NDT 4.0 – Chance or Threat?

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Abstract

We are in the midst of a significant transformation driven by technology. In our everyday live this it becomes apparent through self-driving cars and artificial intelligence. The world around us is changing at a rapid pace – this also changes the way we produce products. Complete industries are transformed with major implications for professionals in this field. This transition is so compelling that it has been named Industry 4.0, the fourth industrial revolution. Also, our industry cannot escape the gravity of these fundamental changes. And the question arises – is this a threat or a chance? This paper will explain the fundamental principles and some specific examples from the field of radiography.

1.0 What is NDT 4.0?

The concept of NDT 4.0 is a subgroup of changes that are driven by the far bigger movement of Industry 4.0. It is important to understand where the term comes from [1]. The first industrial revolution happened between the late 1700s and early 1800s. During this period, manufacturing evolved from focusing on manual labor performed by people to a more optimized form of labor by using water and steam-powered engines and other types of machine tools.

In the early part of the 20th century, the world entered the second industrial revolution with the use of electricity in factories. The introduction of electricity enabled manufacturers to increase efficiency and helped make factory machinery more mobile. It was during this phase that mass production concepts like the assembly line were introduced to boost productivity. The legacy of Ford is a great example of that period.

Starting in the late 1950s, a third industrial revolution slowly began to emerge, as manufacturers began incorporating more electronic—and eventually computer—technology into their factories. During this period, manufacturers began experiencing a shift that put less emphasis on analog and mechanical technology and more on digital technology and automation software.

The fourth industrial revolution is characterized by connected computer systems through the cloud, the Internet of Things (IoT), Smart Factories, Big Data, Artificial Intelligence (AI), autonomous robots, predictive maintenance and additive manufacturing (AM). The adoption of these technologies lead to substantial improvements in productivity and efficiency. As its implementation are not an evolution but rather a revolution of the traditional manufacturing paradigm it is considered as disruptive. Especially, professionals on the shop floor face fundamental challenges and have a steep learning curve ahead as the new tools require a completely different skillset.

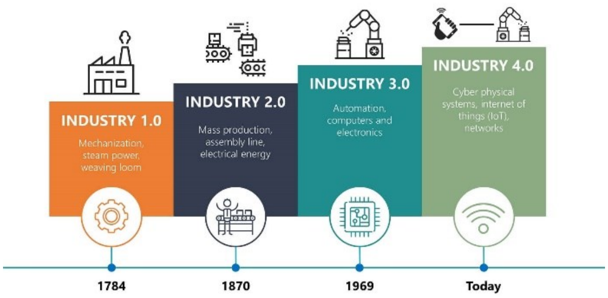

Figure 1 Evolution of Industry 4.0

2.0 The impact on NDT

Figure 2 shows the different fields of Industry 4.0. This section will assess some of them and provide real examples where they already impact NDT today. Due to space constraints this assessment cannot be holistic, but it should provide a good overview.

First, we will investigate robotics and simulation, allowing tedious handling tasks to be automated. This allows higher throughput, lower inspection costs and higher process safety. Figure 3 shows an example solution where three robots work in harmony to inspect airducts and pipes used in the aerospace industry. While two robots do the part handling, one robot has a C-Arm with the X-ray components mounted on it. This way cycle time could be brought down from several hours to a few minutes. When an operator brings a part, he scans a barcode and the system automatically loads the right parameters and part holders. All images are archived under the serial number and full traceability is given and image quality is always supervised as the system performs an automatic long-term performance evaluation according to ASTM E2737 [2]. New programs can be programmed offline by the CAD/CAM simulation tool. This way the system can be utilized 100% for production and does not need to be shut down for engineering purposes. This increases utilization by a big amount.

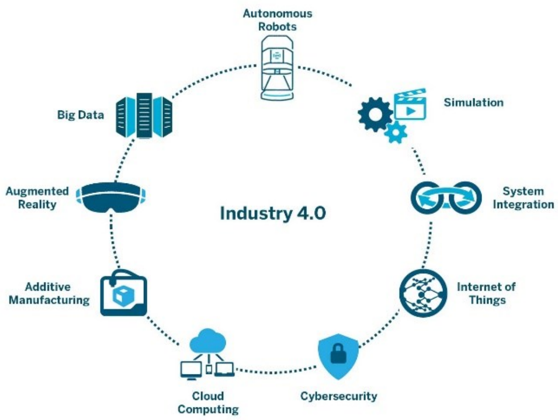

Figure 2 Fields of Industry 4.0

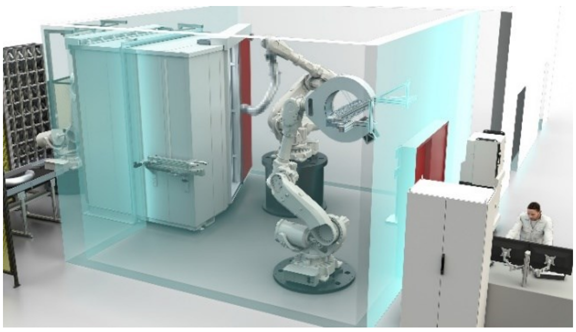

Figure 3 Robots working in harmony in the aerospace industry

The next big segment of Industry 4.0 is Artificial Intelligence (AI) and big data. This is also known as Automated Defect Recognition (ADR) in Radiography [3]. Indications, like porosities, cracks or inclusions, are automatically detected, measured and evaluated against the inspection criteria. Already widely adopted by the automotive industry we finally see other industries like aerospace following. During the transition period it makes sense to adopt an assisted defect recognition strategy, where an AI supports the human operator by cross checking his readings. This approach is also called supervised learning in data processing and allows rapid training of the underlying AI system. As soon as enough data is collected that correlates decisions by the operator and the AI companies can build the required proof for qualification of the ADR system by using probability of detection (POD) methods. With increasing computational power AI unfolds is strength. Figure 4 shows an example where ADR was used to evaluate a digital radiograph of an automotive casting part.

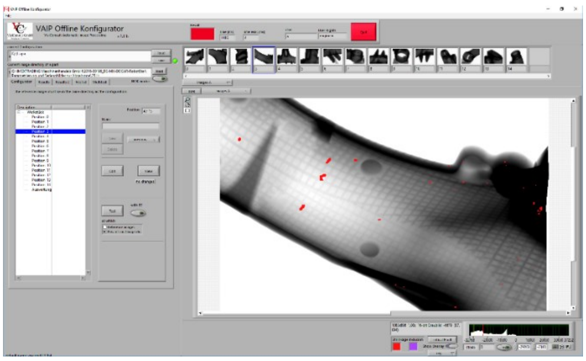

Figure 4 ADR in automotive industry

When looking into Additive Manufacturing (AM) our technology plays a big role. Industry experts identified that Computed Tomography (CT) [4] is probably the only technology that can inspect complex AM parts to qualify them for safety critical environments. Figure 5 shows a scan of a tensile probe; the upper part shows the horizontal cuts and the lower part the vertical cuts. By acquiring substantial amounts of digital radiographs and computing them into a 3D model we can gain information about parts like we have never been before. In manufacturing it is all about the digital twin – what people do not realize is that NDT can supply the perfect digital twin!

The last part we will assess is Cloud connection and system integration. With today's technology it becomes possible to connect systems in factories. If desired even complete factories around the globe. Today it is possible to have image acquisition locally (on the so-called edge) and interpretation centralized in an excellence center. This could be a solution to the lack of qualified personnel that many companies face. Standardized interfaces on machine communication like OPC UA allow systems to interact.

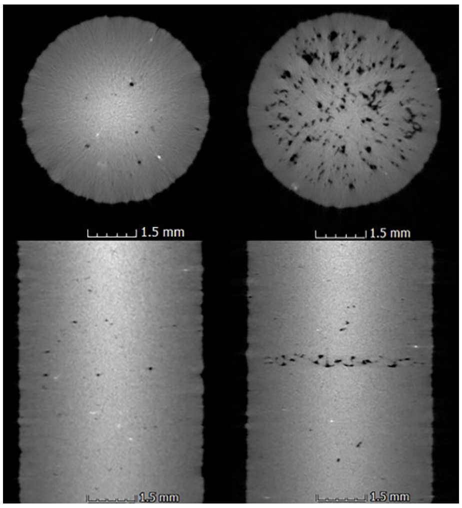

Figure 5 Scan of a tensile sample

Currently NDT is only seen to ensure quality, but it can do so much more. Let us assume the example of a casting company. Every 20 seconds they manufacture one aluminum casting. Sometimes process parameters get out of bound and parts with flaws (porosities) are produced. The company performs digital RT to prevents these parts from being delivered. In the past the X-ray inspection has been on the end of the line with a substantial delay of sometimes days between the two stations. By moving the two stations much closer together the manufacturer has two advantages: Less value-added steps being performed on flawed parts. More importantly the X-ray system can communicate with the casting system to "warn" it that the scrap rate goes up. This way the casting process engineers can correct parameters in order to get back to the desired quality. This way NDT has just saved the company a lot of money.

All those measures alone pose significant gains in efficiency, but they compound each other if done together. Just assume the robotic system above that is installed in factory A and B. As there is a lack of qualified inspection personnel in that region the company decides to transfer all images to factory C, which is its NDT excellence center. Image interpretation is performed centrally for all other locations. At the same time, it is ensured that there is a baseline for inspection quality. All data is archived in a local data center and an AI is constantly being trained. The smarter the system gets the more help do interpreters get, which further improves the interpretation quality. This simple example shows the powerful impact that robotics, cloud connection, system integration and AI can have on our industry.

Quote: *"Data is the oil of NDT 4.0" - Lennart Schulenburg*

3.0 How does this affect me?

The world has never been more complex, as supply chains are spanning around the world and we see the rise of big scale automation on the shop floor and beyond. Especially Western economies face a growing competition from lower cost countries that are quickly catching up in terms of technology. Many other departments of our companies are already transformed by the digital disruption and robots have become a valued colleague in many areas. In every sector from automotive to aerospace the impact of automation is clearly visible. Companies understood that they are in a global competition these days and that just continuing to do it the way we always did it will have severe consequences.

NDT traditionally shows a substantial inertia towards change and there are good reasons for it. In the end all of us are responsible for the quality of the output that leave our companies. Our work is far too important for thoughtless experiments with technology. As the guardians of quality, the NDT industry created a strong network of rigid standards and regulations. On the downside, these rigidities are now slowing us down significantly. Recently, a supplier of the aerospace industry discovered substantial cost savings by roughly factor ten if he would switch from X-ray film to digital radiography, robotics and computer numerical controls. The return of interest (ROI) was amazing and it would help the company to stay in business against its new competitors from Malaysia. Unfortunately, the project had to be abandoned as it was discovered that the parts were governed under a standard established in the 1970s. Such situations are quite frequent in our industry and destroy a huge amount of value that could be captured for our companies and countries.

Even such stories happen frequently, our industry sees a huge transformation. Especially, in industries that have less rigid quality requirements, like automotive, embraced the new technologies. One of Germanies leading automotive manufacturers adopted inline Computed Tomography (CT) to inspect rotors for electric motors. The system uses an industrial robot for part handling and artificial intelligence for the interpretation of the images. The skillsets required for the operators – completely different than in the past.

4.0 How to be prepared for the future?

The initial question was chance or threat. There is no single answer to this as it is highly context dependent. This movement will, one way or the other, change our industry fundamentally and there will be a need for adoption. This process will stretch over the next five years and pressure will be increasing in that time. Nevertheless, this is no reason to panic or activism. We all must remember that our first and foremost job to ensure part integrity and to prevent faulty parts going on the market. This should never be jeopardized by efficiency improvements or new technology. Therefore, it is needed to develop a strategic change roadmap with realistic milestones and contingency measures. A careful process analysis will reveal low-hanging fruits that can be easily approached.

It is also very important to not take two steps at a time. Moving straight from film (2.0) to a fully automated robot system (4.0). The right step would be to first switch from film to digital RT (3.0), then establish new processes, techniques and qualify all operators. The next step would be to then carefully automate and digitize further process steps.

5.0 Does digitization take my job?

There is a big fear that robots, AI and automation will take our jobs. This fear is mainly driven by misleading media articles and futuristic movies. Even though the new technology can do amazing things, they do not even come close to the capabilities of the human brain. We will not see these systems replacing professionals in NDT any time soon. There should be a paradigm shift in the perception of these helpers. Robots help us to move parts and reduce the amount of physical labor. The cloud makes archiving and processing results much easier, while AI helps us to improve our evaluation capabilities. No doubt, our jobs will change and the activities we perform will be more computer heavy. This requires requalification and learning of new skills. In the end, every machine needs a human to supervise it! Let's just think about the other industrial revolutions like electrification – it happened, and we still have jobs. It is more important to approach this new technology with openness and to embrace the chances it has for us. The biggest threat would be to wait for the things to come and get disrupted by others that adopted them earlier.

References

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[2] https://www.astm.org/Standards/E2737.htm

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