Study Committee A1

Rotating Electrical Machines

Paper A1_741_2022

Preventive Maintenance Technology for Enhancement of Turbine Generator Reliability

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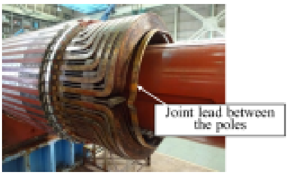
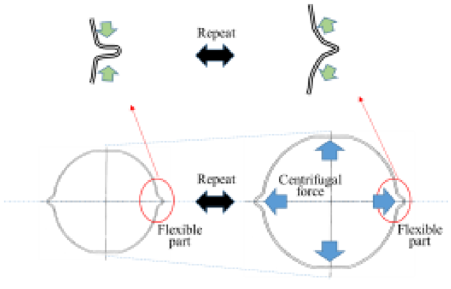
Motivation

- The role of thermal power plants is expected to change from conventional base-load operation to peak-load operation depending on the power demand. As a result, turbine generator will be operated only in a certain time of a day for adjustment of power supply, daily start and stop cycles of turbine generator will increase significantly.
- As it increases, there is growing concern about damage of generator rotor parts due to low cycle fatigue.
- We have developed both large scale 3D structural analysis and a new non-destructive testing (NDT) technology for evaluation of remaining lifetime of turbine generator and planning of reasonable inspection frequency.

About Low Cycle Fatigue Failure of Rotor Parts

- In daily start and stop (DSS) operation, a start and stop cycle is repeated approximately once a day. The number of starts and stops will reach 1,000 in several years.
- While generators are operating, stresses due to centrifugal forces and thermal expansion occur at each section of the rotors, and this tensile force is unloaded when the generator stops. There is a possibility that the parts are damaged because of repeated stress.
- Generally, low cycle fatigue failure occurs at around 10^4 cycles. The threshold of failure is determined by the number of repetitions and the value of stress amplitude, and if the stress amplitude is large, failure may occur after only several thousand cycles.



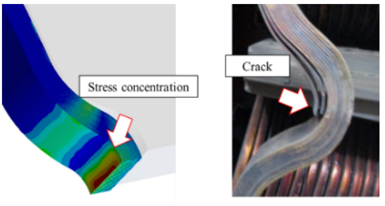


(a)During stoppage (b)During operation

Experience of Breakage Incidents of Rotor Parts

1. Joint lead between the poles

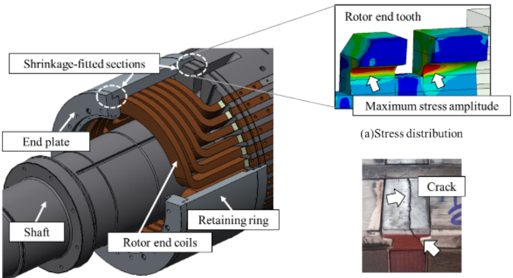
To absorb the deformation against tensile force and suppress the excessive stress occurrence, flexible parts are originally provided in the joint lead between the poles. Circumferential stress is locally concentrated at the center of the flexible parts and the breakage was observed.



(a)Stress destribution (b)The broken part

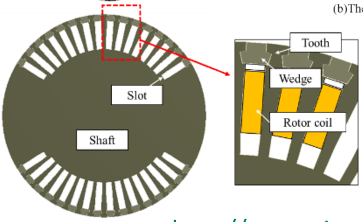
2. Rotor teeth under retaining ring

- The retaining ring is strongly shrink-fitted with the shaft and end plates, and compressive force acts on the teeth under the retaining ring due to the shrinkage fitting during stoppage.
- Because the tensile force during operation and the compressive force during stoppage act in opposite directions, the cyclic stress amplitude of the teeth under the retaining ring is often the largest in the rotor parts and well-known as a potential weak point.



(a)Stress distribution

(b)The broken part



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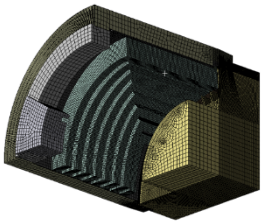
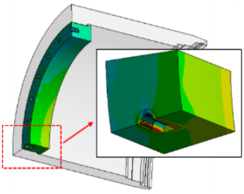
Development of Accurate Lifetime Evaluation with Large Scale 3D Structural Analysis

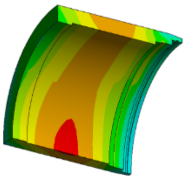
- It is possible to evaluate with higher accuracy the local stress at each section of a complexly shaped rotor with structural analysis of a 3D model of a whole rotor end structure.
- In conventional 2D analysis, the rotor end was assumed to be symmetric in the circumferential direction. However, the results obtained by the 3D analysis have revealed that slight structural asymmetries in actual equipment cannot be ignored when evaluating low cycle fatigue lifetime because asymmetric deformation of the retaining ring also affects the deformation of the rotor teeth, joint lead between the poles, and end plates.



(a) Mesh model

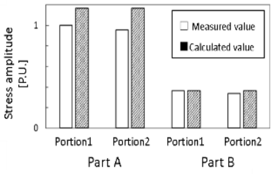


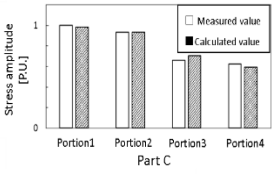
(b) Stress distribution of end plate



(c) Stress distribution of retaining ring

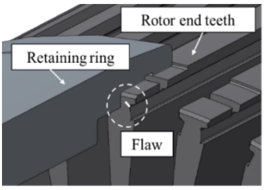
- We used an actual rotor to measure the stress at each section to re-check the accuracy of the stress calculation. The measured circumferential stresses on the rotor wedge and retaining ring are shown as examples. In both cases, the measured values closely match the calculated ones including differences in the circumferential and axial locations, confirming the validity of the current analysis technique.





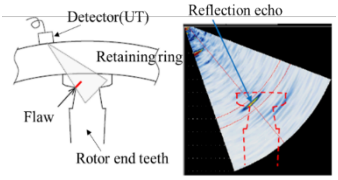
New NDT Method for the Rotor Teeth under the Retaining Ring

- Ultrasound is used to detect a failure in a tooth inside a retaining ring from the surface of the ring. This technology enables us to conduct inspections without disassembling the rotor end parts.
- The position where the detector can detect a flaw is limited depending on the angle and length of the flaw. Therefore, the verification tests were repeated with various damaged teeth models, and we established the appropriate procedure to indicate relationship between locations of the detector and a flaw, corresponding to various rotor structures.



(a)A flaw on the corner of rotor end teeth

(b)Visible dye penetrant test (PT)



(c)Ultrasonic test (UT)

Conclutions

Due to the change of thermal power plant utilization, the number of start and stop cycles of turbine generator tends to increase, and the risk of low cycle fatigue failure of generator rotor parts becomes higher than that initially envisioned. We have developed and introduced the following technologies.

1. Accurate lifetime evaluation of turbine generator to ensure that a generator rotor runs under DSS operation for 30 years with high reliability over 99.9%.
2. New NDT method to presume residual lifetime of rotor end teeth portion and to plan reasonable inspection frequency.

By using these technologies, we will contribute to stable operation and availability enhancement of thermal power plants.

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