Research Trip Summary Report

Task 2. Foreign mobility of WUST doctoral students

I. Data of the doctoral student

1.Full name: Mateusz Jacek Dymek

2.Year of studies: 2 year of PhD studies

3. Educational discipline: mechanical engineering

II. Foreign research trip (research visit)

1. Research institute in which the foreign research was implemented: Aveiro University

2. Name and surname of the host person (mentor): Fabio A.O. Fernandes

3. Dates of the research trip: 01.10.2021 – 01.11.2021

4. Title and date of a seminar delivered during the research trip: *American Football – why and how to maximize the athlete's safety* - 15.10.2021

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

The research stay was focused on working on several different aspects. The initial assumption of the research trip was to investigate the mechanical properties of cork-based composite. This topic was carried out using a drop test, investigating the sample behavior under load and calculating the energy absorbed together with forces and displacements. The test showed that 9 different cork-based composites have strain energy density oscillating at level of 100-100J, whereas the cork AC216 has have strain energy density oscillating at level 380J. Bearing in mind that the PhD dissertation will include the use of energy absorbing materials in American Football helmets it was decided to investigate the agglomerated cork.

Next point is creating a material model in LS-DYNA code. With the hosts experience in ABAQUS software, it was decided to use hyperplastic model with Ogden formulation of strain energy. Several attempts were taken and initial material model was established. The base of the validation are the material test and finite element analysis investigating the force vs displacement curve.

While validating the model, the geometry of cork layer was modelled that will be implemented to the American Football helmet between the outer shell and inflatable padding. The CAD helmet model was modified in order to fit the cork layer and the finite element model was developed.

The last point of the research trip was the continuous improvement of aHEAD models (the host and the student are both involved in the project). The jaw of a middle age person was modelled from the Digital Imaging and Communications in Medicine (DICOM) photos and adapted to the 28 year old aHEAD model. Lastly, the validation of the model was discussed and finished using the HARDY 755 test.

6. Description of the main results obtained:

The main results obtained are listed below:

- Tests and results review of composite cork
- Validation of new cork material model in LS-DYNA code (in continuous progress)
- Geometry of cork layer applicable in American Football helmets
- aHEAD model validation (Hardy 755) with four different material models
- The middle age model is enriched in jaw geometry

7. Future collaborations (if applicable):

The host Fabio A. O. Fernandes is the auxiliary supervisor of the student. The near future collaboration will include continuous work on cork material model in LS-Dyna code. Once that is finished, the finite element analysis will be carried out using the American Football helmets with embedded cork layer and creating the physical helmet model.

8. Title and date of a seminar presenting the results of the trip delivered at Wroclaw University of Science and Technology after returning from the research trip: *How to increase the American Football players safety with numerical simulations?* – 29.11.2021

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)*

2. Additional information and comments

I confirm that all the listed results above were carried out during the students stay in the Aveiro University. I would like to note that Mateusz Dymek is a very motivated student and working with him regarding different topics is a pleasure. Additionally, the student made new scientific connections with prof. Ricardo José Alves de Sousa.

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(Date) (signature(s) of Host)