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Research Topic 21 for the ParisTech/CSC PhD Program

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Subfield: Mechanical Engineering and Manufacturing, Materials Science

Arts et Métiers ParisTech

An Improved 3D Micro-macro Model for Modeling of Hybrid CFRP/Ti Drilling

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Nowadays, hybrid CFRP/Ti stack has obtained considerable demand in the modern aerospace industry due to its enhanced mechanical/physical properties and improved structural functions. Prior to its application, mechanical drilling is usually required to finish the hybrid composite structures in order to ensure tight assembly of the multi-phase material. However, drilling the hybrid CFRP/Ti stack in single shot time is an extremely difficult task in the manufacturing sectors due to the disparate natures of each stacked constituent and their respectively poor machinability [1] . Special issues may arise from the severe subsurface damage, excessive interface consumption, rapid tool wear, etc.

To improve its machinability, tremendous scientific work had been performed in the past few decades but was solely focused on the conventional experimental studies, which exhibits time consuming and high cost. In contrast, the numerical approach would be a promising alternative tool that could help significantly in improving the machining characteristics while drilling these stacked composites by understanding the various mechanisms involved. The previous numerical work done by Xu and El Mansori [2, 3] indicated the excellent suitability of the numerical method in predicting the various cutting phenomena activated during the bi-material machining. However, the proposed numerical models were based on the orthogonal cutting configuration (OCC) and several phenomenological assumptions were adopted.

To improve the numerical models, the key purposes of the PhD position aim to:

- Developing a 3D multi-physical model which can accurately replicate the key cutting physics of hybrid CFRP/Ti drilling. The FE model should include a test of reliability for the numerical integration scheme involving failure and damage criteria of each stacked constituents. The extended constitutive laws and damage criteria for representing the actual

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mechanical-thermal behaviors of the composite-to-metal alliance should be defined precisely through the VUMAT subroutine implementation into the Abaqus/Explicit code.

- The proposed micro-mechanical model will take into account the existing α and β phases of the Ti alloy, and the fiber and matrix phases of the composite phase. For the macro-mechanical model, the CFRP phase can be simulated as an equivalent homogeneous material (EHM) by considering its anisotropic behavior relative to the fiber orientation. A reliable prediction of the chip separation modes and various drilling-induced damage formations including the fiber/matrix failure, interface delamination, exit Ti burrs should be achieved.
- Several experimental investigations will be performed to validate and to improve the credibility of the developed numerical models through rigorous comparisons of various drilling responses. Some required observations (SEM, AFM, etc.) on the mechanisms generated will facilitate the numerical predictions to offer an enhanced CFRP/Ti drilling comprehension.

Keywords: Hybrid Composite Stack, Drilling, 3D Modeling, Micro-macro model, FE Analysis.

Eligibility:

Applicants must have first class master degree in a relevant engineering or science subject (e.g. mechanical engineering, manufacturing engineering, materials science, etc.) and should be enthusiastic about scientific research of manufacturing processes and numerical modeling & simulation. Applicants who show proficient use of ABAQUS software, scientific skills in FORTRAN language and VUMAT programming should be considered as a first choice. Finally, the good communication/writing skills of English are also necessary.

References

[1] J. Xu, A. Mkaddem and M. El Mansori. Recent advances in drilling hybrid FRP/Ti composite: a state-of-the-art review. *Composite Structures* 2016; **135**: 316-338.

[2] J. Xu and M. El Mansori. Cutting modeling using cohesive zone concept of titanium/CFRP composite stacks. *International Journal of Precision Engineering and Manufacturing* 2015; **16** (10): 2091-2100.

[3] J. Xu and M. El Mansori. Finite element analysis when orthogonal cutting of hybrid composite CFRP/Ti. *IOP Conference Series: Materials Science and Engineering* 2015; **87** (1): 012059.