Summary of a Code Case N-499-1 and Estimation Program

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1. Introduction

Korea Atomic Energy Research Institute (KAERI) has been developing a VHTR (Very High Temperature Reactor). The behavior of materials at a high temperature is quite different from that at a normal operating temperature in commercial plants. For the behavior evaluation of materials used at a high temperature, several codes are being studied. One of these is the Code Case N-499-1 of ASME Section III[1]. In this study, the contents of the Code Case N-499-1 are introduced. The program developed to estimate the allowable cumulative time based on the Code Case N-499-1 is also introduced.

2. The Summary of Code Case N-499-1

The Code Case N-499-1 of ASME Section III gives a design guide for SA-533 Grade B, Class 1 plates, SA-508 Class 3 forgings and their weldments used in Section III, Division 1, Class 1 construction at temperatures exceeding 700°F(371℃) up to 1000°F(538℃). Research reports provide additional details regarding the applicability of the Code Case to high temperature reactor applications[2]. The important contents of the Code Case are below:

① Maximum temperature during level events
- Level B event: 800°F(427℃)
- Level C & D event: 1000°F(538℃), limited to a total of 3

② Allowable cumulative time
- 700°F(371℃) ~ 800°F(427℃): 3000 hrs(Level B)
- 800°F(427℃) ~ 1000°F(538℃): 1000 hrs(Level C, D)
- ~700°F(371℃): NB-3000 shall be satisfied.

③ The sum of the creep damage and fatigue damage based on the Minor's Rule, summed over the entire lifetime, shall not exceed the limit of creep-fatigue damage envelope shown in Fig. 1.

④ The Figures and Tables in the Code Case provide the mechanical and physical property values at elevated-temperatures. The properties include:

(a) Isochronous Stress-Strain Curves;
(b) Yield Strengths;
(c) Stress-to-Rupture Values;
(d) Elevated-Temperature Fatigue Strength;
(e) Moduli of Elasticity, and
(f) Instantaneous and Mean Coefficients of Thermal Expansion.

Especially, the values of the stress intensities S_{mt}'s according to an operating temperature and a cumulative time are presented in Fig. 2. In Fig. 2, the S_m and the S_t are a time-independent stress intensity and a time-dependent stress intensity, respectively. The value of S_{mt} is the lower of S_m and S_t at any given temperature.

3. Development of the Estimation Program

If we want to maintain the structural integrity of a component when its temperature and occurring stress are given from the condition, we need to calculate an allowable cumulative time. The program is developed to estimate the allowable cumulative time with the temperature and the stress as inputs. The program is made by means of commercial software such as the MS excel program. The program developed and input data are presented in Fig. 3 and Fig. 4.

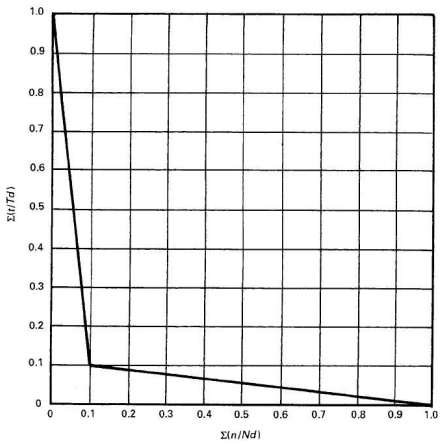


Figure 1. Creep-fatigue damage envelope

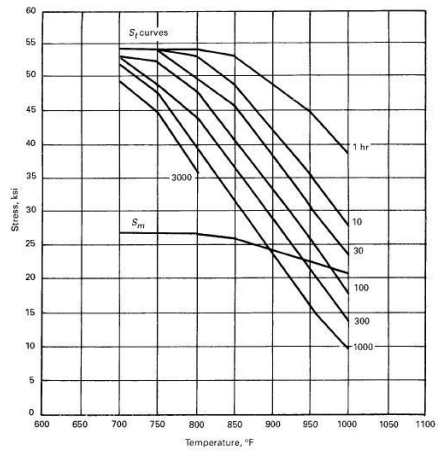


Figure 2. S_{mt} value for SA-533 Grade B Class 1 and SA-508 Class 3

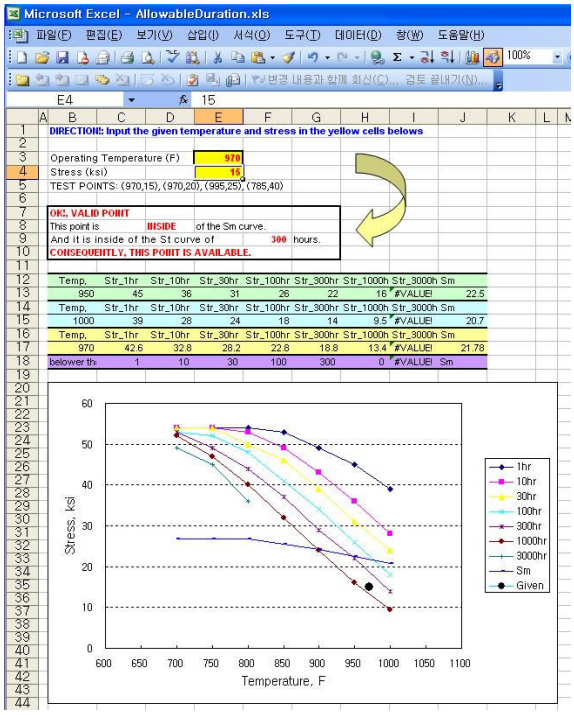
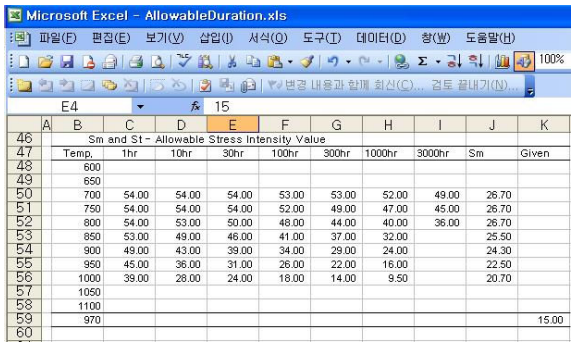


Figure 3. The developed evaluation program



Temp,	1hr	10hr	30hr	100hr	300hr	1000hr	3000hr	Sm	Given
600									
650									
700	54.00	54.00	54.00	53.00	53.00	52.00	49.00	26.70	
750	54.00	54.00	54.00	52.00	49.00	47.00	45.00	26.70	
800	54.00	53.00	50.00	48.00	44.00	40.00	36.00	26.70	
850	53.00	49.00	46.00	41.00	37.00	32.00		25.50	
900	49.00	43.00	39.00	34.00	29.00	24.00		24.30	
950	45.00	36.00	31.00	26.00	22.00	16.00		22.50	
1000	39.00	28.00	24.00	18.00	14.00	9.50		20.70	
1050									
1100									
970									15.00

Figure 4. The input value of S_m and S_t for the program

4. RESULTS

The developed program evaluates and calculates the followings:

(1) Whether a temperature input is in the available range. If the temperature input is in the available range, it prints "OK! VALID POINT" and otherwise "CAUTION!, THIS POINT IS BEYOND DATA.".

(2) Whether a stress input is larger or smaller than S_m. If the stress input is bigger than the S_m, it prints "THIS POINT IS OUTSIDE OF THE S_m CURVE." and otherwise "THIS POINT IS INSIDE OF THE S_m CURVE.".

(3) The smallest value among S_t's larger than the stress input.

(4) The allowable cumulative time matching the smallest value of S_t calculated in (3). It prints, for example, "AND IT IS INSIDE OF THE S_t CURVE OF 300 HOURS.".

(5) Whether a stress input is bigger than the S_m. If the stress input is bigger than the S_m, the stress input is not available. So, it prints "CONSEQUENTLY, THIS POINT IS NOT AVAILABLE." and otherwise "CONSEQUENTLY, THIS POINT IS AVAILABLE.".

Finally, we can find the allowable cumulative time in (4) and the validity of the calculated time based on the inputs in (5).

5. CONCLUSIONS

The Code Case N-499-1 of ASME Section III is studied and summarized to evaluate the availability of SA-533 Grade B Class 1 and SA-508 Class 3 at a high temperature. The program is developed to estimate the allowable cumulative time based on the Code Case N-499-1. It could be helpful to evaluate the structural integrity rapidly and efficiently in a given condition.

REFERENCES

[1] ASME Sec. III, Div. 1, Code Case N-499-1, 2002, "Use of SA-533 Grade B, Class 1 Plate and SA-508 Class 3 Forgings and their Weldments for limited elevated temperature service".
[2] Argonne National Laboratory, 2003, "Review and assessment of codes and procedures for HGTR Components," NUREG/CR-6816, pp.32-34.