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REVIEW REPORT

The doctoral dissertation of MSc, Eng. Torkan Shafighfard entitled
"Diagnostic Methods for Fiber Reinforced Composite Structures with Imperfections"

1. Base of elaboration

The basis for the review is letter of the Deputy Director for Scientific Issues, Grzegorz Żywica, D.Sc., Ph.D. Associate Professor of IMP PAN, No. RN-421-5/23 dated April 8th, 2024.

2. Selection of the topic of the doctoral thesis

The subject of the doctoral dissertation is the imperfection detection on composite structures, understanding imperfections as "voids, gaps between fibre bundles, delaminations, holes, etc. or inclusions".

As a result of the thesis, up to up to 12 journal papers are presented (5 still on review, and 3 of them as first author), one book chapter and 2 presentations on conferences. Book chapter is the compendium of one of the conference (EWSHM 2022). Journals and conferences are related with the topic of the thesis.

3. Title, content, and layout of the dissertation

The proposed title of the dissertation, "*Diagnostic Methods for Fiber Reinforced Composite Structures with Imperfections*"
The entire dissertation was presented on 109 pages in English. It contains 6 chapters and the Bibliography. The bibliography includes 122 items.

Chapter 1 Introduction
This chapter is just a very short explanation of the thesis topic and bases, that maybe could be mixed with the next chapter (SoA), and specially with the point 2.1 Motivation.

Chapter 2 State of the Art.
This chapter review composite materials, additive manufacturing, Structural Health Monitoring (including FBG principia), Machine Learning and the study of the interaction between mechanical joints in composites. In my opinion, the structure of this chapter should have a clear hierarchy and a better organization. For example, Additive Manufacturing and Fused Deposition Modeling are in the same level, but Fused Deposition should be under the level of Additive manufacturing, as it is a technique. Same for FBG and SHM. Additionally, in the

literature review are mixed general information with a very specific one (For example, Shape Memory polymer resins is a very specific issue, and it is not directly related with the Phd topic). Although the organization and some contents could be improved, the bases of the SoA are stated.

Chapter 3 AM for CFRP embedded FBG.
In this chapter, it is proposed to embed FBG sensors on composite materials manufactured with additive manufacturing, in order to fully characterize the manufacturing process and the thermos-mechanical behavior of the material. The test performed in a wide range of temperatures and conditions validate the model of the composite material in traction. However, the bolted joint require compression and bearing test, as the matrix behavior is more complex than in traction. Additional to mechanical test, SEM micrographs were performed, but it is no conclusions related with this information (adhesion fiber/matrix and fiber optic/matrix, for example).

Chapter 4 Application of multi-instrument techniques.
In this chapter, a wide experimental characterization in fabric composites is performed, as well a numerical model is developed. This chapter has a large list of test (DIC, IRT, mechanical testing, fractography) and numerical characterizations with a high level of agreement with all the experimental techniques. This chapter is interesting and not deeply study in the SoA, and the methodology proposed is deeply study and validated.

Chapter 5 Stacked ML model
In this chapter, ML techniques have been uses to analyze the laminate mechanical behavior using numerical data to train and validate the model. This topic is currently very interesting, and it is a wide range of studies. As in previous chapters, the structure of this chapter should have a clear hierarchy and a better organization, in my opinion. The results are good, even if the number of tests seems to be insufficient. The model accuracy is good, aligned with the SoA.

Chapter 6: Summary and Discussion
This chapter is well organized, with different conclusions of every topic under study in the thesis.

4. Evaluation of the thesis

Original elements of the dissertation:

This dissertation studies several topics of different areas: sensors, manufacturing, testing, analysis, data processing...using a huge list of experimental techniques and a vast number of test. It is impressive that a phd student has performed all this tasks. As result of all the different results performed, it is difficult to find a clear road that joint the different topics/chapters. The continuous change of topics, materials and techniques makes very difficult the reading.

The most significant achievements of this dissertation are the study of the interaction between holes in composite laminates and the use of ML to analyze laminate mechanical behaviour.

5. General comments and questions

List of remarks:

- Joint Chapter 1 with point 2.1 Motivation, as the Chapter 1 has not enough entity.
- Fig 3.2: Spectrum is not accurate enough to measure the spectral shift properly.
- MJP acronym is not explained
- The lay-up sequence of the laminates under study in chapter 4 has no 45º layers, as it is required due to standard design rules. The application of the results is limited to cross ply laminates.
- The numerical analysis has no detail any failure criteria, that it is mandatory to understand failure mechanisms.

6. Typographical error

Pag. 33, line 5: 1.75 is not fiber diameter, is the diameter of the yarn.
Pag. 34, Table 3.3: Temperature range is not clear (-75ºC to +180ºC). Same mistake can be found in other parts of the same table with other parameters.

7. Final conclusion

In my opinion, the doctoral thesis entitled "*Diagnostic Methods for Fiber Reinforced Composite Structures with Imperfections*" by Mr MSc, Eng. Torkan Shafighfard is an original solution to a scientific problem and meets all the requirements for doctoral theses by the applicable the Law on Higher Education and Science – Act of July 20, 2018 (Journal of Laws of the Republic of Poland 2018, item 1668, as amended).

The dissertation may be admitted for public defense and constitute the basis for awarding Mr MSc, Eng. Torkan Shafighfard holds a PhD in the engineering and technology field in the discipline of mechanical engineering.

Antonio Fernández López
Madrid, May 25th, 2024