Validation of Non-destructive Examination Methods for Turbine Field Service

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Abstract
Non-destructive Testing (NDT) is a main part of turbine outages and is performed to ensure a reliable and safe operation of the turbine. Due to the high load and big potential of damages caused by service induced material defects, there are strictly defined requirements for the non-destructive Tests in Power Plants. Siemens Energy developed advanced NDT Techniques for reliable inspections of highly stressed turbine components, as all rotating components, as well as components affected by high temperatures and pressures. Especially the NDT techniques for rotor disks, joint bolts, rotors, blade roots, airfoils and blade attachment grooves of turbine rotors have been developed according to specific customer requests. Focus of the development was the retrieval of reliable, high sensitive inspection techniques, which are able to ensure in-situ inspection.

Keywords: validation, ultrasonic, turbine, field service, power plant

1. Introduction

Requirements governing non-destructive testing of power plant components and systems are dictated by technical as well as organizational factors.
From a quality assurance perspective, the different owners and operators of power generation installations make it necessary to exclusively use validated non-destructive examination methods.
Validation serves to confirm that examination methods are suitable for their intended purpose (i.e. that the discontinuities which the applied examination methods are supposed to detect are indeed reliably identified).
This presentation describes the test method validation process using the example of mechanized ultrasonic examination (UT) of turbine casing joint bolts during power plant inspection and maintenance outages. Validation entailed performing an extensive scope of destructive testing and non-destructive examinations. The presentation furthermore looks at possible approaches and procedures for validating non-standardized non-destructive examination techniques.

2. Ultrasonic Examination of Casing Joint Bolts

Casing joint bolts are components to fix the top and bottom parts of the turbine casing together in order to ensure absolute leak tightness. Therefore the bolts are heated (using an induction or flame heating process) during assembly to make use of the shrinkage that occurs during cool down to generate a defined preload of the bolts.
The enormous stresses prevailing in the preloaded casing joint bolts could create incipient cracking in the first part of the bolt thread especially under corrosive conditions, wrong heating conditions or by reassembling. Such cracks can lead to the loss of leak tightness, leakage and possibly deterioration of turbine and generator performance.
On this account, non-destructive examination of casing joint bolts is recommended during steam turbine overhauls [1].

In the past casing joint bolts were dismounted for surface crack inspection of the highly stressed area by applying MT techniques. Conventional ultrasonic examination from the top of the bolts in the in-situ condition is not possible due to the heating bore and waisted shank design.
The request to inspect casing joint bolts in the in-situ condition required the development of an advanced inspection system. The main interest of this request was to shorten the inspection time and to reduce the costs for disassembling the bolts. The new system had to meet the following requirements:

- No need for bolt removal
- Reliable inspection as well as coverage of the highly stressed areas of the bolts
- Inspection from the heating bore inside
- If possible: inspection of the bolts without opening the turbine

The use of advanced ultrasonic technology in conjunction with state-of-the-art manipulation systems enabled the development of an inspection system, which meets the above requirements. The system consists of a dual-axis manipulator, which guides the ultrasonic transducer system at the top of a shaft. For the physical data transmission, a sliding-contact connection is used. A digital ultrasonic device records and displays the data.

Fig. 1: UT Inspection of Casing Joint Bolts of a Turbine

Until today, more than 100 units (approx. 6000 bolts) of nuclear as well as conventional power plants were investigated successfully and in different cases, cracked bolts could be found and replaced in time.
As it was necessary to verify the reliability of ultrasonic test methods for safety-related components it had to be proven, that the test technique is capable of reliably detecting incipient cracks from a defined crack depth in the shaft area of the bolt as well as in the screwed-in threaded area.
As the test system was calibrated on artificial defects, the smallest detectable crack depth was equated to the depth of the smallest detectable notch.

3. Validation of the Ultrasonic Casing Joint Bolts Inspection

Ultrasonic testing had been performed on valve casing bolts in the year 2014 in the course of overhauling a steam turbine in a fossil-fuelled power plant. During the test several cracked bolts were identified.

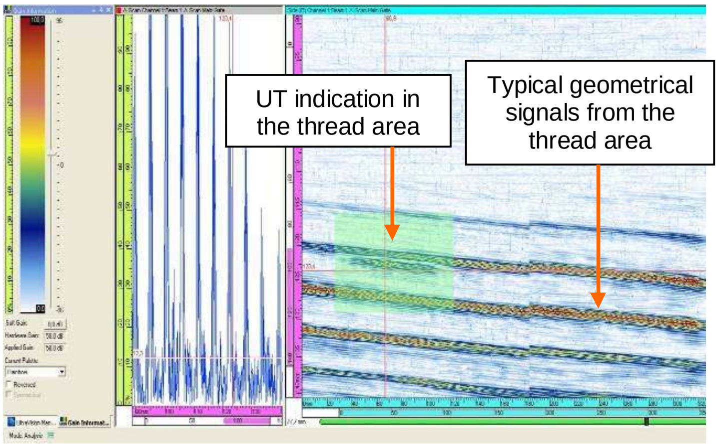

Fig. 2: Result of the UT Inspection of a casing joint bolt (B-Scan)

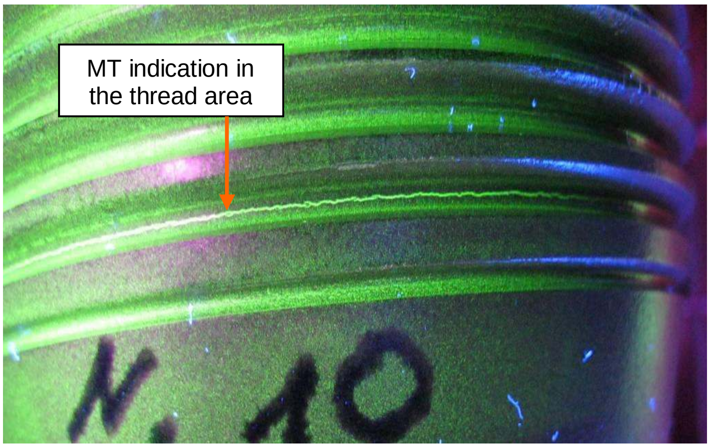

Fig. 3: Result of the MT Inspection of the bolt with an indication in the thread area

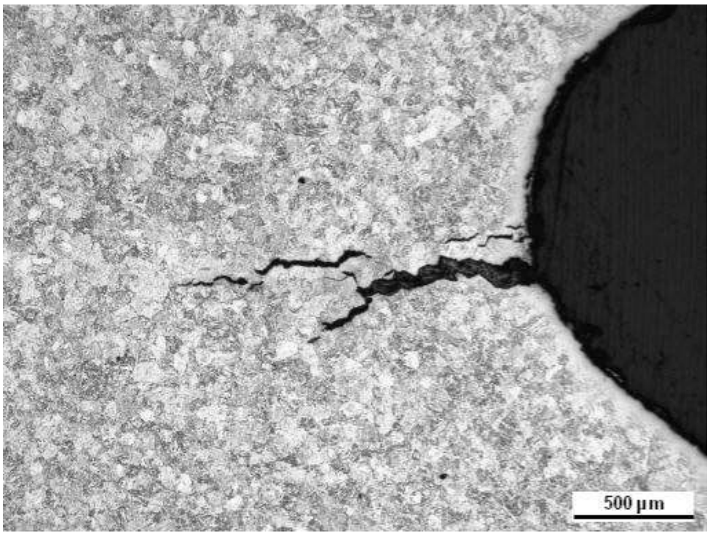

Fig. 4: Result of the microstructure analysis of the bolt with crack indication

Subsequently the bolts were removed and subjected to additional surface crack examination. All the bolts with detected UT indications were confirmed as cracked by magnetic particle examination (MT). Some of the bolts from these valve bonnets were then used for further destructive examination of the bolts.

In order to validate the ultrasonic inspection system, comprehensive investigations were performed on the available bolts made of X22CrMoV12-1 material that showed indications by the UT inspection. Selected bolts were subjected to surface crack testing using MT methods. Subsequent to that additional metallographic examination were performed to determine the actual depth of the detected crack indications. As can be seen in Figure 4 the damage mechanism, i.e. material creep, causes incipient cracks which are showing a distinctive dendritic pattern.

4. Conclusions and Next Steps

Detailed investigations showed that the applied UT method reliable detects crack on casing joint bolts with heating bore.
However, on the basis of these findings Siemens takes additional steps to further improve the UT method used for testing the bolts.
Key objectives of a modified inspection techniques are:
- Improvement of reliability of the inspection technique
- Further improvement of detectability

Based on these requirements an updated and improved inspection technique will be introduced in the near future.

References

1. VGB Guideline R 505 Me (5.2004), Guideline for the Use of High-Temperature Bolting