

NON-DESTRUCTIVE LEAK DETECTION IN GALVANIZED IRON PIPE USING NONLINEAR ACOUSTIC MODULATION METHOD

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Abstract -- *Non-destructive testing is a wide group of analysis techniques used in science and industry to evaluate the properties of a structure without causing damage to it. The main objective of this project is to carry out an experiment to detect leakage in a pipeline using nonlinear acoustic modulation method. The nonlinear acoustic modulation approach with low frequency excitation and high frequency acoustic wave is used to reveal modulations in the presence of a leak. The pipe used in this experiment was galvanized iron pipe. The experiment is started with the experiment of an undamaged specimen and followed by the experiment of a damaged specimen with a manually applied leak. The results obtained are being observed and the difference between the specimen without leak and with leak can be distinguished. The distance between the leak and the distance of the outlet detected is nearly accurate to the exact location which is a leak at 4.0 m and outlet at 6.0 m. Therefore, the results demonstrate that leakage can be detected using nonlinear acoustic modulation, and proved the objective of distinguishing the difference between the results of a specimen without leak and with leak has succeeded. The damage detection process can be eased with the knowledge of the signal features.*

Keywords: *Non-destructive testing; Nonlinear acoustic modulation; Leak detection*

INTRODUCTION

Recent developments in pipeline systems have heightened the need for a study about the pipe defect detection using ultrasonic guided wave method. In recent years, several studies have focused on defect detection in pipeline systems because it is very important used extensively all over the world to transport and distribute natural gas, crude oil, water, and other easy-flowing products. Indeed, in the process of continuous transportation, gas pipeline leakage cannot be avoided because of the corrosion of pipe walls (Arwati and Sianipar, 2018; Jarvis et al., 2016), third-party interference (Liang, 2012) aging of the pipes (Vargas-Arista et al., 2007), and so on. Therefore, leakage detection and localization are one of the paramount concerns of pipeline operators and researchers all over the world (Priyandoko and Fun, 2015).

Many researchers have argued that Non-destructive testing (NDT) is a wide group of analysis techniques used in science and industry to evaluate the properties of a material, component or system without causing damage. NDT is a highly valuable technique that can save both money and time in product evaluation, troubleshooting, and research. Common NDT methods include ultrasonic, magnetic-particle, liquid penetrant, radiographic, remote visual inspection (RVI), eddy-current testing, and low coherence interferometry. According to K Haller

(Sohn et al., 2014), damage can be monitored in many ways.

The choice of composite materials is no longer restricted to specific applications. In other fields, using these new materials as innovation tool and performance rising of their products such civil engineering. It is important first to have the best possible knowledge about these materials in somehow to monitor any changes in these properties and consequently their influence on the structure behavior (Lakhdar et al., 2013; Li and Xu, 2013).

Plastic pipe is a good material because of high resistance, light, cheap and long-life span. Therefore, plastic pipes usually are used to transport gas, water, and chemicals. In general, plastic pipes are widely used in metal or concrete pipes. Due to the material being immune to water corrosion and highly resistant to fouling, it is also being considered as a replacement for stainless steel in safety-critical applications in nuclear power stations (Assunção et al., 2013).

According to Carvalho et al. (2008), researchers have spent an ample amount of time, investigations and researched on non-destructive test techniques. As much as during the setting up phase during their useful life, these techniques are used as a method to assess engineering structures and system (Cheng and Tian, 2011). Crack inspection is a valuable non-destructive test (NDT) method in many industries. The crack inspection method is useful, which

often exhibit complex geometries, are exposed to high thermal and mechanical loads and are expected to satisfy strict safety requirements. Lately, there is a need to expand a powerful crack defect detection method.

Early detection of damage is not necessarily visible from the external face and even when it is the case of visual inspection does not realize its case state. In order of reliable and efficient use, these new materials, the development of a measurement system that can answer the following two questions of primary importance is required whether it could be measured directly in NDT and reliable mechanical properties of a composite structure. Is it possible to detect damage as quickly as possible in order to monitor, evaluate and repair if necessary the structure (Jenal, 2010)?

MATERIAL AND METHOD

Nonlinear Acoustic Modulation

Generally, the method of nonlinear acoustic modulation that is using high frequency acoustic wave and low frequency excitation for damage detection is named as a vibro-modulation method, impact-modulation method, vibro-acoustic method or nonlinear wave modulation spectroscopy method. Even though each method has different approaches for experimental setup, but these methods use similar nonlinear acoustic effects to diagnose the defects in a material. In common understanding, nonlinear acoustic wave modulation is due to an interaction between acoustic waves and low frequency vibration (Jenal, 2010). Most studies have used this parameter to assess the level of

damage in a material. (Zaitsev et. al., 2006) proposed a novel nonlinear-modulation acoustic technique for crack detection which is based on the cross-modulation effect consisting of the modulation transfer from an intensive, initially slowly amplitude-modulated stronger (pump) excitation to the probe signal as shown schematically in Fig. 1. Previously, Zaitsev et al. (Zaitsev et. al., 2002) have successfully tested the nonlinear modulation technique for detecting a weak damage. This technique is very flexible in the choice of operation frequencies which is carrier frequencies and modulation frequency.

Experimental Setup

The first equipment needed for this experiment is galvanized iron pipe. In this experiment, Ni-DAQ software and DASyLab software has been used to interpret the data or signals obtained from the experiment. The metal holders are used to hold the pipe at both ends. The microphone, which acts as a sensor is connected to input channel 1 of Ni-DAQ hardware using a cable and Ni-DAQ hardware is connected to the laptop. The speaker is attached to one end of the pipe to generate the sound wave through the pipe and the cable of the speaker is connected to the laptop. Both microphone and speaker are fixed on the pipe. The microphone is put in one of the drilled holes near the speaker by using plasticine in order to fix the position. Another drilled hole is closed with plasticine. After the setup is ready, the experiment is ready to be conducted. Fig. 2 shows the experimental set up for nonlinear acoustic modulation experiment.

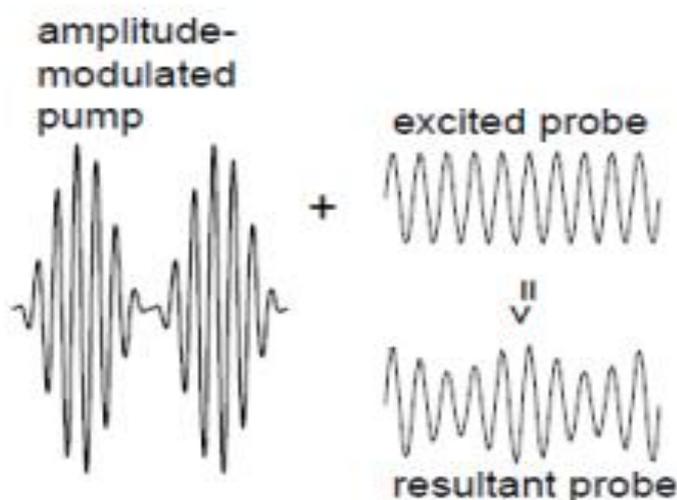


Figure 1. Schematic figure of acoustic-modulation method (Zaitsev, et. al., 2006).

RESULTS AND DISCUSSION

Impact hammer testing is used to obtain natural characteristics such as natural frequencies, damping and mode shapes of the pipe. Natural frequencies obtained from impact hammer testing act as a low frequency excitation for nonlinear acoustic modulation experiment. Each low frequency excitation is applied simultaneously with high frequency acoustic wave to the pipe. Fig. 3- Fig. 4 shows the result obtained from the nonlinear acoustic modulation experiment when 393 Hz of low frequency and 2000 Hz of high frequency are applied to the pipe without leak by using a speaker. There is no wave distortion can be observed in the response signal based on the result obtained.

The highest error value which is 6.88% for leak location is found to be at 24.2 Hz where the time that the wave takes to travel along the pipe to the leak and return to the measuring point is 0.0245 seconds and the distance of the leak calculated is 4.27525 m. Meanwhile, the lowest error value which is 3.83% for leak location is found to be at 393 Hz and 477 Hz where the time taken for the wave to travel along the pipe to the leak and return to the measuring point is 0.0238 seconds and the distance of the leak calculated is 4.1531 m. It is observed that as the low frequency increases, the time taken for the wave to travel along the pipe to the leak and return to the measuring point decreases thus, reducing the error obtained for leak location.

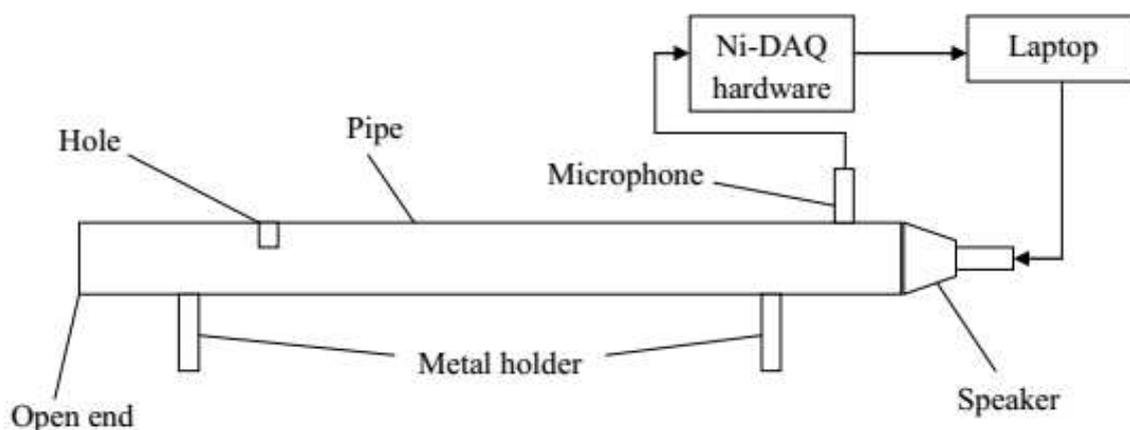


Figure 2. Experimental setup for nonlinear acoustic modulation

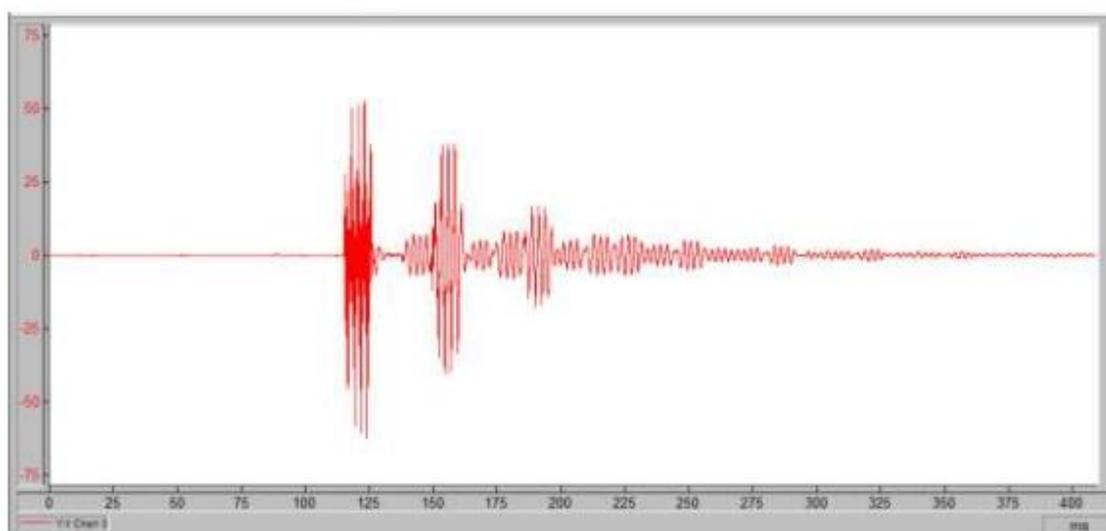


Figure 3. Time domain response obtained without (blue line) and with a single leak (red line)

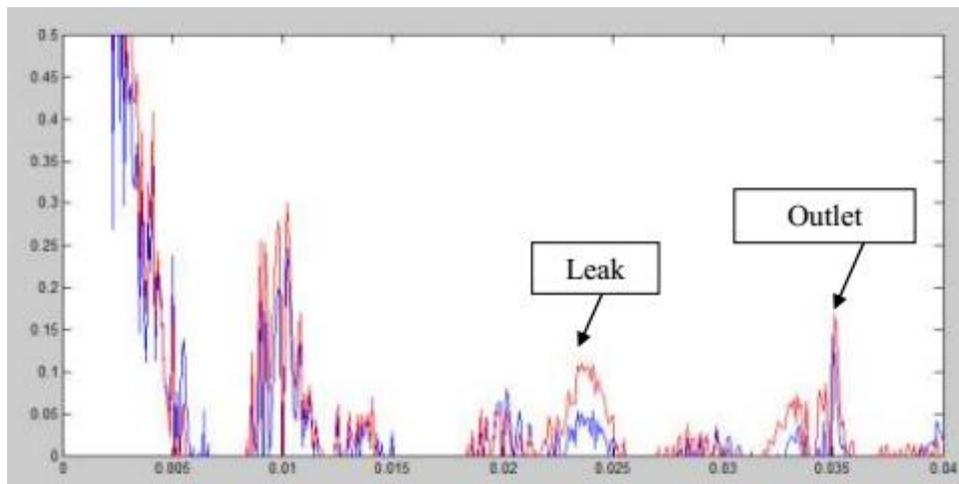


Figure 4. Cepstrum analysis without leak (blue line) and with single leak (red line)

Table 1. Summarized results for cepstrum analysis with various low frequencies

Low Freq (Hz)	Analyzed time for leak (s)	Analyzed time for outlet (s)	Distance of the leak (m)	Error (%)	Distance of the outlet (m)	Error (%)
24.2	0.0245	0.0351	4.27525	6.88	6.12495	2.08
48.6	0.0244	0.0351	4.27578	6.45	6.12495	2.08
142	0.0243	0.0351	4.27535	6.00	6.12495	2.08
193	0.0243	0.0351	4.27535	6.00	6.12495	2.08
252	0.0242	0.0351	4.22290	5.57	6.12495	2.08
318	0.0240	0.0351	4.18000	4.70	6.12495	2.08
393	0.0238	0.0351	4.15310	3.83	6.12495	2.08
477	0.0238	0.0351	4.15310	3.83	6.12495	2.08

CONCLUSION

Nonlinear acoustic modulation was used for the purpose of detecting leakage in the pipe. The method was based on the introduction of two types of waves which are low frequency and high frequency of the pipe. The two types of waves are generated by using a speaker and being allowed to propagate in the pipe. The response signals are captured by using a microphone which acts as a sensor in this study and the results obtained are further analyzed by using cepstrum analysis in order to determine the location of leakage and outlet.

The presence of damage in the structure can be estimated by using the information on the nonlinear acoustic effects. Different types of nonlinear acoustic effects can be studied and more details about the damage can be investigated with the suitable type of equipment.

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