ENVELOP ENRICHMENT METHOD TO APPLY PERIODIC BOUNDARY CONDITIONS ON NON-PERIODIC UNIT CELLS

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Abstract

Accurately predicting mechanical behaviour of composite materials is essential for tailoring performance in various applications. This poster presents an approach to homogenize non periodic microstructure. Non-periodic Representative Volume Elements (RVE), present challenges in applying classic periodic boundary conditions due to the varying properties of the elements at the boundary and irregular meshing. To address this issue, an envelope is created around the RVE, supporting classic Periodic Boundary Conditions (PBC). An iterative process is done to compute the stiffness tensor of the enveloped RVE which is assigned to the envelope before the next iteration until a convergence is observed. The stiffness tensor is computed using the perturbation technique implemented into Finite Element Analysis (FEA). The method is applied on non-periodic arrangements of spherical inclusions embedded within a matrix and compared to existing results[1].

Method

1. Create a RVE suited to the input microstructure with an exterior envelope.

2. Impose periodic conditions on the envelope between pair of nodes on opposite faces.

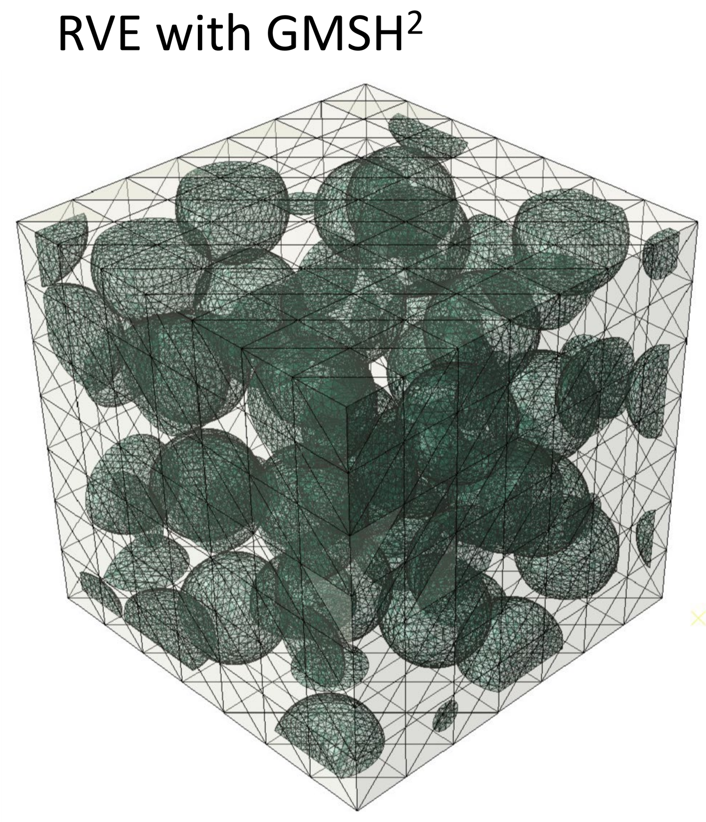
3. Create the embedding conditions on the elements when necessary.

4. Compute each column of the stiffness tensor by computing six strain-driven simulation and update the envelope's properties at each iteration.

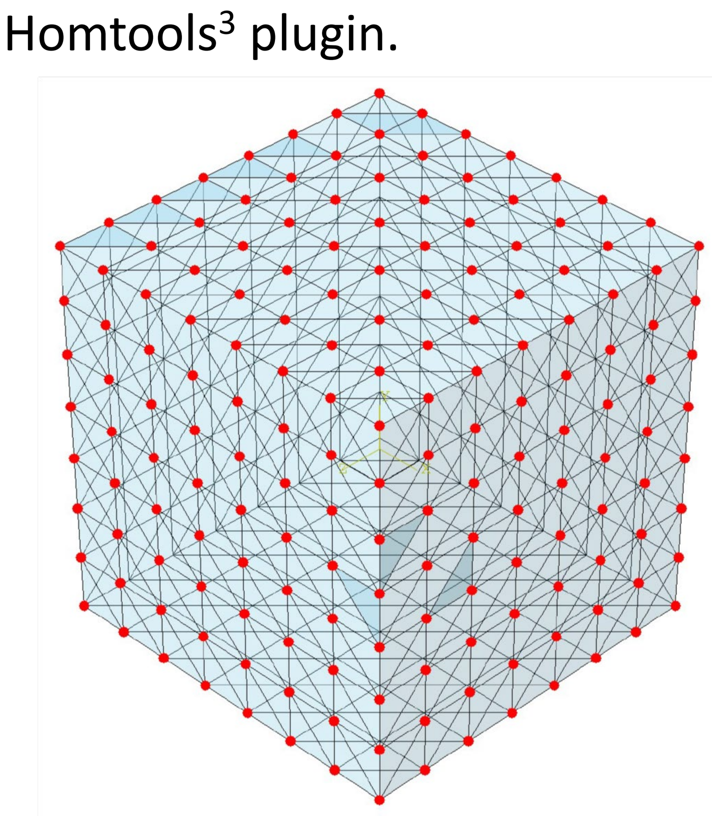
Motivation

- Offer a simple solution to homogenize non-periodic microstructures suited to different architecture (porous, embedded).
- Avoid time consuming process to generate strictly periodic RVE structure and mesh.
- Demonstrate numerically the convergence property of the method.
- Associate the Envelope Enrichment and Embedded Element techniques to facilitate the generation of highly detailed RVE.

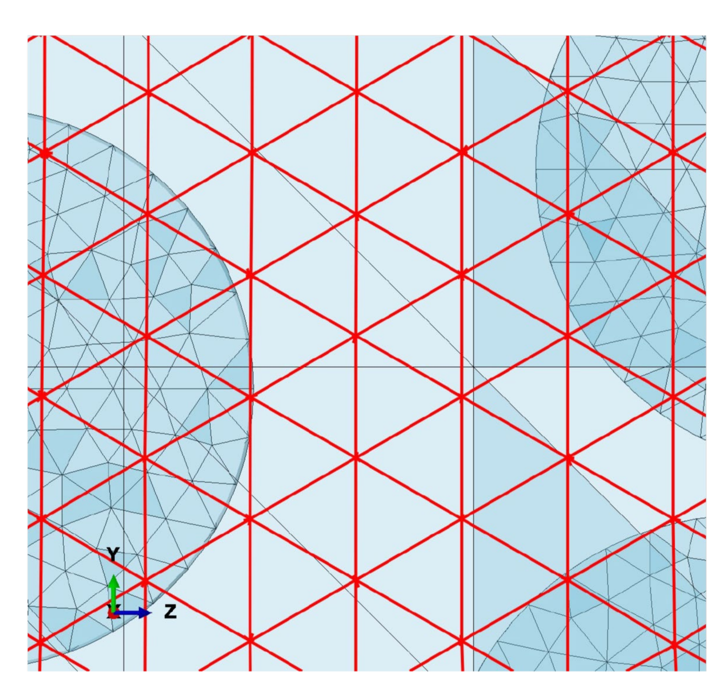
1. Creation of the enveloped RVE with GMSH[2]



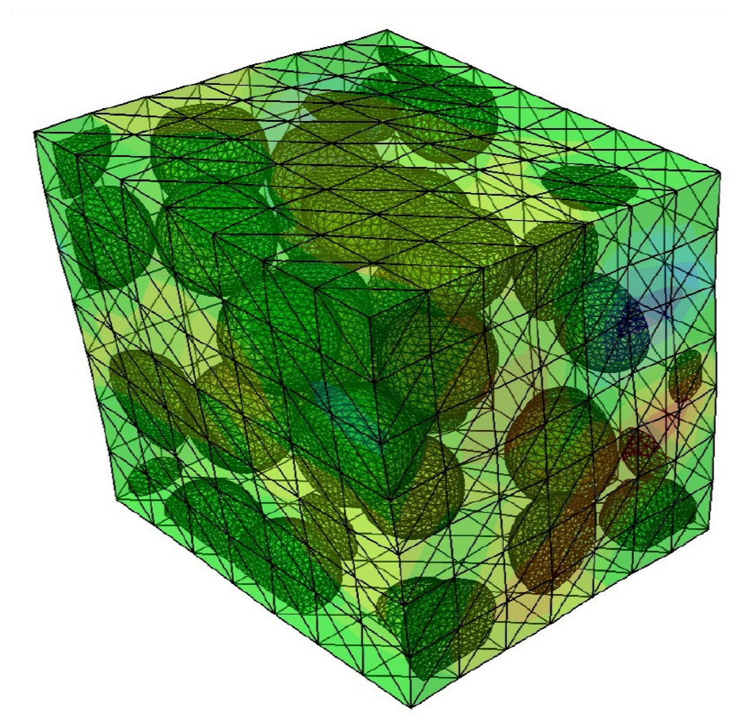
2. Application of the PBC with Homtools[3] plugin.



3. Embeding of the inclusions into the host elements with Abaqus[4]



4. Six strain-driven loading cases are processed at each iteration



The convergence criteria can be set up as a defined number of iteration or a relative difference value on the stiffness tensor's terms

Results and Discussion

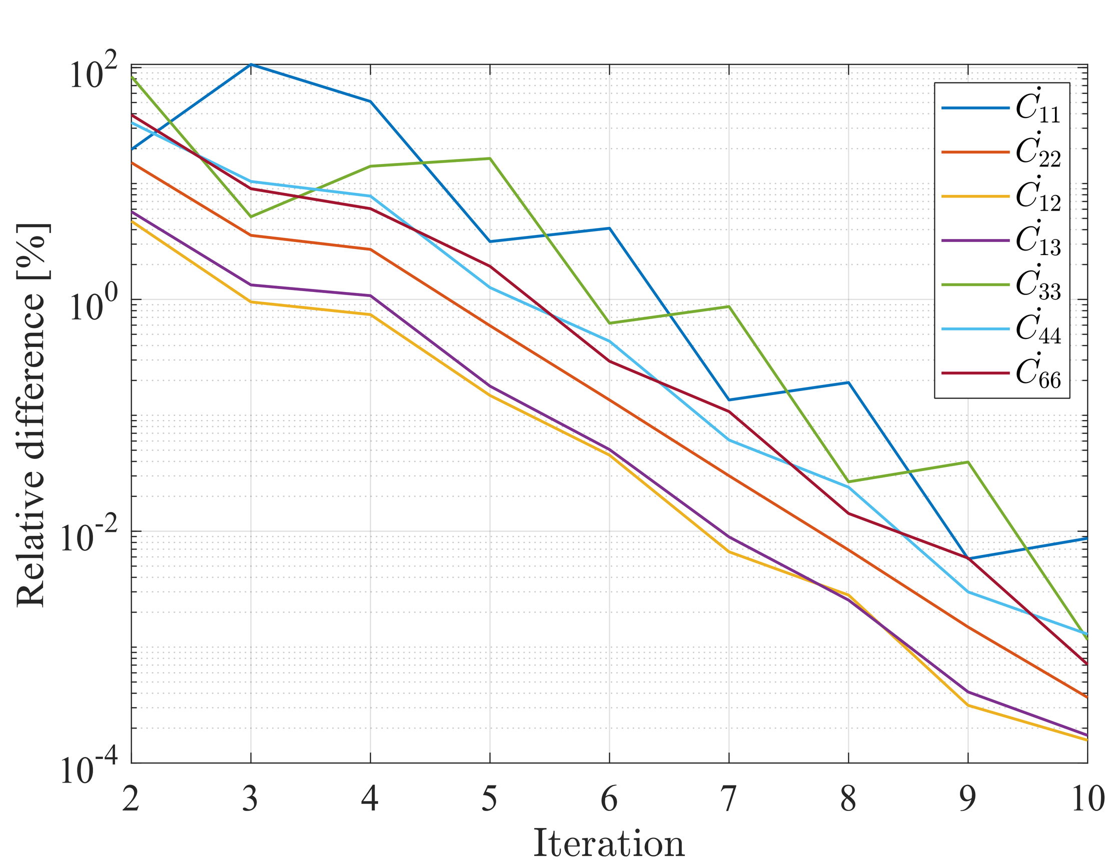


***Figure 1:** Relative difference of the stiffness tensor components between iteration i and i-1*

Figure 1 shows the convergence properties of the computed terms of the stiffness tensor. A greater number of iterations generally leads to a smaller relative difference between each iteration on the studied cases.

Figure 2 shows the values of the elastic modulus of spherical inclusion RVEs with a varying Volume Fraction (VF). Analytical results with the Voigt, Reuss and Halpin-Tsai methods are extracted from another study along with the numerical Asymptotic Homogenization (AH) technique. Perturbation technique is applied on periodic RVE which are then cropped to void the periodicity property and apply the EE method. Values computed with the EE method are found within the Voigt and Reuss bonds and we observe and increase of the elastic modulus along with the volume fraction.

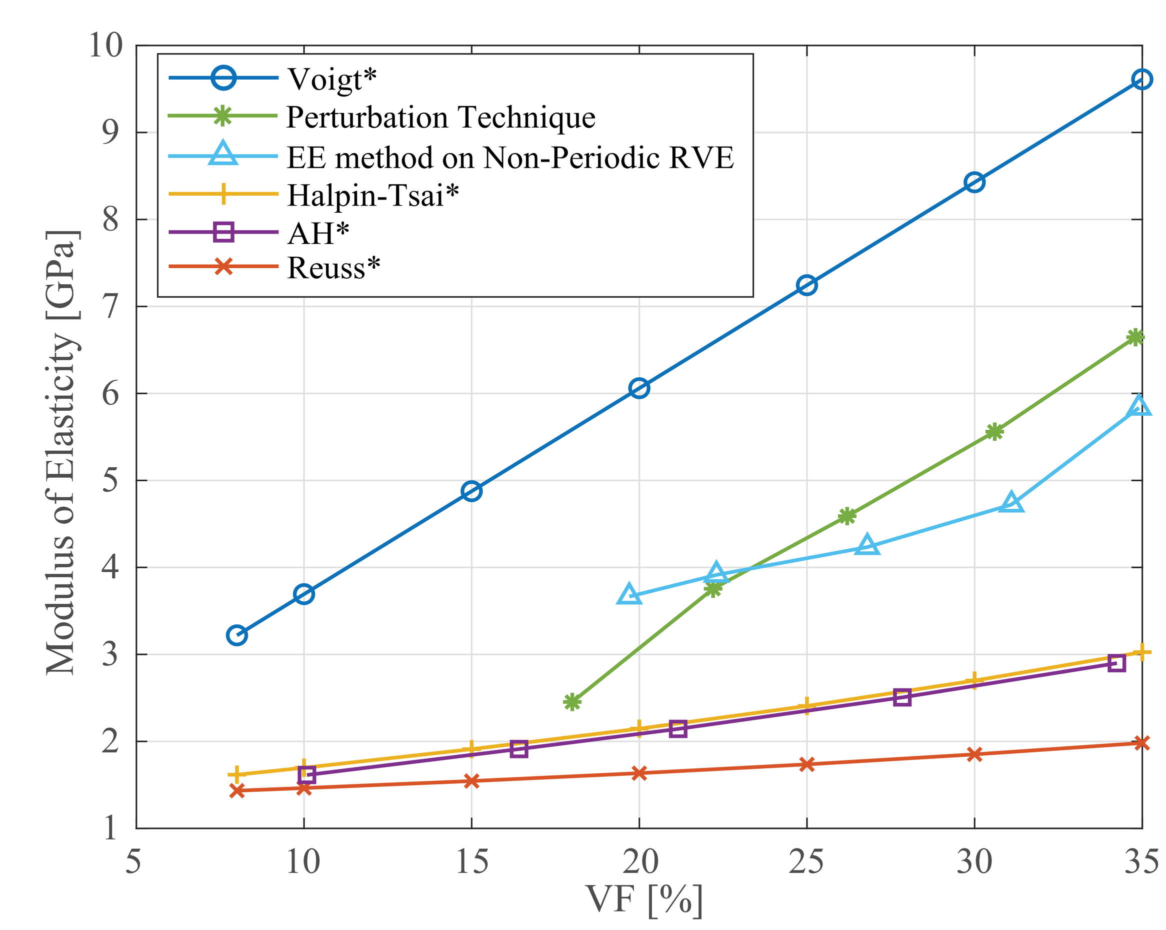


***Figure 2:** Elastic modulus of spherical inclusions composite according to the volume fraction predicted by various models.*
** Results from [1]*

Conclusions

The convergence of the stiffness tensor terms is systematically observed after 10 iterations at a 10^{-5} order.

The envelope enrichment method show great results and can be applied to any reinforcement shape and orientation. It can also be combines to the embedding technique.

Future Work

A study of the impact of different parameters like mesh density or envelope thickness will be conducted.

A plugin based on Homtools will be developed to make the process more straightforward. The user will only need to import the reinforcement mesh.

References

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4. Smith, M. ABAQUS/Standard User's Manual, Version 6.9. Dassault Systèmes Simulia Corp. 2009