Guided Wave Training and Certification

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Introduction

Guided Wave (GW) technology is probably one of the few genuinely new NDT techniques to be introduced in the last 20 years. This in itself presents a whole new set of challenges to ensure that all operators are trained and competent to use the equipment, to gather data and interpret the results. It is widely recognized that the major limitation of the technique is the competence, training and experience of the operator; as the reputation of the technique is inextricably linked to the ability of the operators.

GW technology has been used since the late 90's for rapid screening of long lengths of pipe-work. One of the main attractions to this technique is its ability to screen a relatively long length of pipe from a remote location (avoiding the need to directly access the area to be inspected).

The GW modes present in pipes were first studied by Gazis [1] but this was a purely analytical study. In the early 90's a software was developed at Imperial College (Disperse [2]) which provided a rapid method for tracing guided wave modes for different pipe geometries and materials.

The GW technologies now available in the worldwide market are based either on electromagnetic generation or piezoelectric generation. The patent for the piezoelectric generation of guided wave modes (and the related mode extraction mechanism) was published by Imperial College in 1997[3]. The initial technology developed at Imperial College within a collaborative European project in 1997 was initially using one of the longitudinal modes (L(0,2)). The relative advantages of using the Torsional wave mode T(0,1) were then realised and use of this mode was exploited in the very first production equipment released by Guided Ultrasonics Ltd (GUL) in 1999 [4]. The parameters affecting the sensitivity of this mode to different types of defects were studied at Imperial College [5] and this mode is now used in almost all GW work.

Over the past 10 years the technique has been demonstrated to be effective in several applications such as GW screening of pipes on racks, or insulated sections of pipes, these are now considered routine service inspection. Screening of road crossings, buried pipes, wall penetrations and underwater pipes are more complex applications which have been successfully carried out using the latest developments of the Wavemaker Pipe Screening System (WPSS), for example the GUL Wavemaker G3 and Enhanced Focussing processing algorithms.

Limitations of the technology apply both for the above mentioned 'easy applications' and 'complex applications'. Sensitivity to defects and range of test vary depending both on the conditions of the pipe (material inside, pipe condition, coating and embedding material) and the type of equipment used.

This article will address the issues related to GW operator training in terms of the type of technical information needed to be transferred to the trainee during the training; the close link between the operator training and the Guided Wave tool used; and the experience required for trainers to provide an effective training. This article also discusses a GW operator training scheme created by Guided Ultrasonics Ltd, which has already gained recognition by several international petrochemical companies.

Guided waves: why low frequency ultrasound makes this technique so different from standard UT

1.1 Theory

The Guided Wave modes existing in pipes are described by the dispersion curves[2]. At each given frequency there are several propagating Guided Wave modes (and infinite non-propagating modes). The speed of each mode changes with frequency and this causes the dispersion effect (in a wavepacket the components at different frequencies will travel at different speed causing a distortion of the wavepacket in the time domain). The different modes are characterized by a displacement pattern that at a given frequency is different depending on the mode and for a given mode this would also be changing with frequency.

1.2 Flexibility vs Complexity

The flexibility of the GW testing method means that a wide variety of applications and conditions will routinely be encountered. The exact behaviour of the propagating waves (such as attenuation and coherent noise) cannot be calculated exactly before the test takes place. It is not therefore possible to write tightly controlled procedures which specify every step of the inspection and data analysis process.

The GW propagating occupies the entire cross section of the pipe. For this reason the GW testing method is equally sensitive to defects on the inside and outside surfaces of the pipe wall. Additionally, defects such as circumferential cracking, laminations, porosity, SCC and axial cracking will all cause some degree of reflected signal. The potential to detect such a wide variety of defects is an added bonus of the Guided Wave testing method, but also adds to the complexity of the analysis for the operator. Once a pipe section of concern has been detected by GW it is often difficult to prove up the defects using conventional techniques, as the appropriate technique must be used to detect the particular type of defect which is present.

1.3 Managing complexity

The physical theories governing guided wave propagation are complex and so sophisticated processing algorithms have been developed and implemented by Guided Ultrasonics in their WaveProG3 software.
The GUL training scheme was designed in order to provide the operator with the necessary skills to test simple systems and evaluate the parameters affecting the test (in fact one of the main differences with other existing training schemes is that the operator level is defined on the basis of applications that can be handled by the operators). The Guided Wave operator is required to optimise the test settings and evaluate the quality and range of the inspection whilst on-site which requires logical thinking, training and some degree of experience. Indeed the training scheme was designed to evaluate the capability of logical thinking when the operator faces a new problem (not directly experienced during the training examples).

1.4 Standard UT vs GW

Generally standard UT operators are aware that the higher the frequency, the higher the sensitivity to defects. This basic concept breaks down when using Guided Waves as it was demonstrated by some study conducted at Imperial College [6]. The fact that Guided waves propagate along the length of the pipe and that their sensitivity to defects is related to the mode shape of the specific mode and the other modes (propagating and non-propagating) present at the specific frequency of the test makes guided waves very unlike the standard UT waves.

It is not necessary for the guided wave operator to understand the complex GW theories but it is important that the operator can manipulate the data. Generally the basic information that a operator needs to evaluate includes the amplitude of the echoes, the symmetric and non-symmetric behaviour, the axial extent of the echo, the changes with frequency and the orientation (in

terms of angle) of the echo. The number of parameters to be looked at increases when operators become Level 2 GUL (as per training scheme described in a later section). The concepts introduced in the training and the skills required are therefore more typical of an experienced technician rather than a simple operator (as it is conceived in standard UT). The operator must also have a level of computer literacy which is more advanced than that which is required for most standard UT techniques.

Moreover Guided wave testing aims to perform a screening of long lengths of pipe. This implies that the Guided wave is transmitted through several features along the length of the pipe (welds, supports, bends etc…). The consequence, in terms of analysis, is that a Guided Wave echo from a pipe feature located relatively far away from the transducer ring will be affected to some extent by the features present before it. For example a weld at 20 m distance may not be seen because of some severe corrosion present in the pipe at some distance before it. This effect makes Guided Wave result interpretation very different from the interpretation of standard UT results.

Opposite to standard UT, GW is a very productive screening method by which many hundreds of meters of pipe can be inspected in single day of testing. The GW operator of the equipment must therefore be consistent and accurate in the organisation of the large amounts of information which are generated. The WavePro software has been designed with this in mind and assists greatly in data labelling, storing, printing and retrieval. The guided wave operator must learn to use all of these functions if they are to achieve productive and accurate results.

It is for these reasons that the skills, training and experience required to perform reliable and accurate GW measurements are different to those required for conventional UT techniques.

Guided Waves equipment: many different tools could be available for interpretation

Guided wave systems have been developed independently by different organizations over the last 8 years. The capabilities, productivity and sensitivity vary dramatically from one system to another and the tools provided within the software for each system are radically different, although they may appear similar to a non expert in the field. Previous experience shows that operators trained in the use of other systems (non GUL) cannot adequately operate the WPSS without undergoing the full GUL training course: Simple short courses have proved impractical and unsuccessful.

In order to perform an accurate assessment of the pipe condition there are several tools which should be regarded as essential components of the GW system, these are:

- Reliable reception of both symmetric and non-symmetric wave components; This allows the trained operator to distinguish between symmetric features such as welds and non-symmetric features such as defects. This feature is available in some of the GW systems which are available but is most robustly implemented by the WavePro software.
- Frequency sweeping; The complex behaviour of GW signals means that the ability to sweep dynamically through a range of frequencies is a vital step in the analysis process. This is a patented algorithm which is only available in the WavePro software and is taught during the Level 1 training course.
- Unrolled pipe view; The ability to determine the orientation of non-symmetric signals, in terms of their clock position around the circumference, dramatically improves the reliability of the analysis and prove-up of defective locations on the pipe. This feature is only available in the WavePro software and its use is taught during the Level 1 training course.

There are many other analysis tools which are available to the GW operator using the WavePro software which he must be familiar with if he is to achieve good inspection performance.

It is essential, therefore, that an effective training scheme in GW should be restricted to usage of specific equipment with given interpretation tools (and expected equipment performance).

Training

Guided Ultrasonics Ltd have designed a training scheme for GW operators which has been in use since 2000, and has been continually updated to keep up with new applications and developments. Guided Wave theory background was used for the definition of the interpretation skills required by the operators. The skills taught during the training refer to the tools available to operators using Guided Ultrasonics Wavemaker equipment only. The training also incorporates a large amount of data analysis using real site data which has been collected in a wide variety of application and under all likely conditions. During the level 1 training several applications are considered and the trainee is made aware of how to combine the information given by different interpretation tools in order to achieve the correct interpretation for the given structure. A trainee with several years of site experience has generally an advantage in comparison to non-experienced operator as the signal interpretation also requires understanding of the features present in a

pipe in different conditions. (e.g. features present in a road crossing are different from features present in an insulated pipe.)
A large number of hours of site testing experience was necessary in order to establish testing procedures for all applications and a detailed scheme which leads from Level 1 to Level 2 through supplemental training courses.

Level 1 training comprises 5 days training course and 5 days in field under the tutelage of a GUL Level 2 operator. The field training must be completed within 3 months of the initial course. The course comprises the following main subjects.
∀Data collection
∀Basic Guided Wave theory
∀Basic interpretation
∀Level 1 fault finding
∀Report preparation
In order to examine the trainee's understanding and skills the candidate is tested by means of written, computer and practical exams. Thus, all aspects of the inspection procedure from equipment setup through to final report writing are assessed. An operator who successfully passes GUL examination receives a paper certificate with name of the person, date and company affiliation which states that the operator has successfully passed GUL Level 1 classroom training.

The GUL training scheme also establishes that the operator must gain experience on the use of the Guided Wave tool and interpretation in real site testing under the supervision of a level 3 GW operator in order to receive full level 1 status. They then receive an operator ID card which clearly states the issue and expiry dates of their certification (initially valid for 1 year). After the expiry date, the operator undergoes a revalidation procedure in which experience (in terms of number of days and number of tests) and the performance of the operator is assessed according to GUL standards. Revalidation of the operator's certification is only granted if they fulfill the requirements set out in the GUL training scheme.

A candidate who holds a valid GUL level 1 operator certificate is capable of performing the following operations:
• Set up and check equipment and perform tests under default collection parameters
• Basic fault finding and maintenance of the equipment
• Interpretation for basic applications (such as screening of pipes on rack, insulated lines and similar) and reporting the results
• Varying test parameters under the supervision of a level 2/3

A GUL certified level 1 operator is therefore given more responsibility and expected to exhibit more skills than the equivalent ASNT or PCN level 1 for conventional UT techniques. This strictly necessary to ensure good performance of the technique.

It is also important to note that GUL Wavemaker G3 equipment has implemented an effective method to monitor operator experience, whereby each operator has a personal ID key which stores the information about the number of days experience, number of tests performed and revalidation date together with other useful information to monitor operator quality. Each testing day the operator must logon to the Wavemaker G3 instrument and the information on the key will be updated with the tests performed by the operator. This method for monitoring operator experience and quality is unique and very effective.

Level 2 training comprises of a 5 days training course. The main subjects of the course are:
∀Level 2 Guided Wave theory
∀Advanced interpretation buried pipe, road crossings etc.
∀Use of wide frequency equipment
∀Advanced calibration systems and use of multiple rings and Wavemaker G3 instruments
∀Advanced troubleshooting
In order to assess the level 2 trainee's understanding and skills, the candidate is tested by means of written, computer and practical exams.

According to the GUL training scheme Level 2 operators are deemed capable of performing the following operations:
∀Selecting optimum test parameters
• Carrying out tests and interpretation for advanced applications.
• Supervising and auditing level 1 activities.
• Assisting in training level 1 operators.
• Adapting procedures to be job specific.
• Carrying out advanced fault finding.

A Level 3 operator is an engineer with PhD degree in the field of guided waves and with proven site experience. Also level 3 will have experience in participating as second person in level 1 trainings as second trainer.

Conclusions

Guided waves and standard UT are very different in their operational use, interpretation tools and operator skills required. Many different tools can be

made available to the operators depending on the Guided Wave equipment used and this makes the interpretation procedures radically different when using different equipment. It is therefore essential that the trainee is trained specifically in the use of the Guided Wave equipment which they are using.

Operator quality is very important for the NDT industry and this is especially valid for techniques such as Guided Waves where operator training and experience are key to good performance of the technique.
Existing standards for conventional UT training in Europe (PCN) and USA (ASNT) are not directly applicable for the definition of the training and skill requirements needed for Guided Wave operators (level 1, level 2 and level 3 skill levels and responsibilities are different).

A GW trainer must be a person with strong background in Guided Wave theory and very experienced in the usage of the specific Guided Wave tool introduced during the training.

GUL has in place a suitable and reliable training scheme for training GW operators in the use of the Wavemaker pipe screening equipment. This scheme incorporates the monitoring of operator experience and operator performance which is essential for continued successful performance of the technique.

References

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