Quantitative analysis of the particles distributions in reinforced composites

Pawel Kurtyka, Natalia Rylko

PII: S0263-8223(17)32456-X
DOI: http://dx.doi.org/10.1016/j.compstruct.2017.09.048
Reference: COST 8911

To appear in: *Composite Structures*

Quantitative analysis of the particles distributions in reinforced composites

Pawel Kurtyka[a,*], Natalia Rylko[a]

[a] Institute of Technology, Pedagogical University of Krakow, Podchorazych 2 St., 30–084 Krakow, Poland

Abstract

The subject of the study is development of a quantitative methodology for analyzing the structure of particle reinforced composites. The methodology is based on analytical representative volume element (ARVE) theory, which was developed to determine the effective properties of fiber reinforced composite materials. Further, it can be used for investigation of homogeneous materials. The developed methodology expands the scope of possible applications of ARVE theory to the following issues: (a) comparisons of composite materials of identical composition obtained through different technological processes, (b) assessment of the stability of the technology in the context of obtaining a material of uniform distribution of the reinforcing phase, (c) designation of a minimum area representative of the material, (d) for microscopic examination, detailed analysis of the impact of changes in process parameters on the structure of the composite, etc. The important elements of the developed methodology are the homogeneity and anisotropy parameters of the composite structure. Applied together, they provide additional opportunities to quantify the impact of the selected manufacturing/treatment process parameters on its structure. It is worth noting that the developed methodology is universal and can be applied at different levels, from the reinforcing phase concentration to the effective properties of composite materials.

Keywords: Particle-reinforced composites, Multiscale modeling, Anisotropy, Thermal properties, Plastic deformation

1. Introduction

An explosive growth in applications of composite materials is combined with sometimes exorbitant customers expectations. Together the two factors propel the intensification of research on new methods of the manufacturing, modification and optimization of these materials. Modern casting techniques [1–3], powder metallurgy [4–7] and plastic forming [8–11], are geared towards the formation of composite materials of a predetermined structure. Thus, we strive to achieve the best distribution of the size of the reinforcing particles in matrix, largely responsible for the properties of the resulting material [11–13]. This is the reason why in the conducted tests and studies, the methodology on which the quantitative analysis of the composite structure is based becomes of primary importance. It allows for optimization of the technological process to obtain materials with the required properties. For example, in numerous studies of the manufacturing, modification and bonding of composites by FSW/FSP methods (Friction Stir Welding/Friction Stir Processing), the analysis of changes taking place in the composite structure (in particular, changes in the geometrical distribution of the reinforcing particles) [14–16] is mainly based on the qualitative methods, which involve the examination of microscopic images. In this way, the researchers are able to prove the homogenization of composite structure occurring as a result of the process applied. But are unable to assess the extent of this homogenization and compare the results obtained.

Although the described approach proves to be sufficiently effective for structures different one from the other, it fails when subtle but important changes in the structure are to be traced [11].This can be easily noticed in the studies described by Amirizad [17], who has confirmed the occurrence of two zones in the tested composite but was unable to compare the structural differences. Statistical analysis provides more details, but can not solve the problem, since it is typically carried out for randomly selected regions of the composite, without precise determination of its minimum quantity indispensable for the proper treatment of results. A perfect illustration of this situation is given by Tutunchilar [18]. He examined a region limited to 300 particles, which may be not sufficient, especially in the context of the results obtained in [11, 12, 19]

A more detailed analysis of the changes in distribution of the reinforcing particles can be accomplished by many conventional methods, of which the most popular are the Dirichlet tessellation (also known as the Voronoi tessellation), study of the radial distribution functions or covariance, systematic scanning and variation analysis, etc.[20–26]. All these methods of analysis of the reinforcing phase structure can be successfully applied in composite materials research, but there are issues that require the introduction of objective parameters that define the structure of the composite. For example, such parameters would allow for:

- comparisons of composite materials of identical com-

*Corresponding author:
Phone: +48 126627881,
E-mail addresses: pkurtyka@up.krakow.pl (Paweł Kurtyka)