A three-dimensional random RVEs containing spherical particles achieving isotropy

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1. Introduction

The composite materials, which are currently undergoing much research and development, are used in various structures due to their advantages such as high specific modulus, specific strength, etc [1]. In order to obtain the properties of composite materials required for structural analysis of these structures, predicting equivalent properties have been widely used recently by applying computational homogenization schemes to finite element (FE) models using representative volume elements (RVE). In addition, the trend of molecular mechanics is being used to produce RVEs with a high filler volume fraction, and the research is being conducted on whether or not isotropy is being satisfied to determined proper RVE sizes [2].

In this study, a three-dimensional (3D) random RVE with spherical particles is created using the discrete element method (DEM), and the anisotropic ratio of RVE according to the size of the particles is compared.

2. Generation of 3D RVE model

RVE is divided into three cases, and the size and number of particles used in each case are the same as Table 1. DEM was used to allow the particles to be randomly placed due to collisions between particles, such as Fig. 1. And then, the FE models were created using Abaqus python script/CAE with center coordinates of the extracted particles, as shown in Fig. 2.

3. Physical validation of RVE

Equivalent properties were calculated using computational homogenization schemes for finite element models created in Section 2. The properties of the particle used in this calculation are $E = 10GPa$, $\nu = 0.3$, and the properties of the matrix are $E = 3MPa$, $\nu = 0.4$. Using this computed equivalent properties, anisotropic ratio was calculated as shown in Table 2.

From Case1 to Case3, the average value of anisotropic ratio is gradually increasing from 0.9698 to 0.9762 even it is not so significant. This is because the more diverse the sizes of the particles, the more evenly distributed within the RVE.

Table 1 Three cases of RVEs

	Spherical particles	
	Diameter	Total number
Case 1 ($V_f = 47.79\%$)	1.0	980
Case 2 ($V_f = 47.71\%$)	0.9	320
	1.0	320
	1.1	320
Case 3 ($V_f = 47.78\%$)	0.8	185
	0.9	185
	1.0	185
	1.1	185
	1.2	185

Fig.1 Random position of spherical particles using DEM

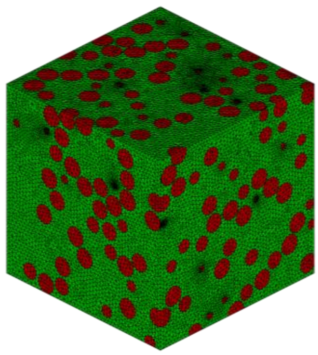

Fig.2 Finite element model of 3D random RVE

Table 2 Anisotropic ratio of compliance matrix

		Case1	Case2	Case3
Anisotropic ratio	$\frac{G_{23}}{E_{22}/[2(1+\nu_{23})]}$	0.9610	0.9707	0.9731
	$\frac{G_{13}}{E_{11}/[2(1+\nu_{13})]}$	0.9701	0.9731	0.9642
	$\frac{G_{12}}{E_{11}/[2(1+\nu_{12})]}$	0.9782	0.9732	0.9913
	Average	0.9698	0.9723	0.9762

4. Conclusion

In this study, the DEM was used to create high volume 3D random RVEs with spherical particles of varying sizes and anisotropic ratios were compared.

The more different sizes of particles included in RVE, the more anisotropic ratios were increased, because the more the sizes of the particles varied, the more evenly the particles could be distributed within the RVE.

Even though we studied how to achieve ideal isotropy 1.0 with spherical particles with a fixed number of particles and size, it is also affected according to the number of particles and size of the RVE. It will be more investigated as a future work.

Acknowledgment

This research was supported by the Space Core Technology Development Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (No. 2018M1A3A4A04047087).

References

[1] D. W. Kim, J. H. Lim, and J. S. Yu, Efficient prediction of the electrical conductivity and percolation threshold of nanocomposite contacting spherical particles with three-dimensional random representative volume elements by random filler removal, *Composites Part B*, 168 (2019) 387-397

[2] G. Li, F. Sharifpour, A. Bahmani, and J. Montesano, A new approach to rapidly generate random periodic representative volume elements for microstructural assessment of high volume fraction composites, *Materials and Design*, 150 (2018) 124-138