Marmara University
Engineering Faculty

Electrical and Electronics Engineering

TRAINING REPORT

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☐ EE300

■ EE400

Electrical and Electronics
Engineering Department

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Student Name : Ali Mertcan KARAMAN

Student ID : 150716074

Department/semester : Electrical & Electronics Engineering / Seventh Semester

The company name : Marmara University Faculty of Engineering

Company Department	**Work Done**	**DATE**		**Department Head**
		Start	**End**	
Electrical and Electronics Engineering	Literature Review of Nondestructive Ultrasonic Testing and Imaging	04.07.20	10.07.20	Dr. Alper Şişman

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Asst. Prof. Alper Şişman

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DESCRIPTION OF THE INSTITUTION

Marmara University

Electrical and Electronics Engineering Department

Contact Address

Marmara Üniversitesi Göztepe Yerleşkesi 34722 Kadıköy – İstanbul / 0216 414 0545

History

Marmara University is one of the oldest educational institutions in Turkey. Established on 16 January, 1883 under the name *Hamidiye Ticaret Mekteb-i Âlisi*, and affiliated with the Commercial, Agriculture, Forestry and Mining industry, Marmara University began its life in a house behind the Istanbul High School for Girls in Cağoğlu. The first graduates (13 people) matriculated in 1887. On 21 September, 1889 the school was affiliated with the Education Ministry; in 1893 the school was closed, with the idea that it would be reformed and reopened in the near future. On 15 October, 1897 the school, still affiliated with the Education Ministry, was reopened; from this date on the university has provided education.

The institution became known as the Istanbul Economic and Commercial Sciences Academy in 1959; in 1982, with regulations that were carried out, the institute became officially known as Marmara University and took its place among Turkish Institutes of Higher Education.

In the 1982 - 1983 academic year, education began at Marmara University, which consisted of 9 faculties, 1 school, 1 institute. Today, the number of faculties is 16, the number of schools is 9, and there are 11 institutes. The number of currently operating associate and degree courses at the university is 199.

Close to 3,000 academic staff and more than 70,000 students are making contributions to Marmara University's academic activities today, making it one of the most important institutes of higher education in Turkey. In the academic faculties, including the Economics Faculty, Business Faculty,Faculty of Fine Arts, Political Sciences Faculty, Engineering Faculty, Medicine Faculty, Dentistry Faculty and Theology Faculty, education is provided in five different languages, Turkish, English, French, German and Arabic; these qualities make Marmara the only multilingual university in Turkey.

Marmara University has rapidly expanded, providing education-training and research activities from 1982 on, in the faculties, institutes, schools and vocational schools and research-implementation centers. In addition to education and training, the University has developed in social services, giving great importance to publishing and consultancy projects; in this century when the industrial society has been replaced by the information society, in keeping with the demands of society, the university has made contributions to the development of man power and technology as needed by the country; the education approach of providing solutions to economic, political, cultural and similar problems of the university has been represented at home and abroad.

Mission

By providing the required information and skills to our engineering students in high standards, they will reach the level of being competitive in fields of research and application in Turkey and also in the world.

Vision

In the field of electrical and electronics engineering, our vision is to comprehend, produce, improve and disseminate all the necessary knowledge, skills and technologies for Turkey and the humanity.

Aim

To educate electrical and electronics engineers and candidates of scientists who

- have a solid basis of knowledge and professional education in the field of electrical and electronics engineering
- can utilize the necessary techniques to the latest engineering applications and use the modern communication tools and hardware effectively
- are able to perform researches and propose projects in applied sciences in nationally and internationally

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- are able to follow, adopt, implement and contribute to the rapid developments in the studies they are working by comprehending the importance of lifelong learning
- have the ability to think creatively and analytically
- are able to analyze and design in an advanced level
- can take responsibilities individually and are prone to team work
- are capable to perform multi-disciplinary studies
- are virtuous and hard-working, and can utilize the professional know-how for the benefits of the mankind and the society
- can take heed of the universal values and are conscious to the environment
- follow professional ethics and possess sense of responsibility
- can set effective oral and written communications
- possess qualities of leadership

To make the students become conscious about the complementary elements of engineering are the social life, the business life, the industry and the human being; To carry out the research activities that contribute to technological developments.

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TRAINING

In this training, I am going to give some information about non-destructive imaging, its definition, what kind of situations it is used, its application and I am going to explain a few articles that are published, I am going to tell what they accomplished show some details about it to see what sort of applications can be done or has been already done so far.

Time of Flight Diffraction Ultrasonics

Time of flight diffraction (TOFD) method of ultrasonic testing is a sensitive and accurate method for the nondestructive testing of weld for defects.

About the **ultrasonic testing (UT**), it is a family of nondestructive testing techniques based on the propagation of ultrasonic waves in the object or material tested. In most common ultrasonic testing applications, very short ultrasonic pulse-waves with center frequencies ranging from 0.1-15 MHz, and occasionally up to 50 MHz, are transmitted into materials to detect internal flaws or to characterize materials.

Ultrasonic testing is one of the subtopic of what we call nondestructive testing in general. Basically, **nondestructive testing** (**NDT**) is a wide group of analysis techniques used in science and technology industry to evaluate the properties of a material, component or system without causing damage.

Coming back to the time of flight diffraction method, as its name suggests, its principle is to measure the time of flight of an ultrasonic pulse to determine the position and size of a reflector instead of the amplitude because measuring the amplitude of reflected signal is a relatively unreliable method of sizing defects since the amplitude strongly depends on the orientation of the crack.

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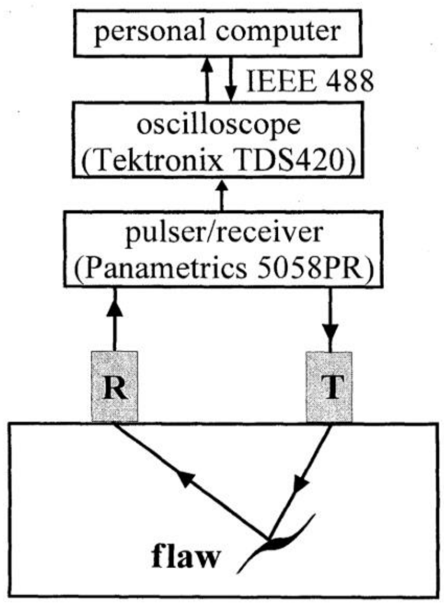
ARTICLE: TIME OF FLIGHT DIFFRACTION IMAGING FOR DOUBLE-PROBE TECHNIQUE

With this technique nonhorizontal flaws can be detected and the block diagram of the experimental system for detecting the nonhorizontal flaw is like this:



T is the transmitter and R is the receiver. The offset between the probes is 10 mm. A pair of 5 MHz and 3 mm diameter transducers are used to transmit and receive data.

In this article, the results of double-probe B-scan image are compared with the pulse-echo B-scan image. The usage of double-probe reflection imaging technique for detecting the non-horizorital flaw can be represented as:

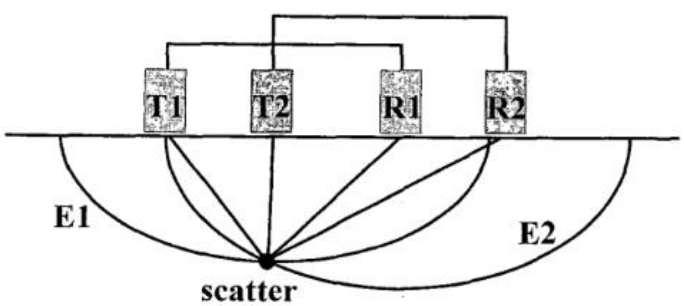


Fig. 1. Double-probe reflection imaging technique for detecting the nonhorizontal flaw by intersection of ellipsoids. Transmitter 1 (T1) and receiver 1 (R1) are the double-probe pair. T2 and R2 are the same pair but moved forward. E1 and E2 are the ellipsoids using T1, R1 and T2, R2 as the focuses, respectively.

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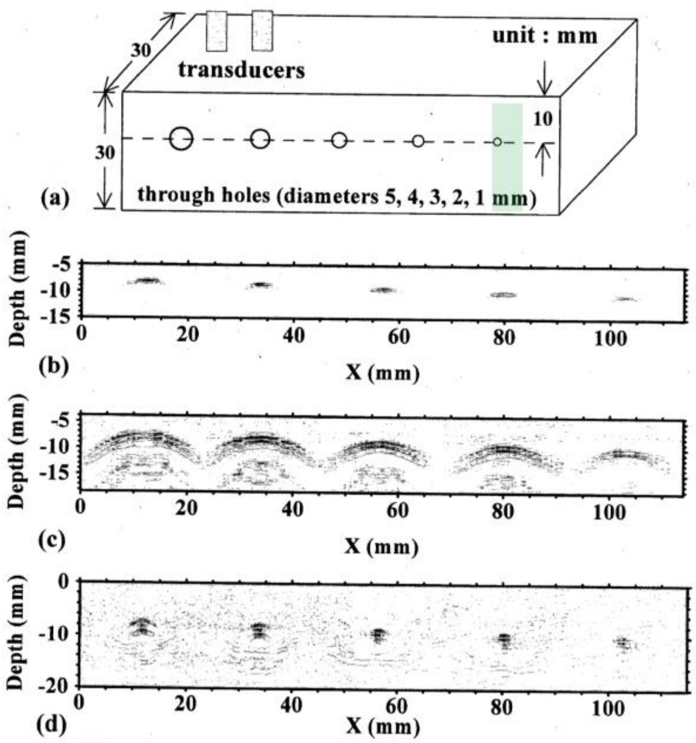
The offset between the probes is 10 mm, and the longitudinal wave velocity of the object is 6356 m/sec. The echo diffracted from the point scatter is simulated with one cycle 5 MHz sine wave.

First of all, A specimen with 5 through-holes and their diameters are 5, 4, 3, 2, and 1 mm, respectively, and with depths of the center of the holes 10 mm was scanned with both pulse-echo and double-probe B-scan technique, the images are as shown in the figure:



The 1-5 mm diameters through holes specimen was fabricated and scanned, and the double probe scan image was processed using the double-probe reflection imaging technique. (a) Configuration of the specimen, (b) pulse-echo B-scan image, (c) double-probe B-scan image, (d) processed double-probe B-scan image.

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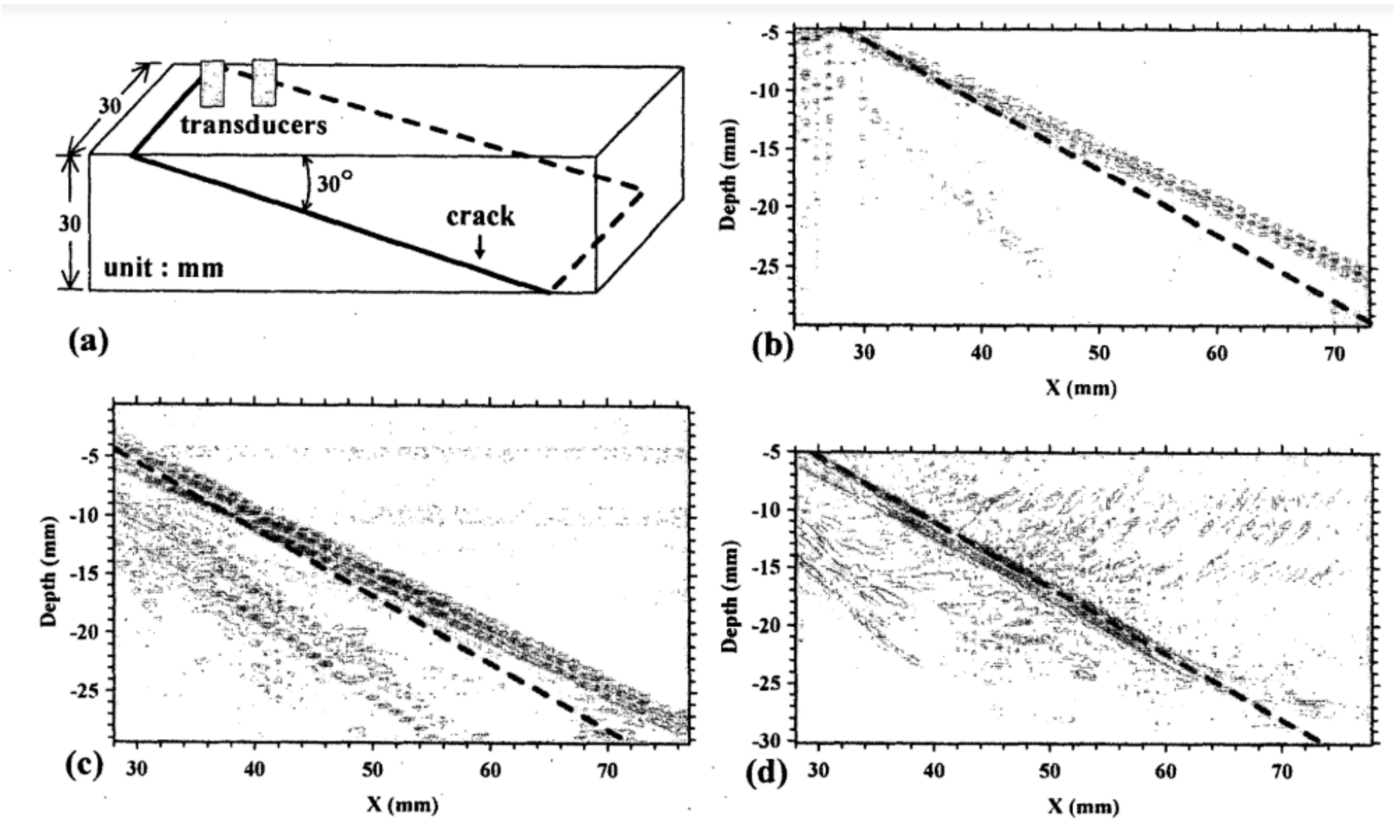
We can see that for point flaws, pulse-echo B-scan method is more successful but after processing double-probe B-scan method can be still used for this purpose.

The double-probe reflection technique usually is used to detect the non-horizontal flaws in the ultrasonic NDT Because there is an offset between the transmitter and receiver, the position and size of the flaw cannot be directly read from the image. Therefore, a digital signal processing (DSP) imaging method is proposed to process the ultrasonic image obtained by double-probe reflection technique.

The experimental results for non-horizontal flaws:

30° Tilted Crack:



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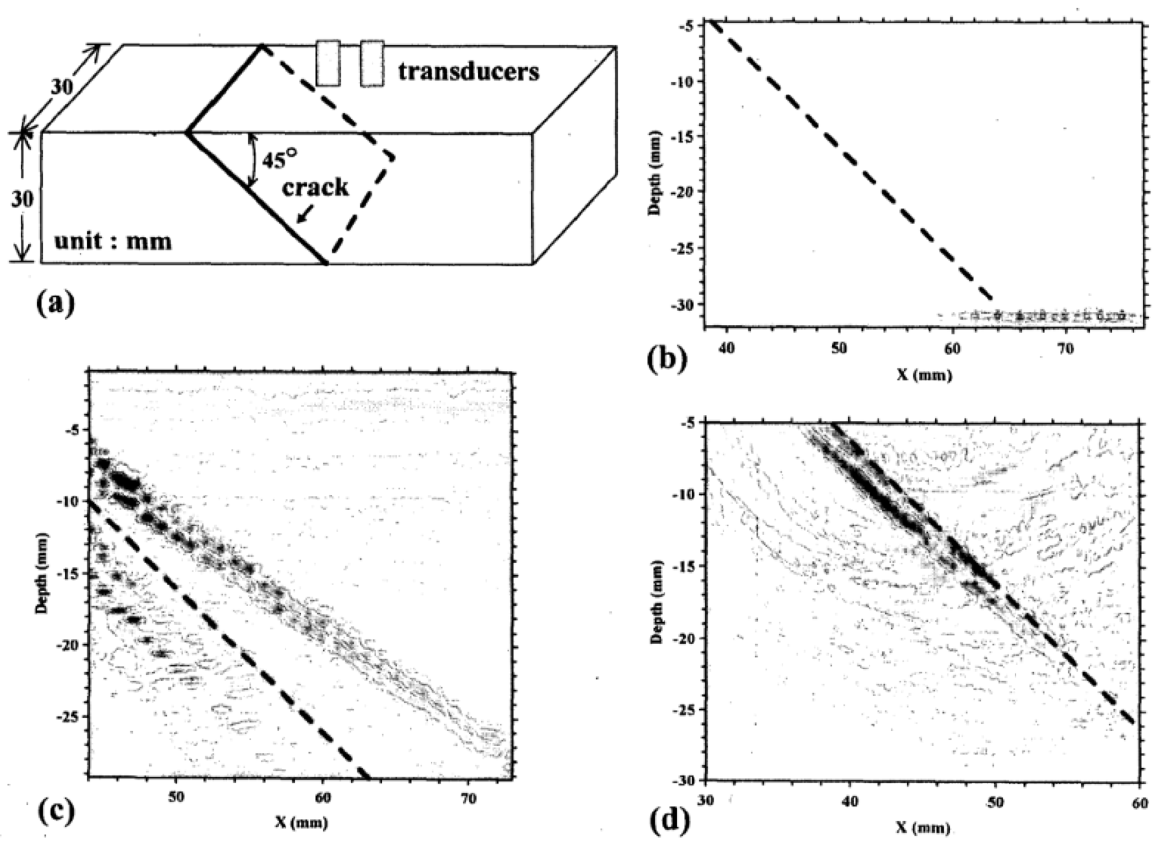
The dashed lines are the true positions of crack. (a) Configuration of the specimen, (b) pulse-echo B-scan image, (c) double-probe B-scan image, (d) processed double-probe B-scan image.

Based on the experimental results, the steep flaw cannot be detected by the pulse echo technique but can be detected by the double-probe method, and the double-probe B-scan image of 30° tilted crack is clearer than the pulse echo B-scan image. However, the flaw image departs from its true position greatly. After processing, the steep flaw image can be moved to its true position.

45° Tilted Crack:



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The dashed lines are the true positions of crack. (a) Configuration of the specimen, (b) pulse-echo B-scan image, (c) double-probe B-scan image, (d) processed double-probe B-scan image.

When the flaws are not greater than the probe largely, the sizes of the flaws are difficult to be discriminated in both pulse echo and double-probe B-scan images. In the processed double-probe B-scan image, the size of the flaws can be estimated successfully, and the images of the flaws are close to their true shape.

When the degree of the crack is around 45 or steeper than that, pulse-echo B-scan method can not detect it but with double-probe B-scan image, it can be detected well according to this experiment.

Phased Array Ultrasonics

Phased array ultrasonics (**PA**) is an advanced method of ultrasonic testing that has applications in medical imaging industrial nondistructive testing. Common applications are to noninvasively examine the heart or to find flaws in manufactured materials such as welds.

A phased array sensor can be controlled easily electronically, and be arranged to focus some specific area with computer-calculated timing without actually move the probes.

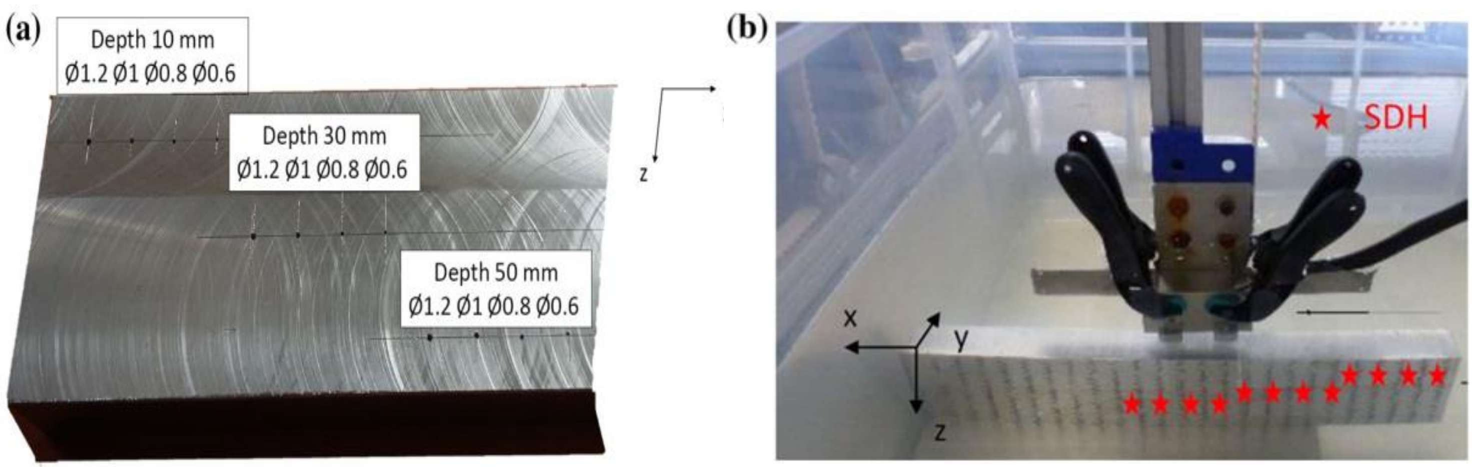
A phased array probe consists multiple small ultrasonic transducers each of which can be pulsed independently. By controlling the timing of each of them, we can arrange a pattern for the wave that propagates.

ARTICLE: TOWARDS DEFECT MONITORING FOR METALLIC ADDITIVE MANUFACTURING COMPONENTS USING PHASED ARRAY ULTRASONIC TESTING

In this article, A 10 MHz probe which has 128 smaller elements inside with an inter element space of 0.3 mm so that only 80 of the elements are activated is used to detect defects.

The frequency of the probe gives a wavelength of 0.6 mm because the experiments are done using aluminum alloys. So the detectable dimension of the flaw size is minimum 0.6 mm. They obtained nice results between the flaw sizes from 0.6 to 1 mm.

One part of the article is about linking the size of calibrated defects to the results of the phased array ultrasonic testing scans. The calibration is performed on an aluminum alloy 5356 WAAM-manufactured multi-layered block, machined to the dimensions of 140 mm, 60 mm and 20 mm. Three sets of four holes, with diameters ranging from Ø0.6 mm to Ø1.2 mm, were drilled at three different depths, namely 10 mm, 30 mm and 50 mm from the top surface, as shown in the figures:



a. Aluminum alloy block designed for the UT calibration. b. Experimental setup for calibration inspections

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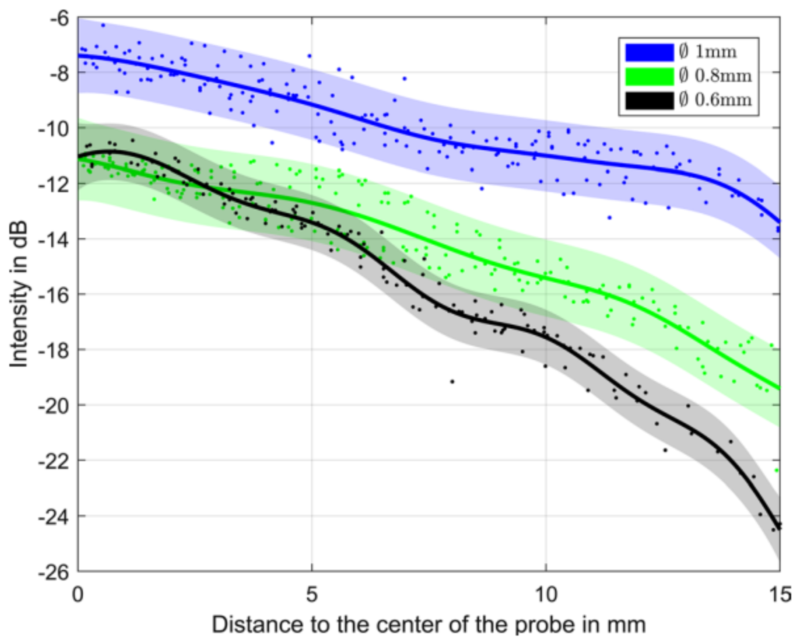
As the calibration block is inspected perpendicularly to the hole direction, side-drilled holes (SDH) are observed. Preliminary inspections have shown that the defect intensity or number of reflected echoes, depends on its depth and lateral position in regard with the probe, its diameter and its shape but also the probe characteristics and the imaging methods. Consequently, in the present paper, the SDH intensity is linked to its diameter and distance to the probe centre. To the authors best knowledge, no analytical model computing the flaw intensity depending on such parameters has been developed yet. That is why, as first approach, a Gaussian process has been chosen to evaluate margins of error depending on the experimental data.

Four different parallel scans have been performed to estimate the method repeatability. For each scan, a data set is acquired every 0.5 mm over a range of 32 mm for a total of 64 data sets per scan. An ultrasonic image is computed for each data set, and the intensity and distance to the center of the probe are computed for each detected flaw.



In the figure, the plain lines show the mean of the posterior Gaussian process while the colored region is a 90% confidence interval which depends on the variability of the samples and the number of samples per region

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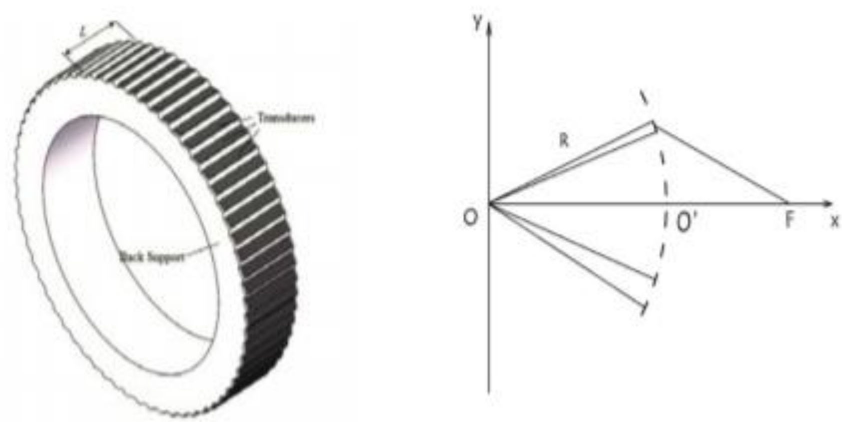
The amplitude is nearly constant around the center of the probe, as it corresponds to an area where all the probe elements are contributing to the defect detection. Then, the amplitude decreases as the distance to the probe center rises. The intensity also rises with the size of the flaws, possibly allowing the determination of the flaw size from the PAUT scans.

ARTICLE: DEFECT IDENTIFICATION BY AN ULTRASONIC CYLINDRICAL PHASED ARRAY

In this article the onjective is to classify the shapes and the sizes of the defects by using ultrasonic cylindrical phased array.



(a) (b)

This is the 3D model of a cylindrical phased array which is in figure a) and Physical description of a cylindrical phased array is shown in b)

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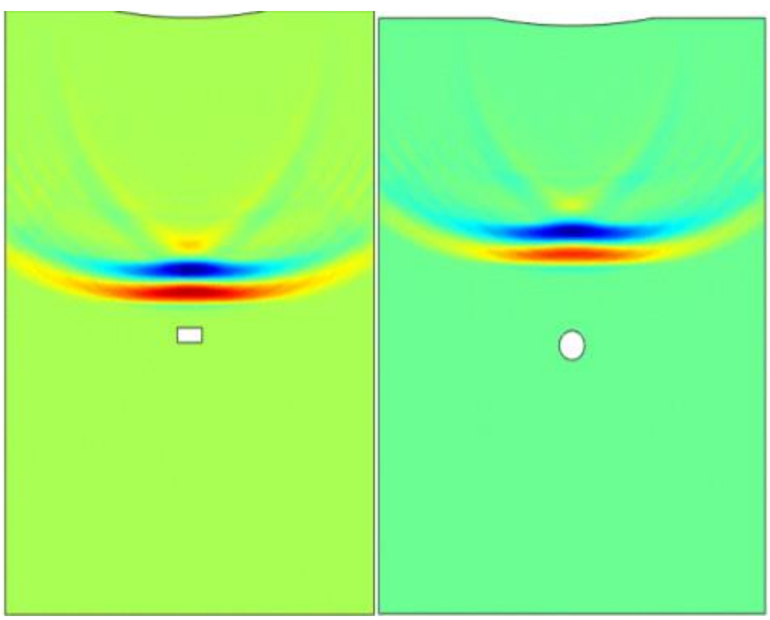
In this paper, they used the 64-element rectangular phased transducers, and the 64 elementary rectangular transducers are equally distributed around the dotted line as shown in Fig. (b) above.

The configuration of the array in each simulation process is that only 8 rectangular transducers of the 64 elementary cylindrical phased transducers are chosen to generate the ultrasonic waves. The coordinate position in the middle is considered as the defect point. And the 8 transducers are modulated with different phase to focus the ultrasonic waves in the defect point.

The distance of the defect point to the array elements is 20 mm and the center frequency of the ultrasonic wave is 500 kHz. Since the defect point can be considered as quite far in this frequency, the waves reaching to the point is treated as plane waves.



The simulation of the wave propagation in square and spherical defects are done and as we can see, the waves can be treated as plane waves when it is close to the defect point.

In this simulation, the delayed time for the four transducers above the x axes is set as 0s, 1.14e-7s, 1.957e-7s and 2.298e-7s, while that of the other four transducers is set symmetrically to the four transducers above the x axes.

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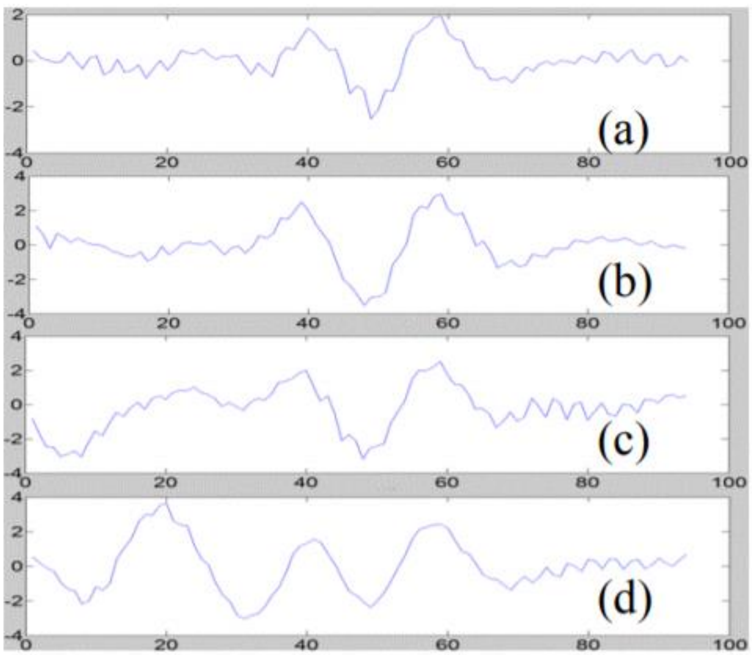
The experiment and the classification is done for 4 different defects: the first one is a sphere defect of 2mm diameter, the second one is 2mm*1mm square defect, the third one is 2mm*4mm square defect and the last one is 2mm*8mm square defect.

Here is the signals that echoed from these four defect points:



(a) sphere defect of 2mm diameter; (b) 2mm*1mm square defect; (c) 2mm*4mm square defect; (d) 2mm*8mm square defect.

There are slight differences between each of them and in order to classify them, they used a typical deep built neural network.

The results of the experiment show that each of 4 different defects can be classified correctly without an error. At the end, this paper can be of a nice help for defect detection and identification.

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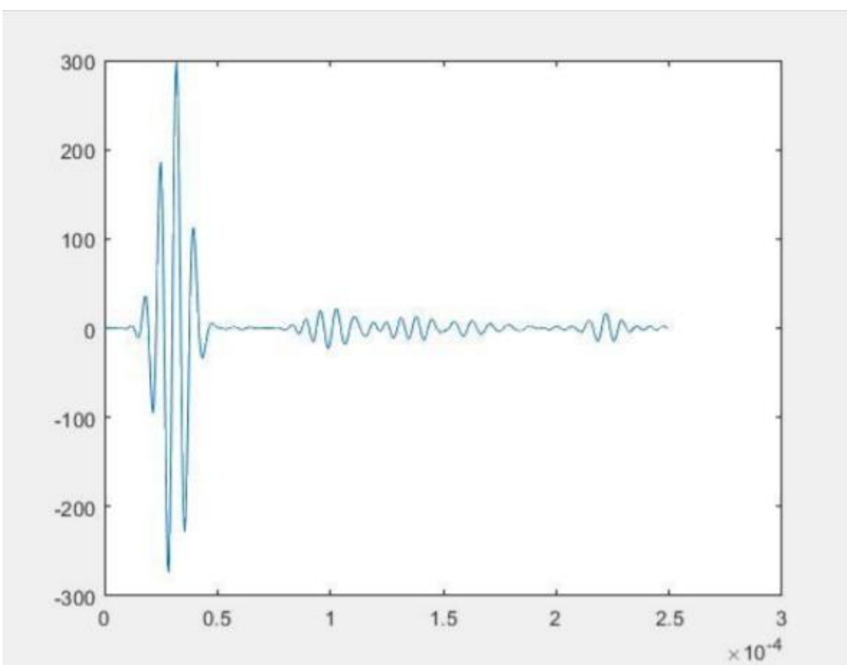
ARTICLE: ULTRASONIC PHASED ARRAY IMAGING METHOD BASED ON MULTI - SCATTERING MODEL

In this paper, they introduced a method to realize super resolution imaging in multi-band phased array. In this method, the damage is detected by multiple phased arrays and they used a specific algorithm for received signals and process them to obtain super-resolution imaging.

In this experiment, they chose to use a 700x700mm aluminum plate with a thickness of 1mm for testing. A hole with a radius of 2 mm is placed on the plate to simulate the damage. At a distance of 200 mm from the damage, a piezoelectric piece is arranged to excite the excitation signal. Then, a scattering paper is attached to the back surface of the piezoelectric sheet, 9 points are marked on the scattering paper, and the signals of the 9 points are received by the Scanning Laser Doppler Vibrometer (SLDV).

The center frequency of the excitation frequency is this time 150 kHz and the number of sampling points is 2048.

The received time domain signal of their experiment looks like this:



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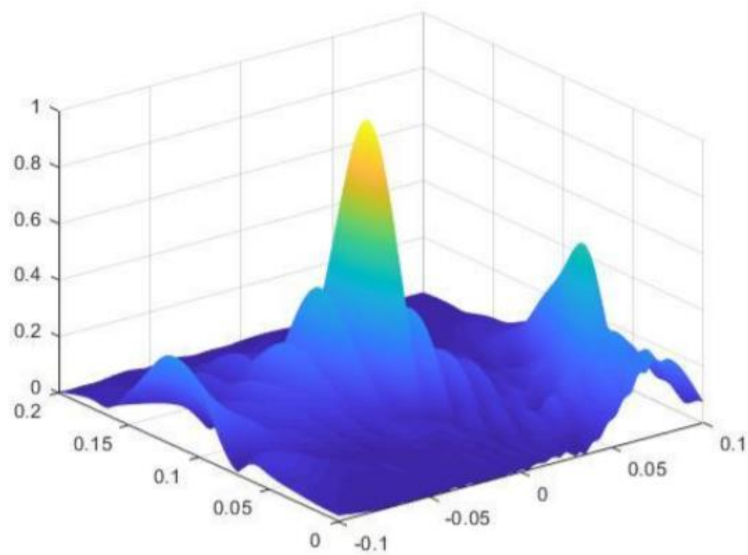
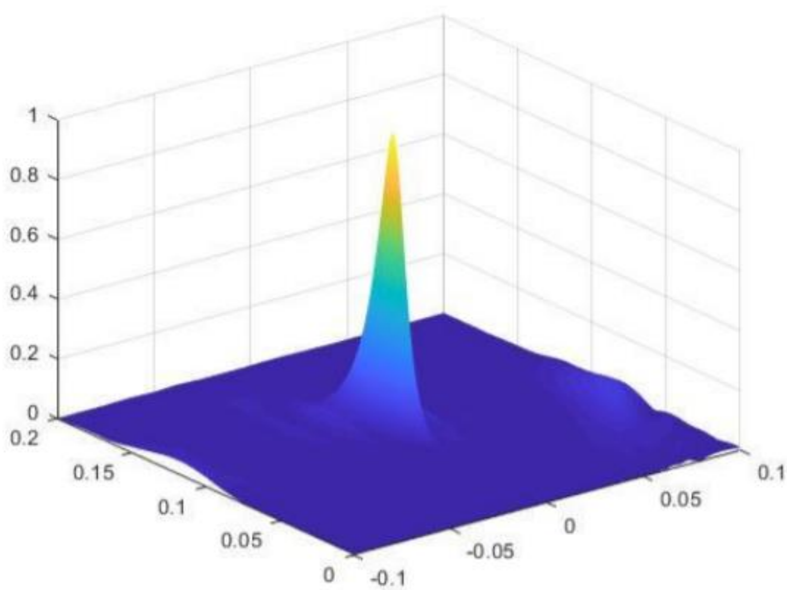
The signal is first processed using a conventional frequency domain delay overlay algorithm. Its result is:



After that, the signal is then processed using a multiple signal classification algorithm.



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From the comparison of the two figures, we can see that the image formed by the frequency domain delay superposition algorithm has peaks in multiple places. Although the location of the damage can be determined by finding the maximum peak, other false peaks have a certain impact on the damage location, and also affect the resolution of the imaging. The image created by the multiple signal classification algorithm only produces a peak at the lesion, which helps us to quickly locate the damage and improve the resolution of the image.

To do that, they performed singular value decomposition on the multi-response matrix. The number of significant singular values obtained after decomposition reflects the number of damages. Based on the singular value, the singular vector is divided into a signal space and a noise space. Using singular values and noise space to develop imaging metrics, super-resolution imaging can be achieved by randomness of noise space, as they explained the process.

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CONCLUSION

In this training, the definition of nondestructive testing and its subtopics ultrasonic testing and time of flight diffraction method is explained. There are several application areas related to this topic such as medical imaging and defect detection for industrial purposes.

I focused on defect detection and made researches about it, read and explained a few of the articles that are related to nondestructive ultrasonic testing and imaging.

There are a number of different ways for detecting a defect inside a material and I saw that most of them during this training, also these techniques are not only use for defect detection but also for other needs.

In the first article that I explained, they used double probe for detecting the flaws that are nonhorizontal and also they used that technique to detect holes of which its sizes are between 1 mm and 5 mm. The results were quite good.

After that, I started to look for the articles in which people used phased array sensors and check how they used it because this topic is similar to our graduation project. So in the second article, a 10 MHz probe which has 128 smaller elements are used and they made the experiments on the flaws of which their size change 0.6 to 1 mm. The results show that as the size of the flow increases the intensity also increases and the amplitude is nearly constant around the center of the probe, as it corresponds to an area where all the probe elements are contributing to the defect detection. Then, the amplitude decreases as the distance to the probe center rises.

The next article was about classifying flaws with respect to their shapes and sizes. The distance of the defect point to the array elements was 20 mm and the center frequency of the ultrasonic wave was 500 kHz and they made experiments on 4 different defects: the first one is a sphere defect of 2mm diameter, the second one is 2mm*1mm square defect, the third one is 2mm*4mm square defect and the last one is 2mm*8mm square defect. With a deep neural network algorithm, they were able to distinguish the flaws.

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Finally, a method based on multi-scattering model is proposed to increase the resolution of the constructed image of the flaw. A hole with a radius of 2 mm is placed on the plate to simulate the damage at a distance of 200 mm from the phased array. It is relatively further from the other experiments and the reason is that they use relatively lower central frequency which is 150 kHz. But at the end they were able to locate the flaw with an increased resolution of the image.

In conclusion, this training became very beneficial for me because I saw many different applications and new methods that are used in nondefective testing and the information I get during the training and the articles gave me some nice ideas about the projects I may be working on in the future.

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REFERENCES

[1] Wikipedia, URL: en.wikipedia.org/wiki/Time-of-flight_diffraction_ultrasonics

[2] Young-Fo Chang and Cheng-I Hsieh, Time of Flight Diffraction Imaging for Double-Probe Technique, IEEE Transactions On Ultrasonics, Ferroelectrics, And Frequency Control, Vol. 49, No. 6, June 2002

[3] A. Chabot, N. Laroche, E. Carcreff, M. Rauch, J.-Y. Hascoët, Towards defect monitoring for metallic additive manufacturing components using phased array ultrasonic testing, Springer Science+Business Media, 30 October 2019

[4] Shi-wen CHEN, Bi-xing ZHANG, Defect Identification By An Ultrasonic Cylindrical Phased Array, 2016 Symposium on Piezoelectricity, Acoustic waves, and Device Applications, October

[5] Jian-zu GU, Bin ZHANG, Rui SU, Lei QIAN, RongCHEN, Ultrasonic Phased Array Imaging Method Based On Multi - Scattering Model, Faculty of Civil Engineering and Mechanics, Jiangsu University, National Center for International Research on Structural Health Management of Critical Components, China, November 2019

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İŞ YERİ
KURUMUN ADI : **BÖLÜM :**
STAJYER ÖĞRENCİNİN DEĞERLENDİRİLMESİ ***(İş yeri yetkilileri tarafından doldurulacak)*** *1: Zayıf.........5: Mükemmel şeklinde notlandırınız.*
İŞ YERİNE UYUM : ÇALIŞKANLIK : YETERLİLİK : KARAR VERME : İŞ DİSİPLİNİ : TAKIM ÇALIŞMASINA YATKINLIK : *DÜŞÜNCE VE ÖNERİLER (VARSA):*   SORUMLUNUN ADI ve SOYADI : ÜNVANI : İMZASI : (Firma Kaşesi/Mührü) Tarih ..../........./..................

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