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Introducing Ultrasonic Non-Destructive Testing in Undergraduate Mechanical Engineering Education

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Abstract

Non-destructive testing (NDT) is a critical component of modern industrial practices, yet it remains underrepresented in many undergraduate mechanical engineering curricula. To bridge this gap, this paper presents the introduction of ultrasonic NDT techniques into a sophomore-level materials testing lab. The lab was designed to familiarize students with ultrasonic testing and to reinforce key concepts related to wave propagation and material properties.

Students used an ultrasonic test system equipped with longitudinal and transverse wave transducers, a pulser/receiver, and an oscilloscope. By generating and analyzing waveforms, students were able to calculate material properties through the time delay between the pulse and corresponding echo. Students measured the velocities of longitudinal and transverse waves in tensile testing specimens, from which material properties such as Young's modulus, Poisson's ratio, and shear modulus were determined.

In parallel, the same specimens underwent traditional tensile testing, providing students with a valuable opportunity to compare Young's modulus values obtained via both ultrasonic NDT and conventional testing methods. This direct comparison deepened students' comprehension of the material properties and highlighted the practical applications of NDT in evaluating the integrity and characteristics of materials without causing damage.

The effectiveness of incorporating ultrasonic NDT into the curriculum was assessed through detailed student reports and reflections. These assessments demonstrated that the lab significantly enhanced students' understanding of both ultrasonic NDT principles and their relevance to industry, particularly in the context of material testing and evaluation. The hands-on experience provided by the lab offers an essential educational experience, preparing students for the demands of modern engineering practices where NDT plays a pivotal role in ensuring material quality and safety.

I. Introduction

Non-destructive testing (NDT) plays a critical role in industries such as aerospace, automotive, energy, transportation, and manufacturing, where ensuring structural integrity and reliability is essential [1]. By evaluating material properties without causing damage, NDT enables safer and more efficient engineering practices. As a result, there is a strong demand for engineers with NDT expertise, highlighting the need for its inclusion in undergraduate engineering education.

Despite its significance, NDT is not commonly incorporated into mechanical engineering undergraduate curricula. A survey conducted by the authors across seven ABET-accredited mechanical engineering programs in the region (Western PA, Upper state NY, Eastern Ohio and West Virginia) found that only one institution explicitly offers an NDT course. Several challenges contribute to this gap. Theoretical concepts central to ultrasonic NDT—such as wave propagation, signal generation, and signal processing—are typically covered in senior-year or graduate-level courses. Other NDT methods, including acoustic emission, eddy current, and radiography, require foundational knowledge in physics, electromagnetism, and materials science, making them inherently multidisciplinary and difficult to introduce at the undergraduate level, particularly to lower-division students.

A broad survey indicates that some institutions introduce NDT as a survey course [2], a lab-based elective [3], or through project-based learning [4]. However, these courses are often technical electives, attracting only students who already have an interest in the field. Additionally, implementing a comprehensive NDT lab requires substantial financial investment, with each mainstream NDT method (ultrasonic, acoustic emission, eddy current, and radiography) requiring a setup costing at least $10,000–$20,000. Without early exposure to NDT concepts, student interest may be insufficient to justify such investments.

At the authors' institution, we recognized an opportunity to introduce new experiments into the sophomore-level testing lab, which traditionally includes tensile, hardness, and impact testing. Given its widespread industrial application and relatively low equipment costs, ultrasonic NDT presents a feasible option for integration. To address the lack of NDT exposure in the curriculum, the authors implemented an ultrasonic NDT system consisting of transducers, a pulser/receiver, and an oscilloscope, with a total cost of under $10,000. This system is multi-functional, capable of material characterization by evaluating properties such as Young's modulus, thickness measurement using pulse-echo techniques, and flaw detection by identifying internal defects through ultrasonic wave reflections. Unlike commercial ultrasonic systems designed specifically for thickness gauging or flaw detection, each costing a similar amount—this system provides a versatile and cost-effective alternative while allowing students to directly engage with the measurement principles.

This paper presents a laboratory experiment designed to introduce ultrasonic NDT at the sophomore level as part of a materials testing course. The experiment aims to:

1. Introduce NDT concepts to students to spark their interest in this field.
2. Provide sufficient background knowledge to help students understand the fundamental measurement mechanisms, including wave propagation and material behavior, without overwhelming them with advanced theory.
3. Enhance students' understanding of mechanical properties of materials through hands-on application of NDT techniques.

By integrating NDT concepts into an existing sophomore-level lab course, this approach seeks to make NDT education more accessible and engaging, laying the foundation for future exploration and specialization in the field.

II. Theoretical Background

This experiment is designed as part of a sophomore-level material testing lab, and therefore, some theoretical background is essential for students to develop a basic understanding of the measurement principles.

Sound travels at different speeds depending on the type of medium—air, liquid, or solid. Similarly, sound speed varies among different solid materials. These variations are directly influenced by the molecular structure of the materials, which is shown as differences in macroscopic material properties such as the stiffness constants. For homogeneous isotropic materials, these stiffness constants are the elastic constants that include Young's modulus, shear modulus, and Poisson's ratio. Based on the fundamentals of wave propagation, differences in material properties are reflected in variations in the velocity of acoustic wave propagation. Therefore, ultrasonic NDT methods utilize ultrasonic waves generated within solid materials to measure wave velocity and evaluate material properties.

To understand the experiment mechanism, the key theoretical principles include:

Ultrasonic NDT Principles: Ultrasonic NDT system consists of three main components: a pulser/receiver, an ultrasonic transducer, and an oscilloscope (as shown in Figure 1). The pulser/receiver generates an electrical pulse signal, causing the piezoelectric element within the ultrasonic transducer to vibrate and produce ultrasonic waves. These waves travel through the solid material and reflect at interfaces, such as the bottom surface of the material. The transducer receives the echo signals of the reflected waves and sends them to the pulser/receiver, which processes these signals and displays the resulting waveform on the oscilloscope.

This basic pulse-echo mechanism [5] is widely employed in the industry for applications such as thickness measurement, flaw and crack detection, and material property evaluation.

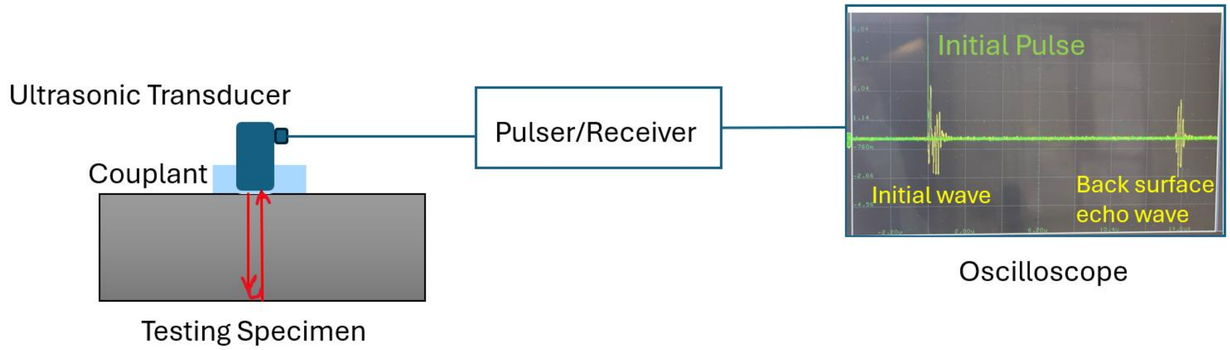

Figure 1: Ultrasonic NDT Principles.

Wave Propagation Principles: Two primary types of body waves can travel through solid materials: longitudinal waves and transverse waves. In longitudinal waves, the particles of the medium vibrate parallel to the direction of wave propagation. In transverse waves, the particles of the medium vibrate perpendicular to the direction of wave propagation (as illustrated in Figure 2).

During the lab, the instructor uses a slinky to describe the difference between the two waves. The propagation velocities of the waves differ when traveling through the same medium, with longitudinal waves typically moving faster than transverse waves. In the experimental setup, longitudinal ultrasonic transducers are used to generate longitudinal waves, while transverse ultrasonic transducers are employed to generate transverse waves.

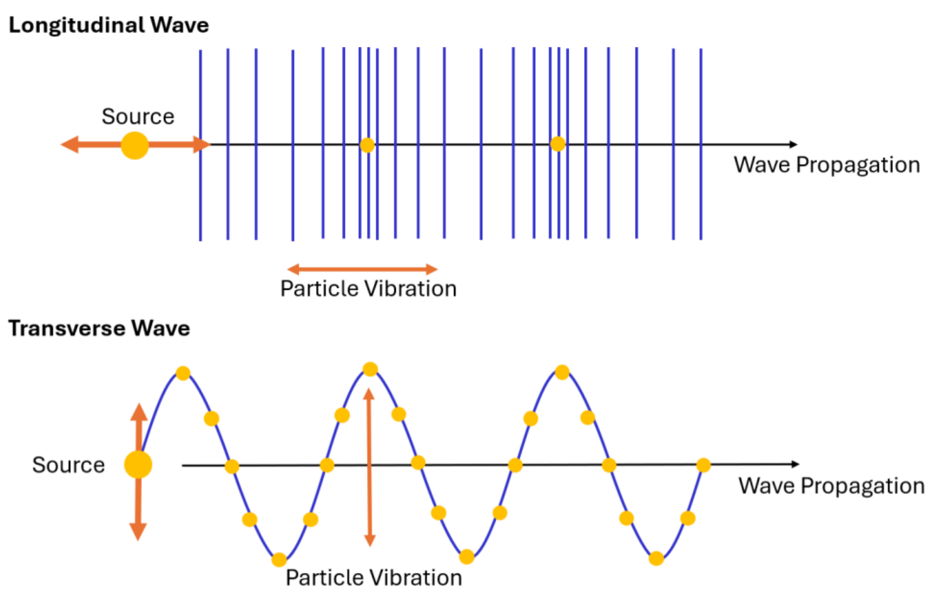

Figure 2: Diagram showing the Longitudinal wave and Transverse wave.

Material Properties from Wave Velocities

The relationships between wave velocities – longitudinal wave velocity V_L and transverse wave velocity V_T – and the material elastic constants (i.e. Young's modulus (E), shear modulus (G), and Poisson's ratio (ν)) are provided for further analysis [6].

$$E = \rho V_T^2 \frac{(3V_L^2 - 4V_T^2)}{(V_L^2 - V_T^2)}$$

$$G = \rho V_T^2$$

$$\nu = \frac{2V_T^2 - V_L^2}{2(V_T^2 - V_L^2)}$$

By understanding these principles, students can better grasp the mechanisms underlying the experiment and appreciate the applications of ultrasonic NDT in evaluating material properties.

III. Experiment and Equipment Description

The experimental setup included the following components:

1. **Ultrasonic Transducers (A110S and V155, OLYMPUS)**: Equipped with longitudinal and transverse wave transducers.
2. **Pulser/Receiver Unit (DPR300 Pulser/Receiver, JSR)**: Generates a pulse signal to initiate ultrasonic wave and receive the echo of ultrasonic wave signals.
3. **Oscilloscope (InfiniiVision DSOX3014G, Keysight)**: Visualizes the waveforms for analysis.
4. **Tensile Testing Specimens**: Standard tensile testing samples of known dimensions and material properties (1018 Steel and Aluminum 6061 are used in the experiment).

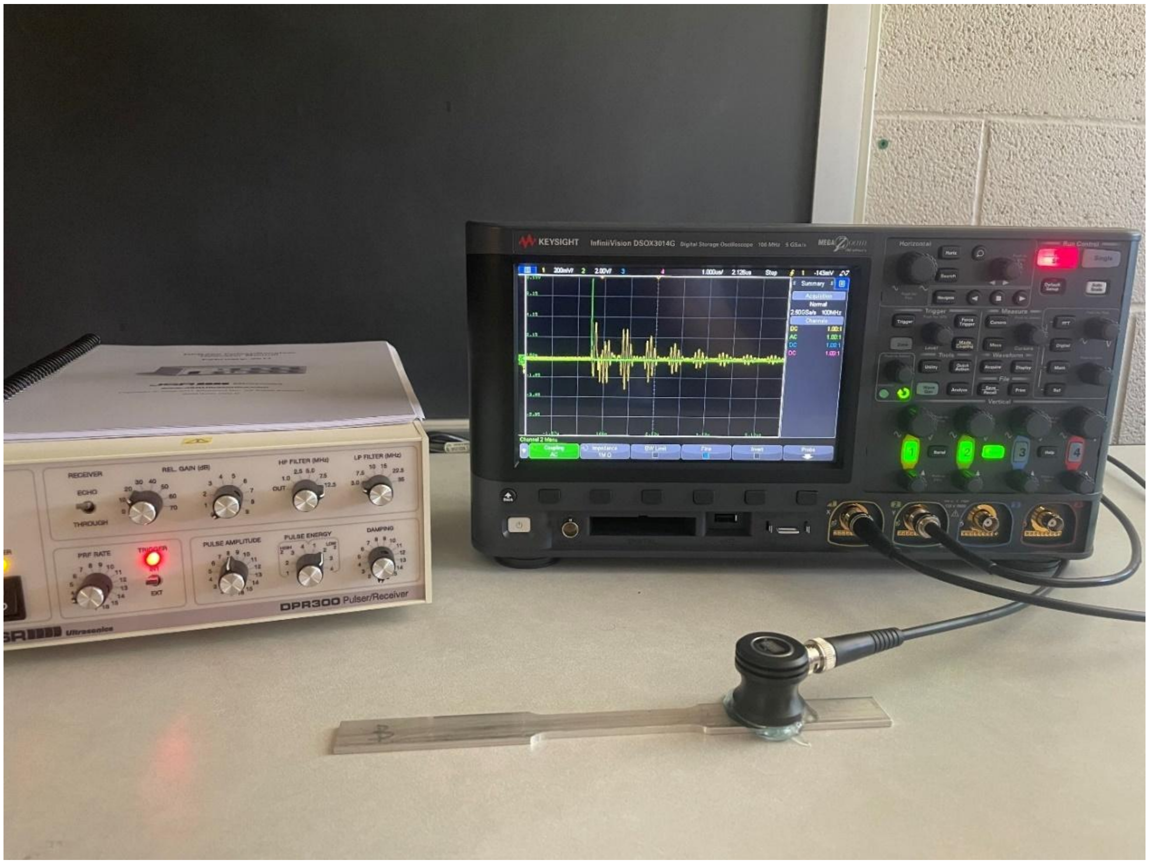

Figure 3: Experiment Setup.

IV. Experiment Procedure:

Demonstrations Performed by the Instructor

1. The instructor demonstrates waveform identification using a longitudinal transducer to perform measurements on two Al 6061 specimens of different thicknesses (about 2 inch and 1/8 inch). Due to the significant difference in thickness, the delay between echoes reflected on the oscilloscope changes noticeably.
2. Next, the instructor repeats this process with standard tensile testing specimens of similar thicknesses but different materials (Al 6061, 1018 Steel, and Copper as shown in Figure 4). The echo delay times vary due to differences in longitudinal wave velocities across the materials.

Through these demonstrations, students gain an intuitive understanding of the measurement principles before conducting their own experiments.

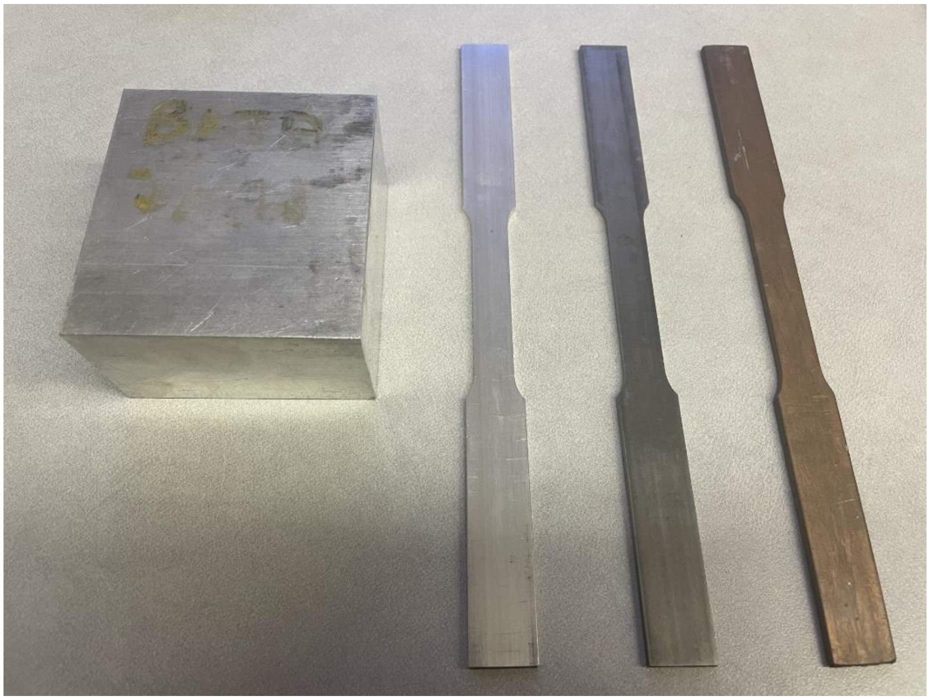

Figure 4: Testing Specimens.
(Left to Right: Al 6061 2-inch thick, Standard testing samples Al 6061, 1018 Steel, Copper)

Student experiment:

1. Students measure the thickness (d in inch) of the specimen. The density of the specimen is provided from handbook values.
2. Students initiate ultrasonic testing by applying ultrasonic couplant to the specimen's surface and placing the longitudinal transducer in contact with the specimen through the couplant. The pulser/receiver emits a high-voltage pulse, and the oscilloscope displays the resulting waveform.
3. By measuring the time delay ((Δt in μs) between the first two echoes, students calculate the velocity of longitudinal waves ($V_L = d/\Delta t$).
4. Steps 2-3 are repeated twice at two additional locations on the specimen. The transducer is then switched to a transverse wave transducer, and the velocity of transverse waves (V_T) is calculated.
5. Using the calculated wave velocities, students determine material properties such as Young’s modulus, Poisson’s ratio, and shear modulus.
6. Traditional tensile testing is conducted on the same specimens to obtain reference values for Young’s modulus.

By following this procedure, students gain hands-on experience with ultrasonic NDT and its application in evaluating material properties.

V. Experiment Results and Discussion

The comparison of material properties obtained via ultrasonic NDT and traditional tensile testing revealed:

Wave Velocity Insights: Students observed that longitudinal wave velocities were consistently higher than transverse wave velocities, as predicted by theory. Table 1 shows an example of student measurement of wave velocity in three test samples. Students repeated similar measurements at three locations on these samples, affirming good replicate data across the entire sample.

Table 1: Wave Velocity Table.

Material	V_L (in/s)	V_T (in/s)
Aluminum 6061	2.57E+05	1.25E+05
	2.62E+05	1.25E+05
	2.58E+05	1.24E+05

Young's Modulus: Results from ultrasonic NDT closely aligned with standard values from the material datasheet, validating the accuracy of the method. Typical student values are shown in Table 2. As shown, the tensile testing data had greater standard deviation than the NDT methods, so students were asked to discuss how error or uncertainty were introduced during the tensile testing experiment.

Table 2: Young's Modulus Comparison Table.

6061 Aluminum Sample #	***Tensile Test*** Young's Modulus (ksi)	***NDT*** Modulus of Elasticity E (ksi)
1	9,177	10,495
2	9,430	10,679
3	10,013	10,583
Average	9,540	10,586
Published	10,000	10,000
% Diff	-5%	6%

These findings emphasized the reliability of ultrasonic NDT and its capacity to complement conventional testing methods. The hands-on approach fostered a deeper understanding of the interrelationship between wave mechanics and material properties.

VI. Student Learning Assessment

Student learning outcomes were evaluated through structured lab reports, with an example provided in the appendix. The report format included predefined questions and prompts to guide students in documenting their experimental objectives, setup, data collection, and analysis. All tables and plots were recorded by students during the experiment.

Evaluation of Student Reports

Student reports were assessed based on their ability to:

- Clearly describe the experimental objectives and equipment setup.
- Record data in an appropriate format.
- Calculate longitudinal and transverse wave velocities and derive material properties such as Young's modulus, shear modulus, and Poisson's ratio.
- Compare ultrasonic NDT results with traditional tensile test data, identifying sources of error and uncertainty.
- Reflect on their preference between NDT and traditional methods and summarize key learning takeaways.

Key Observations

The reports demonstrated that students developed a strong conceptual understanding of wave propagation and its role in ultrasonic NDT. They successfully distinguished between longitudinal and transverse waves and their respective significance in material evaluation.

Most students accurately calculated material properties and recognized variations in wave velocity among different specimens. They also noted that ultrasonic NDT results were generally closer to published values, with an 8% deviation, compared to the 15% deviation observed in tensile testing.

Comparison with Traditional Material Testing

Student reflections emphasized the value of integrating ultrasonic NDT alongside conventional tensile testing. Many appreciated the ability to assess material properties non-destructively and recognized NDT's practical advantages in industry. Comparing results from both methods reinforced their understanding of material behavior and the accuracy of NDT techniques.

Student Feedback and Recommendations

Student feedback highlighted the hands-on nature of the experiment as a key factor in their engagement. They found value in directly comparing NDT with traditional methods within a single lab session. Some students showed interest in other NDT methods in future courses to further expand their exposure to non-destructive evaluation methods.

Overall, this assessment underscores the effectiveness of integrating ultrasonic NDT into the sophomore-level materials testing lab, enhancing students' theoretical understanding and practical skills in modern engineering practices.

VII. After Experiment Writing Assignment

In addition to the laboratory experience, we used a companion writing assignment to introduce the wider capabilities of ultrasonic NDT test methods. Students were given a hypothetical scenario as summer interns at a small manufacturing company. The interns were asked to prepare a recommendation for the company leaders interested in purchasing ultrasonic NDT test equipment. The assignment is repeated below (italics):

*You are to study literature about **Ultrasonic NDT** and write a 300-350 word summary that addresses the following points:*

- *What types of material properties can be measured using ultrasonic NDT?*
- *What types of defects can be detected using ultrasonic NDT?*
- *Could our company use the ultrasonic NDT on metal parts made with additive manufacturing?*
- *What is the approximate cost range (low to high) of purchasing an ultrasonic NDT system?*
- *What features and capabilities (versus cost) are important to include when purchasing?*
- *Do you recommend purchasing an ultrasonic NDT system?*

The audience for your report is the senior leadership of the company. You can assume these people are technically astute, but not specialists. Create your report so anyone with an undergraduate degree in science or engineering can follow the logic.

Students were required to support their recommendation using literature from multiple sources: peer-reviewed literature, technical standards, conference articles, and trade journals. Grading was based on the students' use of citations to logically support their answer to the questions above.

For 63 students, an average score of 89.3% showed that most students could articulate the NDT system tradeoffs between cost, performance, convenience, and accuracy. (Grade distribution shown in Figure 5.) Students also reported on several emerging NDT methods, like phased-array sensors, non-contact methods and contrasted these to some non-ultrasonic methods. Our conclusion was that the combination of the technical writing assignment and the lab experiment produced a working knowledge of NDT test methods.

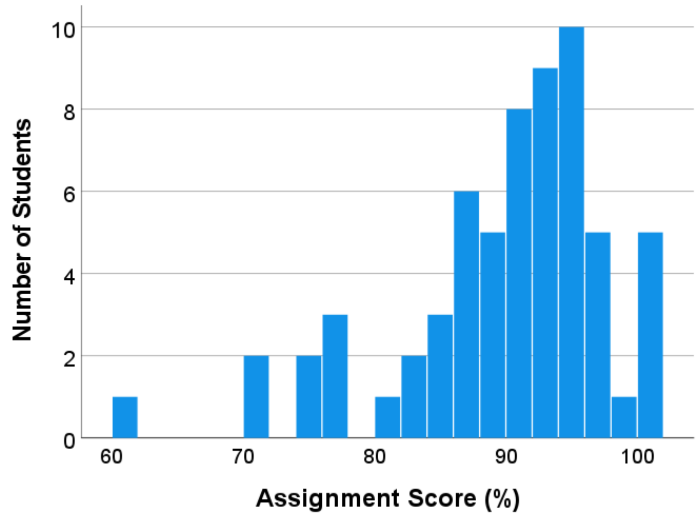

Figure 5: Writing Assignment Score Distribution.

VIII. Conclusion

Integrating ultrasonic NDT into the sophomore-level materials testing lab enhances the educational experience by bridging theoretical knowledge and practical application. Through hands-on experimentation, students gained valuable insights into ultrasonic NDT, wave propagation and material behavior. Students particularly valued the comparison of NDT results with traditional testing methods, which reinforced their understanding of material science fundamentals and the industry relevance of NDT. This student experiment incorporates a cost-efficient ultrasonic NDT system into undergraduate curricula, fostering early interest for addressing the demands of modern engineering industries.

References

[1] https://www.asnt.org/what-is-nondestructive-testing/industries

[2] https://syllabi.engineering.osu.edu/syllabi/weldeng_4303

[3] https://www.cnde.iastate.edu/nde-education/

[4] Akundi, Aditya, et al. "Non-destructive testing (NDT) and evaluation using ultrasonic testing equipment to enhance workforce skillset for modern manufacturing." *2018 ASEE Annual Conference & Exposition*. 2018.

[5] Krautkrämer, Josef, and Herbert Krautkrämer. *Ultrasonic testing of materials*. Springer Science & Business Media, 2013.

[6] Li, Qiuyan, et al. "Characterization of materials fabricated by additive manufacturing method using line focused ultrasonic transducer." *ASME International Mechanical Engineering Congress and Exposition*. Vol. 50633. American Society of Mechanical Engineers, 2016..

Appendix: An example of student report

MECE 251
Mechanical Systems Lab I
Tensile Testing Laboratory

Investigators: Students A, B, C

Objectives:

1. To learn how to perform material characterization using a Non-Destructive Ultrasound Testing system (NDT).
   a. To measure the longitudinal wave velocity (V_L) and transverse wave velocity (V_T) travelling in metal test specimens.
   b. To calculate mechanical properties of metal test specimens such as the Modulus of Elasticity (E), Shear Modulus (G), and Poisson's Ratio (ν).
2. To learn how to perform Tensile Tests using a materials testing system equipped with a video extensometer.
   a. To measure properties of metal test specimens such as the Modulus of Elasticity (Young's Modulus), Yield Strength, Ultimate Tensile Strength, and Strain at Fracture.
   b. To retrieve data from the testing system and format results.
3. Compare NDT measured E values versus the Tensile Testing results.
4. Compare Tensile Test measured values versus FEA simulation results at comparable conditions.

Materials Tested: Tensile specimens were made from 6061-T6511 aluminum.

Equipment:

- Non-Destructive Ultrasound Testing system (NDT)
  - JSR Ultrasonics Pulser/Receiver DPR300
  - Keysight InfiniiVision Oscilloscope DSOX3014G
  - EVIDENT Ultrasound transducers
    - 10 MHz longitudinal wave contact transducer A11S-RB (BLACK)
    - 5 MHz transverse wave contact transducer V155-RB (GREEN)
- Instron 5584 Materials Testing System with an AVE 2 video extensometer

Safety practices:

- NDT
  - Standard GCC laboratory procedures, including:
    - Long pants
    - Shirt with sleeves
    - Sturdy, clothes-toed shoes
- Tensile Testing
  - Standard GCC laboratory procedures as noted above
  - Safety glasses
  - Operational caution when the machine is in use

Results from NDT Spreadsheet and Tensile Test Software:

Table 1. *Non-destructive testing specimen data.*

Specimen #	Location A			Location B			Location C		
	Thickness d (in)	Time Difference t_L (μs)	Time Difference t_T (μs)	Thickness d (in)	Time Difference t_L (μs)	Time Difference t_T (μs)	Thickness d (in)	Time Difference t_L (μs)	Time Difference t_T (μs)
1	0.117	0.908	1.850	0.118	0.904	1.840	0.117	0.908	1.850
2	0.118	0.918	1.860	0.118	0.906	1.864	0.118	0.912	1.854
3	0.118	0.916	1.866	0.119	0.916	1.866	0.118	0.916	1.876

Material	Specimen #	Location A					Location B					Location C					Location Average	
		Thickness d (in)	Time Difference t_L (μs)	V_L (in/s)	Time Difference t_T (μs)	V_T (in/s)	Thickness d (in)	Time Difference t_L (μs)	V_L (in/s)	Time Difference t_T (μs)	V_T (in/s)	Thickness d (in)	Time Difference t_L (μs)	V_L (in/s)	Time Difference t_T (μs)	V_T (in/s)	V_L (in/s)	V_T (in/s)
6061 Aluminum	1	0.117	0.908	2.58E+05	1.850	1.26E+05	0.118	0.904	2.61E+05	1.840	1.28E+05	0.117	0.908	2.58E+05	1.850	1.26E+05	2.59E+05	1.27E+05
	2	0.118	0.918	2.57E+05	1.860	1.27E+05	0.118	0.906	2.60E+05	1.864	1.27E+05	0.118	0.912	2.59E+05	1.854	1.27E+05	2.59E+05	1.27E+05
	3	0.118	0.916	2.58E+05	1.866	1.26E+05	0.119	0.916	2.60E+05	1.866	1.28E+05	0.118	0.916	2.58E+05	1.876	1.26E+05	2.58E+05	1.27E+05

	Tensile Test Young's Modulus (ksi)	***NDT*** Modulus of Elasticity E (ksi)	Shear Modulus G (ksi)	Poisson's Ratio
1	9640	10,900	4080	0.341
2	13600	10,900	4070	0.342
3	11300	10,900	4050	0.342
Average	11,500	10,900	4070	0.342
Published	10,000	10,000	3,770	0.330
% Diff	15%	9%	8%	4%

Published Values

Test Material	*Density ρ (lb/in^3) (MASS)*	*Modulus of Elasticity E (ksi)*	*Shear Modulus G (ksi)*	*Poisson's Ratio*
1018 Steel	*0.2840*	*29,000*	*11,600*	*0.290*
6061 Aluminum	*0.0975*	*10,000*	*3,770*	*0.330*

Figure 1. *Non-destructive testing measurements, calculations, and published values for 6061 aluminum.*

Table 2. *Material data from tensile testing.*

	Maximum Load [lbf]	Automatic Young's Modulus [ksi]	Tensile stress at Tensile strength [ksi]	Tensile strain (Axial Strain) at Tensile strength [in/in]	Tensile stress at Yield (Offset 0.2 %) [ksi]
1	2660	9640	46	0.106	41
2	2680	13600	46	0.107	40
3	2690	11300	45	0.069	34

Table 3. *Initial dimensions of tensile test specimens.*

	Width [in]	Thickness [in]	Operator
1	0.498	0.116	IJW_11_6_2024_test1
2	0.499	0.117	LM_11_6_24_test2
3	0.498	0.119	CS_11_6_24_test3

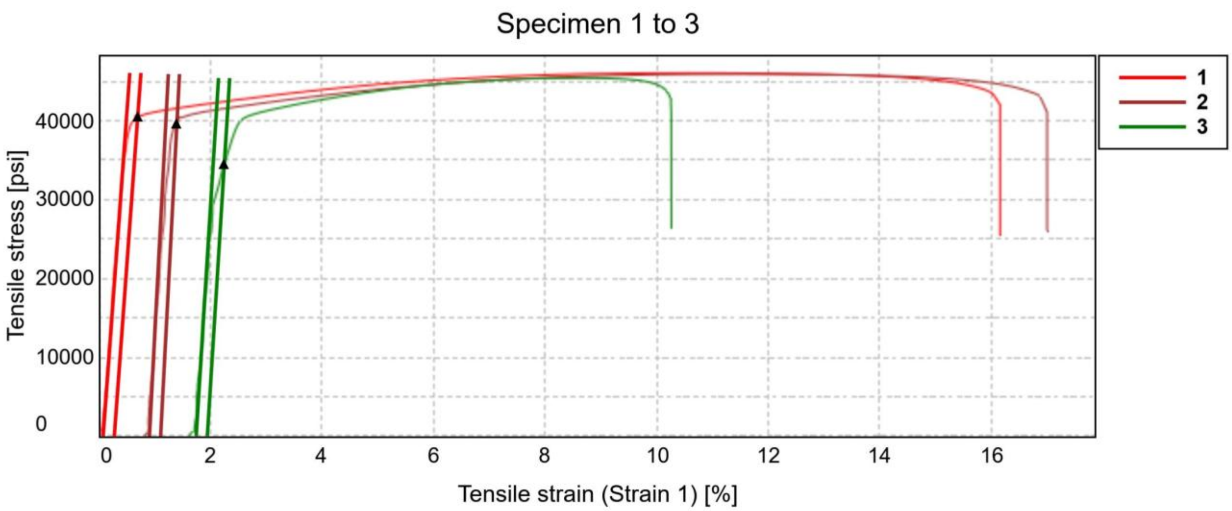

Figure 2. *Raw stress strain curves recorded by the Instron machine.*

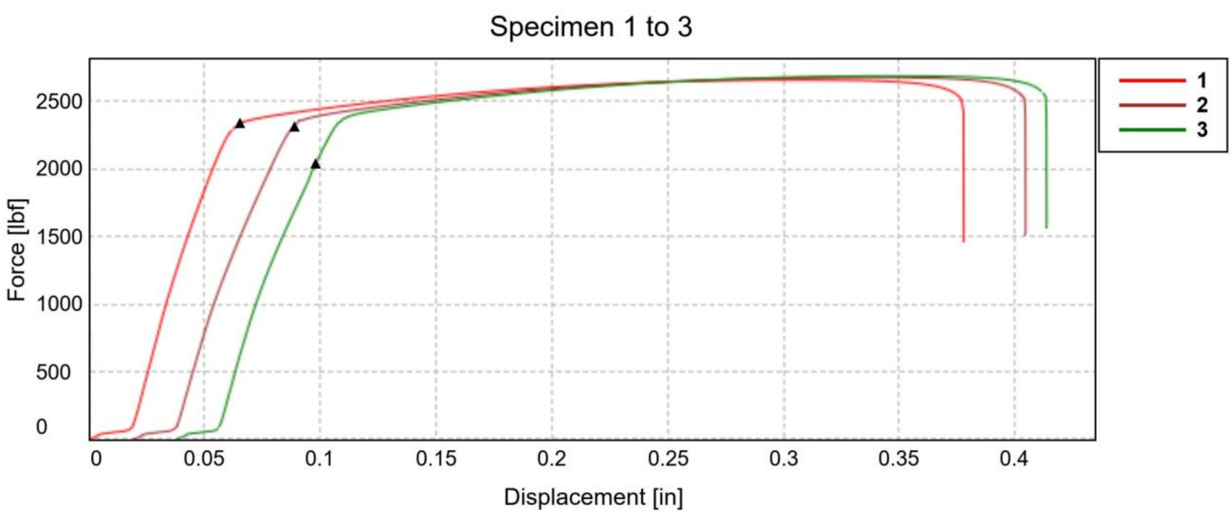

Figure 3. *Stress strain curves with lines of best fit.*

Discussion of Results:

1. Use the Lab_4_Tensile_Testing – Template.xlsx Excel spreadsheet to record your data and calculate values. Your measured **Tensile Test** Young's Modulus (Modulus of Elasticity) and **NDT** calculated values may have differed from the published values. Please discuss your findings. Make sure that you include:

   a. Which testing method (NDT or Tensile Testing) was closer to the published values?

   b. How did each testing method (NDT or Tensile Testing) differ from the published values?

   The values from NDT are closer to published values, with only 8% deviation compared to tensile testing which deviated from published values by 15%.

2. Based on the data collected in the spreadsheet for question 1, what can you conclude about the difference between longitudinal and transverse waves?

   The speed of longitudinal waves is double the speed of transverse waves.

3. Research Question: Please give one other application in which NDT can be used?

   NDT can be used on structures, such as buildings or bridges, that must be monitored for structural integrity but cannot be damaged in any way. NDT would reveal defects, voids, and deterioration in the materials used in these structures.

4. Compare your test results to published handbook data for the specimens that you tested. You can find PDF files containing handbook data for 1018 steel and 6061-T6 aluminum within the */Lab Workbooks and Lectures/Lab 4 Tensile Testing* folder in the course folder. These filenames are *1018_Steel_Properties.pdf* and *6061-T6_Aluminum_Properties.pdf*.

Table 4. *Comparison of published and experimental values.*

Property	Published (handbook) value	Experimental values
Modulus of Elasticity E (ksi)	10,000	9,630; 13,600; 11,300
Yield Strength (psi)	40,000	40,500; 39,600; 34,000
Ultimate Strength (psi)	45,000	46,000; 46,000; 45,500
Strain (elongation) at fracture (%)	17%	16%; 16%; 8.4%

5. Your measured strain values may not have agreed with all the published (handbook) data values. Discuss reasons why the values may be different?

   When testing the third specimen during the tensile test we received an error message during the test, reporting that the strain values were faulty. We concluded that during the experiment the Instron machine had trouble reading the marks mid-test. This led to a slight discrepancy in the strain readings for the raw data. Also, for the third specimen had a lower strain % (roughly 8%) compared to the ~16% strain of samples one and two. We concluded that this discrepancy of strain % could be the result of instrument error or differences between the structural makeup between the first two samples, and the third one.

6. Using the appropriate table template (either Aluminum or Steel) provided in ***Table 5 of Lab_4_Tensile_Testing.docx***, insert below the comparison between your measured strain values and the simulated strain values (***from Table 4 of Lab_4_Tensile_Testing.docx***) for the material that was tested. *Note, you will only be using the data for one of your three test samples.*

Table 5. *Comparison of simulated and experimental strain at three loading values.*

Aluminum			
Load (lbf)	Strain (simulation) in/in	Strain (experiment) in/in	Diff (%)
660	0.001056	0.00177	68%
1000	0.001598	0.00233	46%
1330	0.002126	0.00289	36%

7. Your measured strain values may not have agreed with the simulated strain values. If they differ, some engineers may assume the measured value must be "correct", and the simulation must be flawed. *"We measured it! It's that actual value. The simulation must be wrong."* Why is this not necessarily the case?

   In reality, no set of recorded data will perfectly adhere to the standardized properties for stress or strain. A more accurate assessment of favorable data is to assess if the measured values fall within the specified parameters for a particular function or requirement.

   Our discrepancy is quite significant. We have checked several sources of error. The sample did not slide, the calculations have been triple checked, and we have compared all three trials. Ultimately, the parts that we tested were real physical parts with their own width and thickness that may be different from the simulation. There may have been some unfound errors in the experiment, but the simulation may not be a particularly good model for the samples that we had.

8. Opinion Question: Which testing method (Tensile Test or NDT) did you prefer and why?

   The team prefers ultrasonic NDT. It was a versatile, portable, non-intrusive, and cost-effective method of obtaining many material properties of the aluminum samples. It was also about twice as accurate to simulation data as our tensile tests, though the tensile tests may have shown more practical material results under load. While there may be less calibration on a tensile tester and potentially less overall variation, ultrasonic NDT was a preferable testing experience in a lab environment.

Summary – what you learned:

The team was able to measure the velocity of longitudinal (V_L) and transverse (V_T) waves from ultrasonic transducers using an oscilloscope, which displays the timing of returning waves. Analyzing this data gave material characteristics such as the Modulus of Elasticity (E), Shear Modulus (G), and Poisson's Ratio (ν) calculated in figure 1.

Analyzing the material properties of the aluminum samples via the Instron 5584 Materials Testing System provided a stable process of analyzing samples within a controlled environment. The procedural process of inserting the sample, calibrating the machine and measuring the stress and strain values via measuring stress and strain by means of the video extensometer provides a high degree of accuracy and automation in analyzing the material properties of Aluminum. This method is particularly

The results of ultrasonic NDT are comparable to tensile testing, but had less variation and deviation from accepted values.