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Stress Analysis of an Alumina Structure for the Sintering of SiGe

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1. Introduction

These days, alumina has been widely applied in various fields, including automobile, aerospace, and nuclear industry [1-5].

In general, parts used in the nuclear industry are required strict safety. Thus, some parts are made by sintering in high-temperature to satisfy the strict safety requirements. Alumina is required in production process of sintered body because it has good thermal resistance, wear resistance, and chemical resistance. The structure evaluation of alumina is required because alumina is brittle material before applying to the sintering process [1-5].

In this study, the stress of alumina structure for the sintering of composite materials was analyzed to identify whether the alumina structure is failure in the heating stage of sintering process.

2. Methods and Results

The experiment process involves three steps: (i) the alumina structure mounted sintered bodies is inserted into the furnace, (ii) the furnace is heated up to 1630 °C for 330 minutes(heating rate : 5 ℃/min), (iii) the heated furnace is cooled up to room temperature for about 18 hours.

In this study, only the heating stage was simulated using the ANSYS ™ v15.0.

2.1 FEM(finite element method) model

The alumina structure was designed for multi-stage in order to produce a quantities of the sintered body. Fig. 1 shows the quarter model for structural-thermal analysis. The reason of the quarter model is to save the time. Only the corners of first and second floor were supported by blocks, the fourth floor was stacked on the third floor.

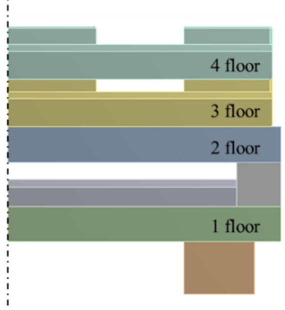

Fig. 1. The quarter model of an alumina structure for structural-thermal analysis.

2.2 Analysis conditions

The analysis method used in this study is structural-thermal analysis. The fictional option is applied to contact of each part during the heating stage because the non-linear contact was taken by thermal expansion and self-load, the coefficient of frictional was set to 0.2. The convection coefficient was set to 30 W/m^2 · ℃, the ambient temperature was set to 1630 ℃.

Table I summarizes the mechanical and thermal properties for various temperature of alumina used in the structural-thermal analysis.

Other properties of alumina is as follow: (i) the density is 3970 kg/m^3, (ii) the poisson's ratio is 0.21

Table I. Mechanical and thermal properties of an alumina for structure-thermal analysis

Temp (°C)	Compressive Strength (Gpa)	Tensile Strength (Gpa)	Thermal Conductivity (W/m · K)
25	2.95	0.26	25
600	1.37		8.78
800	1.26	0.24	6.27
1000	0.88		5.85
1200	0.49	0.13	5.43
1400	0.25	0.03	

2.3 Heat transfer and Thermal stress analysis

Fig. 2 shows the temperature distributions of the alumina structure for the heating stage. It can be seen that the change of temperature during the heating stage. The heat transferred from surface to inner of structure by convection effect.

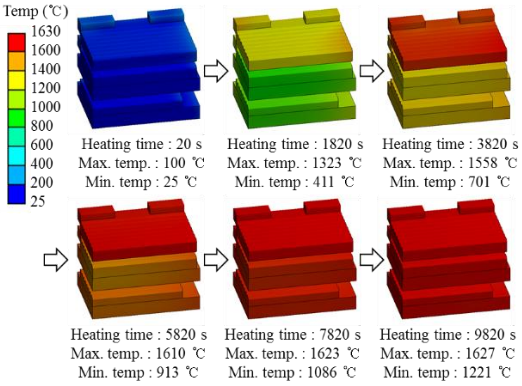

Fig. 2. Temperature distribution of alumina structure for the heating stage

Fig. 3 shows the change of deformation distributions for the heating stage. It can be seen that the inside of alumina structure was subsided and the outside of that was expanded by thermal expansion and self-load.

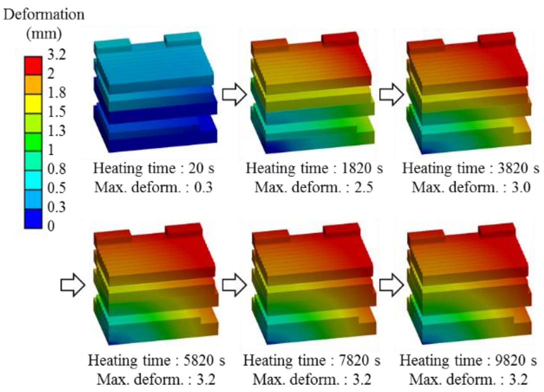

Fig. 3. Deformation distribution of alumina structure for the heating stage

Fig. 4 shows the transient change of the safety factor for the heating stage. Because the alumina is the brittle material, the safety factor was calculated by the Maximum principal stress theory. The equation is as follows:

$$F.S. = \min \left[\left| \frac{\sigma_{tension}}{\sigma_1} \right|, \left| \frac{\sigma_{comprssion}}{\sigma_3} \right| \right] \quad (1)$$

where $\sigma_{tension}$ is the ultimate tensile strength, $\sigma_{compression}$ is the ultimate compressive strength, σ_1 is the maximum tensile stress, σ_3 is the minimum compressive stress. By solving eq. (1), the weak area of alumina structure can be predicted for heating stage.

For the heating stage, the stress of inside was larger than that of outside. It can be seen that the probability of failure was higher than that of outside of alumina structure.

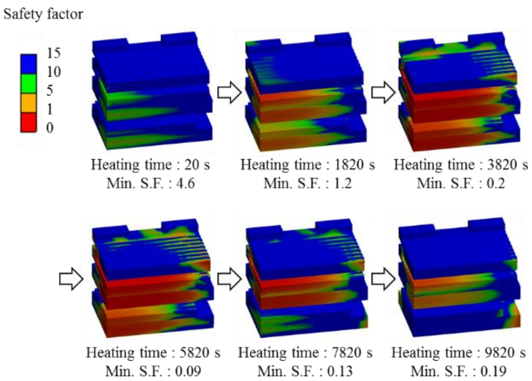

Fig. 4. Safety Factor distribution of alumina structure for the heating stage

Fig. 5 shows the safety factor distribution of top and bottom view of the third floor. It can be predicted that the failure will take form A point to B point

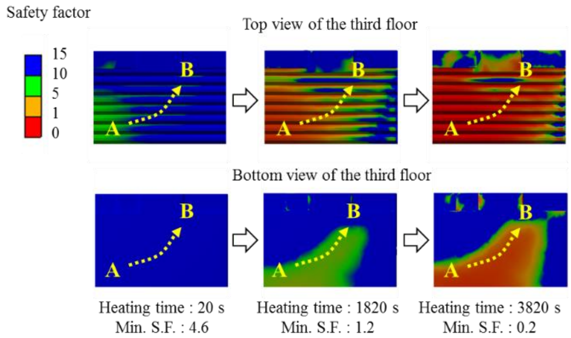

Fig. 5. Safety factor distribution of third floor for heating stage

3. Conclusions

In this study, a finite element analysis was carried out to investigate the failure of alumina structure for the sintering of composite materials during heating stage. Structural-thermal analysis was performed to predict the weak area of the alumina structure and the pattern of failure.

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