On Study of Synergic Effect for PEEK of CEDM in Nuclear Power Plant Using TGA Method

Jae Hyung Kim\textsuperscript{1)} Han Soo Kim\textsuperscript{2)} Keug Jin Bhang\textsuperscript{2)}

\textsuperscript{1)}Equipment qualification center for Nuclear Power Plant, Korea Institute of Machinery & Materials
\textsuperscript{2)}Safety qualification center, Korea Hydro & Nuclear Power Co., Ltd. Central Research Institute
Contents

1. Background
2. Test Result
3. Conclusion
Synergic Effect

Real Situation

Thermal + Radiation

Real Qualification

Thermal -> Radiation

Radiation -> Thermal
IEEE w.r.t. Synergic Effect

Synergic effect shall be evaluated

IEEE 382 2006

IEEE 323 2003
Total dose of Radiation > Threshold

Sequence Change:
radiation -> thermal

The material is damaged
How can I find the threshold value?

- Look up in DB
- Test with some physical property
What is the physical property?

Physical property in NP 2129

- Elongation
- Tensile strength
- Temperature at break
- Elastic modulus
- Flex life
- Impact strength
- Impact resistance
- Compression test
- Oxidation resistance
- Hardness
Leakage due to radiation

Leakage Assessment of Valve Assembly

Leakage of valve is increased suddenly due to radiation.

Why?

Over threshold

Leakage: safety related parameter

Fig. 3–20 Data of seat leakage test

Pil-Sun Kang, Operational reliability assessment of Air-Operated Valve aging test, Department of Nuclear Energy Engineering Graduate School of Industry Chungnam National University Dajeon, Korea
Difficult Test

Long Period

Difficult Measuring of Leakage
Comparison of Activation Energy by EAB and TGA

kFactor : $\frac{Ea(\text{TGA})}{Ea(\text{EAB})}$

Equal range within error bound

High range beyond error bound

But, different absolute value

So, used as reference

Keug-jin Bhang, Study on Aging Life for Non-metallic Component in Nuclear Power Plant Using Thermal Gravity Analysis, Department of Nuclear Energy Engineering Graduate School of Industry Chungnam National University Dajeon, Korea
TGA method as the founding of synergic effect

Easy method in short time

Only used as relative value of Activation energy
Change of Activation Energy After prior radiation exposure

In general, the activation energy is measured without prior radiation exposure? If the activation energy is smaller after radiation aging?
First Question: Is the material is damaged like threshold comparison?
Second Question: does the small activation energy after radiation aging is used?
First Question: Is the material is damaged like threshold comparison?

- Test Result: After radiation exposure over threshold value, there is change to large value of activation energy in out test
- Report: In the radiation exposure below threshold value, there is no damage and no sequence change
- Conclusion: Damage by radiation result to change of activation energy

Second Question: does the small activation energy after radiation aging is used?

- In the conservative view point, the small value of activation energy is recommended.
- But more test with many materials is needed for the reliable conclusion
Evaluation Result

If the activation energy after radiation aging is changed to larger or smaller value, the material is damaged like threshold criteria.

So the comparison of the activation energy with pre-radiation aging to the activation energy without radiation aging is indicating to sequence related issue(synergic effect) by threshold and damage concepts.
Test Result: Application of Activation Energy using TGA to Test Sequence

**Activation Energy of PEEK**

- Activation Energy with radiation treatment is larger than without radiation treatment.
- Conservative Test condition without radiation treatment.
- Consideration of Sequence is possible.

Activation Energy with radiation aging [Ea]

Activation energy of with radiation aging [Ea]

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>2</td>
<td>2.5</td>
<td>3</td>
<td>2.5</td>
</tr>
<tr>
<td>1</td>
<td>1.5</td>
<td>2</td>
<td>2.5</td>
<td>2</td>
</tr>
</tbody>
</table>
Procedure of TGA

Step 1. measure of specimen
Step 2. Testing TGA
Step 3. Analysis of data
### Kinetic Parameters at Different Conversion Levels

<table>
<thead>
<tr>
<th>Conversion %</th>
<th>Activation Energy (kJ/mole)</th>
<th>Log[Pre-exp Factor]</th>
<th>60 min</th>
<th>Half-Life Temp (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>4.9</td>
<td>-2.83</td>
<td>-75</td>
<td>20.0</td>
</tr>
<tr>
<td>2.5</td>
<td>66.5</td>
<td>2.05</td>
<td>562.8</td>
<td>10.0</td>
</tr>
<tr>
<td>5.0</td>
<td>182.3</td>
<td>9.91</td>
<td>598.2</td>
<td>5.0</td>
</tr>
<tr>
<td>10.0</td>
<td>246.2</td>
<td>14.14</td>
<td>530.8</td>
<td>2.5</td>
</tr>
<tr>
<td>20.0</td>
<td>270.7</td>
<td>15.82</td>
<td>526.8</td>
<td>1.0</td>
</tr>
</tbody>
</table>

---

**Run Date:** 2017-07-07 23:13:33  
**Operator:**  
**Sample:** Peek1_4mg_20C  
**Comment:** 2017.07.07  
**Program:** Specialty Library V2.2 Build 2.2.0.1

**TA Instruments Thermal Analysis -- TGA - Modulated**
Case 1. Radiation 2.0X10^6Gy Peek TGA

Kinetic Parameters at Different Conversion Levels

<table>
<thead>
<tr>
<th>Conversion</th>
<th>Activation Energy (kJ/mole)</th>
<th>Log[Pre-exp Factor 1/min]</th>
<th>60 min Half-Life Temp (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>0.0</td>
<td>-3.54</td>
<td>-273.1</td>
</tr>
<tr>
<td>2.5</td>
<td>180.3</td>
<td>10.12</td>
<td>508.1</td>
</tr>
<tr>
<td>5.0</td>
<td>273.7</td>
<td>16.08</td>
<td>520.5</td>
</tr>
<tr>
<td>10.0</td>
<td>295.6</td>
<td>17.51</td>
<td>520.7</td>
</tr>
<tr>
<td>20.0</td>
<td>313.0</td>
<td>18.68</td>
<td>519.6</td>
</tr>
</tbody>
</table>
Conclusion

Usage of Activation Energy of TGA

- Absolute value is differ to the value in EAB test
- Relative comparison is possible based on EQDB result.

Usage of the value change of activation energy

- Comparison of activation energy without and with radiation aging determined the sequence of radiation and thermal aging

Future Plan

- More test is needed to investigate other material