



## Research Trip Summary Report

### Task 2. Foreign mobility of WUST doctoral students

#### I. Data of the doctoral student

1. Full name: Pawel Zielonka
2. Year of studies: 2
3. Educational discipline: Mechanical engineering

#### II. Foreign research trip (research visit)

1. Research institute in which the foreign research was implemented: University of Porto
2. Name and surname of the host person (mentor): prof. Jose Antonio Fonseca de Oliveira Correia
3. Dates of the research trip: 03.06.2023 - 02.07.2023
4. Title and date of a seminar delivered during the research trip: "Application of the Representative Volume Element in hybrid fiber reinforced polymer structure investigation", 30.06.2023
5. Description of work carried out during the research trip:

At the beginning of the research trip the literature review of the applied image processing techniques, application of the Representative Volume Element (RVE) to microstructure examination and various models for finite element analysis were conducted. The review of the literature is based on the scientific databases such as Scopus, ResearchGate. The outcome from the investigation was used to choose proper strategy and tools for further studies.

At the following task the investigation of microstructure obtained from the SEM images of existing pultruded composite profiles was conducted. The images were initially processed to determine their edges, center of the circles, radius and fiber percentage in the selected area. The distribution of the circle radius was compared with the fibers measured during single fiber tensile tests made in preliminary studies. The images were described using Voronoi, Nearest neighbor orientation or Ripley's K function to compare with the results obtained from the generated microstructure.

At the end of the mobility the generation algorithm was created to investigate various microstructures and select the promising results for the experimental campaign. The methods based on the Random sequential adsorption (RSA) are limited by the highest volume fraction, which is insufficient for the pultruded profiles. The further investigation was concentrated on developing algorithms based on Random Sequence Expansion (RSE) or Delaunay triangulation. The development of the algorithm to generate Periodic Boundary Condition (PBC) on the generated RVE was under investigation.

The numerical calculation using Abaqus software and the generated model will be conducted in the nearest future.

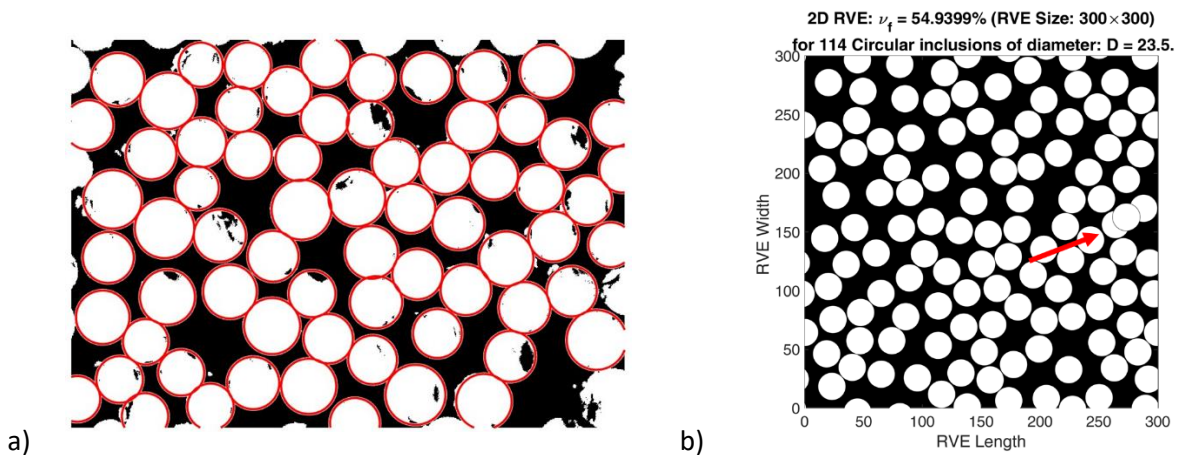


Figure 1 a) Microstructure of SEM image after photo processing and detection of the circles edges, b) generated microstructure with fibre random distribution using RSA algorithm with highlighted failure associated with too high fibre content

## 6. Description of the main results obtained:

During mobility period in the University of Porto the following outcome were obtained:

- The database of the applied analysis method for SEM images, parameters used for description and comparing various microstructures, opportunities of finite element models and results from different type of analysis
- Data from the investigation of the SEM images from manufactured rebars microstructure, examination of the fiber parameters received from images and single fiber tensile test, fibers distribution in the pultruded profiles
- Various microstructures characterized with random fiber distribution obtained using Python and Matlab software. The additional application to generate code for Abaqus software to accelerate the preparation of models for analysis and implementation of Periodic Boundary condition.

## 7. Future collaborations (if applicable):

The cooperation with the team from University of Porto during internship resulted in establishing contacts with team members, getting acquainted with their conducted research profiles and expanding knowledge about research opportunities at the University. In the future, implementation of the cohesive zone and XFEM analysis will be attempted to investigate the crack propagation in the matrix depending on the various microstructures. The awareness of the cooperation possibilities will result with mutual research and upcoming conferences or publications.

8. Title and date of a seminar presenting the results of the trip delivered at Wrocław University of Science and Technology after returning from the research trip: "Application of the Representative Volume Element in hybrid fiber reinforced polymer structure investigation", 28.07.2023 at 15:00



**III. Doctoral student's signature**

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(Date)

.....  
(doctoral student's signature)

**IV. Confirmation and information from the host**

1. Confirmation of compliance of the information contained in the report: I CONFIRM / DO NOT CONFIRM. *(In justified cases, the confirmation of the host may be sent by e-mail to the Dean's Office of the Doctoral School email: [interdocschool@pwr.edu.pl](mailto:interdocschool@pwr.edu.pl))*

2. Additional information and comments

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(Date)

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(signature(s) of Host)