The future of ultrasonic NDT with IoT

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Abstract

Digital products and services are disrupting traditional industries, now, everywhere. The latest generation of smartphones, tablets and wearables play a key role in advancing technological avenues, in providing higher flexibility, and in improving productivity levels. Opportunities arising from the adoption of Internet of Things (IoT) solutions are getting understood and embraced by virtually all industries today, and by more and more companies. These opportunities are also finding their way into the manual ultrasonic Non-Destructive Testing (NDT) market.

Frequently found roadblocks to the uptake of such powerful and versatile digital platforms in NDT are found to be

- regulations, e.g. usage of wireless data transmission in oil & gas (O&G),
- restrictive company rules, e.g. companies blocking smartphones or cameras,
- long standing and user habits, e.g. maintaining inefficient outdated workflows,
- fear of external data storage, e.g. blocking cloud-based backup solutions.

To overcome these and expedite the digital transformation in the NDT markets, NDT supplier companies need to take the efforts to illustrate the huge number of advantages that the combination of NDT and digitalization yield.

On examples from various industries, inefficiencies in ultrasonic NDT workflows will be identified, and faster, more flexible, lower cost, and higher quality testing solutions will be suggested. The authors will illustrate how users have achieved tremendous benefits from using IoT-based solutions.

Based on these case studies, the attractiveness of the business case for investments in digital infrastructure and IoT in NDT applications will be clearly shown, and evidence of savings by using novel solutions will be provided.

1. Introduction: Purpose and history of Ultrasonic NDT

Commercial instruments and transducers to perform ultrasonic testing on materials were introduced in the 1960s and 1970s. Their purpose was to confirm that there were no defects above a target size, to identify and monitor significant defects, and to measure the size of these defects. Ultrasonic NDT is currently used in many industries including steel plant, manufacturing, aerospace, oil and gas (O&G) and transportation sectors. The gathered information about the component being inspected serves as an input to predictions of remaining life based on fracture mechanics.

Since the introduction of these instruments, the inspection has always involved the interpretation of an A-scan by an expert operator. To this day, this remains unchanged. Ultrasonic inspection is a highly-standardized, proven technique that has been working as expected (and advertised) for decades.

The growth of ultrasonic NDT closely tracks technological progress in electronics, displays, and computer processing power. For manual conventional ultrasonic testing, the last big change in the history of products was the move from analog systems to digital ultrasonic flaw detectors. This shift made it possible for users to operate truly portable, handheld equipment. It also enabled operators to reduce errors and save time by providing them with useful features, such as gates, or the automatic calculation of the indication locations – even accounting for skip distances.

If we take an approach to inspection focused on the “jobs-to-be-done” (1), the customer of the inspection service needs a reliable result: for example, to confirm that their asset is suitable for use for a defined period, or to understand the extent of the defects found and so decide on repairs needed – or to scrap the part. Typically, this result is in the form of a paper-based report that needs to be archived for a long period of time.

If the sensitivity for the inspection is set according to a common procedure, then the result should be the same with any equipment used, analog or digital. If not specified in the procedure, the choice of instrument to use is down to the largely subjective personal preference of the inspector.

The customer of an inspection does not typically care which instruments are used, or not even which personnel performed the inspection. The customer needs a solution, typically to the minimum standard of quality, and as cheaply and quickly as possible.

2. Ultrasonic NDT: Current situation and realities

We have identified and addressed five major pain points associated with end-to-end NDT inspection processes as described above. We have done so by observing NDT equipment users in manufacturing and service environments (2).For example, in optimizing workflows we accompanied NDT professionals in the field, observed their working procedure, broke it down into separate steps, and analyzed each step as well as the entire procedure, looking for improvement potential. We have also questioned the status quo of time-intensive activities, such as those in the “reporting phase”.

2.1 Skills shortage and aging workforce:
The first pain point is the skills shortage of experienced expert ultrasonic inspectors, which represents an industry-wide issue. This situation will become worse as a large percentage of skilled inspectors approach retirement age. One severe limitation to replenishing the global pool of inspectors is the lengthy and costly amount of training and experience that is required for an inspector to become qualified. The minimum is 9 months experience for an ultrasonic level 2 inspector trained to the PCN scheme. With

the recent downturn in the O&G industry resulting in lower demand, making a career in NDT seems less attractive to new users in advanced economies. Figure 1 shows an age profile of qualified BINDT members in the NDT industry (3).

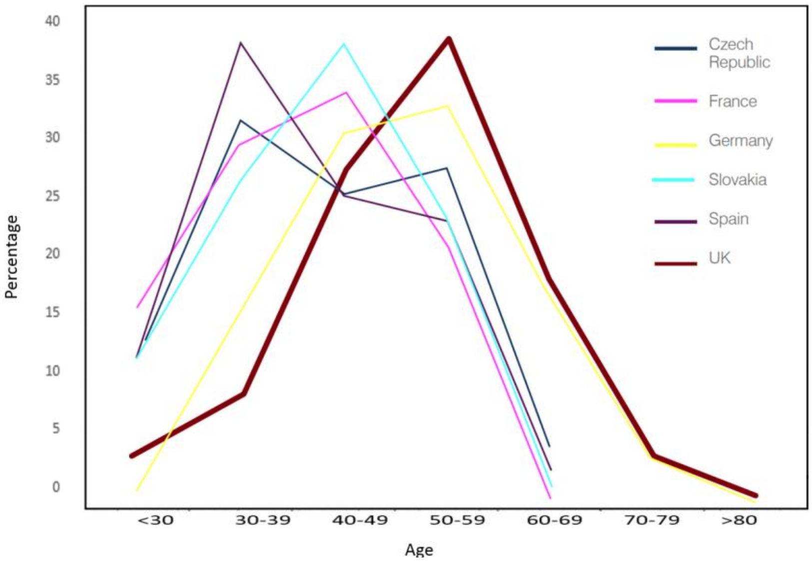

Figure 1: Age profile of NDT operators taken from BINDT, the situation is particularly concerning in the next 10 years in UK and Germany, with many users approaching retirement age.

2.2 Complex user interfaces
Most of the NDT equipment available looks complex and is also complex in use, as it has typically been designed by experts for experts, with the mentality that simplification equates to “dumbing down” the product. Not only the measuring process itself but also the presets intended to ensure the correct setup prior to the measurement exceed, in some cases, the understanding of the user.

2.3 Complicated data interpretation
In analyzing measurement results of A-scan images, competence in analysis and therefore the quality of the findings can vary greatly between operators. While experts often rely on unprocessed data to reach experienced conclusions, new users prefer processed and graphical images to interpret the results.

2.4 Incomplete traceability
Until today, NDT equipment operators have had to manually document measuring procedures in such a way that they can prove the required guidelines have been followed, that the instruments and the probes being used have been properly calibrated and verified, and whether any deviations from the original procedure were made. These issues lead to a lack of traceability along the process. As recent news (4), (5) show, the implications on personnel, business performance, brand, customer trust can be significant.

2.5 Obstructed data sharing
One of the most time-consuming tasks today is to communicate a result in the field. Observations have revealed that the time spent on this task can be a factor between one and two times the actual time used for the measuring task. Communication of results has become an important element when interacting with colleagues on a large investigation site, the back-office, suppliers, or customers. Thus far, data have been typically stored on

paper, on the NDT device itself, or on removable storage. Some devices have relied on manual export of data using said storage, followed by importing this data into tools on a PC to prepare the report – a series of manual and non-value-adding steps with high potential for errors and data loss, also causing distraction from the actual jobs-to-be-done.

3. Current state of technology

The smartphone, web-based email, wireless connectivity and on-demand streaming are consumer products we mostly all take for granted. Mobile devices of the latest generation have shown how operations can be simplified to a level where even children or elderly persons can make use of them.

The user interfaces in many of today's commonly used applications, social media networks and websites, like Facebook, Dropbox, Skype, and Amazon have many layers of options for customization and optimization to cater for a wide variety of user needs. That is also why these product development teams they have designed their products' user interfaces to allow for a simple intuitive usage without any training required – despite the multitude of applications and use-cases enabled. And while a more detailed setup of advanced settings can be done in interfaces dialogs hidden away, new users can start using these tools immediately, without any prior familiarity with the product itself, and for sure without any need to read printed documents, such as leaflets with Operating Instructions or thick User Manuals.

The "Internet of Things" (IoT) is a developing trend and is still in the early stages of growth. McKinsey (6) defines IoT as sensors connected by networks to computing systems. These systems can monitor or manage the health and actions of connected objects and machines. Wikipedia (7) defines it as the network of physical devices, vehicles, home appliances and other items embedded with electronics, software, sensors, actuators, and connectivity that enables these objects to connect and exchange data. We blend these two viewpoints to create our definition as a network of accurate measuring sensors connected to mobile devices and securely connecting these mobile platforms through the Web to allow for interaction with other systems.

We will show how ultrasonic NDT can use today's technology to remove those pain points listed and to enable the inspector's role to be focused on their value-adding operations that ultimately support the goals of the customer. The side-effect is less effort expended on secondary, low-value-adding aspects of their role, such as reporting, and data storage and management. We will go into depth in the following sections on how this is or could be realized.

4. Overcoming roadblocks for early adopter benefits

Whilst the step to today's technology can be established rather easily everywhere, speed of adaptation has been too slow in the industries requiring ultrasonic inspection services to keep the industry healthy and competitive, and established workflows require updating. Across hundreds of interactions, typical roadblocks to the uptake of such powerful and versatile digital platforms in NDT were found to be:

- Regulations; e.g. usage of wireless data transmission in oil & gas, and nuclear environments
- Restrictive company rules; e.g. companies blocking smartphones or cameras
- Long-standing habits of users and stakeholders; e.g. maintaining inefficient outdated workflows
- Security concerns regarding external data storage; e.g. blocking cloud-based or even USB backup solutions.
- A general mistrust of technology-driven systems and services.

Productivity and speed will play an increasing role in the customer's needs. Early adopters will not only need to see their immediate benefits, but also understand the advantages of adopting associated new business models. To break through these roadblocks, the following solutions can act as catalysts:

4.1 Mobile devices

In terms of processing power, modern smartphones reach far beyond that the first portable digital ultrasonic equipment of the mid-1980s – and such devices keep getting smaller and more powerful every year. These devices connect most of the human population and can be tracked for location and usage, making the fleet management of an inspection service provider more insightful. Even in the field of NDT education, mobile devices are replacing bulky textbooks and inconvenient classroom training Newest-generation mobile devices feature video, audio, and on-screen drawing capabilities that enable efficient collaborative analysis between inspection team members.

4.2 Reporting

Direct report generation and immediate access to the investigation data has been proven to enhance not only collaboration, but also to result in the time savings shown in Figure 2. The time to create a report varied significantly depending on the number of defects to be reported. Users with an automated reporting template were significantly quicker.

Figure 2: Values given as average minutes. Increased productivity using the latest generation products vs. the traditional analog system. While the preparation time to the measurement is very similar, the time to do verification and actual measurements are greatly reduced using latest onboard technology. Reporting and IoT significantly reduce the time-to-reporting as well as ease of data sharing.

The time saved on reporting by the inspector can be helpful in allowing to increase the working capacity of existing Level 2 and Level 3 inspectors.

4.3 Activity tracking

Recent commercial activity trackers have transformed the analytics available to runners. Advantages can be seen if this technology and ideas are transferred to the NDT market by logging all activities and relevant change of settings performed by the user. Figure 3 shows how this “Logbook” works in the Proceq Live products Information stored by the Logbook includes user identification, settings, all measuring data and changes and can be complemented by geolocation, pictures, and audio comments. This functionality allows a supervisor to retrace the complete measuring process, if necessary, and ultimately to check data consistency and prevent data manipulation.

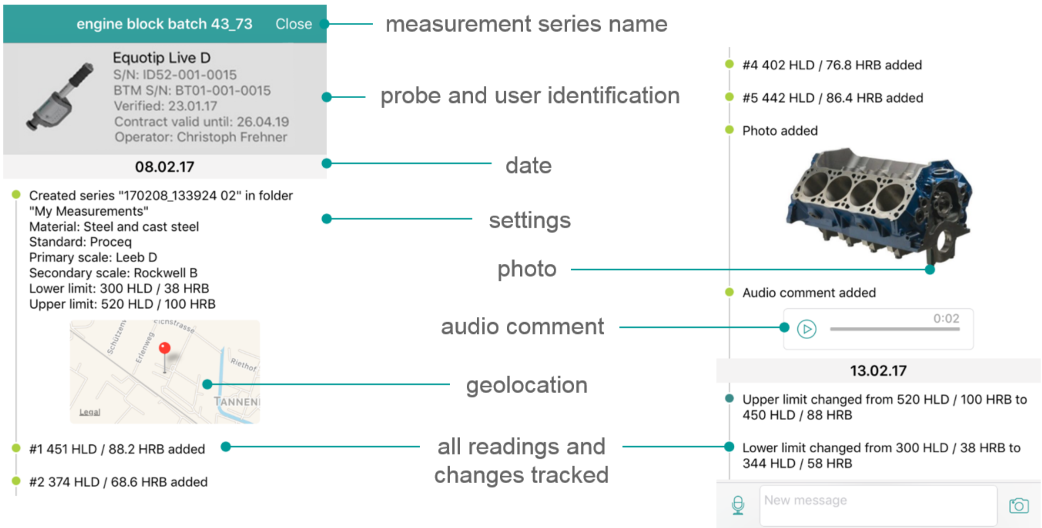

Figure 3: Logbook example of a Proceq Live product which tracks the measuring process. The comprehensive Logbook describes the device and names the user, it logs settings and measurement parameters, and records readings and exclusion of readings. Moreover, it permits adding photos and notes.

As NDT reports are legal documents, they typically require an approval, and this is typically from a highly trained and qualified Level 3 inspector. This stakeholder cannot oversee all activities when an inspection is undertaken, especially if he is responsible for a large team. Therefore, his approval signature requires a lot of good faith. With activity tracking, the Level 3 inspector can have extra confidence that the inspection was carried out to procedure and the customer has an inspection to the required quality.

4.4 Cloud storage

Contemporary instruments make use of secure cloud-storage solutions to back up in real-time the results collected on-site. Together with wireless communication through either a cellular network or Wi-Fi, this has become a powerful tool to immediately sync the data with other collaboration partners or to distribute reports to external parties. Additionally, a browser-based software product allows access to the data independent of location, time and hardware platform. Within the secure network consisting of transducers, mobile devices and a cloud storage, raw data is exchanged. Predefined templates for common export file formats such as PDF or CSV are used to share results outside the secure ecosystem. Direct report generation and immediate access to the investigation data has been proven to enhance not only collaboration, but also to result in significant time savings. Furthermore, With Big Data generated by IoT-enabled equipment, suppliers can develop new components to avoid specific failures and eliminate unused features.

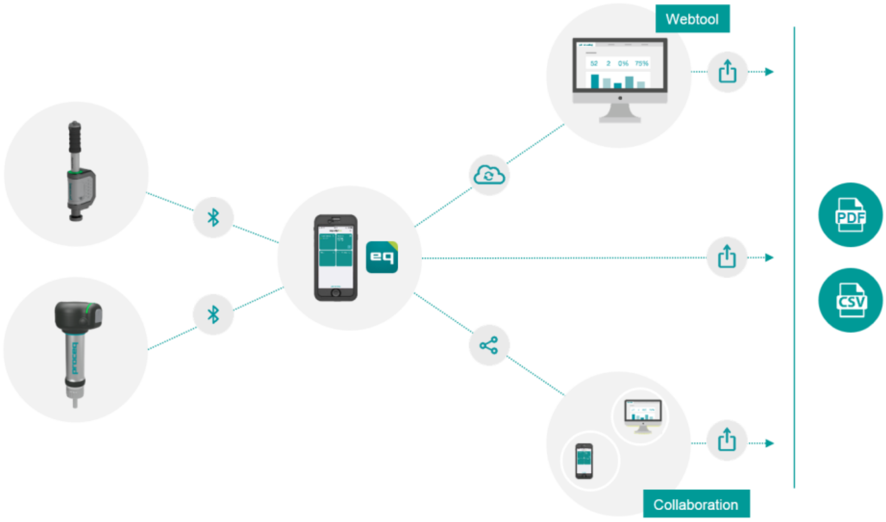

Figure 4: The Proceq Live ecosystem diminishes manual data entry and reporting effort and enables real-time data sharing and collaboration between users. Transducers are connected via wi-fi to the mobile device, which connects to the data backup system wirelessly via WLAN or 3G/4G. Reports, webtool access and collaboration options are facilitated.

5. New business cases

We believe that the Internet of Things for ultrasonic testing has the potential to drastically improve the way we work, how we work and offer efficiencies and capabilities to the customer, while successfully addressing security, privacy and trust requirements.

The business case for the Industrial IoT is rapidly evolving. However, quantifying the business case for the IoT is difficult as it is needed to analyze all the ways in which value could be created. Following a study by McKinsey (6), the total potential market was valued at $3.9 to 11.1 trillion per year in 2025. Not all of this is relevant to NDT, but for the factory and worksite industries recognized to have high linkage to ultrasonic inspections the total market potential was valued at $1.3 to 4.6 trillion per year. Realizing this growth cannot occur without NDT as an enabler.

We can also look at the market situation the other way around: there is, actually, no “IoT-enabled NDT market” any more than there was an “engine-powered market” on top of the “horse-pulled carriage” market. While IoT-enabled NDT products are currently mostly in their infancy, there will come a point where only a handful of NDT products will *not* be IoT-enabled.

As such, early adopters and fast followers will develop a learning advantage and reap earlier the cumulative benefits of IoT-enabled NDT. We are already beginning to see speech recognition, AR, and pattern recognition of streamed data be integrated into mobile platforms, with the opportunity to further improve the usability and reliability of ultrasonic inspections.

The IoT will be disruptive to the traditional way of performing inspections at regular intervals of a components lifetime. Alternative methods, such as condition monitoring, will allow for embedded sensors to take a measurement continuously. An embedded system does not need to be trained to the extent of a Level 2 operator but in some cases, the end-result for the customer will be the same. Some ultrasonic products and services will become obsolete. Some reduction in demand is expected by the adoption of new technologies. When the total running costs of a structure are included, NDT and condition monitoring together are key to maximizing value and extending useful asset life.

6. Conclusion

It has been shown that this technological progress opens new opportunities to address chronic pain points of NDT use-cases. The main achievements of future-proof NDT are increasing ease-of-use with user-friendly and intuitive user interfaces, higher accuracy and efficiency by reducing errors and rework in workflows, establishing traceable procedures with less effort and potential for errors, and enabling unobstructed data sharing for collaboration and quality assurance.

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