Attestation

People's Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research
M'hamed Bougara University of Boumerdes
Faculty of Technology
Mechanical Engineering Department

National Conférence Mechanics Maintenance
Boumerdes 2021

CERTIFICATE OF PARTICIPATION

This certificate is proudly presented to

Brihmat C

Has successfully participated at the

National Conference on Mechanics and Maintenance

15 - 16 November 2021, Boumerdes - Algeria

By presenting a communication entitled:

Damage Crack Growth Detection Of Composite Pipeline Using NDT

Co-authors: LECHEB.S, CHELLIL A, Safi .B , KEBIR.H, Mechakra .H, Tablit .B

15/11/2021
Date

Président du Comité d'Organisation
Dr. LECHEB Samir

Président de la Conférence
Dr. CHELLIL Ahmed

Book abstract

Université M'Hamed Bougara Boumerdes

Faculté de Technologie

Département Génie Mécanique

Conférence Nationale sur la Mécanique et Maintenance

15-16 Novembre 2021

Book Abstract

Président d'honneur: Pr. Yahi Mostepha - Recteur
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Président : Dr. Chellil Ahmed

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La conférence de la Mécanique et Maintenance regroupe tous les acteurs du domaine dans un espace en ligne, a pour but principal de renforcer la communication entre la famille de l'enseignement supérieur et les industriels, rapprocher le secteur socio-économique avec les compétences académiques et l'administration publique. Notre objectif est de mettre en place un écosystème national favorable à l'investissement, par la communication entre les secteurs concernés. Aussi nous souhaitons à travers cette conférence, tracer une feuille de route qui pousse l'économie et le développement national vers le progrès.

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La conférence s'adresse initialement aux doctorants, enseignants chercheurs et opérateurs industriels. Des attestations de participation seront délivrés aux communicants. La participation à la conférence se fait par soumission en ligne d'un *Résumé* via l'email suivant : *ConferenceNMM2021@gmail.com*

3. Echéancier :

- Date de diffusion de l'appel : 15/06/2021
- Date limite des soumissions : 31/10/2021
- Notification des réponses : 07/11/2021
- Déroulement de la conférence : 15-16/11/2021

4. Thématiques :

- Construction et Fabrication Mécanique
- Maintenance Industrielle
- Vibration - Maintenance Conditionnelle
- Mécanique de la Rupture - Fatigue - Endommagement
- Contrôle Non Destructif
- Technique de Détection des défaillances
- Matériaux
- Réparation par patch en Composite

- Tribologie
- Fiabilité
- Mécatronique
- Electromécanique
- Génie Industrielle
- Energie Renouvelable

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Damage crack growth detection of composite pipeline using NDT

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Abstract

This study provides an analysis of the lamb wave propagation for defect detection in a composite pipeline. The problem of wave propagation is similar to any other dynamic analysis. However, there are a few things to consider in order to obtain an accurate analysis. We used Abaqus software to simulate our structure to obtain the signal from our cracked and uncracked pipe for comparison between the two. In the case of an axially directed crack, only the attenuation of the magnitude can be measured in the sensor, no difference in phase and arrival time. In the other cases, a difference in amplitude between the signals was noted due to the discontinuity of the material

Keywords: *Ultrasonic, composite, pipeline, damage, FEM*

Article

Damage crack growth detection of composite pipeline using NDT

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Abstract:

This study provides an analysis of the lamb wave propagation for defect detection in a composite pipeline. The problem of wave propagation is similar to any other dynamic analysis. However, there are a few things to consider in order to obtain an accurate analysis. We used Abaqus software to simulate our structure to obtain the signal from our cracked and uncracked pipe for comparison between the two. In the case of an axially directed crack, only the attenuation of the magnitude can be measured in the sensor, no difference in phase and arrival time. In the other cases, a difference in amplitude between the signals was noted due to the discontinuity of the material

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1. Introduction

Degradation of material properties and defects often occur in engineering structures due to fatigue loading. It is therefore necessary to develop non-destructive testing methods to assess the safety of engineering structures. Especially in the aerospace industry, to ensure the safety and durability of engineered structures, there is a growing demand for early crack detection. Linear ultrasonic testing technology has been widely used to detect cracks, holes, corrosion and other defects in materials, but it is only sensitive to severe defects. The ultrasonic waves pass through them [1]. Therefore, linear ultrasonic testing technology may well fail to detect closed cracks [2]. Compared to linear ultrasonic testing technology, Lamb's long-range, high-sensitivity waves propagate over relatively long distances (a few metres in composites), allowing each ultrasonic pulse to inspect the entire field between the transmitter and the receiver. This is in contrast to traditional step-by-step inspection techniques. The proposed technique will therefore rely on the integration of sensors capable of generating and detecting such waves into the interior or surface of the structures to be tested. The system must be able to automatically control the acquisition, storage and processing of data [2]. The presence of a fault will be identified by changes in the system response relative to a reference response recorded before the structure was damaged. Due to the curvature of a tubular structure, the wave properties are more complex than in a plate. Theoretical and numerical analyses of higher harmonic generation were conducted in non-linear waveguides with arbitrary cross-sections, in weakly non-linear cylinders and in plates with large radius pipes. The simulation showed that cumulative second harmonic generation with longitudinal, torsional or bending mode excitation was also observed in pipe structures when these two conditions, phase velocity matching and non-zero power flow, as in plate structures were satisfied. Furthermore, the method of simulating material non-linearity in plate structures can also be applied to pipe counterparts. Experiments concerning material nonlinearities in pipes also confirmed the phenomenon of cumulative second harmonic generation with longitudinal or circumferential wave excitation. [4] In this context, the theory and interpretation of the temporal characteristics of Lamb wave signals are mainly based on linear elasticity, i.e. the extraction of signal characteristics in the frequency band at which the sounding signals are generated. In this sense, the temporal characteristics, e.g. the ToF delay, show to some extent a linear correlation with the alteration of material or structural parameters due to damage. Thus, they are referred to as linear Lamb wave temporal features in the following, and the associated signal processing exercises are referred to as temporal feature processing. In particular, the ToF, one of the simplest but informative linear temporal features, has proven to be effective in locating gross damage (i.e. damage with a characteristic dimension comparable to the sounding wave wavelength) such as open cracks, through holes, and voids [5]

2. Pipelines defects type

Regarding the different types of defects, the Pipeline Operators Forum (POF) [6] has classified the different existing defects into various categories. It should be noted that ultrasonic inspection cannot detect cracks because they are perpendicular to the pipe section. These types of defects are therefore not relevant to our problem. Four families of defects are predominant and are generally used during inspections:

- Delamination
- Corrosion;
- Geometric defects (sinking and ovalization);
- Metal loss (arc cutting, scratching, grinding, spalling).

In the vast majority of cases, these are natural defects, and consequently their characteristics are extremely variable (size, depth, etc.). characteristics are extremely variable (size, depth, shape, residual texture). Figures 1, 2, 3,4,5 below shown the most popular examples of pipeline defects:

Fig.1 External corrosion

Fig.2 manufacturing defect

Fig.3 Sinking

Fig.4 Delamination

Fig.5 Underthickness

Corrosion is the most frequent initiation causes of damage in hydrocarbon pipelines [7]. It provides a singular degradation mechanism in which the condition of the pipeline decreases with life time. There are a lot of approaches to evaluate corrosion degradation (phenomenological [8], random adjustments [9], stochastic mechanism [10], numerical simulation [11], and empirical study). Based on these degradation mechanisms, the challenge is devoted to predict the condition of the pipeline between inspections to provide any possible internal damage. Given the importance of the fluids transported, containment can result in human, environmental or economic losses. An important challenge lies in on the consideration of several factors that have an impact on the evolution of corrosion, among which: the current state temperature, degradation initiation and chemical composition of the steel. Most of the actual publications dealing with ultrasonic scrapers are focused on concrete pipelines [12]. However, the nature of the defects sought in this application is also different, as in this type of pipeline only large cracks are dangerous. Finally, many publications focus on ultrasonic technology as in [13].

3. NDT of cracked pipeline conception

The numerical simulation of pipeline. The application of Lamb wave in real world has server complexity. Thus, Numerical simulation is one of the best way to understand Lamb wave behavior. Dealing with the Abaqus model will be really helpful .This simulation can give the distribution of displacement and field the displacement, where:

- Geometry: R_{in}=0.09mm; R_{ex}=0.1mm.
- Composite material Carbon/epoxy

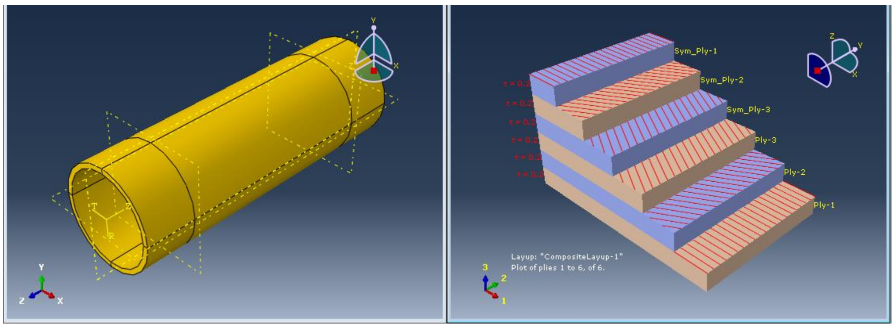

Fig.6 Composite Pipeline

We will use tow models the first without crack and the second with crack.
One sensor was created to check the data along the circumference direction

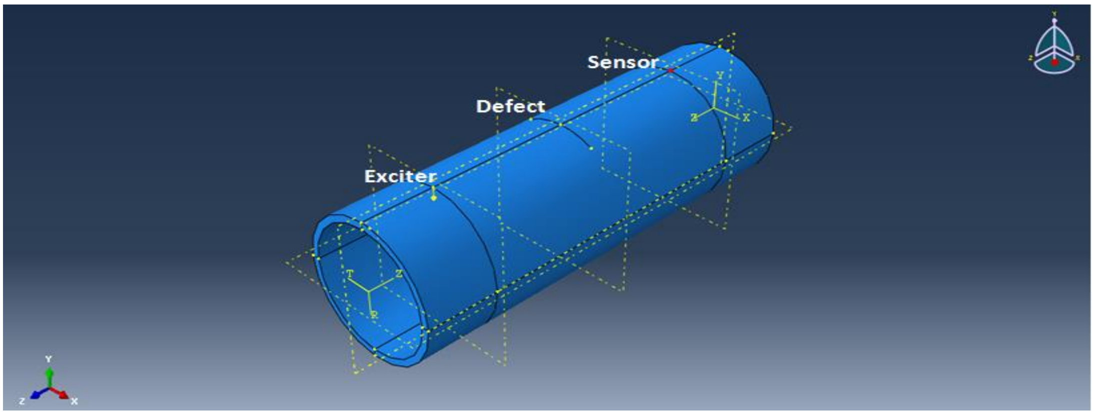

Fig.7 NDT of pipeline

The crack form is shown in figure 8 fellow:

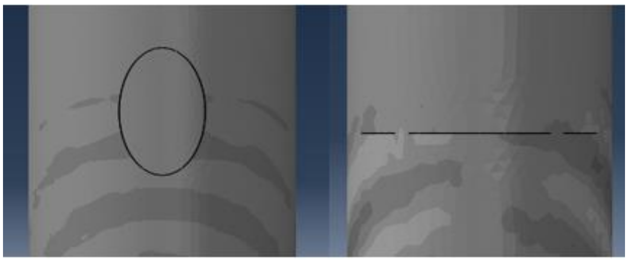

Fig.8 crack form

Firstly, the figure 9 fellow crack size increase, we will take 5 size of cracks in each model a_{1}=0.1mm; a_{2}=0.08mm; a_{3}=0.06mm; a_{4}=0.04mm; a_{5}=0.02mm

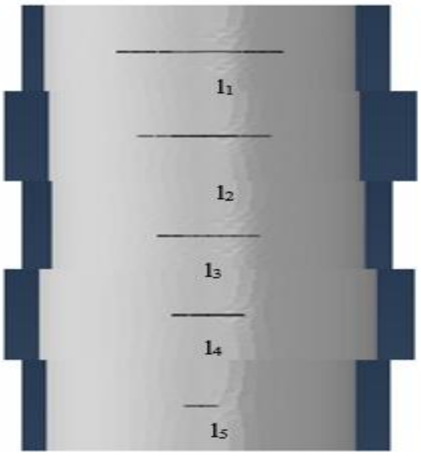

Fig.9 crack size propagation

In order to highlight the of response behavior, we fix the angle θ=0° and change the crack size for a= 0.1 mm, a=0.08mm,a=0.06mm,a=0.04mm,a=0.02mm as shown in figure 10 below:

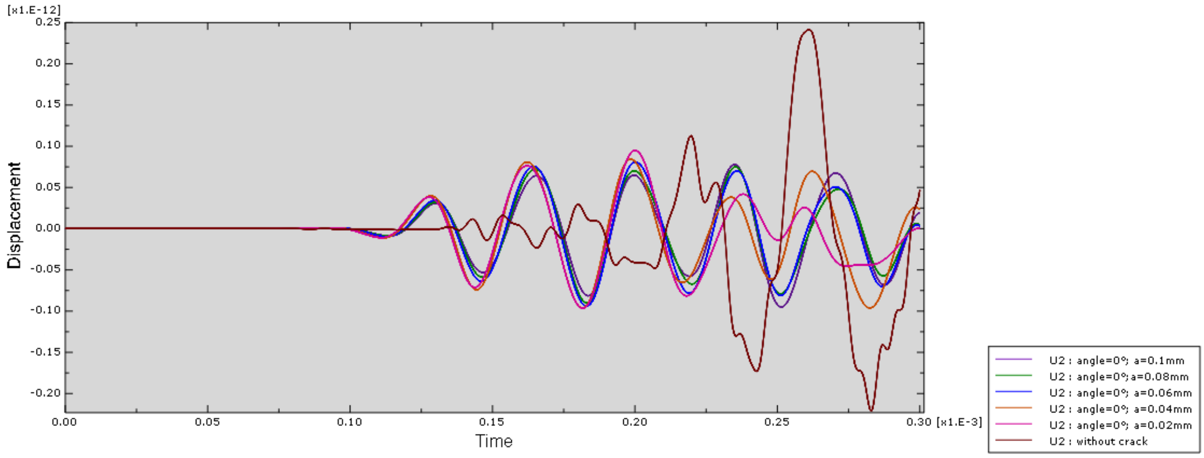

Fig.10 signal of U_2 for θ=0°

We notice that when the angle θ=0°, the crack initiation cause the attenuation of amplitude signal response.

Same with angle θ=30°; the crack growth for a= 0.1 mm, a=0.08mm, a=0.06mm, a=0.04mm, a=0.02mm as shown in figure 11 below:

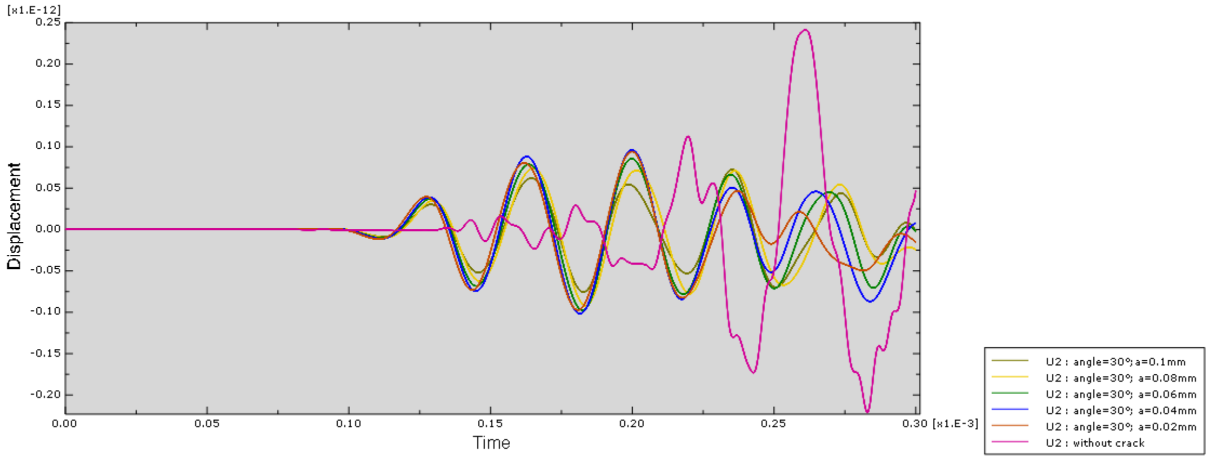

Fig.11 signal of U_2 for θ=30°

This graph of angle θ=30° shown that the amplitude decreases as function a crack size increases.

For angle fix θ=45°; and crack size growth to a= 0.1 mm, a=0.08mm, a=0.06mm, a=0.04mm, a=0.02mm:

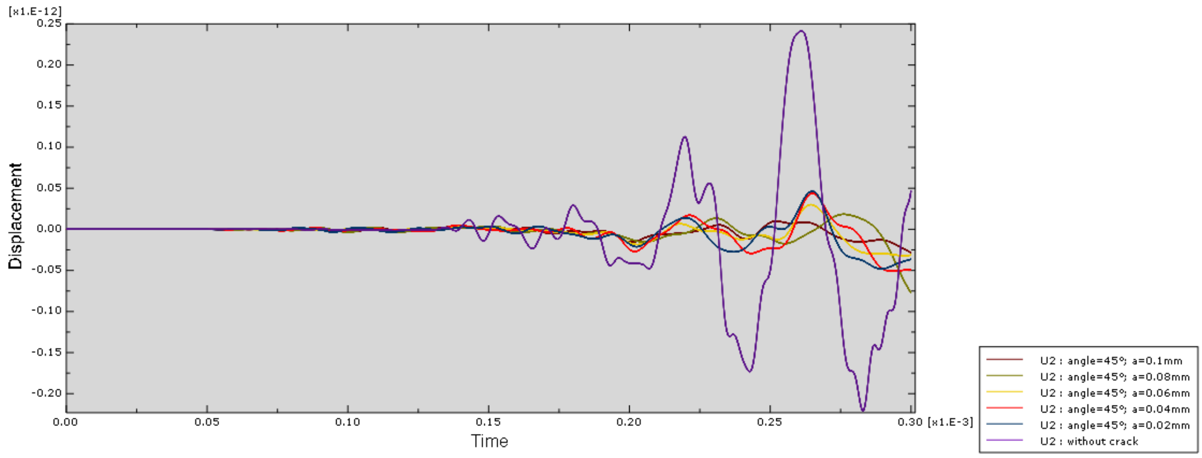

Fig.12 signal of U_2 for θ=45°

From the graph θ=45° we notice the important decreases of amplitude with crack initiation.
For angle fix θ=60°; and crack size growth to a= 0.1 mm, a=0.08mm, a=0.06mm, a=0.04mm, a=0.02mm:

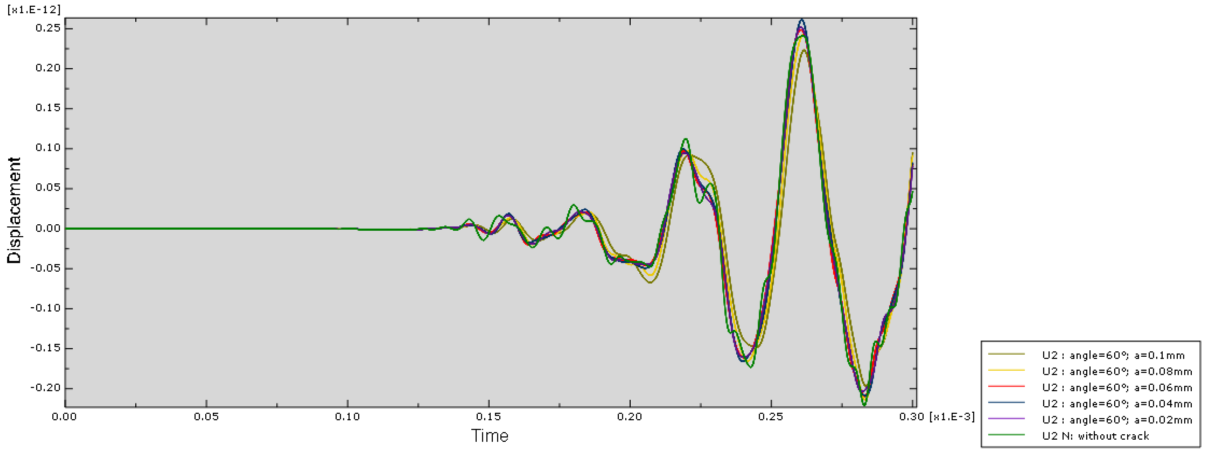

Fig.13 signal of U_2 for θ=60°

In this case, the difference between the signals responses is negligible.
For angle fixed θ=90°; crack propagation to a= 0.1 mm, a=0.08mm, a=0.06mm, a=0.04mm, a=0.02mm:

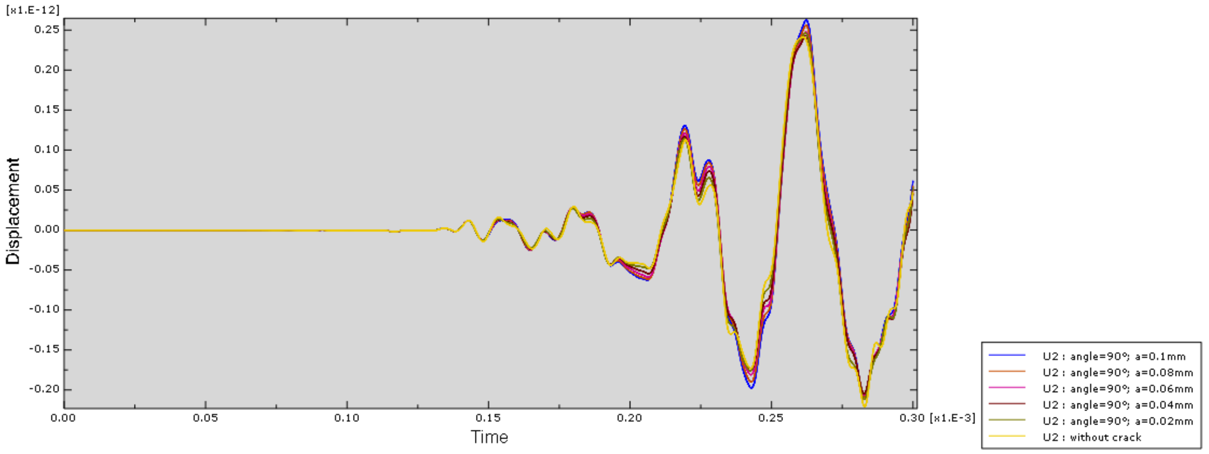

Fig.14 signal of U_2 for θ=90°

Logically, in this case of angle fixed θ=90° the signals is identical, this phenomena is one of the limitation of ultrasonic test named parallel crack.
Secondly we change the crack orientation, We will take 5 orientations of crack in each model θ=0°; θ=30°; θ=45°; θ=60°; θ=90° as shown in figure 15:

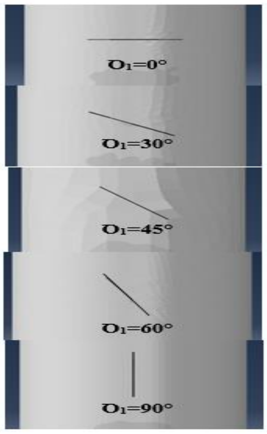

Fig.15 crack orientations

This field data shows the value in global coordinate, we can see some plus/minus U1 signal at the excitation source because of the origin of global coordinate located at the y-z plane.

For crack size fixed at a= 0.1 mm, and crack angle to θ=0°, θ=30 °, θ=45 °, θ=60 °, θ=90 °:

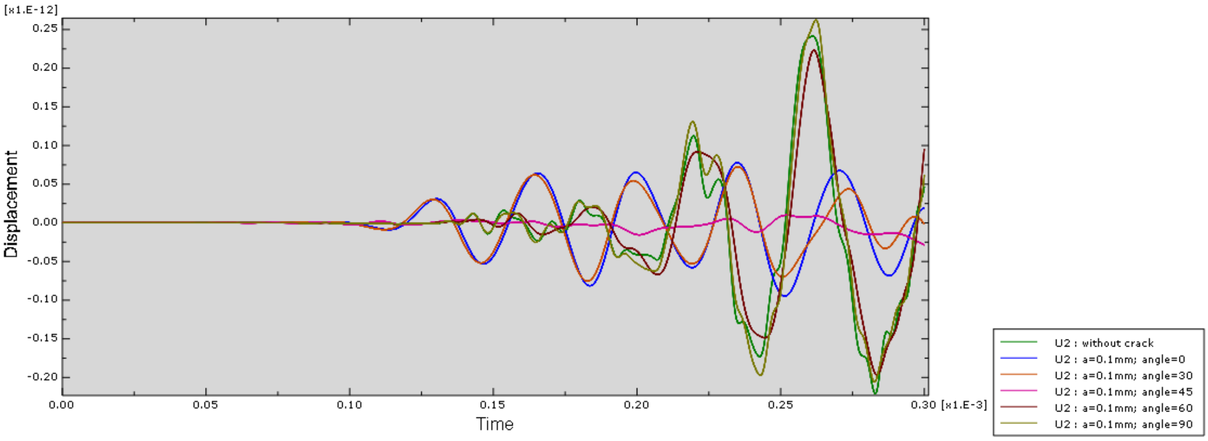

Fig.16 :signal of U_2 for a=0.1mm

We notice that the response of without crack and crack angle θ=0° are same.

For crack size fixed at a= 0.08 mm, and crack angle to θ=0°, θ=30 °, θ=45 °, θ=60 °, θ=90 °:

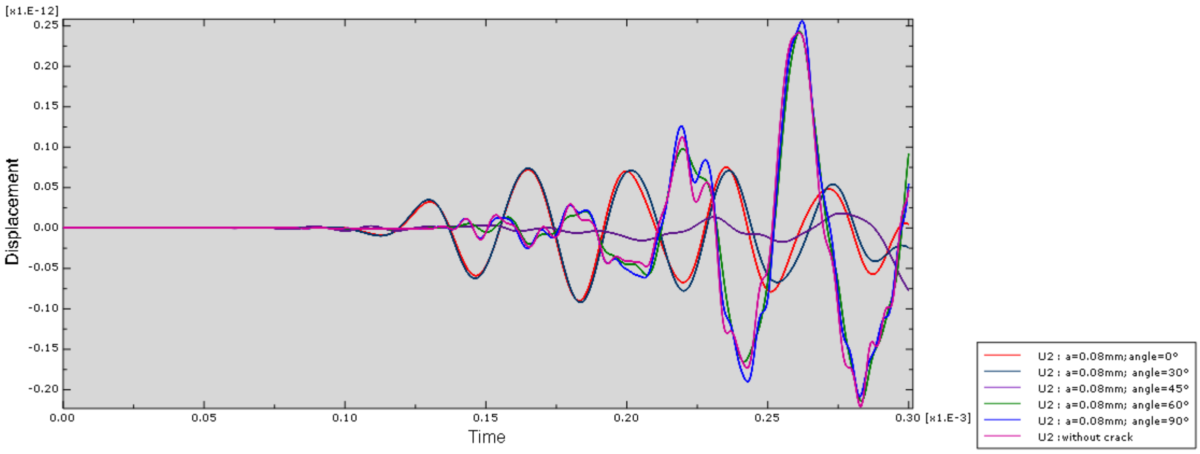

Fig.17 :signal of U_2 for a=0.08mm

We notice that the time of resception respones are diferents as function a crack angle oriontation.

For crack size fixed at a= 0.06 mm, and crack angle to θ=0°, θ=30 °, θ=45 °, θ=60 °, θ=90 °:

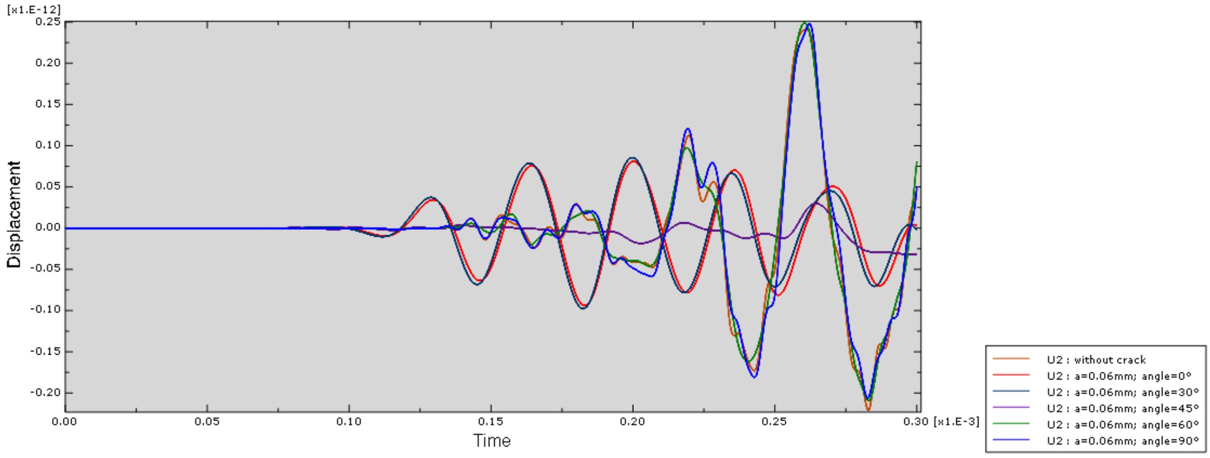

Fig.18 signal of U_2 for a=0.06mm

For crack size fixed at a= 0.04 mm and crack angle to θ=0°, θ=30 °, θ=45 °, θ=60 °, θ=90 °:

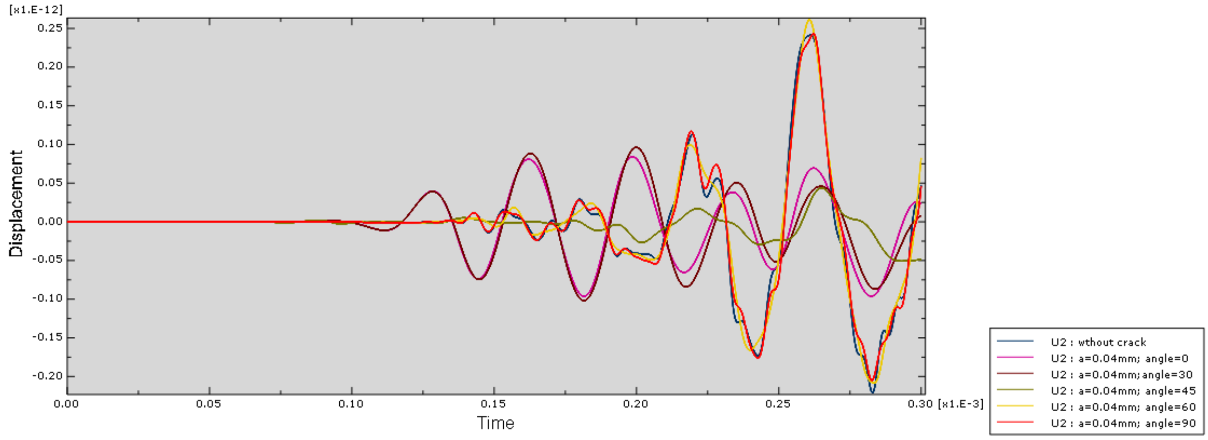

Fig.19: signal of U_2 for a=0.04mm

For crack size fixed at a= 0.02 mm and crack angle to θ=0°, θ=30 °, θ=45 °, θ=60 °, θ=90 °:

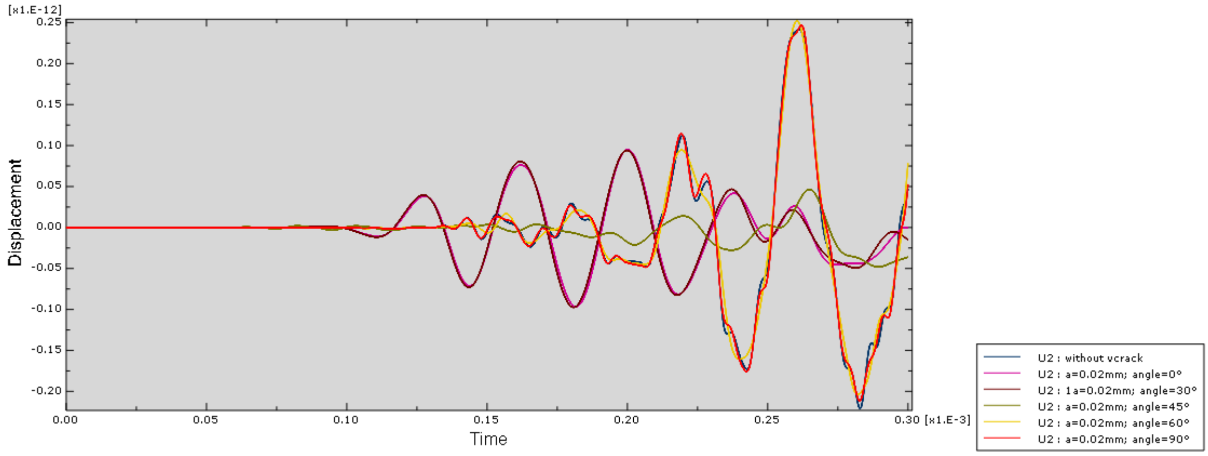

Fig.20 :signal of U_2 for a=0.02mm

For Experimental comparison the [14, 15] Measurements were made in damaged areas as well as in healthy areas on flat structures and on pipelines; they obtained a reference signal in the healthy area, and then they repeated the signal obtained in the presence of defects.

4. Conclusion

At the end, the two time signals were superimposed, and the comparison between the two signals showed an amplification of the signal with the defect, consequently a frequency shift between the two areas. The characteristics of the Lamb wave time signal are compared for the detection of different damages in an aluminium tube, using a sensor. Two damage indices, based respectively on characteristics of Lamb waves. We can conclude that this difference in amplitude is due to the absence of matter (discontinuity) in our study a part of the waves that propagates in the pipeline walls. during this time the signal amplitude of the waves would be largely attenuated. this phenomenon is called the scattering of lamb waves. We notice that when the angle θ=0°, the crack initiation cause the attenuation of amplitude signal response. For angle θ=30° shown that the amplitude decreases as function a crack size increases. From the graph θ=45° we notice the important decreases of amplitude with crack initiation. In the case of θ=60°, the difference between the signals responses is negligible.
Logically, in this case of angle fixed θ=90° the signals is identical, this phenomena is one of the limitation of ultrasonic test named parallel crack. The response of without crack and crack angle θ=0º are same. The time of resception responses are different as function a crack angle orientation. Finaly all this signal responses shapes can be used for identification of crack: depth, length, shape and orientation of crack.

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