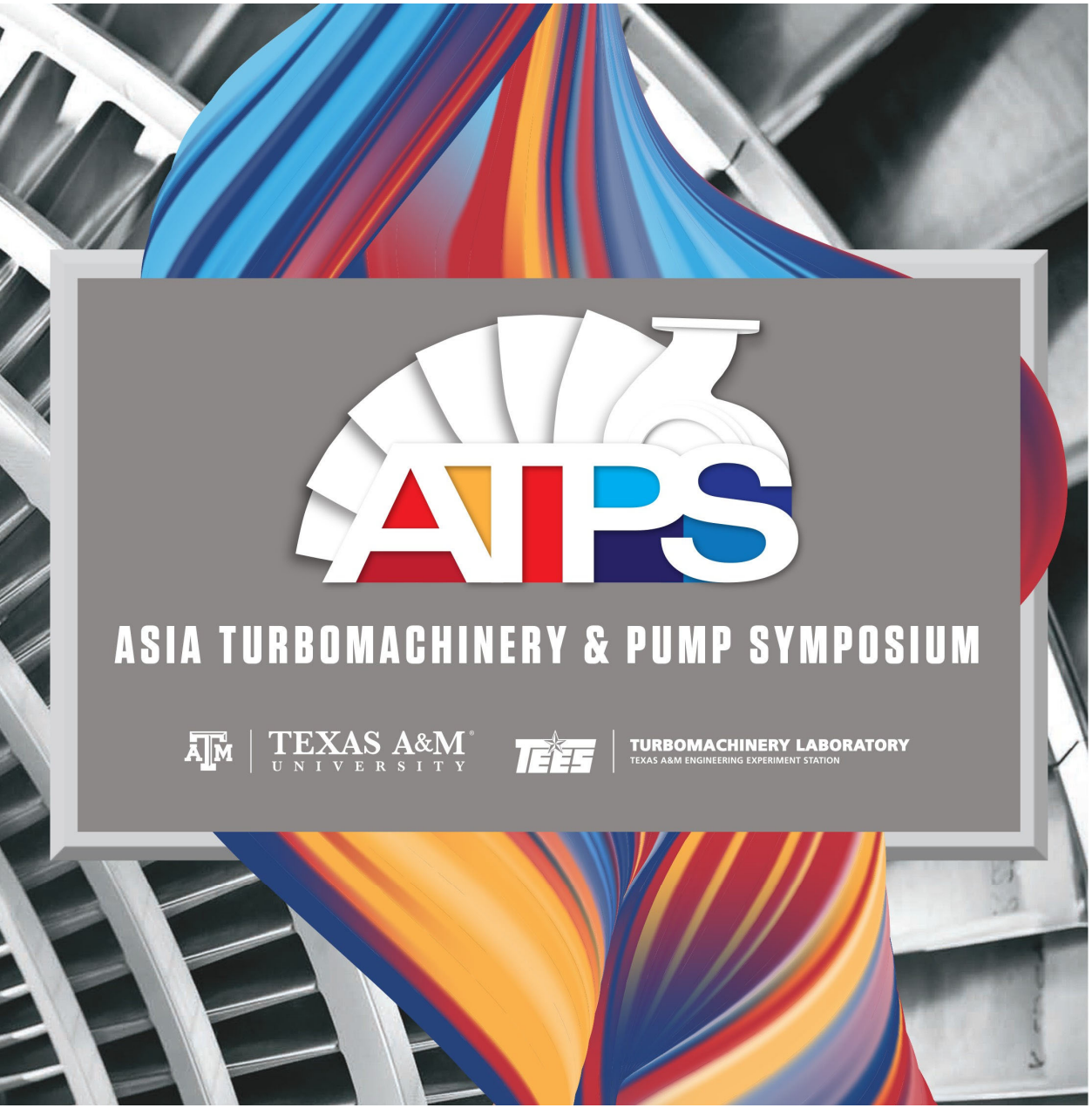

Introduction of SCC life time estimation for fir tree design on steam turbine

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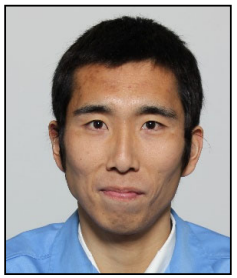

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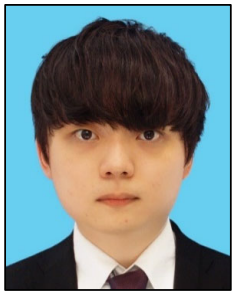

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(SCC : Stress Corrosion Cracking)

1. Problem Statement

During inspection of a steam turbine rotor, cracks are found on the Fir tree blade groove. When this occurs, it is necessary to have a quick evaluation of the residual life in order to decide the maintenance plan and repair scheme.

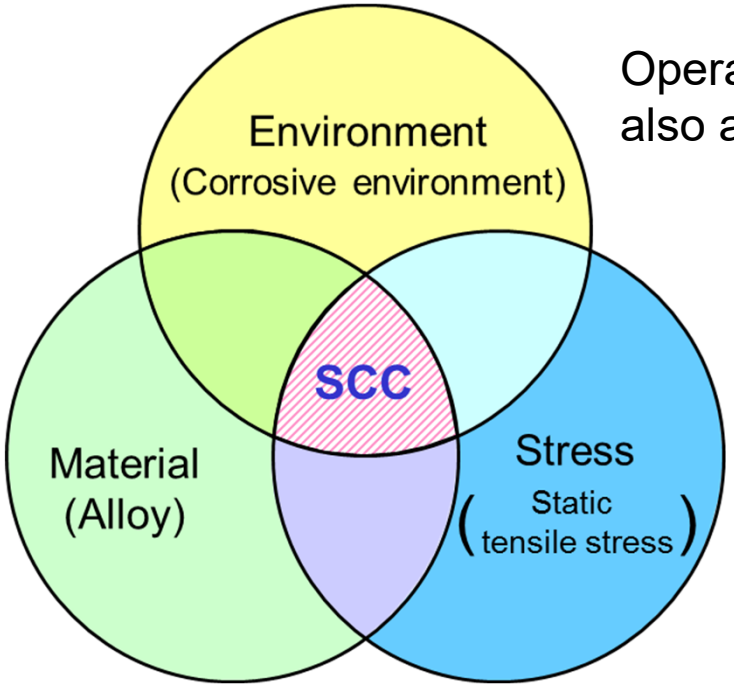
This presentation describes:

- a fast method to assess Stress corrosion cracking (SCC) residual life
- the assessment of remaining life for the turbine of the case study

2. What is SCC ?

- SCC (Stress Corrosion Cracking) is the growth of crack deformation in corrosion environment
- What makes SCC dangerous is the possibility of unexpected sudden failure.

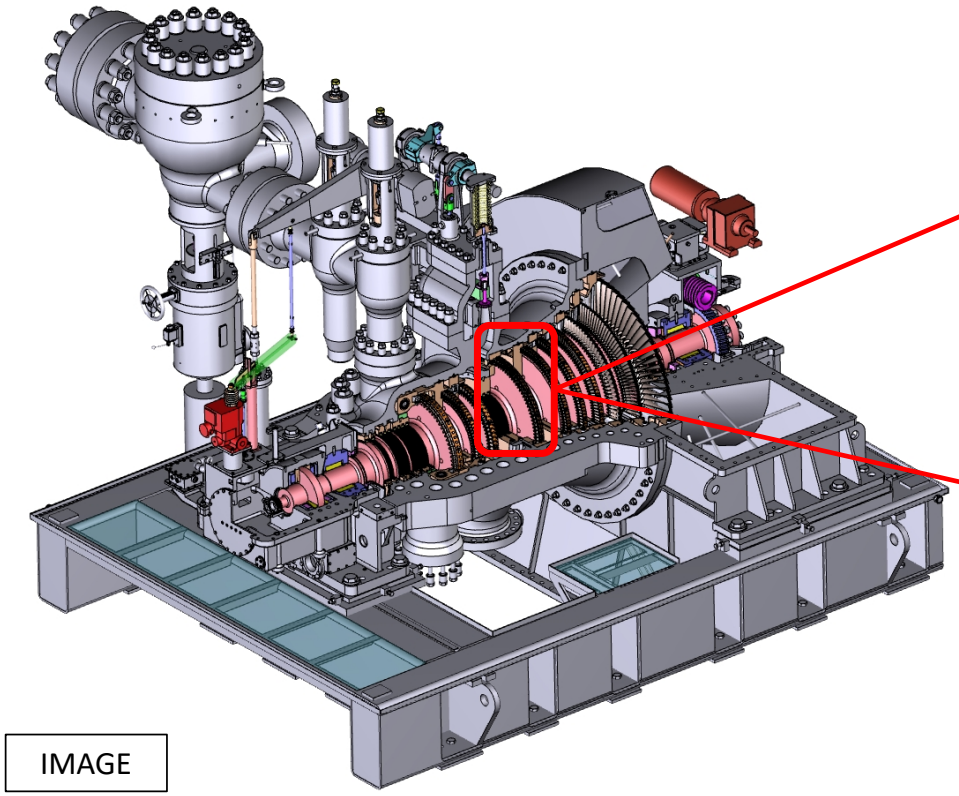
➢ Factors affecting SCC



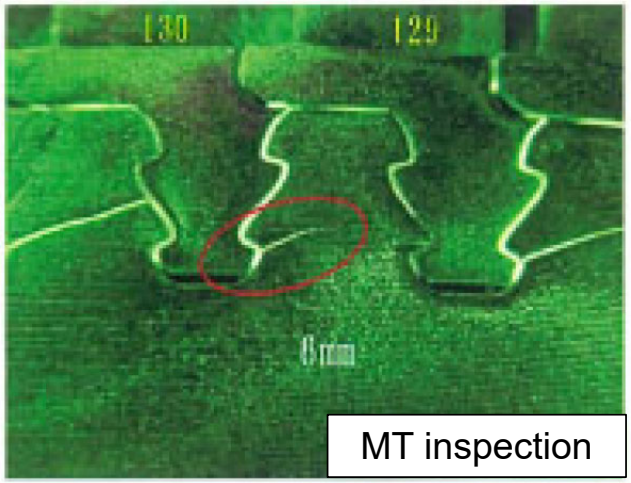
Operating time
also affects SCC.

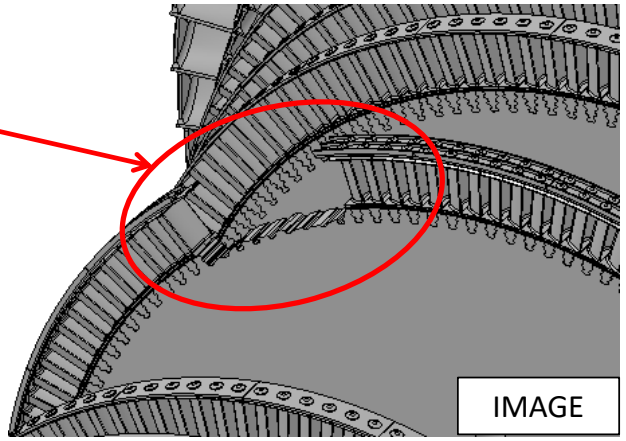
SCC will occur when these three factors occur at the same time.
(Stress, Material, Environment)

3. Background



IMAGE

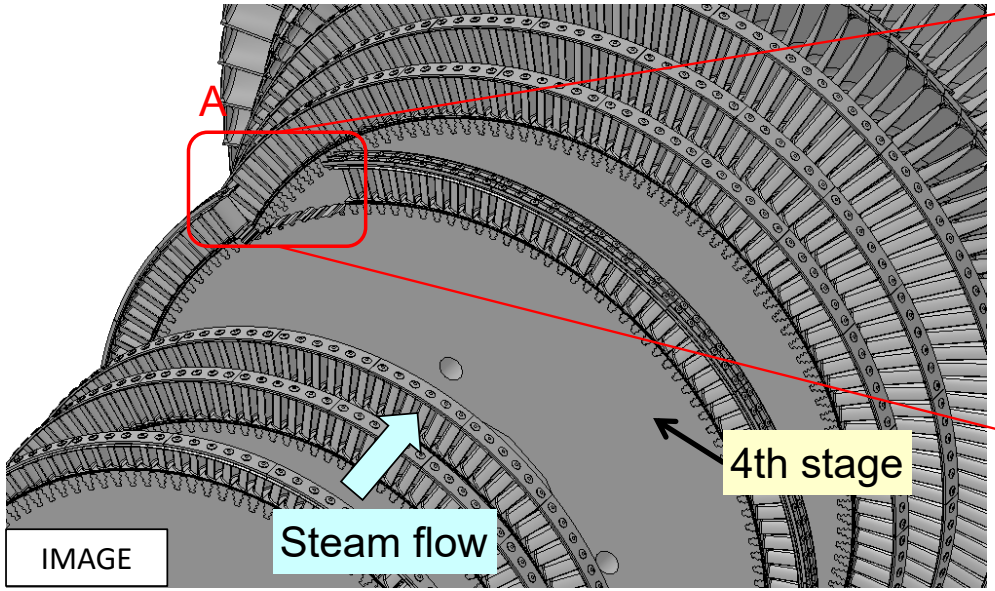




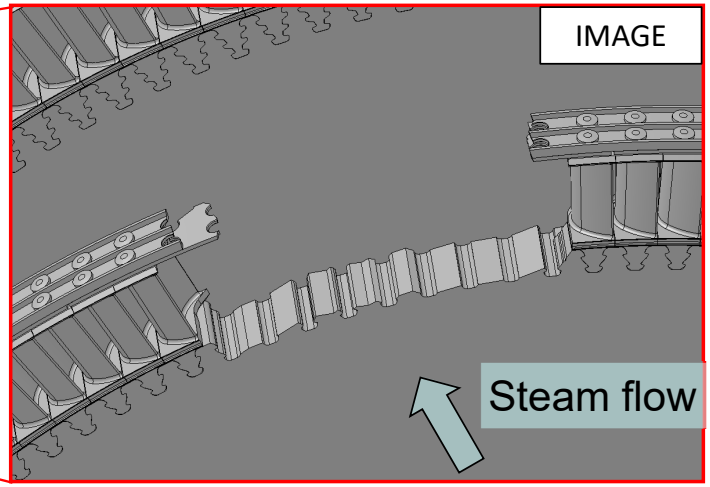
IMAGE

In 2016, the compressor drive steam turbine was tripped by high radial vibration. After that, turbine casing was opened for internal parts check.

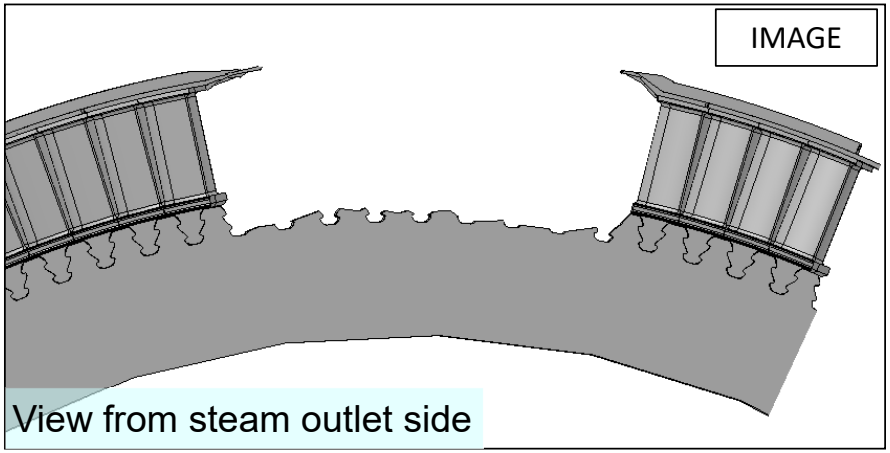
3. Background



Rotor condition



4th stage disk condition (Magnification A)



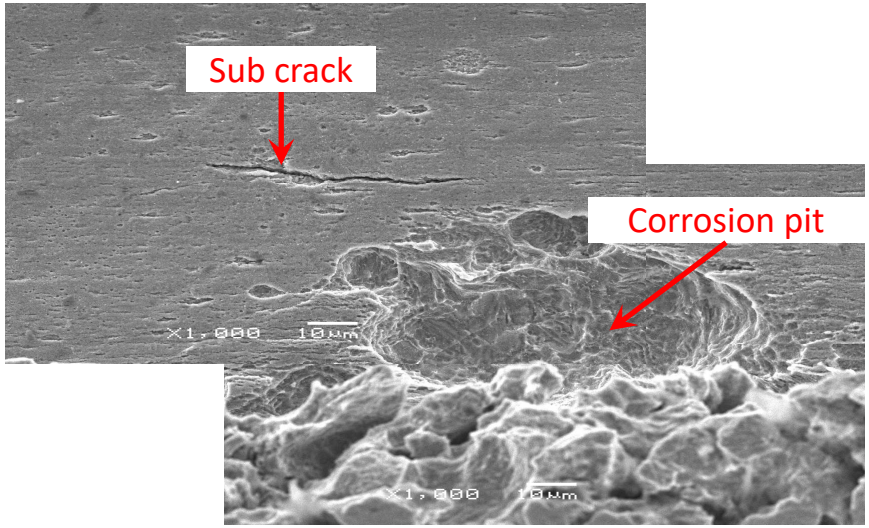
4th stage disk condition (After cut)

- 4th stage disk failure was found
  - 9 blades broke away and disc failure occurred at serration part of the groove.
  - 8 blade roots of disk side situated next to failed blades were cracked

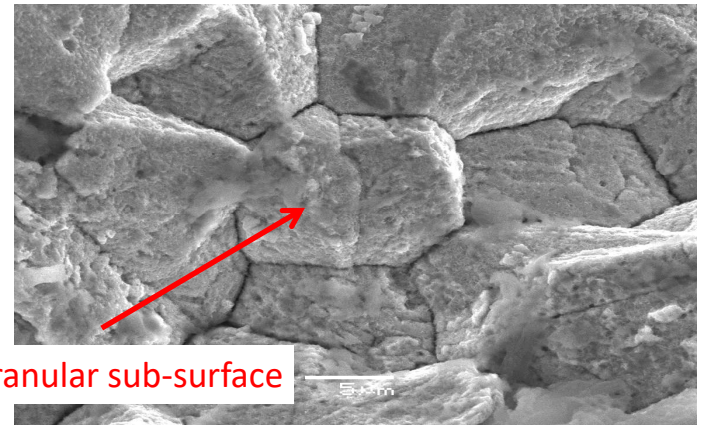
3. Background

Typical characteristics of SCC

Fractured surface



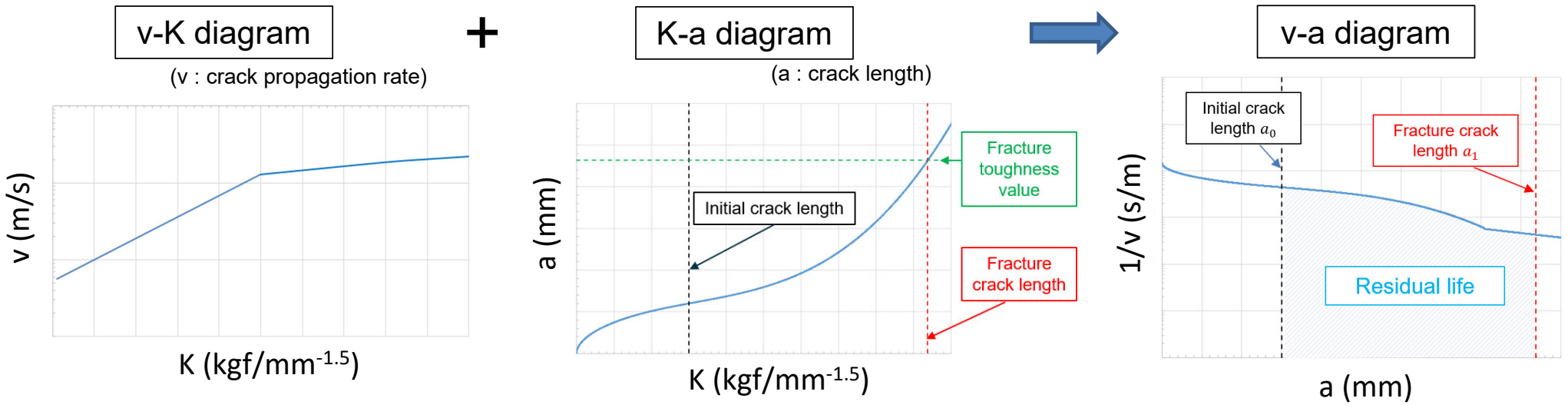
- Some corrosion pits and sub-cracks were found on disc surface near the crack.
- The intergranular sub-surfaces were observed on fractured surface.
- Corrosive material such as Na, Cl were detected on fractured surface.



Cracks are because of corrosion cracks (SCC)

4. Residual life evaluation method

- **Calculation procedure**



- v-K diagram is result of past SCC test for standard rotor material
- K-a diagram is obtained by the general formula between K and a
- The residual life is calculated using v-a diagram*

$$\text{Residual life} = \int_{a_0}^{a_1} \frac{1}{v} \mathrm{da}$$

* v-a diagram is drawn as combining v-K diagram and K-a diagram. Residual life time evaluation method is well proved one with v-a diagram.

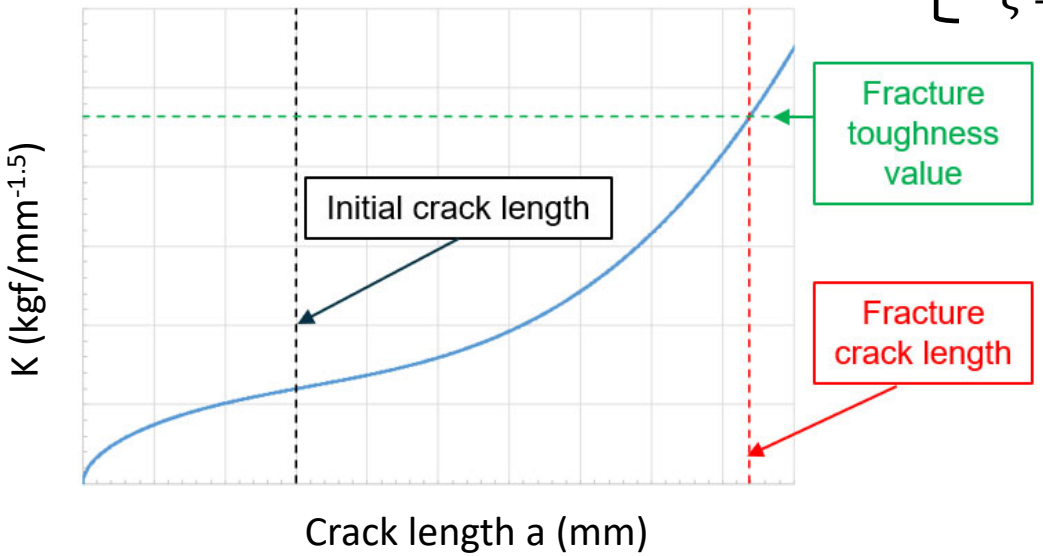
4. Residual life evaluation method

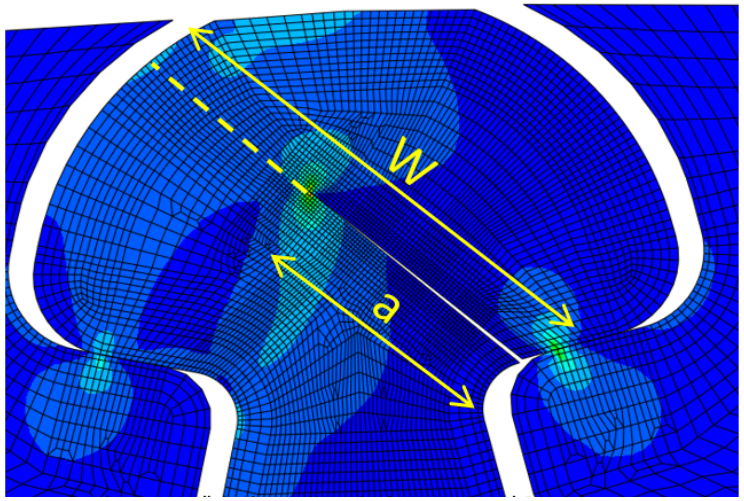
The stress intensity factor K describes the stress state at a crack tip and is used to calculate the residual life

General formula for K

$$K = \sigma_t \sqrt{\pi a} \cdot F(\xi)$$

- σ_t : tensile stress
- $F(\xi)$: coefficient of shape
- a : crack length
- W : width of groove
- $\xi = a/W$





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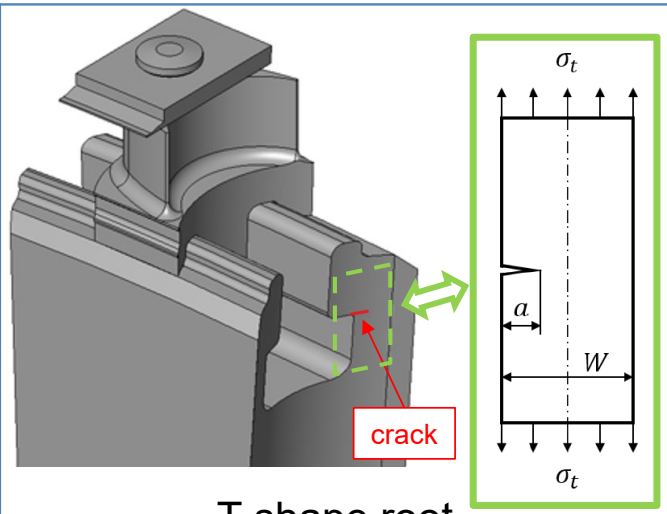
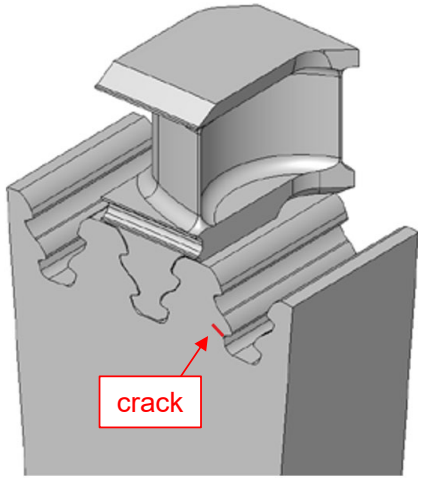
4. Residual life evaluation method

Root type 	 T-shape root	 Fir tree root
F(ξ) for each shape	General formula of F(ξ) for flat plate can be used	There is no general formula of F(ξ) for this shape
Calculation method of residual life by General formula of F(ξ)	Established	**Not established**
Analysis for F(ξ)	Unnecessary	Analysis for F(ξ) is necessary each time

Take much time to perform the analysis each time for information to customer

5. Purpose of this study

- **Determine coefficient of shape F(ξ) of Fir tree root groove by using FEA**
- **Establish a residual life calculation method for SCC of Fir tree blade groove without FEA for each time**

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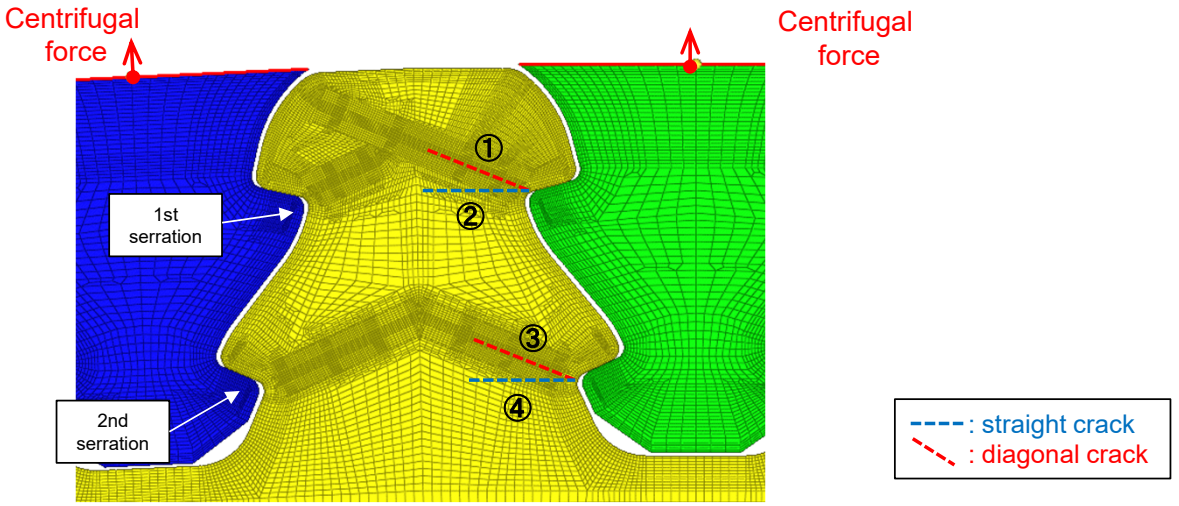
6. Stress FEA analysis for F(ξ)

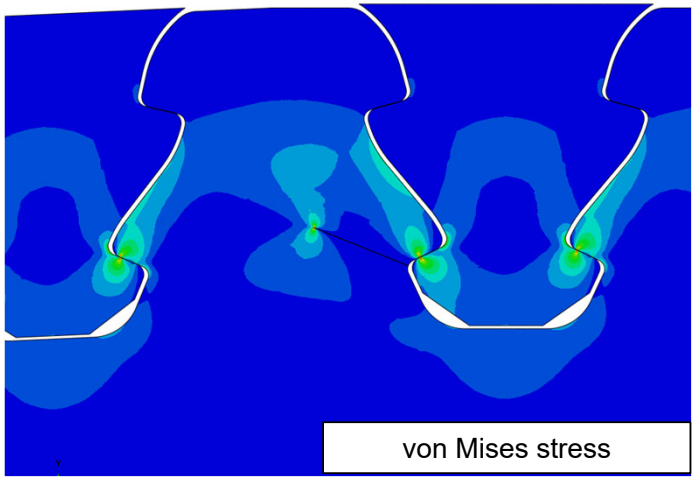
Analysis using models of Fir tree root with cracks of various conditions → **Determine F(ξ) of Fir tree root**

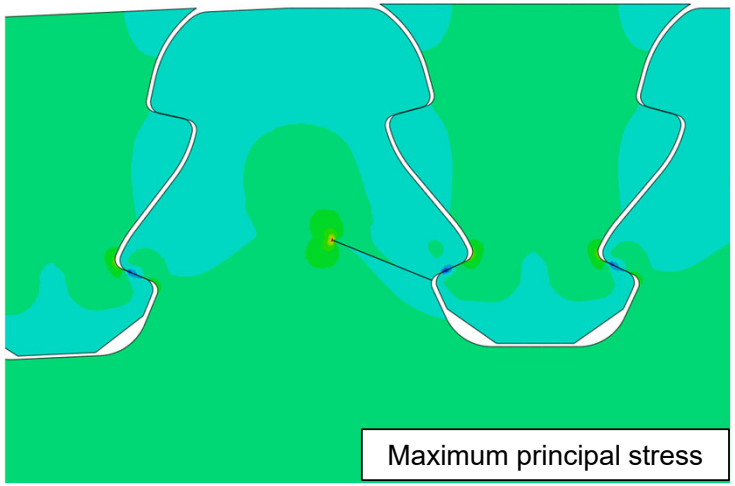


Root type	2 serrations			
Crack position	1st serration		2nd serration	
Crack angle	diagonal	straight	diagonal	straight
Condition Number	①	②	③	④
Crack length	4 models with different crack length is prepared for each conditions			

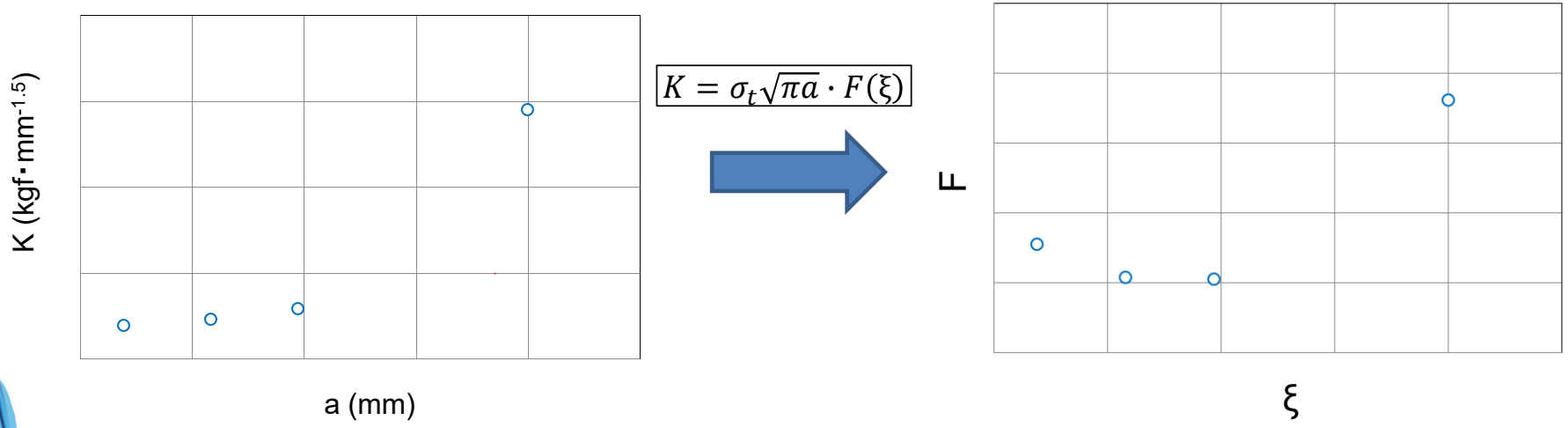
6. Stress FEA analysis for F(ξ)

Stress countour diagram (Condition 3)



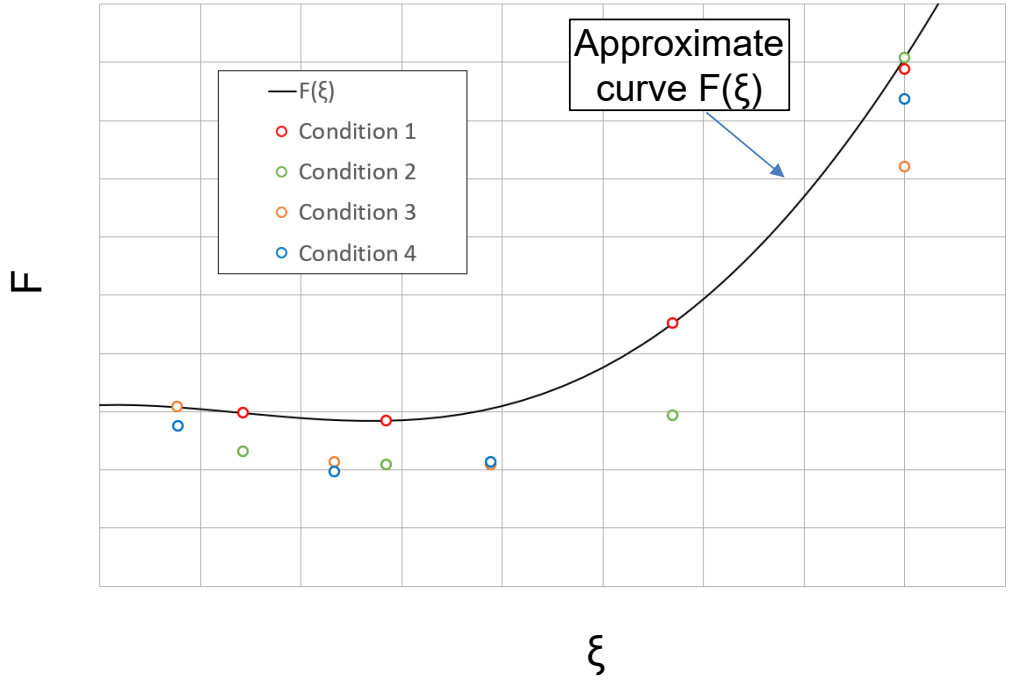


Conversion from K-a to F-ξ (Condition 3)



7. Residual life estimation method for Fir tree root

F-ξ diagram under all conditions



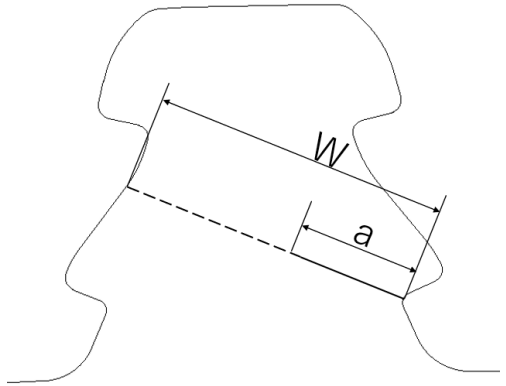
Maximum values of F

Comprehensive evaluation

Approximate curve F

General formula for K of Fir tree root

$$K = \sigma_t \sqrt{\pi a} \cdot F(\xi) \qquad \xi = a/W$$



This equation made it possible to calculate residual life

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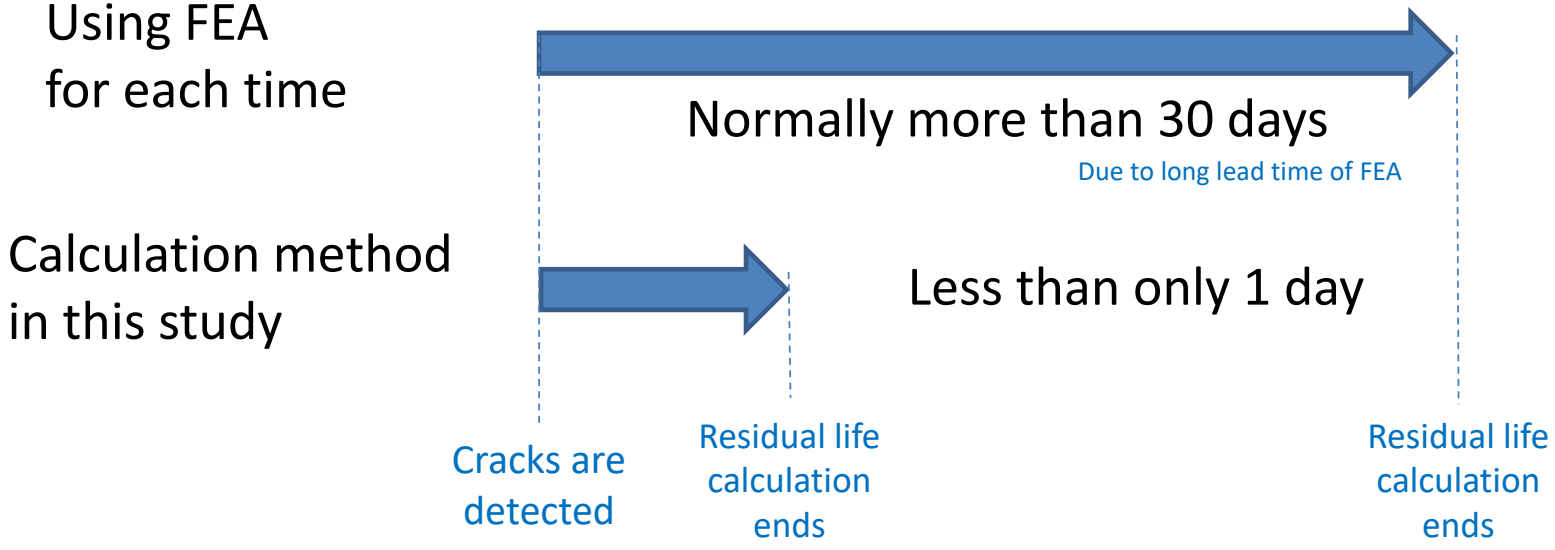
7. Residual life estimation method for Fir tree root

- **Comparison of lead time**

The residual life of Fir tree root groove calculated by…



This evaluation method determined in this study can give residual life in a short time (during maintenance operation), so that corrective actions can be taken immediately.

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8. Lessons and learned

- The evaluation method for SCC of fir tree blade groove without FEA is determined in this study. It would be helpful to decide the concrete action during the short term like turn around period since there is no requirement of FEA to estimate the lifetime.

- OEM can advise the status of SCC phenomenon on a timely basis and related parties can start the next action like replacement of rotor from working to spare rotor, further investigation and so on.

END

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