AUSTRALIAN NETWORK OF STRUCTURAL HEALTH MONITORING

Newsletter

Issue 21, September 2019

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President Message

Tommy Chan

Professor in Civil Engineering, Queensland University of Technology

Dear All,

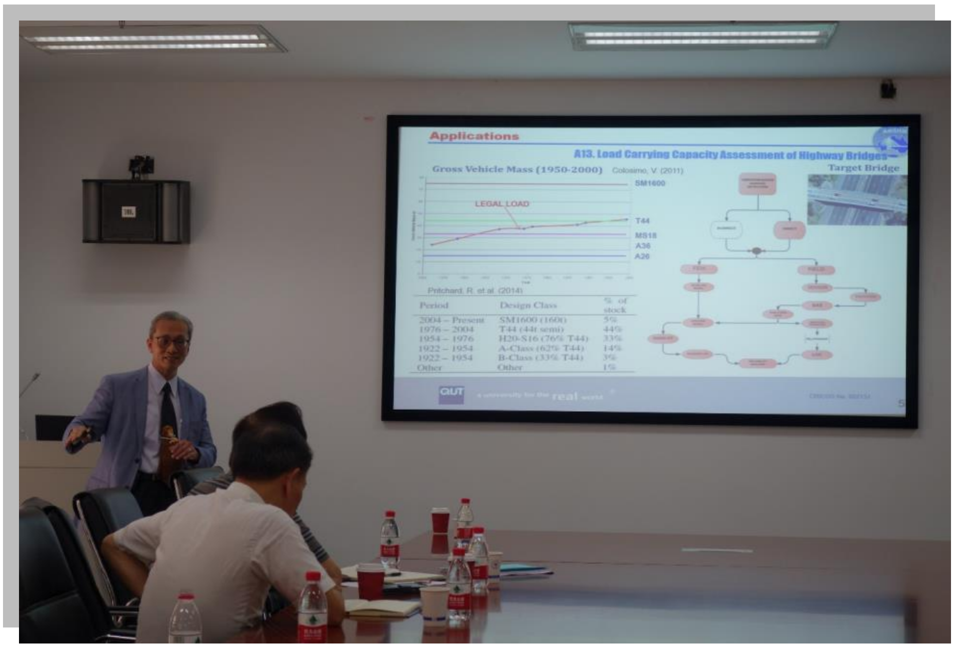
First of all, may all of us congratulate Prof Brian Uy for being named as Sir John Holland Civil Engineer of the Year 2019. He received the award at a celebration marking the centenary of Engineers Australia at Sydney. The Sir John Holland Civil Engineer of the Year award is a national award presented to a leading civil engineer who has made a major contribution to the sector, including service to the community, involvement in major projects and the development of new technology and research. Brian is well deserved for this award. He has been contributing to ANSHM as its Advisory Board Member since its establishment in 2009. He is one of the few who has attended all of our annual ANSHM Workshops and he has tried his best to help ANSHM grow and work on its objectives for the promotion of the association and the development and application of the SHM Technologies, including pushing the inclusion of SHM in AS5100.

Once again, Brian,
Congratulations and many thanks to you!

Professor Uy won the Award **of** *Sir John Holland Civil Engineer of the Year*

For more details, please click
https://sydney.edu.au/news-opinion/news/2019/08/22/academic-named-civil-engineer-of-the-year.html

In early June, I was invited by Prof Yuan Feng Duan, the Department Head of Civil Engineering of Zhejiang University, China to visit the university. The College of Civil Engineering and Architecture there is a huge college with more than 200 academics staff. During the visit, I gave a half day seminar presenting the basics of SHM as well as its latest developments to the professors, researchers and postgraduate students there. Prof Chung-Bang Yun, the Professor Emeritus both at KAIST and UNIST in Korea, Prof JJ Roger Cheng of the University of Alberta were there as well and they also attended my seminar. The presentation was very well received and they were amazed by the developments that we have in Australia. A lot of questions were asked during the discussion section and there was one important point raised by Roger which is worth mentioning here. He remembered that when he was still the Chair (Head) of the Department of Civil and Environmental Engineering of the University of Alberta, an area which attracted a lot of research funding from the industry for the department was the SHM application for the laying and monitoring of utility services including pipelines, powerlines and optical fiber cables. It is because there are a lot of uncertainties involved when dealing with the soil and underground conditions but SHM technologies will be very helpful for these. All these confirm the importance of our ARC Training Centre of SHM as the laying and monitoring of utility services is within one of the Programs of the Centre.



My presentation at Zhejiang University

Photo with Prof JJ Roger Cheng (on my right), Prof Chung-Bang Yun (on my left) and Prof Yuan Feng Duan (on Prof Yun's left)

Below are the updates of the month.

Celebration of ANSHM 10th Anniversary

I made a mistake in my last month updates by incorrectly stating the ANSHM 10th Anniversary Celebration Coordination Sub-Committee composing of Jun, Jianchun and Alex. Actually it should be Lei, Jianchun and Alex and Lei is the main coordinator. In our last EC meeting held on 28th Aug 2019, we had further discussions on how to consolidate the celebration plan. Basically the celebration will include the followings:

i. 11th ANSHM Workshop
   - We will encourage the presenters to present the research outcomes of their organisation for the past ten years
   - There will also be other activities/sessions held to celebrate the anniversary

ii. an Issue in ANSHM Newsletter
   - Tentatively the December issue will be the main issue celebrating the anniversary, including description on the past 10 year achievements of ANSHM and individual organisations, which could be continued to other issues if necessary.

iii. The ANSHM special issue in International Journal of Structural Dynamics and Stability

iv. an ANSHM Technical Workshop, which could be held either this year, or early next year.

ANSHM 11th Annual Workshop

The organising of the Workshop has been progressing well. In our last EC meeting, we have a prolong discussion on various matters relating to this Workshop. We will open the Calls for Abstracts very soon. It was suggested that to follow our traditions, we will have one presentation per organisation. The call will be started from 1st of September to 30th September. As mentioned earlier, that we would like to have presentations reporting the progress of their SHM studies or SHM applications for the past ten years. The time for each presentation will be scheduled for around 15 to 20 minutes including Q & A time, depending on the number of presentations that we have. Same as before, we will also have an Industry Forum as a highlight of the Workshop, which will be facilitated by one or two members from the industry. The Workshop welcomes any ANSHM members; even you are not making a presentation. Registration will start soon and has tentatively scheduled to close in mid-October. The Registration Fee will be nil for ANSHM members, but you need to register for catering purpose.

Please note that this important ANSHM annual workshop will be an event to celebrate our 10th Anniversary, which will be hosted by Griffith University, held at their Gold Coast Campus from 2 – 3 December 2019. Details could be found via https://www.griffith.edu.au/cities-research-institute/news-and-events/seminars-and-events/11th-anshm-annual-workshop.

ATCSHM

At the time, I am preparing this updates (29 Aug 2019), the official grants outcome for the Industrial Transformation Training Centre (ITTC) has not been announced yet. The ITTC is one of the two schemes under the Australian Research Council (ARC) Industrial Transformation Research Program (ITRP). Although the grants outcome for ITTC has not been announced, yet the other ITRP scheme, the Industrial Transformation Research Hubs (ITRH) outcome has been announced on 18 August 2019. Normally the two schemes announce on the same date. It is very strange that for this year, the two schemes are announced separately.

Regarding ITRH, the successful rate has dropped from 44% last year to 31% this year. There are 13 applications and only 4 are successful. Although the official announcement of the ITTC have not been announced yet, there are media releases for the establishment of three ITTCs, one on 27 August 2019 and two on 28 August 2019.

Research Collaboration

On 9th Aug 2019, we are excited to know that the AustRoads called a tender for a consultancy project of an amount $240k (ABT6203 Structural and Real-Time Bridge Health Monitoring). The main deliverable is a guideline on SHM. After some discussions with Jianchun and the other members of the Executive Committee, we consider that it is a very good opportunity for us to work together collaboratively under ANSHM and also to demonstrate to the road authorities how SHM could work for them. More importantly, it will be very meaningful if the AustRoads Guideline on SHM is developed by ANSHM. Although the time frame is short with the deadline of the submission of the tender to be 5:00 PM on 26 Aug 2019, we agreed to take up the challenge to prepare the tender document accordingly. Since we had only two weeks to work on it, I used my leave so that I could work at home focusing mainly on the preparation of the tender. Once again the Executive Committee has demonstrated well our team spirit and finally we prepared a very strong proposal which was ready for submission on 26 Aug 2019. However, in just less than three hours before the deadline, we were informed that the deadline of the submission had been extended to 2nd Sep 2019. Anyway, we will submit the tender by the deadline and we look forward to having it awarded as a celebration of our 10th Anniversary.

ANSHM Special Issue

As mentioned before, we are preparing a special issue in the International Journal of Structural Dynamics and Stability (IJSSD) for the presentations at the 10th ANSHM Workshop as well as the ANSHM Special Session in ACMSM25, to celebrate our 10th Anniversary.

Please note that the submission deadline is **30th Sep 2019**. Other Key dates for this special issue are stated as follow:

- First Round of Reviews: 30th Nov 2019
- Revision and Final Review: 30th Jan 2020
- Ready for Publication Date: 1st March 2020

Please kindly note that the scope of this issue is on structural health monitoring related to structural dynamics and stability, and 1) Significant difference (>50%) is required if the submission is an extension of conference papers to ACMSM25 or ANSHM workshop; and 2) Similarity check will be conducted by the journal officers, if you are interested to submit articles.

We have already four manuscripts and they have all been sent out for review. We expect to receive more manuscripts by the submission deadline by 30th Sep. The submission guidelines for authors regarding the format are available at:

https://www.worldscientific.com/page/ijssd/submission-guidelines. You are welcome to submit your papers to any of our four guest editors at tommy.chan@qut.edu.au; junli@curtin.edu.au; Andy.Nguyen@usq.edu.au; and taoy@uow.edu.au.

If you are invited to be a reviewer, please accept the invitation and return your review report timely. In order not to overload any of us, we created a document via Google Docs so that all the editors, Jun, Andy, Tao and myself could update it once we have invited reviewers for a submitted manuscript. We will only show the name of the reviewers and not the details of the manuscripts so that we, even as the editors will not know who are reviewing our manuscripts if we have one submitted, to avoid any conflicts of interests. We aim to have no one will review more than two papers. Many thanks in advance to those who are helping or will help us review the manuscripts.

Special Sessions/Mini Symposia

EASEC-16

Six abstracts have been received and the full paper submission deadline is due on 31st July. The authors are welcome to submit the full papers, or choose to submit abstracts only to register and attend the conference.

IPDO2019

Another ANSHM Mini Symposium is "Recent regularization methods for dynamic load identification" (http://ipdo2019.ipdos.org/Minisymposiums.html) in the Fifth International Symposium on Inverse Problems, Design and Optimization (IPDO2019) which will be held in Holiday Inn Riverside, Tianjin, China, during September 24-26, 2019. Anyone who is interested to present at this MS, please send me a message.

This Issue of the ANSHM Newsletter

Thank Richard for looking after this issue of the Newsletter. For this issue, we have two technical publications: one paper focuses on elastic waves-based structural health monitoring for steel pipes, and the other one is a technical note looking into non-destructive technologies and their application in stress free temperature (SFT) measurement for continuous welded rails (CWR), which is about the practical applications of three non-destructive technologies applied in Australian railway industry. These two technical publications show the on-going research activities and capacities from the WSU SHM Research Team.

We should also congratulate Mehri for getting the JSPS Fellowship in Kyoto University for staying in Japan for 8 months. Since she will be away for 8 months, she applied for a special leave of her Executive Committee during her time being overseas. We discussed that and approved her request until the end of her two-year term of service as an Executive Committee member, i.e. 4 months from now. During these 4 months, Andy is so kind to take up her role as an editor of the ANSHM Newsletter, while still working the duties of his role as the External Affairs Officer. Once again, we can see how we are so devoted to ANSHM and so prepared to take up the loads of others when necessary. Many thanks, Andy!

With kind regards,

Tommy Chan
President, ANSHM
www.ANSHM.org.au

Elastic Waves-based Structural Health Monitoring for Steel Pipes

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Abstract

In the age of change, pipelines become indispensable parts in many processing industries, such as oil and gas refineries, fertilisers, chemical and power plants, etc. However, the condition of those pipelines is exerting profound impact on their work. For long pipes, the wide area corrosion and pitting corrosion are two major factors leading to catastrophic situation, which is including the wall thickness reduction and pinhole damage. To detect and evaluate the defects existing in pipelines, a lot of methods and techniques are developed.

This research aims to develop an elastic-wave based structural health monitoring system for steel pipes at the development, which combines the merits of finite element modelling and simulations for determining mode dispersion, conducting selection of ultrasonic circumferential guided waves and determining their propagation characteristics in typical steel pipes.

Introduction

Guided wave-based structural health monitoring (SHM) technique, which is a process of implementing an in-situ damage identification and detection, has been developed in several decades and it brings significant influences on non-destructive defect detection of engineering structures [1]. Many researchers contributed to this field of research for the applications of the guided waves which can propagate for a long distance in an engineering structure and detect defects of small sizes in the structure based on the collected wave signals. However, there are several technical problems on developing such an SHM system for pipes, which are typical shell-like structures, including dispersion relations, wave mode selection, wave propagation characteristics, wave mode conversion in complex structures [2], etc. When piezoelectric materials are used to act as actuators and/or sensors to generate and collect signals of elastic waves in pipes, their performances need to be evaluated too. As the most useful and powerful numerical tool, finite element method-based dynamic analysis has been widely employed to capture guide waves' characteristics in complex engineering structures. To develop robust and cost-effective finite element-based models, researchers [3-4] have developed effective or equivalent models for piezoelectric actuators and/or sensors using different theories.

In this study, to develop elastic waves-based SHM system for steel pipes, the evaluation of elastic wave propagation in steel pipes is conducted numerically by devising finite element models For the proposed finite element models of the pipes, the enhanced effective PZT actuator model [4] developed in the authors' previous work is further applied and the performance of piezoelectric actuators used including the shape effect is investigated. For validation purpose a steel pipe is tested using a 16-actuator/sensor network to understand the elastic wave propagations. Furthermore, the relationship between the defects and the elastic wave propagation is identified. To achieve the goal of the proposed research, the following research objectives are conducted to a) develop a series of finite element models and dynamic analysis procedures to simulate guided wave propagations in steel structures; b) Characterise wave propagation in typical steel structures within the scope of SHM; and c) Validate the proposed finite element models and dynamic analysis procedures via conducting a benchmarking.

Fundamentals of Elastic Wave Propagation in Cylindrical Structures

Considering a solid medium, the governing equation for the propagation of free harmonic waves along a hollow circular cylinder is the Navier's equation of motion which can be given in a vector form as (6),

$$\mu\nabla^2\mathbf{u}+(\lambda+\mu)\nabla\nabla\cdot\mathbf{u}=\rho\left(\partial^2\mathbf{u}/\partial t^2\right) \tag{1}$$

where $\boldsymbol{u}$ is the displacement vector, ρ is the density, μ and λ are Lame's constants, and ∇ is the three-dimensional Laplace operator, respectively. For an anisotropic cylinder hollow pipe with outer diameter a and inner diameter b the roots of Eq. (1) can be assumed as follows:

$$u_r=U_r(r)\cos(n\theta)\cos(\omega t+\varsigma z) \tag{2}$$

$$u_\theta=U_\theta(r)\sin(n\theta)\cos(\omega t+\varsigma z) \tag{3}$$

$$u_z=U_z(r)\cos(n\theta)\sin(\omega t+\varsigma z) \tag{4}$$

where $u_r(r, \theta, z, t)$, $u_\theta(r, \theta, z, t)$, and $u_z(r, \theta, z, t)$ are radial, circumferential and axial displacements, and $U_r(r)$, $U_\theta(r)$, and $U_z(r)$ are amplitudes described using Bessel functions, respectively. There are three modes for guided wave propagation in pipes: longitudinal mode L(0, m), torsional mode T(0, m) and flexural mode F(n, m). Only the dispersion characteristics of the elastic waves are of research interests and hereby the characteristic or dispersion equation is listed without reproducing its complicated algebraic expressions in details for the sake of brevity,

$$D=\begin{vmatrix} C_{11} & C_{12} & \cdots & C_{16} \\ C_{21} & C_{22} & \cdots & C_{26} \\ \vdots & \vdots & \vdots & \vdots \\ C_{61} & C_{62} & \cdots & C_{66} \end{vmatrix}=0 \tag{5}$$

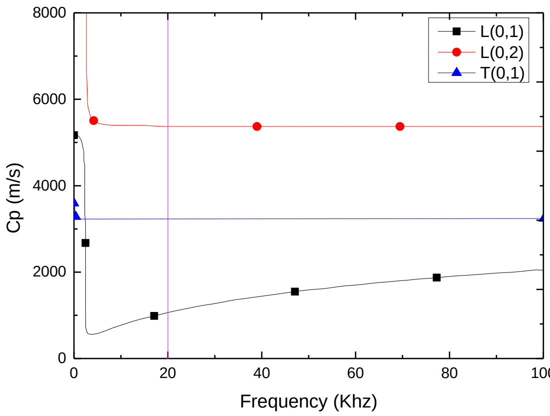
where C_{ij} are constants, and i, j = 1, 2, 3, 4, 5, and 6. Considering guided waves have a zero wave number, $\varsigma = 0$, Eq. (5) can be broken into the product of two sub determinants as

$$D_1 D_2 = 0 \tag{6}$$

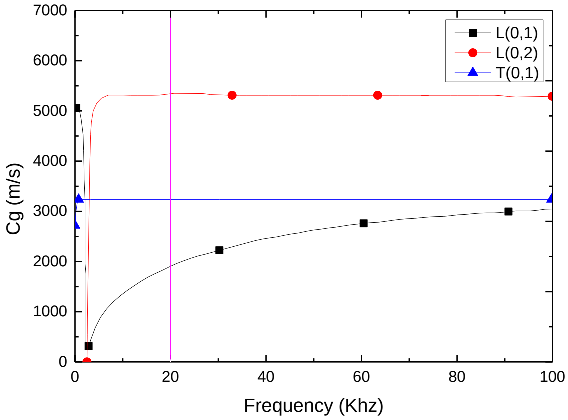
where

$$D_1 = \begin{vmatrix} C_{11} & C_{13} & C_{14} & C_{16} \\ C_{21} & C_{23} & C_{24} & C_{26} \\ C_{41} & C_{43} & C_{44} & C_{46} \\ C_{51} & C_{53} & C_{54} & C_{56} \end{vmatrix} \text{ and } D_2 = \begin{vmatrix} C_{32} & C_{35} \\ C_{62} & C_{65} \end{vmatrix} \tag{7}$$

Hence, either D_1 or D_2 is equal to zero to satisfy Eq. (5). The case of $D_1 = 0$ corresponds to plane-strain vibrations L(0, m) whereas the case of $D_2 = 0$ is for longitudinal shear vibrations T(0, m) (6). The dispersion curves of a steel pipe with an outer diameter 323mm and a wall thickness 6.4 mm based on Eq. (7) can be obtained as given in Fig. 1.



(a) Phase velocity



(b) Group velocity

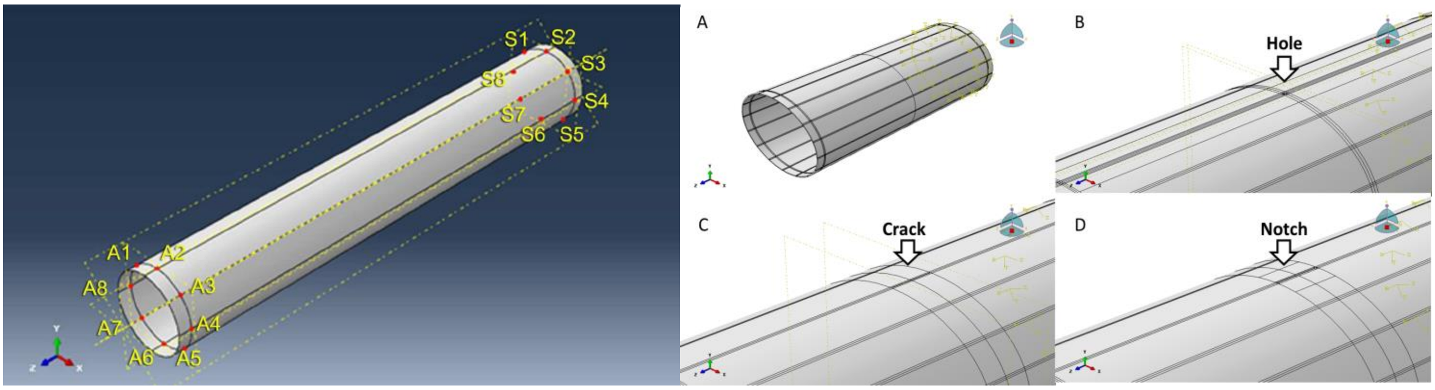
Figure 1 Disperse curves of a pipe with an outer diameter of 323mm and a wall thickness of 6.4 mm

As can be seen from Fig. 1, it is clear that the group velocity and phase velocity will change when the frequency increases. It is necessary to select a suitable wave mode and frequency for appropriate guided waves used in the proposed structural health monitoring system and in current study, and the longitudinal L(0, 2) wave mode at 20 kHz was chosen due to a low attenuation (5).

Finite Element Modelling and Simulations

In this study, steel pipes are of 1500 mm in length, 323 mm in outer radius and 6.4 mm in wall thickness and are widely used for both liquid transport and piling in reality. The steel has a Young's modulus of 210 GPa and a Poisson's ratio of 0.27. A sensor network with 16 PZT actuators/sensors was devised. Eight actuators/sensors were installed at each end of the pipe and they functioned as either generating or collecting the signals of elastic waves. Two different pipes were tested using different shaped PZT patches (round or rectangular) to determine if there is a shape effect influencing the results.

As for the finite element modelling, the steel pipes were treated as a 3D deformable solid and meshed with 684,512 C3D8R solid elements, which were chosen properly according to wave length. Since piezoelectric materials are used to act as actuators and/or sensors to generate and collect signals of elastic waves, the enhanced effective PZT actuators model [4] developed by the authors were further applied in the finite element models of steel pipes. In the FE models, A1 to A8 are standing for actuators while S1 to S8 are for sensors, as shown in Fig. 2 (a).



(a) (b)

Figure 2 FE models of pipes with/without defect: (a) FE model and actuator/sensor networks; (b) FE models with various defect scenarios: A - no defect for benchmarking; B – a hole; C - a crack; and D - notch

The defects added to the pipe model are a hole of diameter 12 mm and depth 5 mm, a crack of length 120 mm and width 2 mm and a notch of length 120 mm, width 12 mm and depth 5 mm as shown in Fig. 2 (b). Those defects were designed to locate at the middle of the pipeline and kept aligned with the actuator-sensor pair: A_1 and S_1. In addition, to investigate the shape effect of PZT actuators, another two pipe models without defect were also devised. In these two models, PZT actuator models with round and rectangular shapes were considered respectively, using the effective displacements applied at relevant nodes around these actuators. The waveform used for the testing was selected as 40 kHz tone-burst in a 5-cycle Hanning window. The Hilbert-transform (HT) was utilised to decompose collected signal into different frequency bands, thereby making the useful wave components appeared after screening broadband noise.

Results and Discussion

Fig. 4 shows the processes of wave propagation along a pipeline, which is without any defect for benchmarking. It can be clearly seen that there are two kinds of wave modes generated in pipes and they are L(0, m) wave modes and F(n, m) wave modes, respectively. Since this figure only illustrates displacement outputs from numerical analyses of steel pipes in the longitudinal direction and thus the results do not include T(0, m) wave modes.

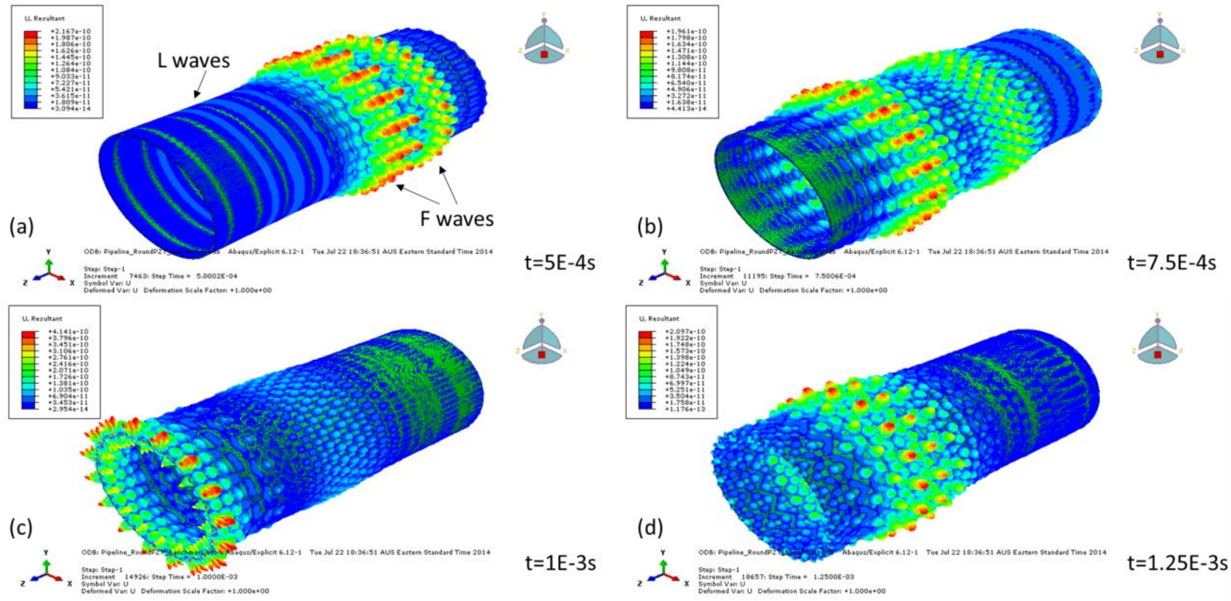
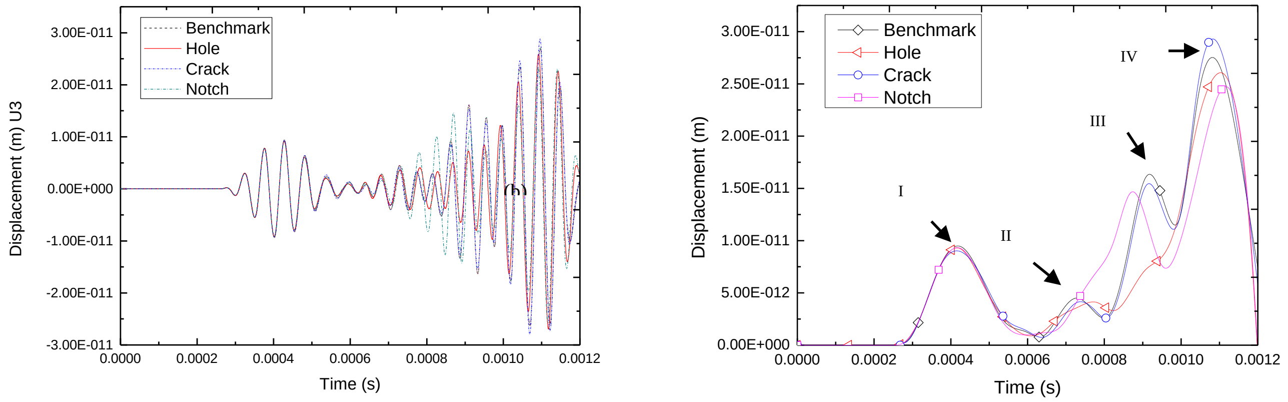


Figure 4 Displacement outputs from FE dynamic simulations along the longitudinal direction of the pipe

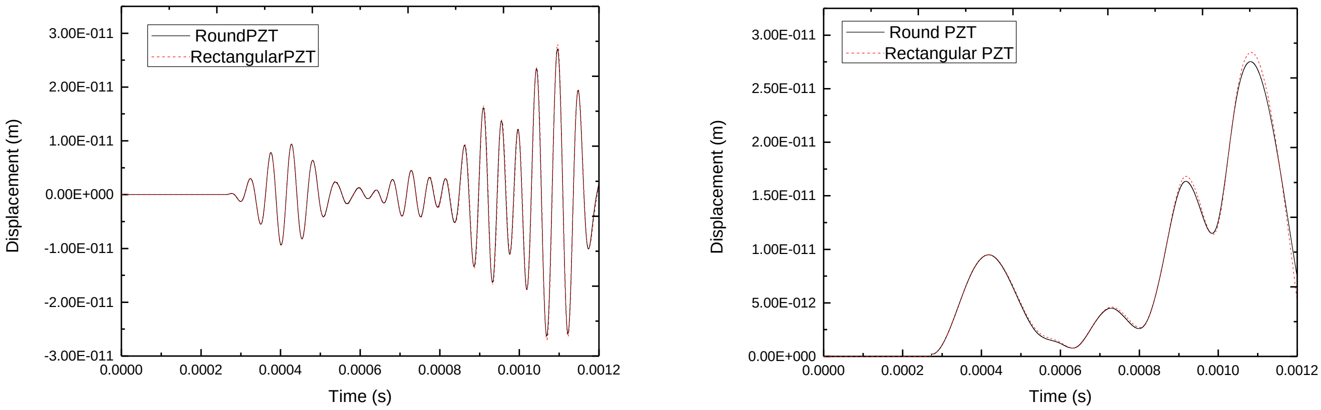


(a) (b)

Figure 5 Displacement signals from FE dynamic simulations of steel pipes with and without a defect, a) Before HT-processed and b) after HT-processed

To investigate the relationship between the guided wave propagation and defects, wave modes were identified based on their group velocities. According to Fig. 1 (b), the group velocity for L(0, m) mode is the fastest. Then, the wave packet I in Fig. 5 (b) should be longitudinal axial symmetric modes L(0, m). According to simulation results, the group velocity was calculated as 5278 m/s. According to Fig. 1 (b) (C_g = 5400 m/s), it is evident that wave packet I is L(0, 2). The result is consistent with the experimental result of 5300 m/s. The group velocity which we calculated for wave packet II is 2107.90 m/s. This value is very closed to the group velocity of L(0, 1) at 20 kHz in Fig. 1 (a). Then, the wave packet II is L(0, 1). In addition, the wave packet III in Fig. 5 (b) must be F(n, m) modes. For the wave packet IV, it could be an F(n, m) mode combined with L(0, m) mode. This is because the amplitude of VI wave packet is the largest. Wave packet II contains various wave modes and reflection waves. In brief, wave packet I is L(0, 2) mode, wave packet III is F(n, m) mode and wave packet II is L(0, 1).

The basic relationship between the guided wave propagation and defects can be determined. First of all, L(0, 2) mode is hard to detect the longitudinal defects, which means the results from the crack structure are almost identical to the benchmark ones in wave packet I. Rose [7] had the same opinion in his works. Besides, L(0,1) can be used to detect the circumferential cracks. This is because there are differences between the results from the model with a notch defect and those from the benchmark model in the region of 0.0006 s to 0.0008 s. Moreover, the F(n, m) is useful to detect some large defects. According to wave packet III depicted in Fig. 5 (b), it is clearly indicated that the results from the model with a hole defect show there is no F(n, m) mode compared to those from the benchmark model. Lastly, according to the comparison on the results from the model with a notch defect and the ones from the benchmark, it can be found that the notch can lead to waveform transformation, especially for the period between 0.0008 s to 0.001 s.



(a) (b)

Figure 6 Displacement signals from FE dynamic simulations of steel pipes with different shaped PZT actuators

As for the shape effect of PZT actuators on the elastic wave propagation in pipes, Fig. 6 illustrates the displacement outputs in the FE models using different shaped actuators. It is worth to point out that the rectangular PZT actuator can generate a slightly stronger excitation in the pipe than the round one with close size, as depicted in Fig. 6 (b).

Conclusions

Guide wave propagation in steel pipes and the relationship between the guided wave propagation and defects have been evaluated and investigated mainly using finite element modelling and simulations in the present study. The enhanced effective piezoelectric actuator model has been further applied in the FE models and the results show their effectiveness for generating elastic waves although a shape effect has been observed. Based on the numerical results, the longitudinal axially symmetric modes L(0, m) cannot be used on the detection of longitudinal defects while the non-axially symmetric modes F(n, m) are sensitive to different kinds of defects, which can be focused in future research for more comprehensive understanding on them.

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A Technical Note on Non-destructive Technologies for Stress Free Temperature (SFT) Measurement of Continuous Welded Rails (CWR)

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KEYWORDS: Non-destructive technologies, SFT measurement, CWR track, Australian mainline network

Introduction

Continuous welded rails (CWR) significantly strengthen railway track, and they provide the foundation for high speed and heavy haul railway revenue. However, by eliminating rail joints and gaps between rail sections, as the ambient temperature changes during a year from extremely cold winter to hot summer, high thermal stress may exist and change within welded rails. In some circumstances, if the CWR structure is combined with poor track maintenance, it may cause catastrophic disasters such as track buckling, broken rails, or/and derailment. To ensure the CWR track in stable, longitudinal stress (Neutral temperature of CWR) measurement via measuring and monitoring Stress Free Temperature (SFT) is the "Holy Grail" of the CWR track maintenance. Using the non-destructive method to measure and monitor the longitudinal thermal stress in CWR tracks is one of key efforts for railway track engineers and researchers for decades. In recent years, several relatively "matured" technologies have been applied in the field of non-destructive measurement of the neutral temperature of CWR.

Last decade in Australia, three types of non-destructive technologies were approved by the railway infrastructure authorities for neutral temperature in-field measurement. These includes the Magnetic Barkhausen Noise (TRACKSAFE RELEASE or RailScan), mechanical method (VERSE and A-Frame) and vibration method (D'Stresen). In this technical note, physical theories and technical background of these three technologies are introduced and discussed and a brief review of their results is conducted based on large amount of in-field measurement/verifications results and data comparison.

Magnetic Barkhausen Noise Method

The magnetic Barkhausen noise technology is equipped within a smartly designed machine – TRACKSAFE RELEASE system to carry out the measurement of longitudinal stress distribution in the CWR track. Based on the micro-magnetic theory, every part of ferromagnetic materials contributes to the uniform magnetisation. The TRACKSAFE RELEASE system is designed based on magneto-elastic principle to measure the stress distribution and the Neutral Temperature of continuously welded rails (CWR). The device operates by means of non-contact gauging and allows fast measurement and documentation of the actual Neutral Temperature of rails. The longitudinal stress and the Neutral Temperature are determined by measurement of characteristic magnetic values. The TRACKSAFE RELEASE system consists of a manually operated railcar, a central unit, and a pair of probe as shown in Figure 1. The central unit contains the computer-operated measuring electronics. A separate battery provides the power supply for the equipment. The probe consists of two yokes that are pressed around the rail-head. The rail temperature is measured by integral infrared thermometer.

The rail is magnetised by the application of an alternating magnetic field. Interaction of the magnetic field with the magnetic microstructure is orientation dependent and can be measured with an appropriate probe. The measured signal contains the pulses generated in the rail and has a noise-like spectrum. The amplitude of this termed Magnetic Barkhausen Noise (MBN) depends significantly on the longitudinal stress in the rail. Tension increases the amplitude of the MBN, whilst compression leads to its decrease. The higher the longitudinal stress, the higher the signal amplitude for the MBN.

Figure 1 TRACKSAFE RELEASE unit

After completing the measurement, the raw data are downloaded to a laptop for further evaluation. The final results are obtained by evaluating and plotting the measured values of the magnetic parameter and rail temperature vs. the longitudinal coordinate and measuring point number and further by depicting the load stress determined by means of the averaged magnetic parameters and calibration curve.

Mechanical Method – VERSE®

The mechanical method and with its devise - VERSE® is a technology patented by Vortok International. This technology is commercialized for CWR neutral temperature measurement by using the equipment of VERSE®. It is based on the beam-column bending theory, in which the axial load affects the vertical force required to lift a rail. The principle is to assume that the rail can be schematised as a simply supported beam – Euler-Bernoulli beam under concentrated loading to estimate the longitudinal stress in the track.

Figure 2 VERSE® equipment used on CWR track

VERSE® claimed that it can measure the CWR neutral temperature with an accuracy of 0.2°C and a standard deviation of 1.3°C. The method can be adapted to different kinds of rails and get instant result of CWR neutral temperature. As the method can be applied to tracks in tension, the ambient temperature must be lower than the true CWR neutral temperature.

D'Stresen Vibration Method

D'Stresen system has the potential of estimating the neutral temperature condition quickly and non-destructively. System components include a variable speed shaker, tune bar (TB) with accelerometer, magnetic rail temperature probe and data acquisition system.

Figure 3 shows the D'Stresen motorised shaker and the Tune Bar (TB). The shaker contains an eccentric weight which operates over a speed range of 65 to 80 Hertz (Hz) (3,900 to 4,800 rpm). The shaker is clamped to a railhead via mechanical cams. The Tune Bar – a cantilever beam and accelerometer that vibrates sympathetically, due to the shaker's rotation when clamped to the railhead nearby. After installation, a computer controls the motor through a narrow sweep encompassing the cantilever's first bending resonance, then records the largest resulting peak-to-peak velocity signal. According to the manufacturer, this velocity can be related to the existence of longitudinal load in the rail. Roughly stated, the velocity is largest for a rail without longitudinal stress and is reduced in a predictable fashion as either tensile or compressive thermal stress exists.

Figure 3 D'Stresen system mounted on CWR track

Comparisons on Three Non-destructive Technologies

Magnetic Barkhausen Noise Method

The Magnetic Barkhausen Noise method has a significant limitation of applicability when it is used on Australian mainline track. This is because of there is a significant asset management differences between the Continental European Railway (also including the Chinese, Japanese and Russian Railways) and the English-speaking countries' railways. That is the non-English speaking countries usually have a fixed interval of rail changing policy, this can either based on the years after installation or million gross tons of traffic passed. However, the English-speaking countries usually utilising the "condition based rail changing policy" i.e., they only replace the defected rails that are found by the inspection. Hence, after many years of traffic revenue, within one CWR module, it may be consisted many rails made in different years, by using different manufacture methods, with different head-hardened way, etc., although their profiles are the same or very similar. For example, in Melbourne Metro, for the rails in one CWR modules, the predominant track structure over the Belgrave Line consists of 5 types of AS 53 kg/m profile rails – AIS 107LB, AS 107 O.B Colvilles, AIS 53kg/m, BHP 53 kg/m, and One Steel 53 kg/m. These rails can be mixed in one CWR module and their calibration curves are significantly different. A significant advantage of the MBN method is, because of its measurement results are only based on the stress condition of the rails, hence, it has the capability/potential to be used to measure the neutral temperature of CWR on sharp curves, non-ballast girder bridge and turnout area (stock rails and closure rails).

Mechanical Method – VERSE®

Because of its relative simple physical background and easy for operation, it was acknowledged as a most reliable device and can provide accuracy results. It has been approved by all the major railway authorities in Australia and has been included into the technical standards of CWR stability management. Major shortcomings for this device including:

- Low productivity: VERSE® testing needs to unclip and re-clip the fasteners for at least 20-30m track in length. At least 3 to 4 labours are required, including an operator, P.O. and labours for unclip and re-clip fasteners. The measurement process needs about 40 minutes;
- Limitation of locations: VERSE® cannot be used on curved tracks, which have a radius of equal or less than 700 m, non-ballast bridges, and locations close to fix points;
- Ambient limitation: VERSE® is the device that only can be used to measure the neutral temperature of CWR when it is in the tension, e.g., VERSE® cannot be used when rail temperature is reached to the designed neutral temperature (in Australia is 38 °C or higher, e.g. ambient temperature is 33°C);
- High cost: About $ 6,000 – 7,000 per working day.

D'Stresen Vibration Method

D'Stresen method shows some good results at some verification trial and in-field measurement services. However, it still has not developed a quick in-field calibration/verification process to ensure its reliability and the accuracy of their results. Before further improvement can be achieved, it cannot be used as a stable technology to carry out day-to-day CWR measurement. Based on its physical theory, it has the capability to be used to measure the neutral temperature of CWR on sharp curves, but no evidences showed that it has the potential to be used on non-ballast girder bridge and turnout area.

Conclusion

A large number of neutral temperature results of CWR track measured by the Magnetic Barkhausen Noise (TRACKSAFE RELEASE), mechanical method (VERSE®) and vibration method (D'Stresen) have shown that all of these three methods have the capability to carry out the CWR neutral temperature measurement. However, some further improvements are required for TRACKSAFE RELEASE and D'Stresen methods to ensure them suitable for Australian track conditions.

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Conference News

- Special session "Recent Research Advances on Innovative Techniques for Structural Health Monitoring" in the 16th East Asia-Pacific Conference on Structural Engineering & Construction (EASEC-16), 3-6 Dec 2019, Brisbane, Australia. Organized by Dr Jun Li and Dr Qingzhao Kong. https://easec16.com.au/
- The 9th International Conference on Structural Health Monitoring of Intelligent Infrastructure, 4-7 August 2019, St Louis, Missouri, USA. https://shmii-9.mst.edu/
- The International Conference on Mechanical and Manufacturing Engineering Research and Practice (iCMMERP-2019, http://icmmerp.net.au) will be held on 24th-28th November 2019, Sydney, Australia, Organised by Prof Richard Yang. http://icmmerp.net.au

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