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STUDY ON CHANGES OF DYNAIC CHARACTERISTICS ACCORDING TO CRACKED CONDITION IN A TURBINE BLADE

Kyeong-hyeon Yang*[1], Chul-whan Cho[1], Chun-hee Bae[1], Gye-yeon Kim[1], Wook-ryun Lee[1] and Oh-seop Song[2]

[1]Korea Electrical Power Research Institute
103-16 Moonji-dong, Yoosung-gu, Daejeon, 305-380, Korea
[2]Department of Mechanical Engineering, Choongnam University
220 Gung-dong, Yuseong-gu, Daejeon, 305-764, Korea
yangkh@kepri.re.kr(e-mail address of lead author)

Abstract

In this paper we investigate whether the dynamic characteristics of a blade is close to the resonance range when a blade has a crack. Although dynamic characteristics of most blades with no crack generally aren't close to the resonance range, it could not guarantee that dynamic characteristics of a blade be free from the resonance when a blade has a crack. So if we could know the truth in advance, it is very valuable.

Therefore we do the modal test using a fixing device in cracked case and no cracked case for a single turbine blade used in a nuclear power plant, and from the test results we analyse dynamic characteristics in cracked case and no cracked case for the FEM model under operation condition (rotation speed, temperature). On the basis of that, we conclude that we can research and predict the resonance possibility due to change of dynamic characteristics.

INTRODUCTION

Blades transfer the steam force which requires rotating the turbine system rotate, and have a very close relation to revolution speed of the turbine. So blade makers consider both the static condition and the dynamic condition to design a blade because some blades have the possibility to damage them if natural frequencies of them are close to harmonics orders of the rotor speed. But if a blade is damaged by another problem, natural frequencies will be changed according to the length or quantity of a crack. Also if this condition meets with harmonic orders of the rotor speed, we can predict that a crack is very quickly progressed.

Therefore we do the modal test using a fixing device in cracked case and no cracked case for a single turbine blade used in a nuclear power plant, and from the test results we analyse dynamic characteristics in cracked case and no cracked case for the FEM model under operation condition (rotation speed, temperature). On the basis of that, we conclude that we can research and predict the resonance possibility due to change of dynamic characteristics

SPECIFICATION OF THE TESTED BLADE

The blade that we use in this test is one of 10th turbine blades for lower pressure that had been used in a nuclear power plant in Korea (*Figure 1*). The length of the blade is 75cm, the weight is 10.2kg. The specifications of the blade are as follows (*Table 1 and Table 2*). Also natural frequencies and Campbell diagram of the blade presented by the manufacturer are as follows (*Table 3 and Figure 2*) :

Figure 1 – The tested blade

Table 1 – Chemical composition

Element	Weight-%	Cr	11.0 to 12.5
C	0.18 to 0.24	Ni	0.30 to 0.80
Si	0.10 to 0.50	Mo	0.80 to 1.20
Mn	0.30 to 0.80	V	0.25 to 0.35
P	max. 0.035	W	max. 0.60
S	max 0.035	Nb	max. 0.05

Table 2 – Mechanical properties

Item		Unit	Amplitude
tensile strength		N/㎟	900 to 1050
yield strength or 0.2%-proof strength		N/㎟	min. 700
elongation	longitudinal	%	min. 11
absorbed impact energy	longitudinal	J	min. 20

Table 3 – Natural frequencies of 10th blades presented by the manufacturer

	Blade		Calibration blade	
Set values	from	To	from	To
1st	77.9Hz	94.8Hz	88.8Hz	89.6Hz
2nd	203.0Hz	215.0Hz	192.0Hz	196.0Hz

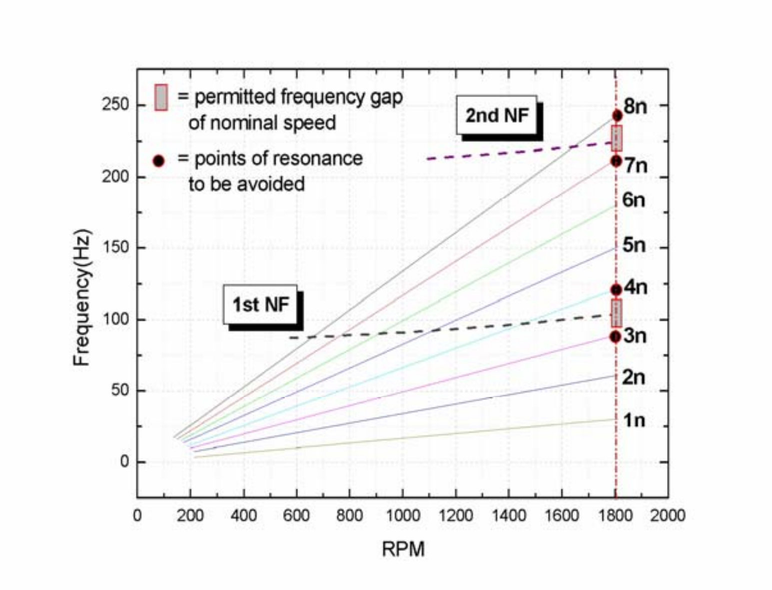

Figure 2 - Campbell diagram for the 10th stage blade

A MODAL TEST FOR THE CRACKED BLADE

Setup

Figure 3 shows a schematic for the test. It is tested in the same way as general modal test, but the blade is fixed using a device to jack the blade with a hydraulic system that we develop to perform a test similarly as the test method of the blade manufacturer. Also it is added a dummy mass to lower part of the device to support sufficiently the weight of the blade. It is considered thoroughly that the slot into which the blade is put is contacted with some lines.

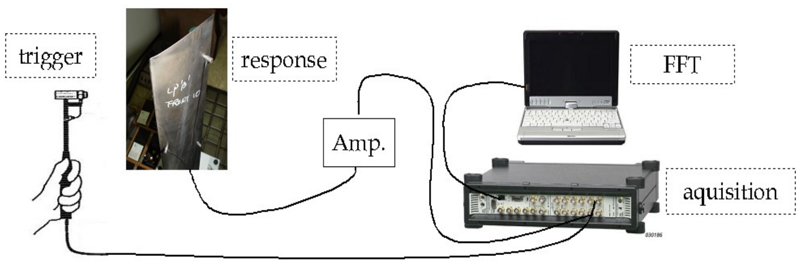

Figure 3 – A schematic for the test

Test process

We have the test process as follows:

- ❑ Tune-up of tightening pressure to fix the blade
- ❑ The modal test for the blade with no crack
- ❑ The modal test for the blade according to change of crack length

Test result

We obtain *Figure 5* as test results. Each mode in no crack condition appears within the frequency range presented by the manufacturer as *Table 3*, which the 1st mode of natural frequencies is 84Hz and the 2nd mode of that is 204Hz. From results that do test in changing crack length near the blade root part as *Figure 4*, we can find that the 1st mode of natural frequencies changes a little with respect to the crack length (about 8%), but the 2nd mode of that does considerably (about 27%).

Figure 4 – Crack in the blade

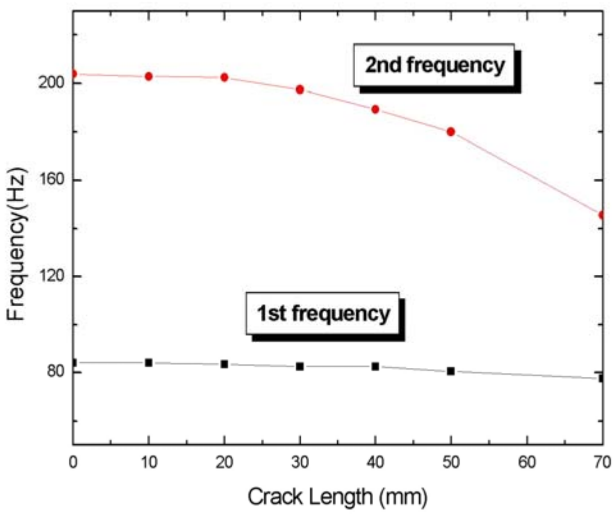

Figure 5 – Frequency with respect to crack length

FEM ANALYSIS

Creation of a blade model for FEM

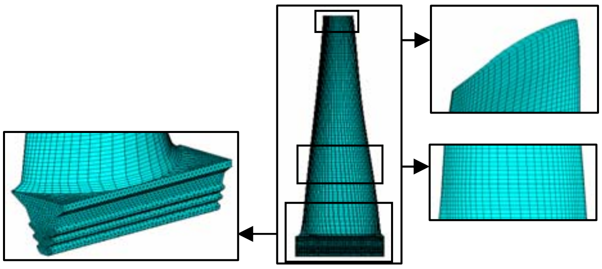

Figure 6 – Frequency with respect to crack length

We set up the blade model for FE analysis from the test blade. The shape and dimension is made after the pattern by using the 3M ESPE, meshing of the model is used to hexahedral type. It is applied normal contact force to longitudinal line for upward direction on inner face of slot shapes to consider the contact condition for root part of the blade model.

Acquisition of natural frequencies under the static condition

As well as the modal test of blade test, it is applied 160bar in gage pressure to contact condition of the blade model. The crack length is applied from 0mm to 120mm by 10mm to line element of the model. *Figure 7* shows together both results of FEM analysis and results of measurement. We can effectively approve the FE model for the blade in viewpoint that two results are very similarly. Natural frequencies in no crack condition of the blade model appear within the frequency range presented by the manufacturer as *Table 3* too.

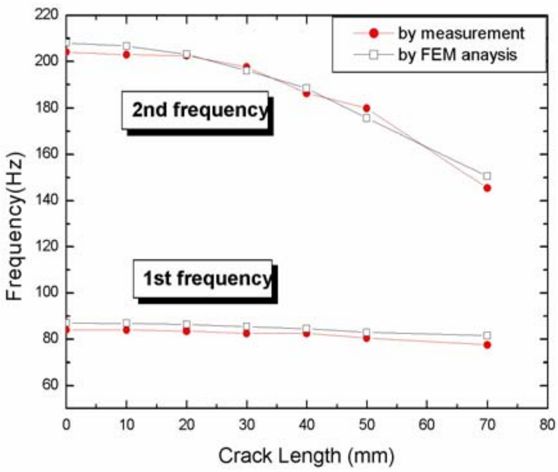

Figure 7 – Natural frequencies for FEM analysis and measurement

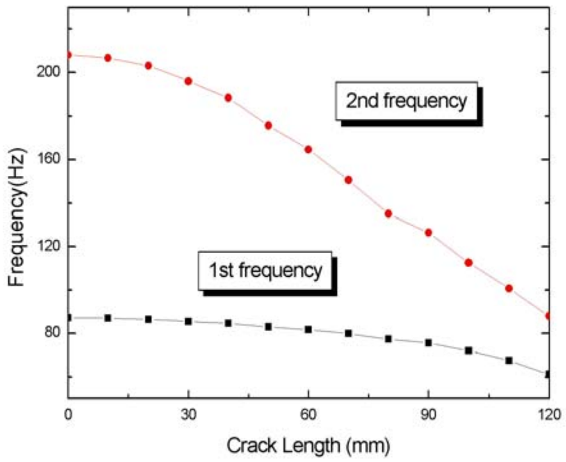

Figure 8 – Change of natural frequencies for FEM model under the static condition

Figure 8 shows changes of each natural frequency for FE model from 0mm to 120mm by 10mm in crack length. According to increasing crack length, the 1st mode of natural frequencies decrease to 29.9% and the 2nd mode decrease to 57.7%.

Acquisition of natural frequencies under the dynamic condition

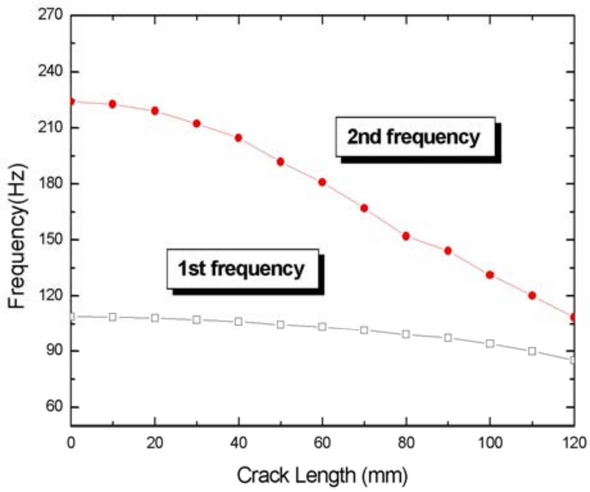

Figure 9 - Change of natural frequencies for FEM model under the dynamic condition

From the blade model, we obtain the data of mode shape and natural frequencies under the dynamic condition including centrifugal force by rotor speed (1800rpm) and thermal condition (65℃) by steam flow. The crack length is applied from 0mm to 120mm by 10mm to line element of the model as same way as under the static condition. *Figure 9* shows changes of natural frequencies for FE model under the dynamic condition. Under no crack condition the 1st mode of natural frequencies is 108.8Hz and the 2nd mode is 208Hz, and it can be valuably thought test results in point that modes of the blade model are within the permitted zone of the Campbell diagram as *Figure 3*.

The 1st mode of natural frequencies under the dynamic condition compared with under the static condition increase about 125% and the 2nd mode does about 108%. The 1st mode decrease to 21.9% and the 2nd mode does to 51.6% according to increasing crack length. This can be inferred to the result that change rate of each mode is different because the strength of the blade model increases more under the dynamic condition than under the static condition due to the effect of centrifugal force.

Investigation of resonance possibility

We can investigate resonance possibility by knowing how natural frequencies of the blade model with respect to the crack length change.

From test result, the 1st mode of the blade model isn't close to resonance range (that is harmonic orders of the rotating speed) although the crack length becomes 120mm. The 2nd mode isn't close to the resonance range when the crack length is small, but it is close to the resonance range when the crack length is over 10mm. This means that it would be transient state due to the 2nd mode if the crack appears in the blade, so the blade may be more quickly fractured.

SUMMARY

In this paper we show the way to investigate whether the dynamic characteristics of a blade are close to the resonance range (harmonic orders of rotating speed) when a crack is in the blade.

Finally we summarize as follows:

1. We apply this test to a fixing device with hydraulic system to perform a test similarly as the test method of the blade manufacturer. And it is performed the modal test for both the blade with no crack and the blade with a crack length.
2. We set up the blade model with identity for FE analysis from the blade and analysed each mode of natural frequencies for both the blade with no crack and the blade with a crack length.
3. We investigate resonance possibility by knowing how natural frequencies of the blade model with respect to the crack length change.

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