two time instances using a pair of cursors (explained in last section). So go measure the Δt as illustrated in Figs. 9 and 10 and verify if the water path is accurate. Adjust the water path accordingly.

Next, following our sequential search strategy, you need to locate the back surface echo from the disk. This will bring us closer to find the flaw signal, since the flaw is located very close to the back surface. Here you employ $D=0.5\times V\times\Delta t$ again inversely. By measuring the disk thickness and knowing the UT speed in the disk specimen (steel) is 0.58 cm/μs, now you should be able to determine the time between the front surface and back surface echoes. Once the back surface echo is located on the scope display, you can start searching spatially for the flaw signal to appear right before the back surface echo. By "searching spatially" we mean to check on all possible spatial locations on the disk front surface. For this, you and your teammates would work as the robotic arms by pushing the scan rig back and forth or left and right. With a little patience, your group should be able to find it!

The final task is to determine the flaw size by using amplitude profiling. As described on page 17 of lecture notes, amplitude profiling is done by measuring the peak-to-peak amplitude of flaw at each location as the transducer moves some distances away from the flaw center until the amplitude drops eventually down to zero. Here we assume the flaw amplitude reaches maximum at the flaw center. Preform the amplitude profiling on both sides along a line through the flaw center, then the overall end-to-end distance would be an estimate of the flaw size. The flaw size so obtained, however, is grossly overestimated as page 17 of lecture notes pointed out (why?) Clearly we can't gauge the flaw size from the zero-to-zero amplitude profile, and have to settle at a higher amplitude threshold. It turned out an empirical threshold (backed by some theory) at 50% is good for our application. Perform the same amplitude profiling again on the metal disk sample, except that this time stop moving transducer when this amplitude threshold is met, i.e. when the flaw amplitude has dropped 50%. The flaw size estimated in such way should be smaller and likely more accurate. The distances you moved/translated the transducer in amplitude profiling can be measured by sticking a ruler against the scan rig and measuring the difference of movement at each stop with respect to a reference mark (Fig. 11). To increase the accuracy, go estimate the flaw size a couple more times and take an average. Make sure you indeed find the maximum flaw signal, i.e. the center of the flaw, before you start the amplitude profiling.

Remember to record the process how you find the flaw and estimate its size. Take a few A-scan data by first saving them in the designated USB flash drive and then transferring to your own storage device. Also take photos throughout the process, and write down the calculations leading to the final flaw size estimation.

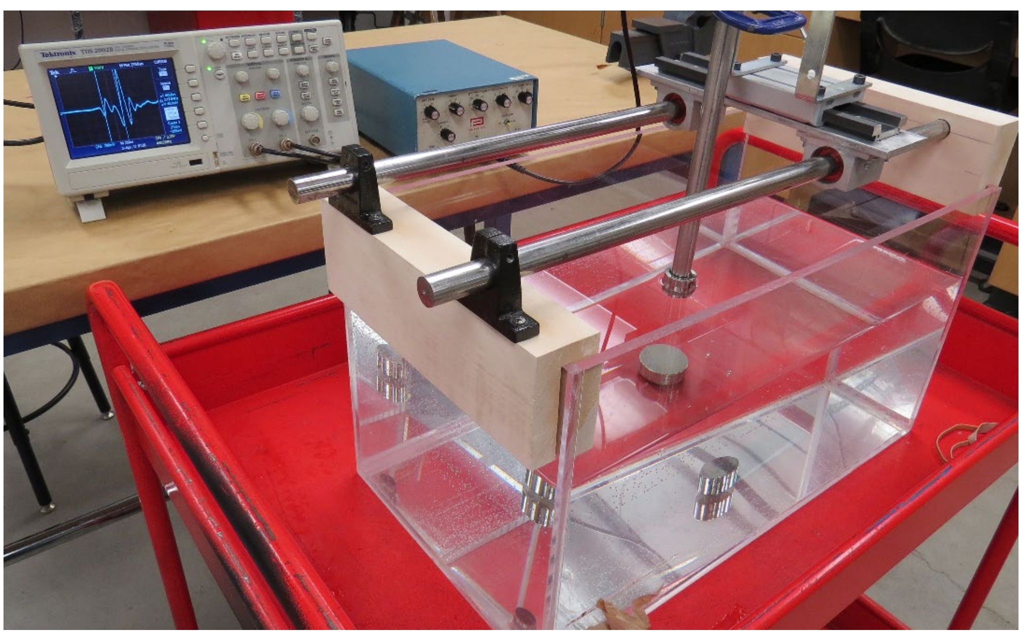

Figure 8. A conventional UT immersion system.

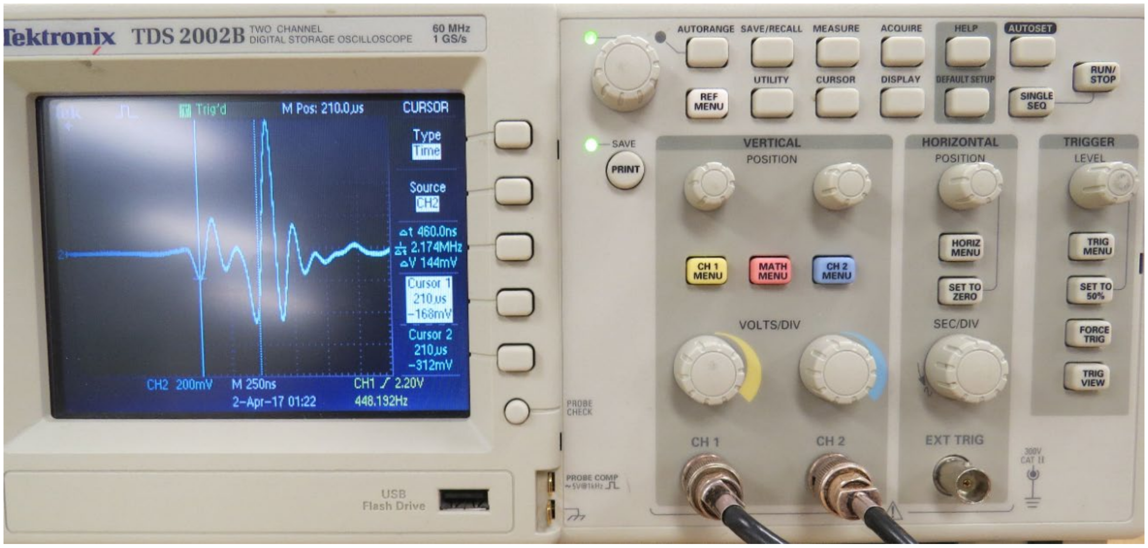

Figure 9. The oscilloscope's display (left) and control panel (right)

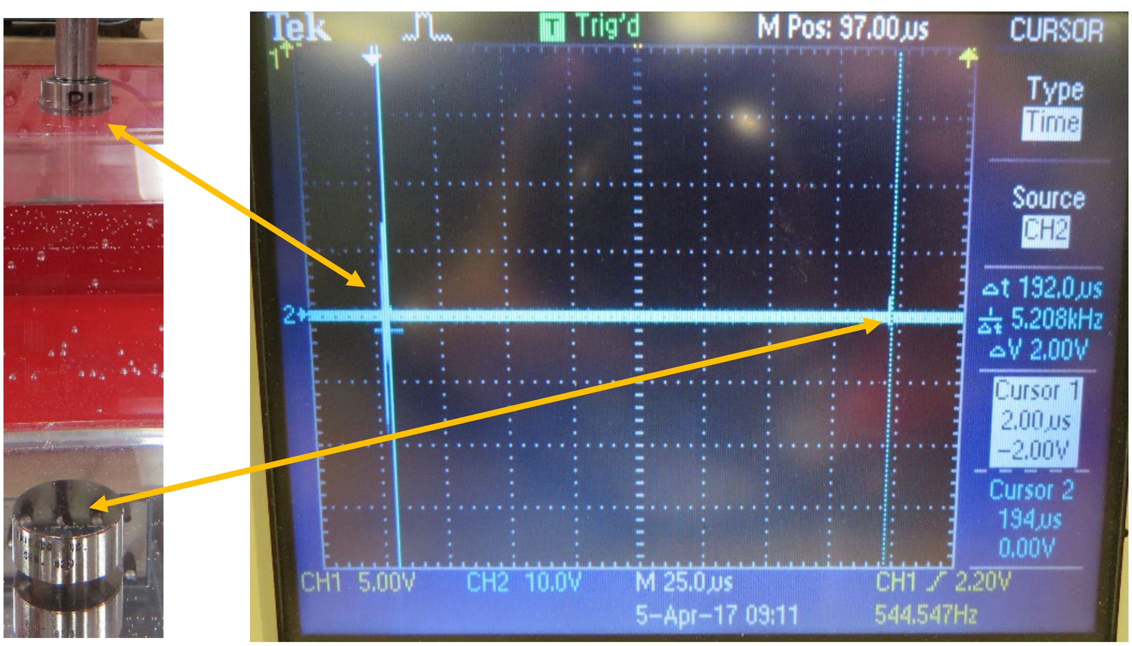

Figure 10. Transducer vs. disk specimen in the water tank (left) and the corresponding UT echoes shown on scope.

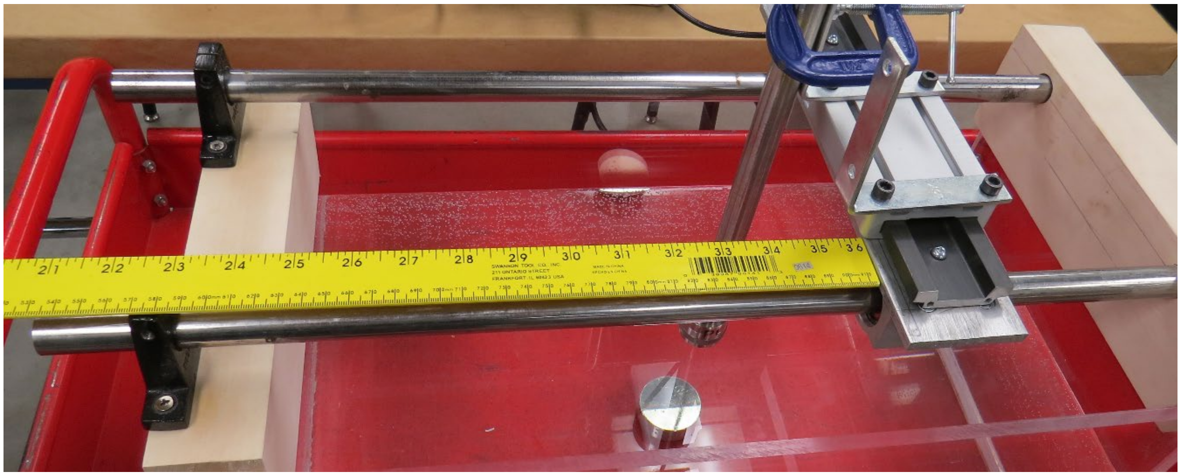

Figure 11. Differential measurement using ruler as an estimate of the flaw size.

2.4 Ultrasonic (UT) simulation

In this lab unit, your team is tasked to conduct a virtual UT experiment by using a computer simulator called UT S/N Sim developed here at ISU by CNDE. This simulation software represents the current state-of-the-art for optimizing inspectability in UT NDE. It is particularly unique in handling inspection problems with severe microstructural grain noise interferences. The simulator is designed to be used as a first-pass tool to obtain quick assessment of the inspection need on hand. The users can then iterate more simulation runs to optimize the results in a short turn-around time.

UT measurement, as you can understand now, is a very complicate physical process. Simulating this process hence is quite involved. To accurately define a UT measurement process in the simulator, there are many input parameters to be specified as illustrated in the startup screen of Preview tab (Fig. 12). In order to limit the scope of this simulation task or virtual experiment to a manageable size, you will only adjust a few key parameters and leave most of other settings to their default values.

Task

By "playing" with the simulator, your team is *to determine a set of "Probe" and "Inspection" settings that will be able to find #1 flat bottom holes (FBHs) located between 2.5 and 3.5 cm depth in a flat nickel block of medium grain microstructure, while maintaining a signal-to-noise ratio (SNR) higher than 4.5 at each FBH location*. Viewing from Fig. 12, this is like placing the #1 FBH hypothetically in every depth between 2.5 and 3.5 cm. FBHs are flat-end round holes drilled in from the bottom of the test samples and are commonly used as synthetic defect standards. The size (diameter) of FBHs is specified by a whole number: #1 is 1/64”, #2 is 2/64”, etc. SNR is defined as the ratio between peak amplitude of defect signal and peak amplitude of grain noise signal (page 33 of lecture notes). The latter is typically three times of root-mean-square value of grain noise level.

Startup

The simulator can be accessed from the PCs connected with the three Instron load frame stations. Double click the shortcut “UT_SN_Sim” on the desktop of the PC to start the simulator. It may take up to a minute to start for the first time or after a long break. The first screen appeared is a command prompt and the starting GUI tab of Fig. 12 will appear right after. The command prompt is for diagnosis purpose so you can safely minimize it for the rest of simulation. Depending on the screen resolution of the computer monitor, the GUI may take up significant screen height, and its bottom edge may be blocked by Windows taskbar. If this happens, *set taskbar to auto hide mode* to avoid such blockage.

Setup

1.-3. below are some key parameters across several tabs of the GUI that you need to change from default. They will be set at the prescribed values and then left unchanged throughout the entire simulation.

1. *Simulation Tab:* set *Defect type* to FBH and *Defect size* to 1/64 inch (on the middle left side)
2. *Material 1 Tab:* set the *Metal alloy type* (on the top left corner) to nickel and *Grain size (Dz)* (on the middle right side) to 100 microns
3. *Inspection Tab:* set *Wave mode in metal* to L (for longitudinal mode)

The parameters described in the following paragraphs are the main parameters you will change iteratively over a number of simulation runs in order to meet the criteria set in the Task section above.

In Probe tab (Figs. 12 and 13; see also pages 18- 21 of lecture notes):
<u>Transducer type:</u> this control has several options: Circ. (for Circular), Ellip. (for elliptical) or Rect. (for rectangular) coupled with the choice of focused or unfocused. Out of the three transducer types (shapes), circular is most common and suitable for our flat sample block. Focused transducer converges ultrasonic beam to achieve better spatial resolution and should be your choice.
<u>Transducer diameter</u>: this control determines the size of the transducer of circular or elliptical shape. A larger transducer diameter makes a larger beam field and hence a larger coverage of inspection. Larger transducers are also capable of tighter focus with higher sensitivity.
<u>Focal Length</u>**:** this is the distance between the transducer face to the location the sound energy converges in water. Every focused transducer has its specified focal length. In a solid medium, the speed of sound will increase, making the beam focus shorter than in water due to refraction. As shown on page 21 of lecture notes, given the media properties and transducer focal length you can use the focal law to determine the focal point in solid.
<u>Center Frequency</u>**:** This is the frequency at center of the transducer’s frequency range. As

you practice with the simulator, you will see that UT at lower center frequencies suffers less attenuation (due to grain noise loss), but also has lower sensitivity to small defects. Higher frequency attenuates fast, but is more sensitive. You will need to strike a balance to find the flaw with the best choice of center frequency.

Bandwidth**:** the bandwidth is a measure of the range of frequency content that is in the beam. A narrow bandwidth results in a longer UT pulse and worse temporal resolution and vice versa. You can experiment with this during your search. After you run a simulation you can click on the *Graph Reference* button to see what the UT pulse looks like in the time domain. For this simulation task, keeping the bandwidth at the default 60% will work fine.

In Inspection tab (Fig. 14):
The only control useful to you in this tab is the water path. This is the distance between the transducer face and the front surface of the sample. Again see page 21 of lecture notes to see why and how water path is important.

As mentioned above, all other parameters of the simulator should not be changed and left with their default values.

Results

When you have change all necessary settings and are ready to execute a simulation run, click on the *run* menu at the top left of the GUI window and then select *Run Simulation*. After a short pause, a result window as shown in Fig. 15 will appear. The first plot on the top displays the profiles of defect signal amplitude and the grain noise amplitude as functions of depth. Note that these two curves use different vertical scales: defect scale on the left and noise on the right. The middle graph plots the SNR, based on its definition that combines the two curves in the top plot. The bottom-left and bottom-right plots show the A-scans (see page 15 of lecture notes) for FBH signal and noise response at a specific defect depth. The left one shows the defect and noise signal separately and the right one composes the two together as appeared in reality. Clicking on different depth in the top plot will update the bottom two A-scans representing that defect depth.

*The SNR plot in the middle is where you determine if you have found the best inspection setups for the task***.** *At the very bottom of the result window, the most important output parameters such as SNR value are also listed. After a few simulation runs, you will have better ideas how to set the parameters for Probe and Inspection, and in a few more runs you will be able to obtain the settings satisfying the 4.5 SNR requirement.* You should also study the contents in the preview tab (Fig. 12). In conjunction with the result plots, these contents would help you to get a better understanding on the type of calculation being done by the simulator.

Right above the bottom line of the output parameter list (Fig. 15), there is a row of operation icons, which allow you to further manipulate the plots. Particularly, you can save the output window as an image by clicking the disk icon.

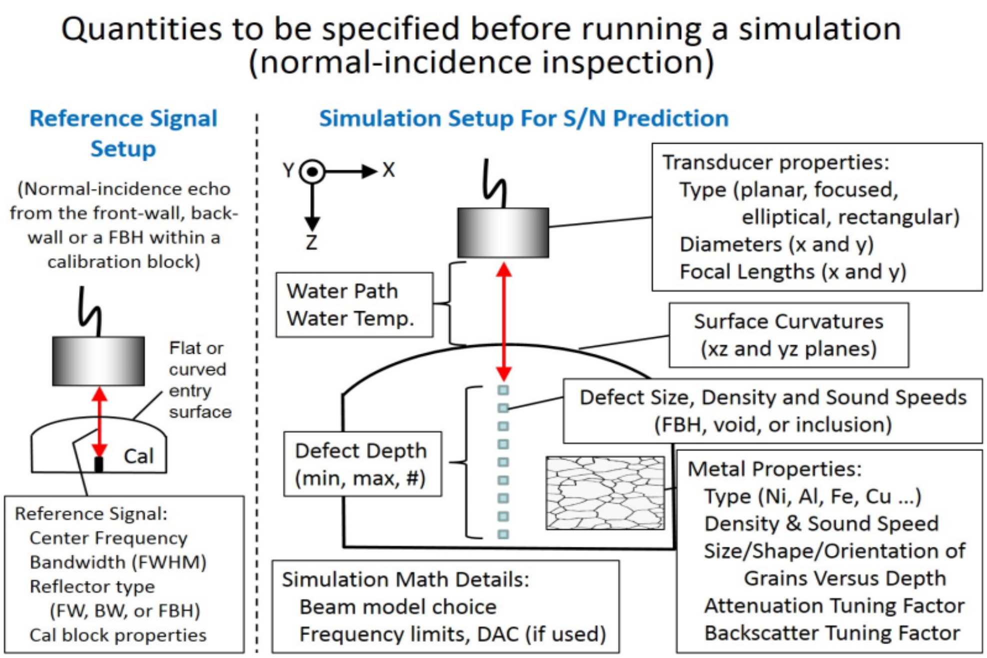

Figure 12. Simulator's startup Preview tab illustrates the required specifications for the simulation

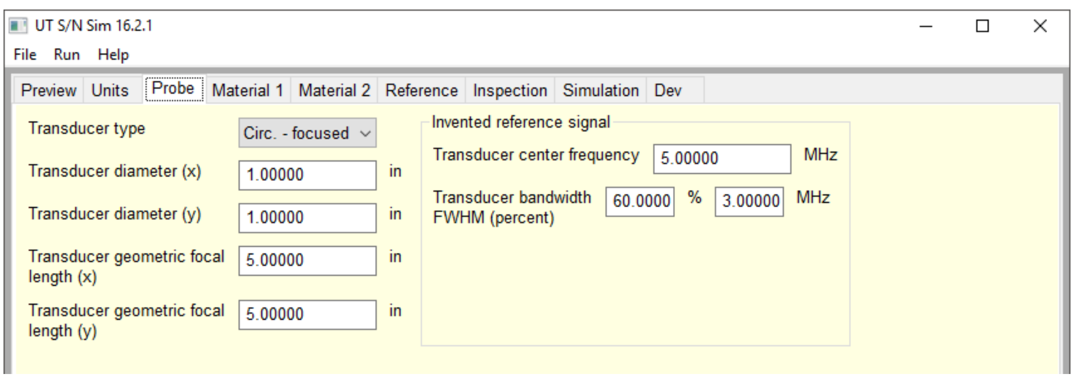

Figure 13. Probe definition tab

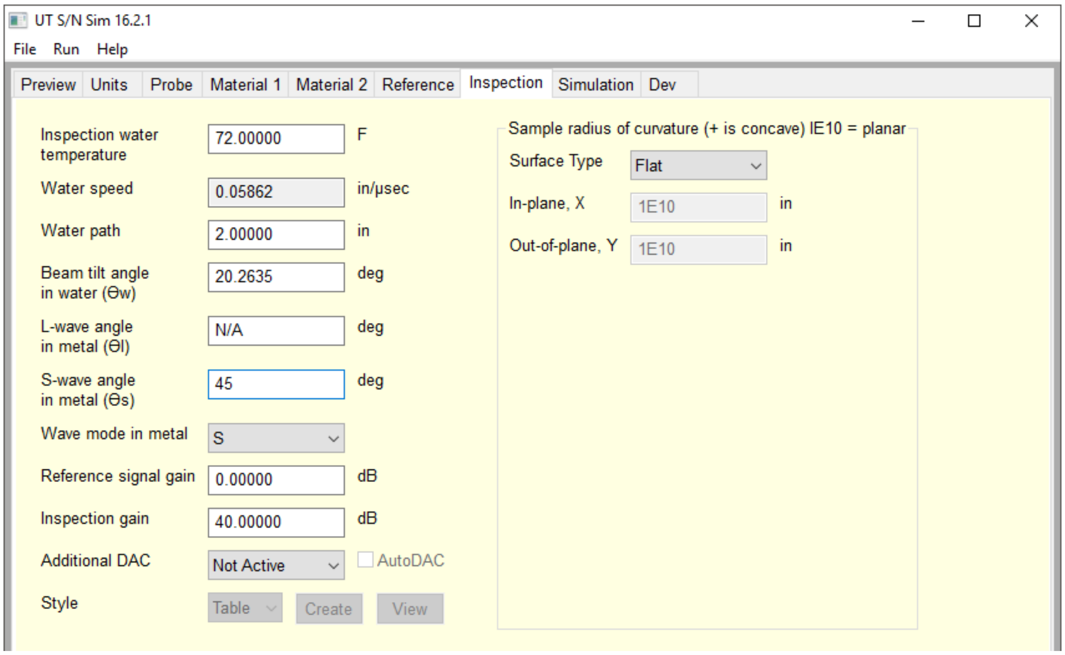

Figure 14: Inspection definition tab

3. After Lab

Compile and analyze all your test results from all three NDE testing techniques and prepare to answer the following questions:

Tap testing (25%)

1. How many defects in the four enclosed areas (as shown on Fig. 4) the tap tester can detect? Any difference between the left and right group of the “crushed core” type of defect? Do you think that the left-right group difference (if any) has anything to do with the core size, i.e. .25 vs. .187?
2. How did the preset ¼” tap spacing affect the detectability of the smaller defects? Can you still detect the smaller defects if the tap spacing (resolution) increased to ½“?
3. Recall that the honeycomb test panel has a three-layer structure: top skin – honeycomb core – bottom skin. Now you are told that the defect type “delamination” means separation between the top skin and the honeycomb core and the type “core unbonds” has separation between the honeycomb and bottom skin. How would this new information help you justify the difference between the tapping results of these two types?

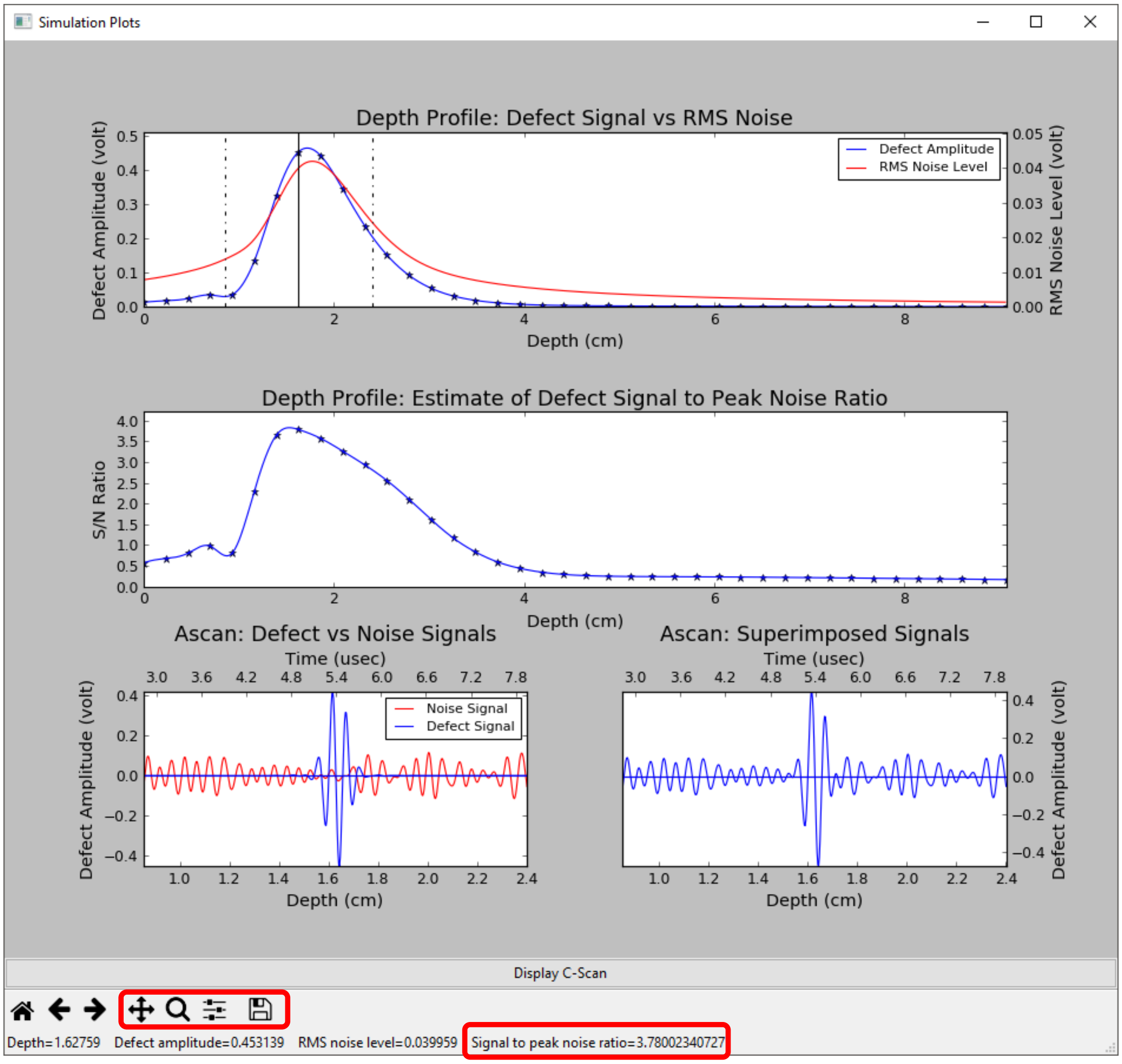

Figure 15. Main simulation output window (enclosed in red boxes are the SNR output and plot manipulation icons)

<u>Eddy current testing (25%)</u>

4. You were asked to perform the "lift-off" calibration. Now after you have gained some EC experience, what would be the possible reasons for doing this calibration?
5. You needed to change frequency in order to detect the hidden cracks. Which direction you changed the frequency: higher or lower and why? Based on page 27 of lecture notes, provide some theoretical justification.

<u>Ultrasonic testing (30%)</u>

6. For the immersion UT testing, you were asked to set the water path at 4.5”. Given the thickness of the sample disk you measured and the transducer’s focal length specification of 8”, can you verify that this water path is indeed accurate enough? See page 21 of lecture notes.
7. You were asked to estimate the flaw size by using the flaw amplitude profile. You now know that the size would be grossly overestimated if zero-to-zero amplitude profile, i.e. flaw signal amplitude decreasing to zero at the two ends of profile line, is used. From page 17 of lecture notes, you also learned that this is largely due to the finite beam width of the UT transducer. Could you make some sketches to illustrate why and how does this overestimation come to be? Page 12 above instructs you to use a 50% amplitude threshold to correct such overestimation. What is your flaw size estimation using this 50% threshold? If you are now told that the flaw size (diameter) is about 5mm. Is your flaw size estimate accurate enough?

<u>Ultrasonic Simulation (10%)</u>

8. Of all the parameters that you will iteratively change to meet the SNR requirement, which one seems to dominate? Transducer diameter, focal length, center frequency or water path? Which one is the second most influential parameter? Can you see why?

<u>NDE and Design (10%)</u>

9. Suppose you join a team in designing an underground waste storage tank. To save cost, it is suggested to completely seal the tank from all sides. The past history, however, indicated that waste storage tanks like this one over time will leak due to inside out cracking. Any environmental concern you may have with this design? Now that you are an NDE expert after taking this course, what NDE remedies would you recommend to resolve such issue?

Group lab report due in Canvas as usual.