Reactor Pressure Vessel and Internals Become Visible by Means of Remote Moulding Inspection, AVT.

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Abstract. Reactor pressure vessels and internals are often inspected with remote controlled NDE techniques such as automated ultrasonic, automated eddy current and visual inspection techniques. Scratches, tool marks and other geometrical indications cause severe problems for traditional surface techniques and may even cause unnecessary repair work.
FORCE Technology has developed new remote tools for application of the moulding inspection technology above water as well as under water. The specialized remote tools can be utilized for fast inspection of simple and complex geometries, which are impossible to inspect with other inspection techniques e.g. weld surfaces in restricted areas under water. The specialized remote inspection tools can make a copy or imprint of the surface, which lets you see surface structures, cracks or similar with a resolution of 1 µm.
The tools are typically designed and fabricated for special areas or components but once tested and approved they allow for fast mobilisation and insertion. As the resolution reference is build into the tools the lead-in time is kept low.
Recently, the remote inspection tools have been utilized in a water-filled nuclear reactor pressure vessel (see fig. 1 below). OKG Aktiebolag was in urgent need for an alternative non-destructive testing of level measuring nozzles, which are located under water in the reactor pressure vessel. “We are pleased, that FORCE Technology managed to mobilise technicians and an engineer within 24 hours from Denmark”, said Lars Johansson, OKG Aktiebolag, who further pointed out that the whole inspection was carried out within 24 hours to everyone’s satisfaction.

Figure 1. New remote tool for application of moulding material under water. A copy of the level measuring nozzle in the reactor pressure vessel has been made by means of the remote inspection tool.

1. Introduction

FORCE Technology has utilized moulding material for many years within our metallurgy department. The moulding material has been utilized as replica technique in order to reveal anomalies in materials on a microscopic level, where grain structures and other relevant parts can be viewed easily.

The moulding material has been applied on surface temperatures up to 80ºC, on complex surfaces looking for heat treatment, creep damage, crack type identification, documentation of surface defects and other types of damages (see fig. 2a and fig 2b.). Details down to 1 µm can easily be resolved with the new replica technique.

As documentation for the high resolution, we have included an image of the human cheek or more accurately, a microscopic image of a human beard after shaving (see fig. 2c).

The high resolution and the unlimited possibilities of the moulding material gave a group of engineers the idea to apply the moulding material remotely on complex geometries and difficult or restricted accessible areas. Thus, the initial trials for remote application were performed in the 90'ties.

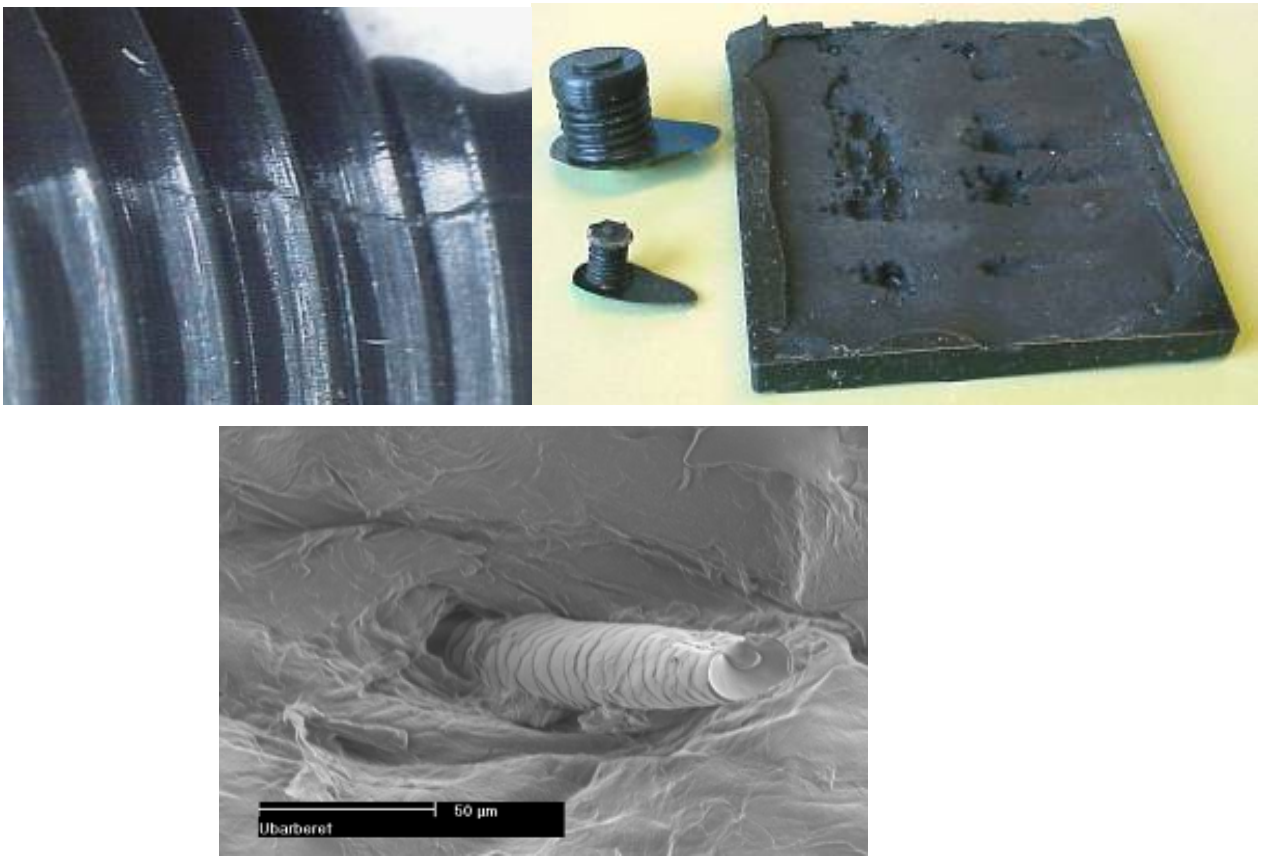

Figure 2a, b and c. Upper left hand image shows a crack detected in a thread. The crack is running transverse to the thread. Upper right hand image shows a copy of a heavily corroded surface in a vessel. The lower image is a copy of a human hair after the chin has been shaved for illustration of the resolution capabilities only. The picture is viewed in a modern FIB-SEM.

2. Field Proven

Since the beginning of an extended accreditation and acceptance process of moulding inspection within the Swedish nuclear power plants FORCE Technology has designed and manufactured many different remote application tools. All with a sophisticated qualify assurance and retraction possibilities in spite of complex and restricted access conditions.

Typical sensibility, accuracy, etc. under ideal conditions is cracks down to 1 µm in width and 0.5 mm in length. Qualification for the Swedish nuclear power plans with a target of: Cracks down to 3 µm in width and 1.5 mm in length. Directions: Defects located in all directions can be detected. Temperature: +15°C to +50°C. The method can be utilized at lower and higher temperatures; however, this has not been qualified for the nuclear power plants.

2.1 Down comers

The first remote application was constructed for verification of findings in one of the research reactors located in Denmark. The remote application of moulding material was performed trough a 6" opening in the upper part of the reactor with a 6 axis robot. The result confirmed the ultrasonic findings as more than 50% wall reduction was visualized (see fig. 3).

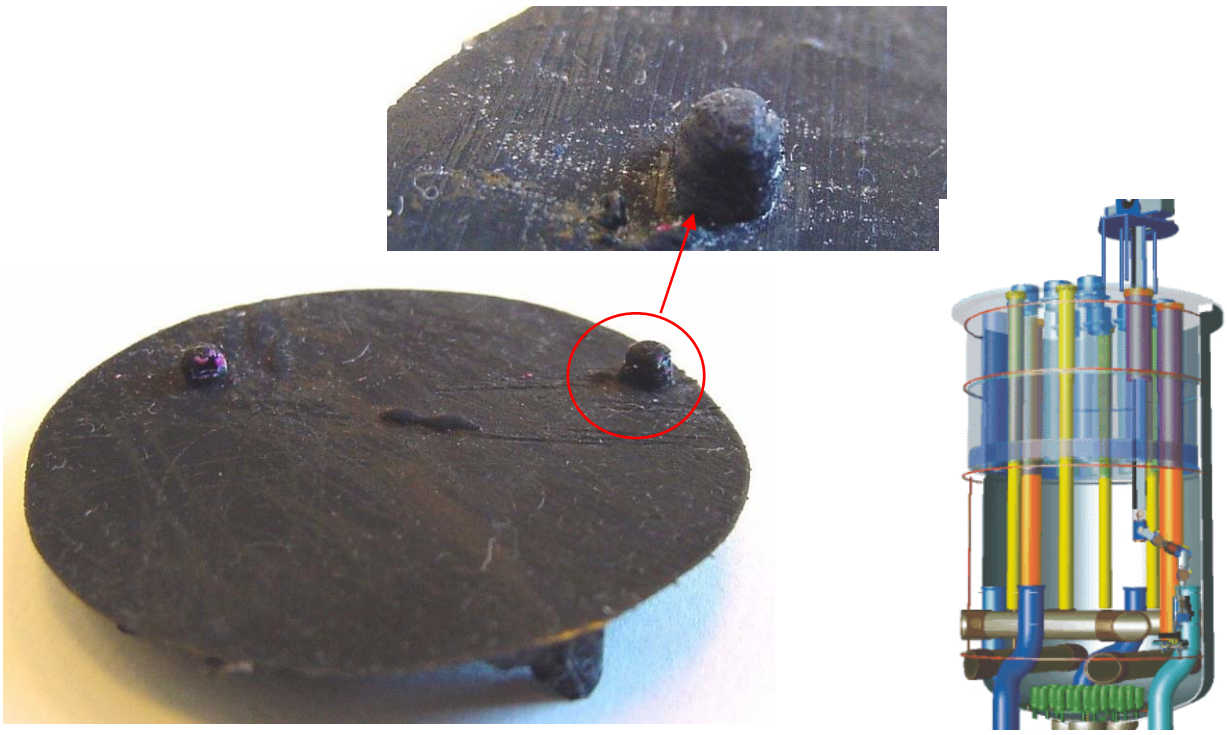

Figure 3. Remote application of moulding material through a 6” opening in the rector vessel head by means of a 6 axis robot developed by FORCE Technology. The left figure shows the result of a wall reduction and the figure to the right shows the robot installed in the reactor vessel.

2.2 Level measuring nozzles

OKG Aktiebolag and Ringhals AB had during the past years made moulding of surfaces on different occasions. However, the inspection performed of critical components (inspection group A) must be performed by an accredited inspection company. Given the background and the knowledge that FORCE Technology had gained with the moulding technique within the metallurgy department and the NDE applications, FORCE Technology was asked to qualify the technique for manual application within the Swedish nuclear power plants. The technique was qualified through technical justification and practical demonstration. The qualification was performed according to the ENIQ recommended practice with hard work from all parties. In parallel, the accreditation was obtained through documentations of European standard and documentation of FORCE Technology capabilities. Two main products and several colours were qualified by the Swedish Qualification Center, SQC.

The sensibility of the moulding techniques are less than 1 µm, when viewed in an electron microscope like a focused ion beam sweep electron microscope (FIB-SEM). However, in view of all practical applications, a crack target of 1.5 mm in length and 3 µm in width was found reasonable to document as required. All cracks will be detected with the technique, regardless of orientation. Note, different crack targets apply for the different moulding masses and colour of the moulding masse. Furthermore, the temperature of the components has a radical effect on the curing time, but components with temperatures up to +80°C can easily be moulded. In order to limit the experimental evidence the technique was qualified for a temperature interval of +15°C to +50°C.

However, in order to reach areas below water, FORCE Technology manufactured a tool for remote application of the moulding masse on the level measuring nozzle (fig. 4). The tool includes the possibilities to assure, that the moulding is performed as requested. Furthermore, the tool can evacuate water from the specific area of interest.

Just recently, the remote inspection tool has been utilized in a water filled nuclear reactor pressure vessel. OKG Aktiebolag was in urgent need for an alternative non-destructive testing of level measuring nozzles, which are located under water in the reactor pressure vessel. The inspection was perform as planned within a short inspection window and with a positive result for OKG Aktiebolag.

Figure 4. The remote application tool is shown fixed in the level measuring nozzle at a water depth of 26 meters. The yellow part forms the outer mould and the component form the inner mould.

2.3 Emergency cooling nozzle and boron injection nozzle

Similar tools have been manufactured and qualified for the remote application of moulding masse on the emergency cooling nozzles and the boron injection nozzles located in the bottom of the reactor pressure vessel – approximately 26 meters under water. The tools must pass through the core grid and other reactor pressure vessel internals. Both tools have been qualified and demonstrated according to the ENIQ recommended practice.

2.4 Scram Nozzles

Scram Nozzles are located under the reactor pressure vessel and is a 2” piping connected to the control rood drive housing. The scram nozzle is only accessible through the control rood drive housing. Based on an assignment given by Ringhals AB, a flexible remote application tool was manufactured and mounted on a 2 meter long bar (fig. 5). The flexible tool construction allows the operator to remove the tool and the moulding masse, if the mould could not be removed as intended. The tool enters through a thread, which is smaller than the weld area of interest. This means, that the tool must allow the moulding masse to harden and after the masse has hardened it shall be pulled out through a smaller diameter. The mouding can reveal surface indication in the based material and in the threaded area.

During the 2005 outage, more that 17 scram nozzles where inspection by means of flexible moulding tool.

Figure 5. The flexible remote application tool mounted on a 2 meter bar for installation into the scram nozzle. Shown to the right, the mould has been made of the scram nozzle.

2.5 Main re-circulation loop welds

Local surface repairs with the erosion sparked method or grinding will often be impossible to inspect by means of ultrasonic or eddy current inspection methods. But these areas are easily inspected by means of the moulding technique. Thus, a tool has been manufactured for remote application of the moulding masse in repaired areas of main recirculation loop welds.

An advantage of moulding repaired areas is not only the detection ability, but also that the material is form stable. Thus, the moulding can be utilized for documentation of the excavation in the components, which is impossible to obtain with dye penetrant, ultrasonic or eddy current surface methods.

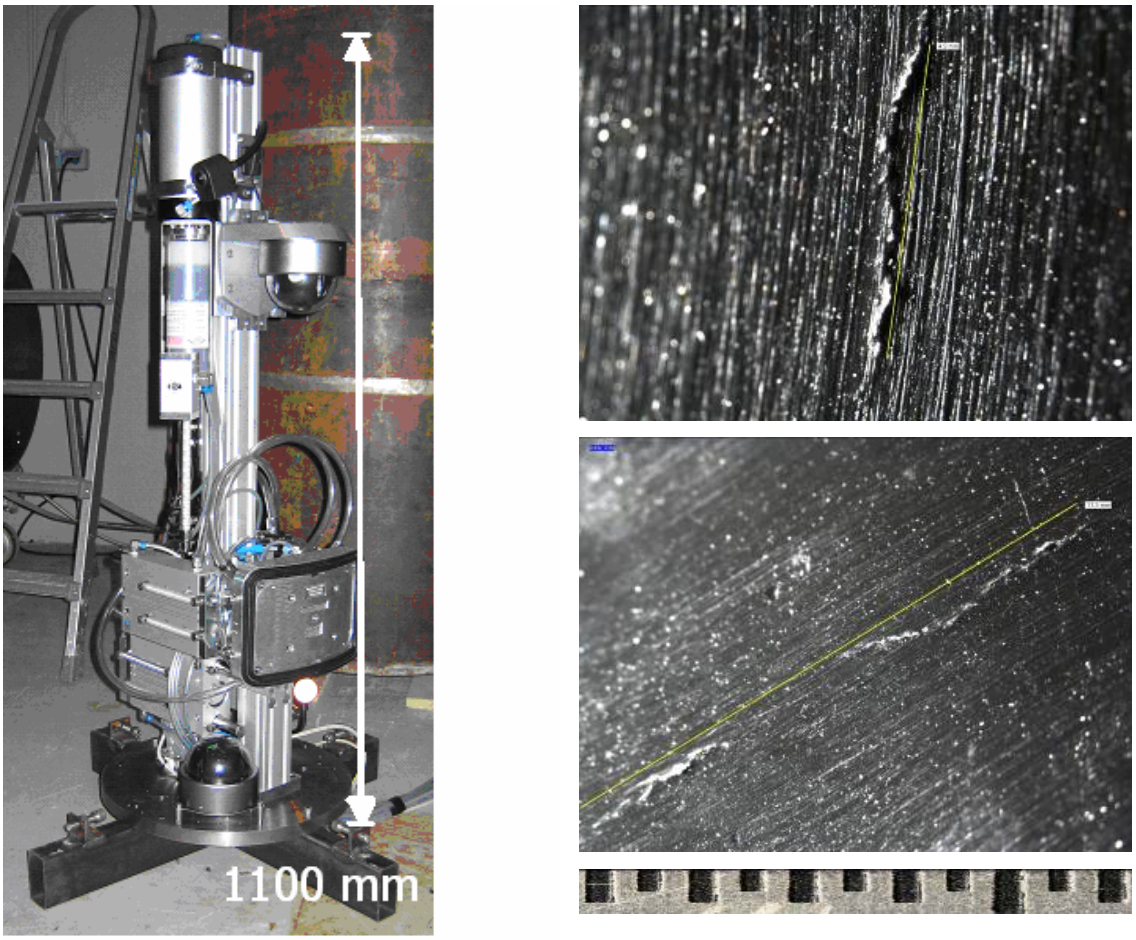

Figure 6. The left hand picture shows the remote application tool with surveillance cameras, identification and quality assurance possibilities. The right hand pictures show two microscopic images of two different cracks in an inconel alloy. On the microscopic pictures the surface conditions of the component can be viewed. Below the right hand picture a scale (11 mm) has been included.

2.6 Feed water nozzles

Based on a request from the nuclear power plant, Forsmarks Kraftgrupp, FORCE Technology has designed a complex tool for remote application, which shall be used for inspection of the feed water nozzle. The interesting area is located around the reducer and as such the moulding tool will cover the area in front of the reducer, on the reducer and a part after the reducer. The remote application tool will be utilized under water in the feed water nozzles proving evidence of surface irregularities, if any, and provide an exact copy of the geometry in the reducer area.

So far all documents like technical justification, technical data sheets etc., which has be prepared according to the Swedish requirements, have been approved by the client. Within the following months the personnel, procedure and equipment will be qualified for in-service inspection. The remote application tool will be utilized during the upcoming outage, 2006.

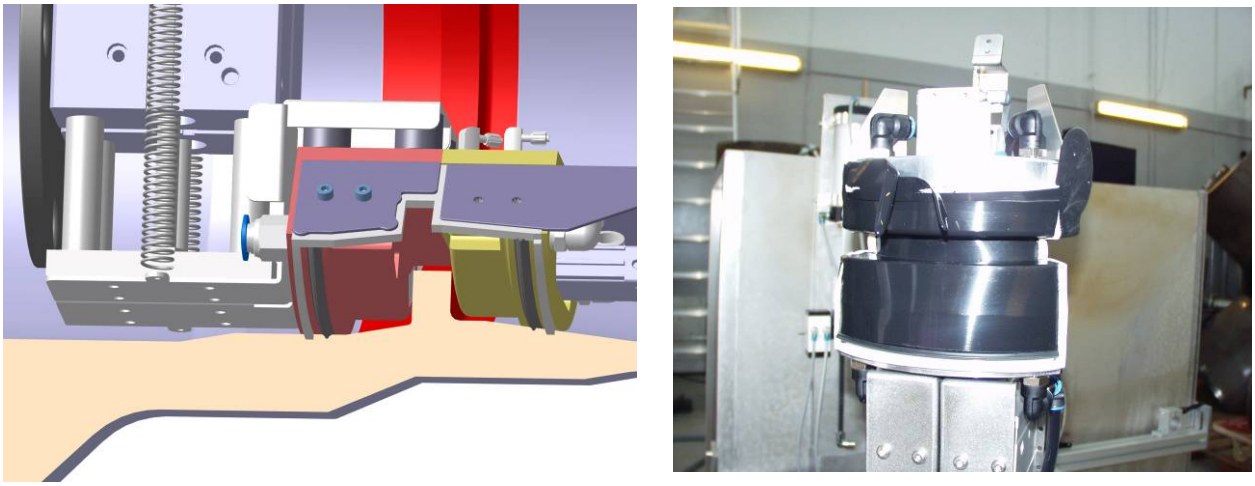

Figure 7. The left hand picture shows an advanced two part remote application tool. The remote application tool is equipped with surveillance cameras, identification and quality assurance possibilities. On the right hand picture, the first mould with the advanced moulding tool has been documented.

3. Acknowledgement

Special thanks shall be given to our contact person at Ringhals AB, Forsmarks Kraftgrupp AB and OKG Aktiebolag.

4. World Wide Services

As owner of the new remote moulding application tools for e.g. under water inspection of level measuring nozzle, auxiliary feed water nozzles, boron injection nozzles etc. in nuclear reactor pressure vessels FORCE Technology provides the inspection services throughout the world. More information may be found on our home page; www.forcetechnology.com