# ASSESSMENT OF LOCAL/GLOBAL STRUCTURAL HEALTH MONITORING OF COMPOSITE PIPES

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### Abstract

*Composite pipelines made of winded fiber reinforced resins are increasingly used, especially in petroleum and gas industry, for their good mechanical properties, combined with reduced weight and excellent behavior under hostile environment conditions. These entire advantages counterbalance the higher cost required by the material used and for the manufacturing technology.*

*Having in view that high reliability is required for such pipe networks, it is mandatory to have in view trusting nondestructive inspection (NDI) methods for achieving efficient structural health monitoring (SHM). A good combination of global and local methods is to be desired for meeting such demand. The paper presents some aspects concerning application of Lamb wave method and infrared thermography (IRT), considered to be best combinations mentioned above, with high efficiency and versatility, enabling successful field inspections.*


## 1 Introduction

Composite pipes offer a good solution for the transport of various fluids due to a number of important advantages [1]: (i) low propensity to corrosion in various environments, especially aggressive ones, like see water proximity; (ii) non-existence of paraffin deposits, in case of petroleum transit; (iii) low weight; (iv) easier joining of different segments.

Dissemination of such pipes greatly depends upon the provided data concerning its reliability in service [1]. This quality consists in the high residual mechanical performance of damaged pipes and the possibility to assure trusting structural health monitoring (SHM) services. In turn, SHM has to be provided by adequate nondestructive inspection (NDI) methods, generally combined from the two main classes: (a) global methods, able to detect the presence of a defect or damage, and (b) local methods, from which sizing and characterization of the defects is expected, which allows adequate measures to be taken during exploitation and maintenance of pipes, according to the field conditions.

The paper presents results obtained in the health monitoring of GFRP pipes using the Lamb wave method and IR thermography method as global/local inspection methods. Kissing bond defects in the coupling area and low velocity impact damages were focused during the inspection procedures.

## 2 Global Inspection

### 2.1 Studied Items

The research was performed on glass/epoxy 6" pipes, with an average 4.5 mm wall thickness. Basically, two coupling sections were considered in for these pipes: collar couplings (fig. 1) and tapered couplings (fig. 2).

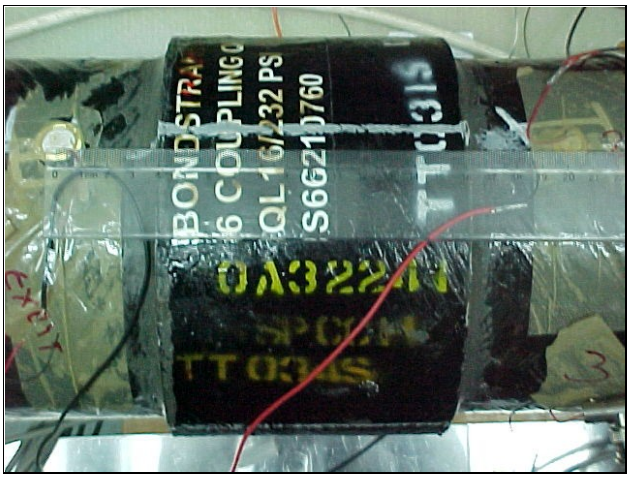

Fig. 1. Collar type coupling

Fig. 2. Tapered type coupling

## 2.2 Evaluation of Lamb Wave Method

It is generally accepted that the Lamb wave method is an effective long range inspection tool. Nevertheless, the inspection is more difficult for pipes, where the variety of wave modes is extended and therefore transmission has to be carefully monitored [2].

Accordingly, the Lamb wave method was applied following a numerical-experimental approach, with continuous result inter-checking. Various PZT wafers, from inexpensive small mobile buzzers (see fig. 1) to flexible encapsulated rectangular transducers, with weak and strong interface with the pipe wall were evaluated. It was evaluated especially the wave directionality which can be obtained with single, inexpensive or removable transducers. A finite element (FE) simulation, using LS-Dyna code, run under an ANSYS platform, shows that this is fairly possible for rectangular wafers (fig. 3). Multiphysics and structural only models were used when the strong interface was considered.

As flexible PZT patches are quite expensive, it was studied the possibility to replace such a transducer with a battery of cheap PZT buzzers, with similar efficiency in generating directional waves. To this end, four such buzzers were modeled with structural only technique [3], on a similar FE model (fig. 4). The results obtained seem not to be encouraging, as a powerful circumferential wave was generated this time. It is still hoped that a mere carefully chosen spacing between buzzers, in accordance with the frequency for the intended waves will solve this problem.

The transmission of Lamb waves through a damaged area, created by a low velocity impact event proved to present a significant distortion (fig. 5).

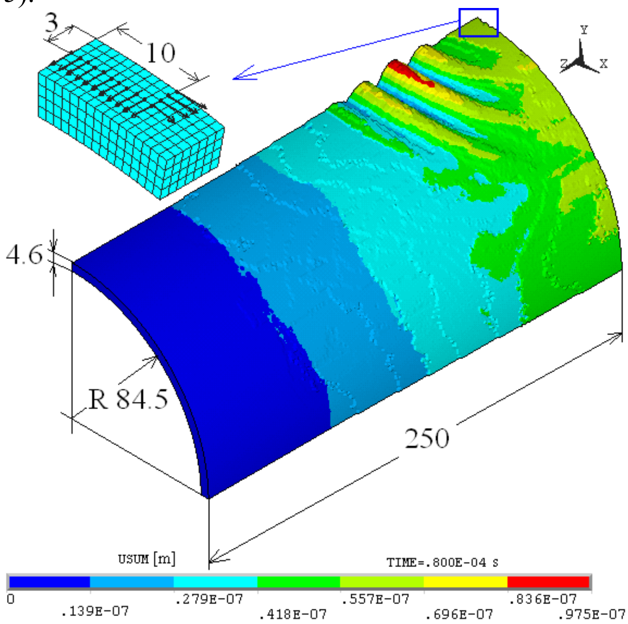


Fig. 3. Directional Lamb waves excited by rectangular PZT, outlined by numerical simulation

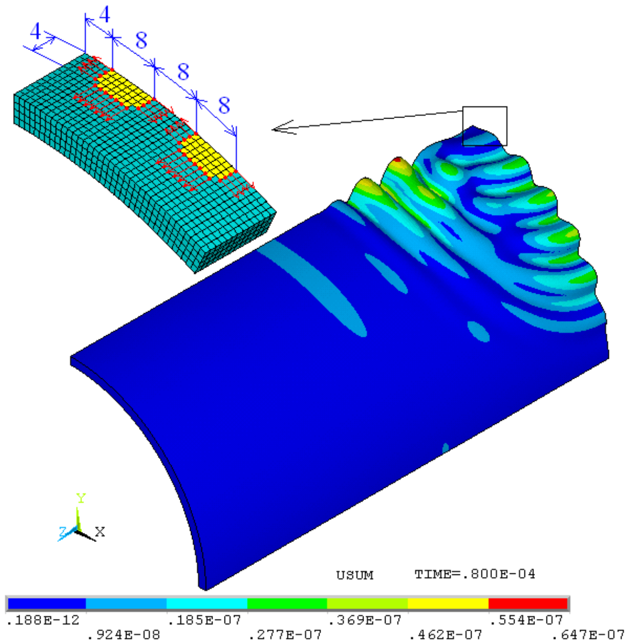


Fig. 4. Lamb waves excited by PZT buzzers

There were not detected so far important, detectable echoes produced by the Lamb waves crossing a damaged area, at least not for the damages produced so far ante experiment. No important effect of the water filling was detected, either.

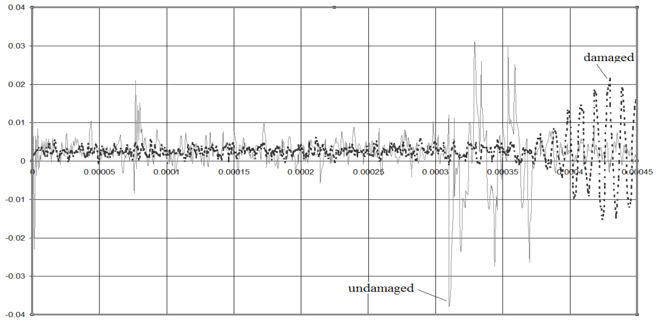


Fig. 5. Lamb wave distortion obtained by transmitting through a damaged area

## 3 Local Inspections

The IR thermography method was used in two variants: (1) passive like variant, when warm or cold water was filling the pipe sections, and (2) active variant, with xenon lamps. In both cases, a Therma Cam PM 350 device, with 256 x 256 matriceal de detector, spectrum band 3.4 ÷ 5 µm and thermal sensitivity > $0.1^0$ C.

### 3.1 Passive-like IR Thermography

The passive variant was able to put in evidence imperfections/defects in the collar coupling area (Fig. 6), where the local total thickness of the wall should make quite impossible the use of the active variant. The tapered type coupling proved to be better made (fig. 7).

Areas damaged by a low velocity impact event were also successfully scanned using this variant, with a careful choice of the temperature gradient between the inside warm water and the ambient temperature.

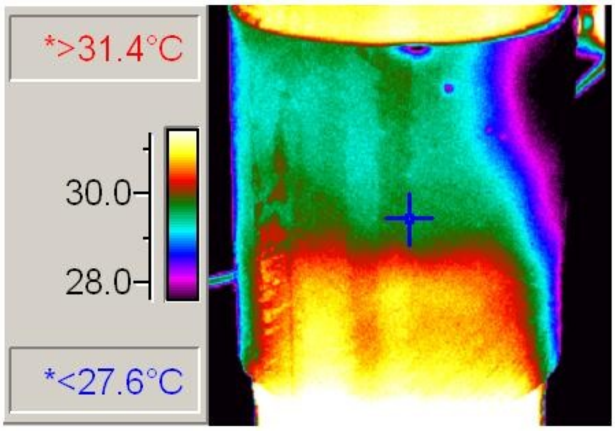


Fig. 6. IRT image of defects in a collar type coupling, passive-like variant

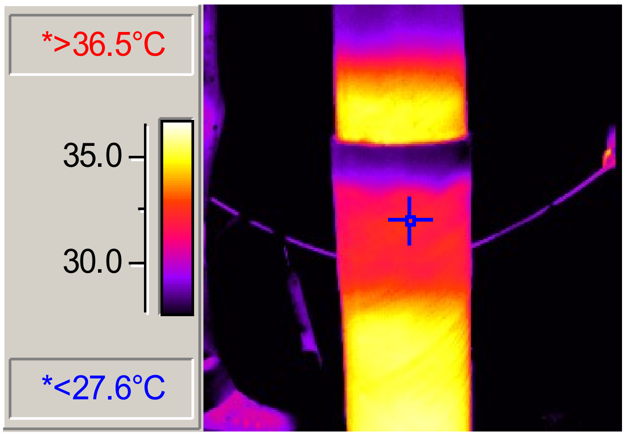


Fig. 7. IRT scan of a tapered type coupling, passive-like variant

A damage produced by a 20 J low velocity impact can be seen on figure 8, while in figure 9 is presented a damage produced by a 30 J impact event.

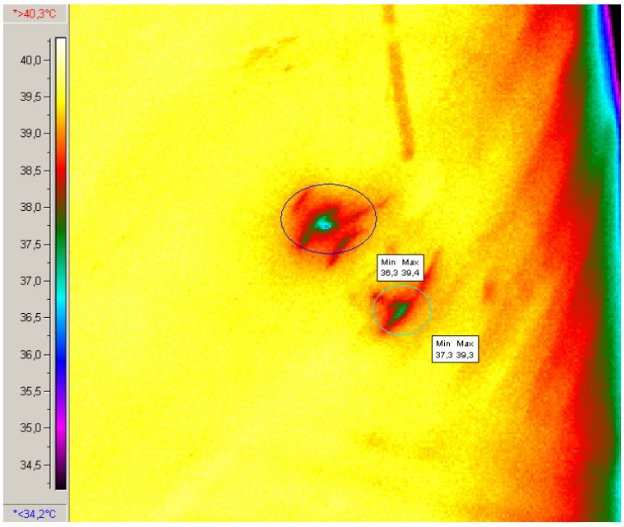

Fig. 8. IRT image of a damaged area produced by a 20 J low velocity impact event, passive-like variant

### 3.2 Active IR Thermography

The active method, using the xenon lamps for inducing the local thermal gradient in the inspected area, met inconveniences incurred by the inherently rough outer surface of pipes, which cannot be avoided at this stage of the classic fiber winding technology used in the manufacturing process. The problems were caused by the important reflections produced on the highly reflecting and irregular outer surface.

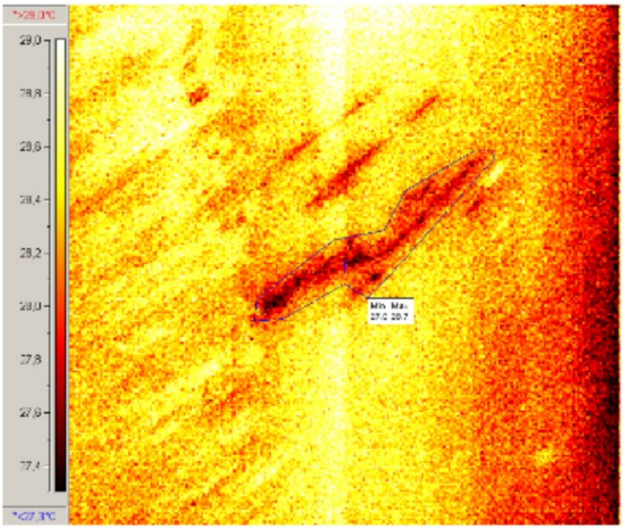

Fig. 9. IRT image of a damaged area produced by a 30 J low velocity impact event, passive-like variant

IRT scans using this method for the damaged areas previously inspected with the passive like method can be followed in figures 10 and 11 with careful avoidance of excessive reflections.

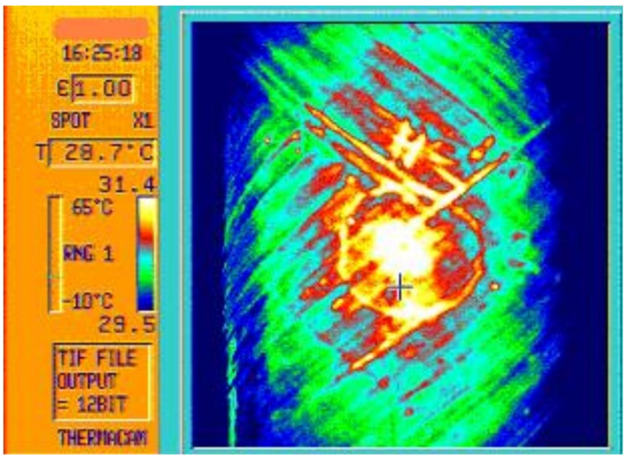


Fig. 10. IRT scan of the damaged area produced by a 20 J low velocity impact event, active variant

## 4 Conclusions

The combination used for local/global inspection of composite pipes looks well adapted for field NDI of such items. The IRT method provides good scans by in the two variants, on condition that the operator has some experience and patience to find the good temperature gradients or angles to get the images. Some improvements in interpreting the images and the enhancement of the contrast with more sensitive cameras and more elaborated software will continuously increase the quality of IRT scanning.

Further work on increasing the efficiency of Lamb wave inspection on distances ranging at least the length of smooth standard pipe sections in the case of such highly anisotropic and dispersive materials is still desired. Also, interaction of the two methods, meaning getting sonically stressed damaged regions, easier to image by IRT method, which was not concluding in this research stage, could also bring very interesting added value in this approach.

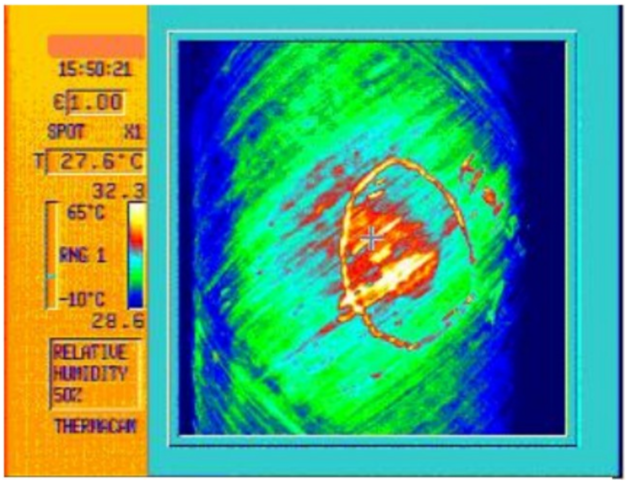


Fig. 11. IRT scan of the damaged area produced by a 30 J low velocity impact event, active variant

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