Stress Corrosion Cracking on Steam Turbine Rotor Grooves: Experiences and Countermeasures from EGAT Power Plants

POWER-GEN Asia Conference 2009
9th October 2009
IMPACT Exhibition & Convention Center
Bangkok, Thailand
Presentation Topics

- EGAT Steam Turbine Portfolio
- SCC on Steam Turbine Rotor
- Life Assessment and Evaluation
- Experiences and Countermeasures
- Summary
- Questions and Answers

*SCC refers to Stress Corrosion Cracking*
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EGAT Steam Turbine Portfolio

EGAT Power Plants

Statistical Data

30 Steam Turbines
- 12 combined cycle plants
- 28 thermal plants

Largest 600 MW Oldest 35 years
Smallest 109 MW Newest <1 years
Average 274 MW Average 17 years

Total Generation Capacity 8.2 GW
EGAT Steam Turbine Portfolio

EGAT subsidiaries

**Statistical Data**

- 15 Steam Turbines
  - 10 combined cycle plants
  - 4 thermal plants
  - 1 co-generation plant

Largest 735 MW   Oldest 29 years
Smallest 14 MW   Newest 1 year
Average 240 MW   Average 11 years

Total Generation Capacity 3.7 GW
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SCC on Steam Turbine Rotor

550 MW Steam Turbine

Double Flow LP Rotor

Blade Attachment

Crack

SCC
SCC on Steam Turbine Rotor

SCC failure is the function of
- Stress Intensity
- Rotor Material
- Steam Environment

The probability of occurrence is high especially in attachments of the 3 last stages.

SCC could be found in all blade attachment designs but the most prevalent is fir tree type!
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Life Assessment and Evaluation

(1)* Blade Removal
(2) Groove Cleaning
(3) Magnetic Particle Test
(4) Replication Test
(5) Crack Grinding
(6) Indication Measurement
(7)* Remaining Life Assessment

Evaluation
Critical Crack Depth and Crack Growth Rate

Note: (1) 10% sampling of all L-0 blades for life assessment is normally applied
(7) In case of determination of critical crack depth and crack growth rate, EGAT shall consult with OEM
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Experiences and Countermeasures

- Experiences
- Countermeasures
  - Crack Grinding
  - Running (until next outage)
  - Blade Cutting or Removal
  - Steeple Machining
  - Welding Repair
  - Rotor Replacement
Experiences

- The first steam turbine life assessment program had been carried out since 1997.
- SCC were found in 11 out of 21 steam turbines that life assessments were done.
- SCC were found in L-0, L-1, and L-2 around 53%, 47%, and 20% respectively.
- The periods for steam turbine life assessments in EGAT range from 15 to 42 years with an average of 21 years.
- Several corrective actions had been implemented for example crack grinding, running until next outage, blade cutting or removal, steeple machining, welding repair, and rotor replacement respectively.
Countermeasure: Crack Grinding

**Advantages**
- one of low cost options
- first common corrective action to every crack found
- may stop further crack propagation

**Disadvantages**
- suitable for only shallow cracks
- crack may propagate at other areas instead

**Plants**
- SB-T (2 units)
- MM-T (5 units)

*Short to Medium Term*
Countermeasure: Running (until next outage)

Advantages
- economical choice

Disadvantages
- requires complete remaining life evaluation
- unacceptable outage duration unless remaining life assessment has been prepared in advance

Plants
- BPK-T (2 units) can extend for 5 years operation but need LP groove end face inspection every 2 years
Countermeasure: Blade Cutting or Removal

Advantages
- comparatively low investment cost
- suitable for unit which has very deep cracks

Disadvantages
- lost of performance or efficiency
- may require baffle plates in order to prevent consequence failure in other blade rows (~2 weeks)

Plants
- SB-T (2 units) with baffle plates install and 90% load limitation
- MM-T (1 unit) without baffle plates install and 75% load limitation
Countermeasure: Steeple Machining

CASE 1

CASE 2

- Advantages
  - will reset the SCC cycle
  - possible to reduce stress by enlarge groove radii

- Disadvantages
  - geometry limitation
  - high cost for maintenance
  - unfavorable extended outage (~6 months)
  - requires some modifications for blading

- Plants
  - SB-T (3 units) by dropped steeple machining in case 2

Medium to Long Term
Countermeasure: Welding Repair

**Advantages**
- will reset the SCC cycle
- can apply weld material with high resistance to SCC

**Disadvantages**
- high cost for maintenance
- unfavorable extended outage (~6 months)
- may have effect on rotor material particularly in HAZ

**Plants**
- SB-T (1 unit) by partial welding because steeple machining can’t eliminate some deep cracks

Medium to Long Term
Countermeasure: Rotor Replacement

- **Advantages**
  - archives thermal efficiency or heat rate improvement
  - higher SCC resistant by upgrade rotor material or improve design

- **Disadvantages**
  - high investment cost
  - requires time to implement (~2½ years)
  - should consider for compatibility with nearby components

- **Plants**
  - BPK-T (2 units) with 13.9 MW up from 550 MW each
  - MM-T (3 units) with 5.0 MW up from 300 MW each

**Long Term**
Countermeasures

Life Assessment

SCC? No

Operation (without restriction)

Yes

Remaining Life Assessment

Critical Crack Depth ($a_c$)
Crack Growth Rate ($da/dt$)

If $a \geq a_c$

If $a < a_c$

Blade Cutting or Removal

Operation (with restrictions)

Crack Grinding (all cracks)
Running (until next outage)

Operation (with restrictions)

Remaining Life Evaluation

Rotor Replacement
Welding Repair
Steeple Machining
## Experiences & Countermeasures

<table>
<thead>
<tr>
<th>No.</th>
<th>Plant</th>
<th>COD (year)</th>
<th>Inspection (year)</th>
<th>SCC Indication</th>
<th>Sampling (/stage)</th>
<th>Countermeasures</th>
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<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td>L-0</td>
<td>L-1</td>
<td>L-2</td>
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<tr>
<td>1</td>
<td>NB-T1*</td>
<td>1961</td>
<td>2003</td>
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<td>No</td>
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<tr>
<td>2</td>
<td>SB-T1*</td>
<td>1970</td>
<td>1998</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<td>3</td>
<td>SB-T2*</td>
<td>1971</td>
<td>1997 2000</td>
<td>Yes</td>
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<td>4</td>
<td>SB-T3</td>
<td>1974</td>
<td>1997 2000 2001 2006</td>
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<td>Yes</td>
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<td>5</td>
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<td>1975</td>
<td>2001 2005</td>
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<tr>
<td>6</td>
<td>SB-T5</td>
<td>1977</td>
<td>1999 2002 2007</td>
<td>No</td>
<td>-</td>
<td>No</td>
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</table>

**Note:** NB-T is North Bangkok Thermal Power Plant and SB-T is South Bangkok Thermal Power Plant
## Experiences & Countermeasures

<table>
<thead>
<tr>
<th>No.</th>
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<th>Inspection (year)</th>
<th>SCC Indication</th>
<th>Sampling (/stage)</th>
<th>Countermeasures</th>
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<tbody>
<tr>
<td>7</td>
<td>MM-T1*</td>
<td>1977</td>
<td>1998</td>
<td>- Yes -</td>
<td>5 grooves</td>
<td>Grinding</td>
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<td>8</td>
<td>MM-T3*</td>
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<td>1999</td>
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<td>1984</td>
<td>2002</td>
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<td>2008</td>
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<td>11</td>
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<td>2005</td>
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<td>2007</td>
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<td>13</td>
<td>MM-T8</td>
<td>1989</td>
<td>2004 2006 2008</td>
<td>Yes Yes No Yes</td>
<td>100% 12 17</td>
<td>Grinding</td>
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<td></td>
<td></td>
</tr>
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<td>14</td>
<td>MM-T9</td>
<td>1990</td>
<td>2006 2007</td>
<td>Yes Yes Yes</td>
<td>100% N/A</td>
<td>Blade Removal</td>
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<td></td>
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<td></td>
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<td></td>
<td>(without Baffle Plate installed)</td>
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<td>LP Turbine Retrofit</td>
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<td>15</td>
<td>MM-10</td>
<td>1991</td>
<td>2006 2009</td>
<td>Yes Yes No</td>
<td>100% 10</td>
<td>Grinding</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>LP Turbine Retrofit</td>
</tr>
</tbody>
</table>

**Note:** MM-T is Maemoh Thermal Power Plant
## Experiences & Countermeasures

<table>
<thead>
<tr>
<th>No.</th>
<th>Plants</th>
<th>COD (year)</th>
<th>Inspection (year)</th>
<th>SCC Indication L-0</th>
<th>L-1</th>
<th>L-2</th>
<th>Sampling (/stage)</th>
<th>Countermeasures</th>
</tr>
</thead>
</table>
| 16  | BPK-T1 | 1983       | 2003              | No                 | Yes | No  | 1 group at end face N/A | Grinding  
Running (until next outage)  
LP Turbine Retrofit |
|     |        |            | 2005              |                    |     |     |                  |               |
| 17  | BPK-T2 | 1983       | 2001              | No                 | Yes | No  | 1 group at end face N/A | Grinding  
Running (until next outage)  
Running (until next outage)  
Running (until next outage)  
LP Turbine Retrofit |
|     |        |            | 2003              | No                 |     | Yes |                  |               |
|     |        |            | 2005              | No                 | Yes | No  |                  |               |
|     |        |            | 2006              | No                 |     |     |                  |               |

Running (until next outage) requires Remaining Life Assessment and Evaluation.

**Note:** BPK-T is Bangpakong Thermal Power Plant
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Summary

- Root causes of SCC are the combination of applied stress, steam environment, and susceptible material.
- Determination for major root cause is crucial for long term operation.
- Steam turbines operating more than 15 years are prone to this failure mechanism.
- There is no unique countermeasure for solving SCC problem on LP rotor groove because of inspection, operation, and economical constraints.
- Critical crack depth, outage duration, spare parts, and cost benefit analysis are the key factors for deciding on which suitable action should be taken.
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End of Presentation

Thank you for your attention!

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