Simplified Elastic-Plastic Analysis Methods in the JSME Rules on Design and Construction*

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Abstract
In a fatigue analysis for Class 1 components in the Rules on Design and Construction for Nuclear Power Plants (The First Part: Light Water Reactor Structural Design Standard) in the JSME Codes for Nuclear Power Generation Facilities, a simplified elastic-plastic analysis is used when the primary plus secondary stress intensity exceeds 3 times the Design Stress Intensity. The simplified elastic-plastic analysis is to multiply elastic-analysis-based stress by a Ke-factor. It is well-known that the Ke-factor of the ASME Boiler and Pressure Vessel Code Section III has a large amount of conservatism. Hence, to develop an appropriate Ke-factor evaluation method, the Ke-factor Advisory Committee was established in June 1999 as a research committee of the Thermal and Nuclear Power Energy Society. Typical basic models were selected from actual structures. Elastic analyses and elastic-perfectly plastic analyses were performed for the basic models and the Ke-factors were calculated. Ke equations were established by bounding the Ke-factors. The new Ke equation was verified by using experimental data of piping. The Ke factors for typical actual nozzles of which Ke-factors were relatively higher were directly analyzed and it was confirmed that the developed Ke evaluation method could be higher than the Ke-factor directly analyzed. Based on those evaluations, the Ke' equation expressed by Primary + Secondary Stress Intensity ($S_a$) and the Ke" equation expressed by Primary + Secondary + Peak Stress Intensity ($S_p$) were developed. The Ke' equation has been taken in the JSME Design and Construction Code and the Ke" equation has been taken in the Code Case, "Alternative Structural Evaluation Criteria for Class 1 Vessels based on Elastic-Plastic Finite Element Analysis".

Key words: Fatigue, Structural Design, Plastic Design, Structural Analysis, Finite Element Method, Elastic-Plastic Analysis, Elastic-Perfectly Plastic Material

1. Introduction

The provision for Class 1 Vessels in the JSME Rules on Design and Construction for Nuclear Power Plants (The First Part: Light Water Reactor Structural Design Standard)\(^{(1)}\) (hereinafter called JSME D&C Code) specifies to perform fatigue evaluation by multiplying the elastic-analysis-based stress by a factor with some conditions in the case that the primary + secondary stress intensity ($S_a$) is greater than 3$S_m$ ($S_m$: Design Stress Intensity Value). This method is called Simplified Elastic-Plastic Analysis Method and the factor is
called Ke-factor.

The Ke-factor was incorporated into the ASME Boiler & Pressure Vessel Code Section III\(^{(2)}\) (hereinafter called ASME B&PV Sec.III) and incorporated into the Notification No. 501 of Ministry of International Trade and Industry, "Technical Standards for Construction of Nuclear Power Plant Components"\(^{(3)}\) (hereinafter called MITI Notification No. 501). Here, the MITI Notification No. 501 includes not only the Ke-factor equation of the ASME B&PV Sec.III but also the evaluation equation that expresses the concentration of peak plastic strain.

The Ke-factor equation of the ASME B&PV Sec.III was developed based on a simple model and it is well-known that the Ke-factor of the ASME B&PV Sec.III has a large amount of conservatism.

When the effects of light water reactor (LWR) coolant environments that have become evident during recent years are considered, the fatigue evaluation will be severe than that by the conventional design fatigue curve in air. The plant life management (PLM) evaluation performed on the Japanese operating plants has already included environmental fatigue and the JSME issued "Environmental Fatigue Evaluation Method for Nuclear Power Plants"\(^{(4)}\). Design transients that specify design conditions for fatigue analysis also have conservatism and those can be rationalized by reviewing the design transients\(^{(5)}\). Refining the Ke-factor can rationalize the fatigue evaluation without rigidification of the design transients and also keep appropriate conservatism.

In order to study the Ke-factor, the Ke-factor Advisory Committee chaired by Professor Y. Asada was established from June 1999 to April 2000 as a research committee of the Thermal and Nuclear Power Energy Society (TENPES)\(^{(6)}\).

The Ke-factor Advisory Committee developed not only a new Ke-factor equation expressed by \(S_n\) in a similar way to the ASME B&PV Sec.III but also a new equation expressed by primary + secondary + peak stress intensity \((S_p)\). The new Ke-factor equation expressed by \(S_n\) was incorporated into the JSME D&C Code 2001 Edition and the new Ke-factor equation expressed by \(S_p\) was incorporated into the code case on alternative design methodology by using elastic-plastic FEA for Class 1 vessels\(^{(7)}\) (hereinafter called JSME EPD Code Case).

This paper explains the concepts of the Ke-factor equations incorporated into the JSME D&C Code and the JSME EPD Code Case.

2. Concept of a Ke-factor

In PVB-3300 "Simplified Elastic-Plastic Analysis" in the JSME D&C Code, when \(S_n\) is not less than 3\(S_m\), an alternating peak stress intensity \((S_p)\) used for fatigue analysis is given by \(S_p\) and a Ke-factor as follows.

\[
S_f = \frac{K_e \cdot S_p}{2}
\]  

(1)

The Ke-factor is considered when the stress cycle induces plastic strain. When elastic-perfectly plastic material is assumed for the relationship between stress \((\sigma)\) and strain \((\epsilon)\), the load that causes plastic strain induces greater strain than that by elastic analysis and the Ke-factor is defined as the ratio of the elastic-plastic strain and elastic strain. The Ke-factor depends on load conditions and structures. For instance, the Ke-factor will indefinitely increase if primary stress \((P_m)\) of load-controlled type becomes greater than the yield stress \((\sigma_y)\). Here, \(P_m\) is limited by \(S_m\) that is defined not less than two-thirds of the yield stress or one-third of the tensile strength, whichever is lower, and such thing will not happen.

On the other hand, when a thermal expansion causes only secondary stress of displacement-controlled type, the strain caused will be controlled by the thermal expansion.
However, when major portions of a structure show elastic response and plastic strain occurs on a limited portion of which thickness is relatively thin, i.e. such portion has relatively low stiffness, elastic follow-up by other portions than the limited portion will cause strain concentration on that.

As stated above, Ke-factors depend on the load conditions and the structure.

3. Ke-factor equation of the other codes

3.1 ASME B&PV Code Sec.III

The Ke-factor equation of the ASME B&PV Code Sec.III is shown as follows.

\[
K_e = 1 + \frac{1 - n}{n(m - 1)} \left( \frac{S_n}{3S_m} - 1 \right)
\]

(2)

Here, \( n \) and \( m \) are provided for each material.

The above equation was developed based on a study on plastic strain caused by tensioning a simple plate with a taper\(^{[8]}\). Then the ASME B&PV Code committee made further study and developed a new Code Case on Ke-factor evaluation\(^{[9]}\).

3.2 MITI Notification 501

The MITI Notification 501 considered effects on redistribution of nominal strain and concentration of peak plastic strain. The Ke-factor equation of the ASME B&PV Code Sec.III was incorporated as the former effect and the following equation was developed for the latter effect. Here, the Ke-factor of the ASME B&PV Code Sec.III or the following equation, whichever is greater, shall be used for fatigue evaluation.

\[
K_e = 1 + A_0 \left( \frac{S_n}{3S_m} - \frac{S_n}{S_p} \right)
\]

(3)

Where, \( A_0 \) is provided for each material.

The above equation (hereinafter called \( A_0 \) equation) was developed in order to incorporate the effect of concentration of peak plastic strain around \( S_n \) of 3\( S_m \) while the ASME B&PV Code Sec. III did not consider that\(^{[10]}\).

3.3 JSME Fast Reactor Design Code

The JSME Fast Reactor Design Code\(^{[11]}\) prescribes the following Ke-factor equation (hereinafter called Ke' equation) expressed by an elastic follow-up parameter (\( q \)) that is a ratio of plastic strain estimated by elastic analysis (\( \varepsilon_p' \)) and authentic plastic strain (\( \varepsilon_p \)) as shown in Fig. 1.

\[
K_e' = 1 + (q - 1) \left( 1 - \frac{3S_m}{S_n} \right)
\]

(4)

Where, \( q = 3.0 \).
The above equation expressed by the elastic follow-up parameter was first introduced to the Japanese fast reactor design code applied to MONJU\textsuperscript{(12),(13)} and unique to Japan. Also, the JSME Fast Reactor Design Code uses Neuber's rule\textsuperscript{(14)} for the effect of concentration of peak plastic strain.

4. Development of Ke-factor Evaluation Equation

4.1 Basic outlines of study

Ke-factor evaluation equations have been developed based on the following concepts.

- The MITI Notification 501 used the Ke-factor of the ASME B&PV Code Sec.III for redistribution of nominal strain and the $A_0$ equation for concentration of peak plastic strain. This study paid attention to redistribution of nominal strain that was dominant in the relatively high stress region and a new Ke-factor evaluation equation would be developed to replace the Ke-factor of the ASME B&PV Code Sec.III. Here, the $A_0$ equation was kept to evaluate concentration of peak plastic strain.

- The form of Ke-factor evaluation equation for the Fast Reactor Design Code to which the elastic follow-up parameter was adopted, as shown in eq.(4), was used for the new Ke-factor evaluation equations and the elastic follow-up parameter ($q$) was studied so as to be appropriate to light water reactor (LWR) components.

- The material was conservatively assumed to be elastic-perfectly plastic material of which yield strength was $1.5S_m$. Here, the above Ke-factor evaluation equations use $S_m/3S_n$ as a parameter and this means that the loads considered cover reversed loading cycles. When monotonic loading is applied, the parameter shall be $S_n/1.5S_m$.

- Typical basic models were selected from the actual components. The Ke-factors were calculated by elastic and elastic-plastic analyses for the basic models with those loading conditions. New Ke-factor evaluation equations were established so as to bound the Ke-factors calculated by adjusting elastic follow-up parameters.

- The new Ke-factor evaluation equation established was verified for piping mock-up test results for seismic loading.

- The applicability of the new Ke-factor evaluation equation established was confirmed for typical nozzles of existing components of which Ke-factors were relatively high.

4.2 Evaluation for basic models

Cylinder, nozzle, thermal sleeve/safe-end, canopy and support skirt models were selected with paying attention to structural discontinuity of class I components such as reactor pressure vessels. Here, thermal stress was applied by the following.

- Temperature analysis and elastic analysis were performed for temperature condition determined.

- The maximum thermal stress was identified and the temperature distribution at that time was extracted.

- The temperature distribution extracted was proportionally applied to the analysis model and the elastic analysis and the elastic-plastic analysis were performed. The Ke-factors for $S_n$ and $S_p$ by the elastic analysis were calculated as follows.

$$K_e = \frac{\varepsilon_{ep}}{\varepsilon_e}$$  \hspace{1cm} (5)

where,

- $\varepsilon_{ep}$: Mises equivalent strain by elastic-plastic analysis and described as follows.

$$\varepsilon_{ep} = \frac{\sigma_{ep}}{E} + \varepsilon_p$$  \hspace{1cm} (6)

- $\sigma_{ep}$: Mises equivalent stress by elastic-plastic analysis

- $\varepsilon_p$: Mises equivalent plastic strain calculated from plastic strains by elastic-plastic analysis
\[ E : \text{Young's modulus} \]
\[ e_e : \text{Mises equivalent strain by elastic analysis and described as follows.} \]
\[ e_e = \frac{\sigma_e}{E} \]  
\[ \sigma_e : \text{Mises equivalent stress by elastic analysis} \]

The results of analyses for the basic models are as follows.

**a. Cylinder model**

To investigate the fundamental effect of pressure and thermal stress, a cylinder model with no structural discontinuity was applied. Ke-factors for \( S_n \) were analyzed for 9 cases that consisted of 3 cases of pressure that were determined by \( P_m \) and 3 cases of thermal stress that consisted of linear temperature distribution in thickness, step coolant temperature change and difference temperature between upper and lower sides. The analysis models are shown in Fig.2 and the results are shown in Fig.3.

For the linear temperature distribution in thickness, the plastic strain tended to occur for high pressure, and so higher pressure caused higher Ke-factors. Here, small difference can be seen around \( S_n/1.5S_m = 1.0 \) in each result and this is because \( S_n \) is calculated based on Tresca stress and the Ke-factor is calculated based on Mises stress. However, the difference is small and it can be negligible.

For the step coolant temperature change, the thermal stress caused by step temperature change showed locally high stress on the inside surface, however that gives a small influence on thermal bending stress for the thickness and there was little difference of the Ke-factors among three cases on relatively high region of \( S_n/1.5S_m \). On the other hand, the lower pressure caused the higher Ke-factor. \( S_n \) has the same value and this means the contribution of thermal stress is higher for the lower pressure. This gave locally higher
thermal stress on the surface and imposes the earlier yielding.

In the case that the difference temperature between upper and lower sides caused thermal stress due to the difference of displacement, the higher pressure caused the higher Ke-factor. This loading condition gave more influence of elastic follow-up than the other loading conditions and the effect of pressure clearly appeared as compared with the other cases.

b. Nozzle model

Nozzle shape is a typical structural discontinuity and 2 types of nozzles were prepared. One is performed reinforcement of the opening to only nozzle side and the other is performed it to only shell side. Pressure was set to 17.16 MPa constant that was design pressure. Cooldown rate of the coolant was set to 55 °C/H that was sever condition for thermal stress.

The analysis model and the results of Ke-factors are shown in Fig. 4. Both models shows that the Ke-factor of the evaluation point of thicker thickness is the highest and we can concluded that the effect of thickness is basically dominant. Stress (strain) concentration occurs at the nozzle corner, however this stress is peak stress and the effect on Ke-factor may be small. Also, the Ke-factor of the nozzle side for the model reinforced on shell side linearly increases against $S_n/1.5S_m$. The thickness of the nozzle is thin and the stiffness of the nozzle is weaker than that of the shell. This gives elastic follow-up effect.

c. Thermal sleeve/safe end model

Two types of models of thermal sleeve/safe end attached to nozzle were prepared. One is called BWR model and has onefold thermal sleeve. The other is called ABWR model and has twofold thermal sleeve. Pressure was set to 8.62 MPa constant that was design pressure. The step temperature change, which was dominant, was applied and the temperature changed from 300 °C to 40 °C as stepwise.

The analysis models and the results of Ke-factors are shown in Fig. 5. The rapid cooling by the coolant caused shrinking of the thermal sleeve and bending stress occurred at the root portion of the thermal sleeve. This bending stress is dominant for the Ke-factor. On the other hand, the stress due to pressure gave an effect on the Ke-factor at the evaluation point of BWR model (onefold thermal sleeve), however the stress due to pressure gave no effect on that of ABWR model (twofold thermal sleeve) and the Ke-factor of BWR model was greater than that of ABWR model at the range of relatively smaller $S_n/1.5S_m$. The shrinking of the thermal sleeve due to the rapid cooling caused tensile stress on the inside and compressive stress on the outside. The compressive stress on the outside was counteracted by the tensile stress due to pressure. The stress concentration at the corner gave an effect and the Ke-factor showed the same trend of that of stepwise temperature change of the
cylinder model.

On the other hand, the stress due to pressure gave no effect on the Ke-factors of ABWR model and the thermal bending was dominant. The elastic follow-up also gave a influence and the Ke-factor showed relatively monotonic increasing.

d. Support skirt model

Typical models for BWR and ABWR support skirt were used for evaluation. Pressure was set to 8.62 MPa constant that was design pressure and heat up thermal transient, which was dominant, was applied.

The analysis models and the results of Ke-factors are shown in Fig. 6. Both results show the same trend. The temperature of the shell increased in response to the rise of temperature of the coolant at the heat up. However the temperature of the support skirt was lower than that of the shell because of the time lag by heat conduction and heat transfer between the skirt and the air by reason of no thermal insulation. Therefore, the difference of the displacement caused the relatively high stress on the root of the support skirt and also the elastic follow-up gave relatively great effect on this structure.

This feature also caused relatively high thermal membrane stress, and the requirement of the range of primary plus secondary stress intensity excluding thermal bending stress ($S_n'$) was not satisfied for $S_n'/1.5S_m > 1.98$ for BWR model and $S_n'/1.5S_m > 1.72$ for ABWR model. Therefore, the Ke-factors of the support skirts shall be intended for the range in which $S_n'$ is satisfied. Here, when $S_n'$ is not satisfied, whole section will become plastic region and the shakedown and thermal ratchet evaluation will not be satisfied. Hence, the above regions can be out of scope for evaluation of Ke-factors.

e. Canopy seal model

Canopy seal between PWR reactor vessel head penetration and control rod drive mechanism (CRDM) housing was selected as a typical structure that had relatively large difference of stiffness. Pressure was set to 17.16 MPa constant that was design pressure. The temperature transient of loading to 100% full power of which temperature changed from 300 °C to 350 °C in 1000 sec was dominant and applied.

The analysis model and the results of Ke-factor are shown in Fig. 7. The temperature of
the inside surface increased by the coolant but the outside surface was cooled by the air. Especially the thickness of canopy seal was thin and the temperature difference between the canopy seal and the flange tended to be greater. The flange made thermal expansion but the canopy seal did not. Hence relatively high thermal bending stress occurred at the root of canopy seal. Also the difference of stiffness between the canopy seal and the flange was relatively great and this caused elastic follow-up and relatively high Ke-factors.

4.3 Elastic follow-up parameter

The elastic follow-up parameter, \( q \), was determined so as to bound the relationships of Ke-factors and \( S_n \) for the basic models and \( q = 3.1 \) was obtained as shown in Fig. 8. Here, the elastic follow-up parameter of the fast reactor code is \( q = 3.0 \). The above elastic follow-up parameter is very close to that of the fast reactor code and can be considered to be valid.

The \( A_0 \) equation is also adopted. When the \( A_0 \) equation does not intersect with the Ke' equation, the \( A_0 \) equation shall be adjusted so that the equation is the tangent line with the Ke' equation from the point of \( S_n/3S_m = 1.0 \).

4.4 Verification for piping experimental data

Based on the study on the experimental data of nuclear power plant piping for seismic design(15),(16), verification of the new Ke' equation was performed for the experimental data and piping. 11 cases were selected regarding experimental models, thickness, pressure and applied loads as shown in Table 1.

The Ke-factors obtained from the displacement control experimental data were calculated by using the data measured by the nearest strain gage to the crack initiation point. The Ke-factors were determined by the ratio of the strain measured by the experiment and that by the elastic analysis.

The loading cycle evaluated was selected from the cycle of the early stages that showed stable behavior. The Ke-factors of the experimental data for elbows, tees and straight pipes
are show in Fig. 8 with the Ke equation \( (q = 3.1) \). Two types of data are plotted for each case. One is for "forward" of the loading cycle and the other is for "backward" of that. There is small difference between the Ke-factors of forward and backward because of ratcheting, however Fig. 9 has confirmed that all Ke-factors by experimental data are lower than the Ke equation \( (q = 3.1) \).

Table 1 Matrix for Experimental Data of Piping

<table>
<thead>
<tr>
<th>Case</th>
<th>Type</th>
<th>Material</th>
<th>Sch.</th>
<th>Press.</th>
<th>Applied Load</th>
<th>Bending</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Elbow</td>
<td>Carbon</td>
<td>Sch40</td>
<td>Sm</td>
<td>X</td>
<td>Base data of elbow tests</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Elbow</td>
<td>Stainless</td>
<td>Sch40</td>
<td>S_m</td>
<td>X</td>
<td>Effect of material</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Elbow</td>
<td>Carbon</td>
<td>Sch160</td>
<td>S_m/2</td>
<td>X</td>
<td>Effect of thickness</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Elbow</td>
<td>Carbon</td>
<td>Sch40</td>
<td>S_m/2</td>
<td>X</td>
<td>Effect of pressure</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Tee</td>
<td>Carbon</td>
<td>Sch40</td>
<td>S_m</td>
<td>X</td>
<td>Base data of tee tests</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Tee with different Dia.</td>
<td>Carbon</td>
<td>Sch40</td>
<td>S_m</td>
<td>X</td>
<td>Effect of different diameter</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Tee</td>
<td>Carbon</td>
<td>Sch40</td>
<td>S_m</td>
<td>X</td>
<td>Effect of applied load</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Straight Pipe</td>
<td>Carbon</td>
<td>Sch40</td>
<td>S_m</td>
<td>X</td>
<td>Base data of straight pipe</td>
<td></td>
</tr>
</tbody>
</table>

4.5 Evaluation for actual nozzle structures

A spray nozzle of pressurizer of PWR and a feedwater nozzle of reactor pressure vessel of BWR were selected as typical nozzles of which Ke-factors were relatively high and the applicability of the new Ke’ equation was verified.

a. PWR pressurizer spray nozzle

The analysis model and the results of Ke-factor are shown in Fig.10. Point 1 on the safe end showed relatively high Ke-factors. Here, the region II of Fig. 10 has a thermal sleeve in the actual components and the heat transfer coefficient of the region II is smaller than that.
of the region I. Therefore the effect of temperature change of the coolant on Point 2 and 3 was smaller than that on Point 1.

The Ke-factors of Point 1 show the almost same trend as the case for stepwise temperature change of the cylinder model in Fig. 3(2). This is because the temperature transient was stepwise temperature change, there was no structural discontinuity at Point 1 and the effect of discontinuity of the surrounding structure was small.

b. BWR feedwater nozzle

The analysis model and the results of Ke-factor are shown in Fig.11. The Ke-factor of Point 2 was the highest.

The Ke-factors of Point 1 show the almost same trend as the case for BWR thermal sleeve/safe end model in Fig. 5.

4.6 Ke-factor evaluation equation for surface stress

The above results have confirmed that the new Ke-factor evaluation equation (Ke' equation) for $S_n$ provides conservative Ke-factor for typical structural discontinuities of class I components.

Here, reevaluation of all Ke-factors obtained for the above basic models with a parameter of surface stress intensity ($S_p$) will give a new Ke-factor evaluation equation that can directly calculate a Ke-factor from the surface stress intensity and this equation need not to perform stress classification. This new equation is called Ke'' equation and the Ke-factors for the basic models are plotted for $S_p$ as shown in Fig. 12. The same form of the Ke' equation is applied to the Ke'' equation and the following equation is obtained.

$$K_{e''} = 1 + (q_p - 1) \left( 1 - \frac{1}{S_p/S_m} \right)$$

(8)

Where, an elastic follow-up parameter, $q_p$, is assumed to depend on the ratio of plastic strain and total strain. Then the following equation can be obtained.
\[ q_p = (q_1 - q_0) \cdot \left( \frac{\varepsilon_p}{\varepsilon_t} \right) + q_0 \]

\[ = (q_1 - q_0) \cdot \left( \frac{S_p/E - 3S_m/E}{S_p/E} \right) + q_0 \]

\[ = (q_1 - q_0) \cdot \left( 1 - \frac{1}{S_p/3S_m} \right) + q_0 \]

\( q_0 \) and \( q_1 \) are determined so as to bound the Ke-factors of all models as shown in Fig. 12.

\[ q_0 = 1.5, q_1 = 4.0 \quad (10) \]

The Ke-factors may be greater than 1.0 under \( S_p/3S_m \leq 1.0 \), but the Ke-factors are determined to be treated as 1.0 because \( S_p/3S_m \leq 1.0 \) shows shakedown. However, the Ke" equation has a value from yielding at the surface. Especially for the portions that have peak stress the Ke-factor has to be considered on such portion that the Ke-factor is equal to 1.0 for \( S_p \)-base Ke-factor evaluation equation. This means Ke" equation is conservative. Therefore, it is recommended that the Ke-factor should be calculated by elastic-plastic analysis for the structure evaluated, \( q_p \) should be calculated based on the Ke-factor and then the accurate Ke" equation can be appropriately obtained for each structure.

5. Conclusions

The material was conservatively assumed as elastic-perfectly plastic material of which yield strength was 1.5\( S_m \). Typical basic models were selected from the actual components. Elastic and elastic-plastic analyses were performed for the models and the load conditions and the Ke-factors were calculated. The new Ke-factor evaluation equation was developed to bound those Ke-factors obtained. The new Ke-factor evaluation equation was verified by using piping experimental data and the applicability of that was confirmed by using the analyses of the typical actual nozzle structures. Based on the above results, the Ke' equation for \( S_p \) and the Ke" equation for \( S_p \) were developed. The Ke' equation has been incorporated into the JSME D&C Code and the Ke" equation has been incorporated into the JSME EPD Code Case.

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