

## Research Trip Summary Report

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

#### I. Data of the doctoral student

1. Full name: *Szymon Jan Duda*.....
2. Year of studies: *2<sup>nd</sup> year*.....
3. Educational discipline: *Mechanical Engineering* .....

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

1. Research institute in which the foreign research was implemented: *Norwegian University of Science and Technology (NTNU)*
2. Name and surname of the host person (mentor): *prof. Filippo Berto*
3. Dates of the research trip: *02.06.2022 – 24.06.2022*

4. Title and date of a seminar delivered during the research trip: *Modelling aspects of the multiaxial fatigue of CFRP thin-walled cylindrical structures. 20.06.2022.*

5. Description of work carried out during the research trip:

*The work during the internship at NTNU was divided into 3 tasks that were pursued simultaneously. First, the literature review in terms of failure criteria (static and fatigue) for continuous fiber composite materials was followed to analyze the possibilities and weaknesses of the available models for failure prediction in composite materials. This review of the literature was based on scientific databases such as Web of Science, Scopus, and ResearchGate. It has allowed me to choose the group of most suitable criteria for multiaxial loading conditions.*

*The second task concerns the FEM analysis of the CFRP thin-walled cylindrical structure under various static loading conditions. This analysis was based on the experimental results of torsion and compression. The semi-empirical approach was applied to obtained parameters for the FE model. The first step consisted of calibrating the effective elastic properties of the composite structure. It was based on the micromechanical approach. Many micromechanical approaches (Rule of Mixture, Puck, and Abolish) were applied to fit the stiffness of the structure. This analysis also allowed checking the influence of the elastic properties on the orthotropic material under various loading conditions. The second step dealt with the failure modelling issue. For this purpose, the Hashin failure criterion was used to predict the failure of the structure. To apply this criterion, several parameters are compulsory i.e., strength in each direction and damage evolution energies. The failure strength parameters were taken from the literature otherwise, and the energies that were evaluated by curve fitting and deformation/failure pattern obtained from the FEM.*

*The last task was devoted to collecting S-N fatigue data for composite materials under multiaxial loading conditions. A few papers were found with such data and collected. It is a relevant step for model verification in terms of fatigue prediction.*

6. Description of the main results obtained:

*During the 3-week period at NTNU the following results were obtained:*

- *Database of the static and fatigue models based on the micro and micromechanical approach. The comparison of the models available in the literature allowed choose appropriate for investigated material and loading conditions,*
- *FE model for stress analysis of the CFRP thin-walled cylindrical structures under various static loading conditions,*
- *Hashin criterion – strength and damage evolution parameters. Applying semi-empirical approach and FEM, it was possible to deliver the parameters to predict failure of investigated composite material,*
- *Database of the multiaxial fatigue results (S-N approach).*

7. Future collaborations (if applicable):

*The cooperation with Prof. Berto's team that has been intensified during the internship will result in mutual research activities, scientific publications, and research projects in the field of fatigue and fracture of engineering materials. The visit to NTNU has enabled us to get to know the research possibilities in terms of the available facilities and laboratory equipment. This knowledge has allowed mutual research to be found in the area of interest and will result in future conference and journal papers.*

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: *Modelling aspects of the multiaxial fatigue of CFRP thin-walled cylindrical structures; 28.07.2022; 9.15 - 10.00*

### 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)