Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

Ultrasonic Inspection of Nuclear Power Plant Low Pressure Turbine Disk

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1. Introduction

The catastrophic failure of a low pressure (LP) turbine disk because of SCC in the keyway at the Hinckley Point nuclear power station in the United Kingdom in 1969 and the first discovery of stress corrosion crack (SCC) in the blade attachment region of nuclear LP turbine disks around the late 70's, industry concern with regard to this problem has increased significantly [1]. These concerns were corroborated by an Electric Power Research Institute (EPRI) survey of U.S. nuclear and fossil utilities in 1995 which reported a significant increase in the incidence of rim cracking compared with an earlier EPRI survey in 1980 [2]. Data collected by EPRI through 1995 from nuclear utilities, revealed LP rim attachment cracking in 41 of 109 operating units in the U.S. The cracking mechanism reported was predominantly SCC with a few instances of corrosion fatigue and high cycle fatigue [3].

2. Methods and Results

2.1 Structure and Cause of Failure

Numerous attachment designs have been used to affix turbine blades to the disk rims. The fir-tree designs are by far the most prevalent on large such as nuclear and fossil LP turbine rotors. In recent years, these designs have experienced an increasing occurrence of SCC normally in the corners of the disk side fir tree hooks. In the straddle mount type disk that has been used in KSNP, the fir tree attachment is machined around the periphery of the disk rim and the blades straddle and engage the disk hooks. Two or three hooks are common, and the sides of the disks are generally flat and parallel, or near so, and amendable to ultrasonic inspection.

2.2 LP Turbine Inspection Techniques

Reliable ultrasonic inspection methods for the detection of SCC in steam turbine blade attachment area are essential to the rotor run/repair/retire decision making process. The broad beam conventional ultrasonic inspection technique was characterized to have inadequate resolution for flaw sizing and a tendency for false calls. Both of these characteristics necessitated blade removal for flaw confirmation. But the phased array technique by improved detection capability and resolution could decrease blade removal and also increase coverage of the examination areas with less scanning required.

2.3 Experiments

Stress concentrations are occurred in the corner where the disk and blade are hooked up and easy to cracked. According to the stress analysis and previous data, experimental mockups with disk including EDM notches are made for various sizes. Figure 1 shows LP 1st stage mockup with phased array transducer and encoder to demonstrated detection ability, length and depth sizing capabilities. 10 MHz, 32 elements, 0.32 mm pitch phased array transducer is used for disk inspection.

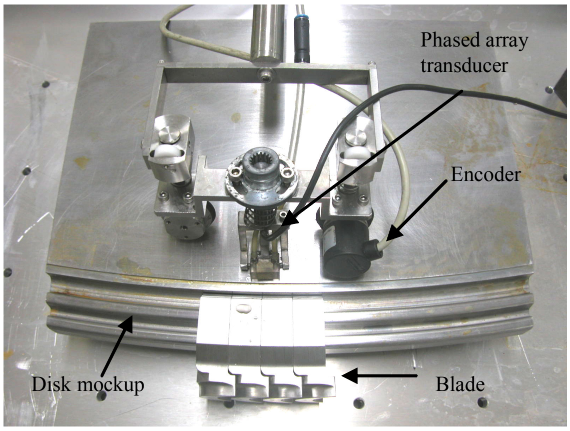

Figure 1. LP turbine disk experimental mockup

If a crack is present, its image will be displayed among the geometric reflectors like the right images of figure 2 with notches compared with the left images without notches especially in disk. If the crack is deep enough, it may shadow the normal reflection from geometric reflectors. The smallest notch (1 mm length, 0.3 mm depth) in disk mockup can be detected.

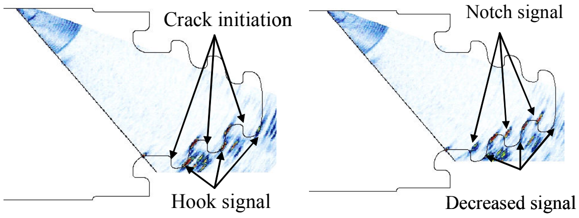

Figure 2. Sector scan of LP turbine disk

Length sizing results by 6 dB drop, 12 dB drop and fully drop methods were compared with each other and RMS error by 6 dB drop method showed better result than other methods in disk. For example, RMS errors from these 3 methods are 1.85 mm, 4.42 mm, 6.08 mm for 3rd stage lower hook disk like shown on figure 3.

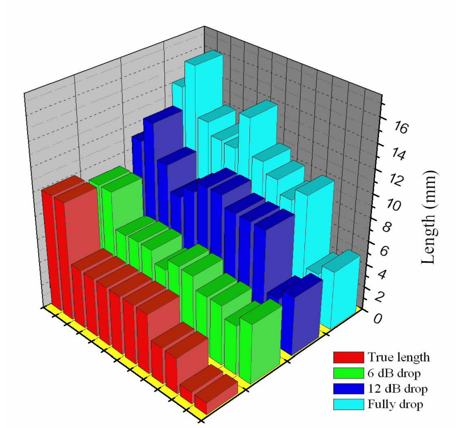

Figure 3. Length estimation for notches in 3rd stage lower hook disk

For determining the location of the crack, tip diffraction has long been recognized as an excellent method of determining the location of a crack tip. But the most of cracks that must be detected in early stage are not sufficient enough to determine depth using tip diffraction. To size smaller defects, a technique that uses the known distance from one angle position to the next is performed. Improved sizing could be possible if the increment between beams could be reduced. Figure 4 shows depth estimation obtained by this for the notch in the 3rd stage disk. Most of these notch depths are not big enough to generate tip diffracted signal and can not be measured by absolute arrival time technique (AATT) or relative arrival time technique (RATT) technique and also by shadow effect.

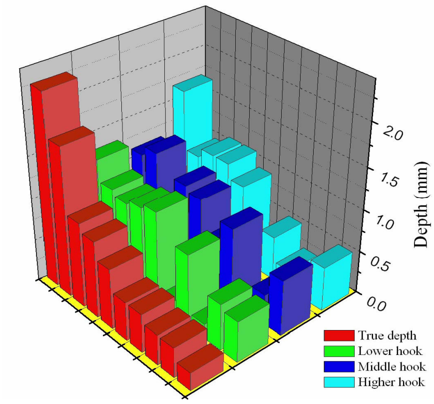

Figure 4. Depth estimation by sector image for notches in 3rd stage disk

2.4 Field Application

To apply for real LP turbine in KSNP, different scanner was manufactured to gain access to the inspection point. This scanner is moved along the rail that is installed on the floor parallel to the turbine and turbine stand. Turbine on the stand can move axially when rotating but this scanner can cover axial movement by sensing and adjusting contact pressure between the inspection surface and transducer. Figure 5 shows developed scanner for turbine inspection with 6 axes. Disk inspection for the real turbine is shown in figure 6 and the results were successful.

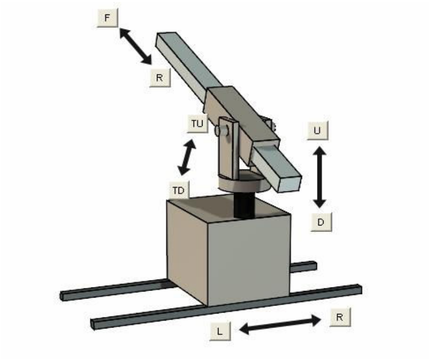

Figure 5. Scanner for the turbine inspection

Figure 6. Field application of LP turbine disk inspection

3. Conclusion

Application of phased array ultrasonic technique to straddle mount type low pressure turbine disk in KSNP was studied in this paper. Disk mockups including notches are made and used to demonstrate detection, length and depth sizing capabilities. Phased array UT technique can detect even 1 mm length and 0.3 mm depth notch in disk mockup. Length sizing results by 6 dB drop, 12 dB drop and fully drop methods were compared with each other and RMS error by 6 dB drop method showed better result than other methods both in disk and blade. Depth information can be obtained by sector image even without tip signal. This technique was applied for field inspection with new 6 axes scanner and developed by KEPRI.

REFERENCES

[1] J. L. Gary, "Investigation into the consequences of the failure of a turbine-generator at Hinckley Point 'A' power station", Proceedings: Institute of mechanical engineers, 1972.
[2] F.F. Lyle, H.C. Burghard, “Steam turbine disc cracking experience”, NP-2429, EPRI, 1982.
[3] D.A. Rosario, C.H. Wells, G.J. Licina, “LP rotor rim attachment cracking survey of utility experience”, TR-107088, EPRI, 1997.