NUMERICAL MODELING OF DELAMINATION DURING MACHINING OF LFRP COMPOSITES

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Summary. This work focuses on the numerical modeling of composite cutting. Three dimensional approach is required in order to analyze delamination induced during cutting process.

1 INTRODUCTION

The combination of attractive properties of Long Fiber Reinforced Polymer (LFRP) composites, mainly fatigue and corrosion resistance, light weight, and elevated specific stiffness and strength, have led to their extensive application in different industrial sectors. Although composite components are usually manufactured close to the final shape, some machining operations, such as drilling and milling, are usually needed to achieve dimensional and assembly requirements.

One of the most important limits for the use of composites in high responsibility applications is delamination damage. In fact, in the aerospace sector, a significant percentage of rejected parts during the last stages of assembly process, is due to delamination induced during drilling [1].

Up to date, most numerical models of composite cutting are two dimensional and assume the hypothesis of plane stress. However the onset and progression of delamination damage are dependent on the matrix behavior when out-of-plane and tensile and shearing loads are applied. Thus the formulation of three dimensional models is required when delamination should be accounted.

In this paper, a 3D numerical approach for modeling of composite cutting is presented with special attention to the development of delamination damage.

2 NUMERICAL MODEL AND RESULTS

The commercial Finite Element code ABAQUS/Explicit was used to develop a 3D model of orthogonal cutting of LFRP composites. Dynamic explicit analysis was carried out using C3D8R, 8-node brick elements with reduced integration available in ABAQUS/Explicit [2].
The numerical model is presented schematically in Fig.1. The composite behavior was modeled with a VUMAT subroutine, based on the 3D Hashin failure criteria, completed with the Hou formulation for delamination [3], including a procedure to degrade material properties. Maximum strain criteria were implemented in the VUMAT subroutine to remove the distorted elements. The tool was assumed to be rigid. The contact interaction at interface workpiece/tool was modeled by using the algorithm surface–node surface contact available in ABAQUS/Explicit with a constant coefficient of friction equal to 0.5.

The onset and progression of delamination damage are mainly dependent on the matrix behavior when out-of-plane and tensile and shearing loads are applied. On the other hand the matrix cracking and crushing modes those are dominant damage mechanisms in the laminate plane [4], are also influenced by the out-of-plane stresses in a 3D formulation. The matrix crushing evolution for a 45° fiber orientation is shown in figure 1.

Figure 1: Left, scheme of the 3D model; right, evolution of the matrix crushing with the cutting time for a 45° fiber orientation.

REFERENCES
[2] HIBBIT.