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Optimization of Fiber-Metal Laminate (FML) Milling for the Aerospace and Automotive Industries

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Introduction

The pursuit of energy efficiency in the aerospace and automotive sectors has led to the widespread use of fiber-metal laminates (FMLs), such as the multi-material Al/CFRP/Al, which combines light weight, high stiffness, impact resistance, and corrosion resistance[1].

Despite their high structural performance, milling these laminates presents critical challenges. Their anisotropic nature and low thermal dissipation accelerate cutting tool wear and contribute to severe structural defects, such as delamination[2].

To enable dry machining with surface integrity and lower production costs[3], it is essential to optimize cutting parameters by integrating force analysis, vibration analysis, ta-C-coated tools, and computational simulations.

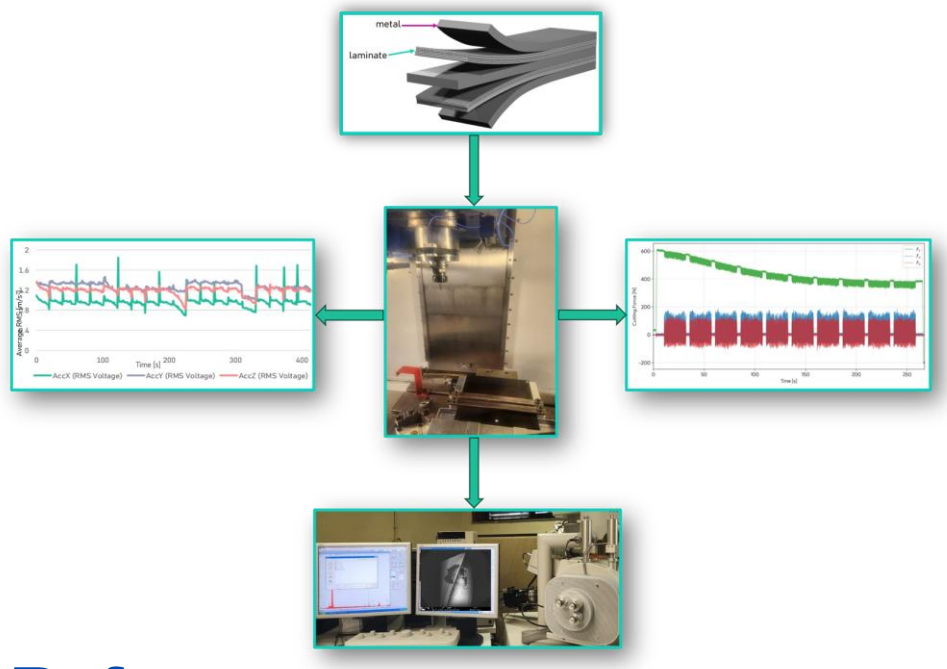
Objectives

i. Model and optimize dry milling of Al/CFRP/Al laminates using simulations.

ii. Evaluate cutting forces, vibrations, and the efficiency of ta-C-coated tools.

iii. Analyze tool wear, chip morphology, and material integrity.

Methodology



Results and Discussion

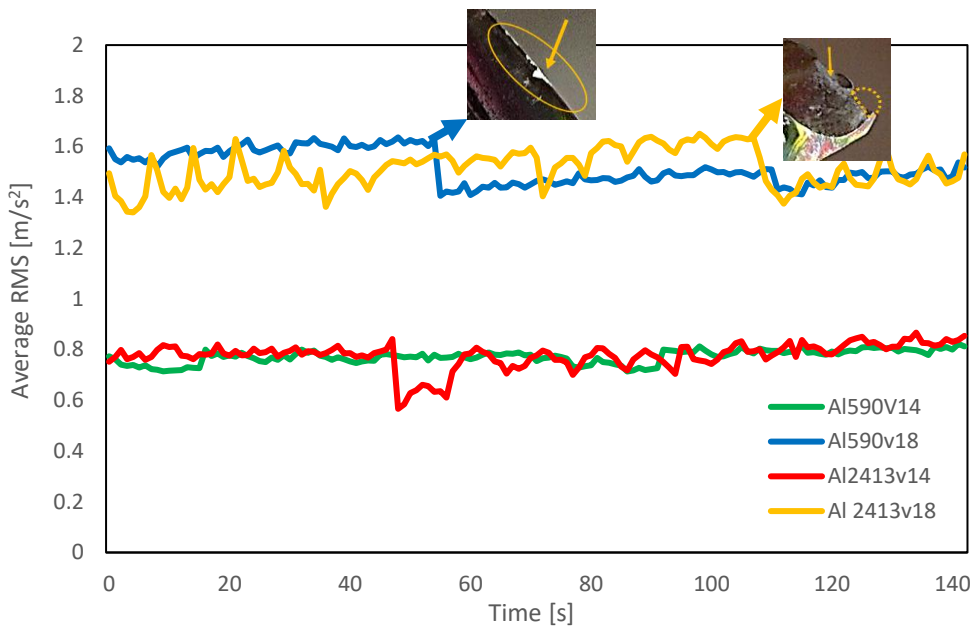


Figure 1. Average RMS evolution as a function of relative time obtained during the Al/CFRP/Al laminate milling process using the tools 590 and 2413 and cutting speed of 140 m/min and 180 m/min.

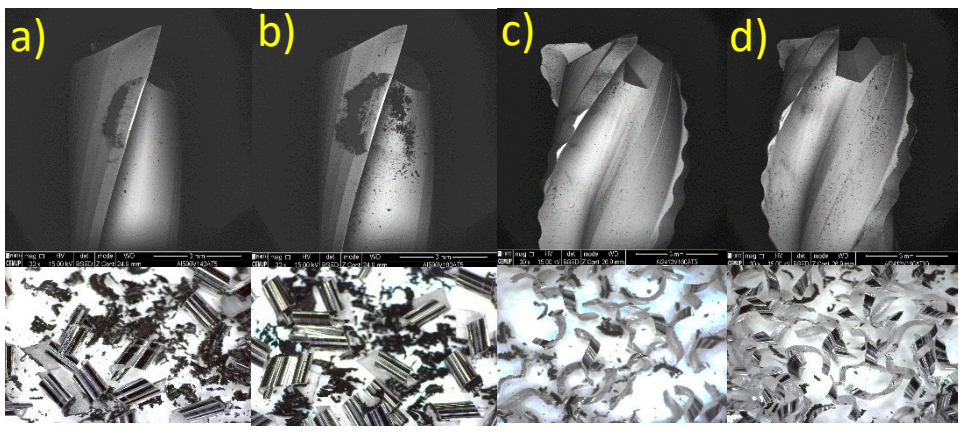


Figure 2. Tool deterioration imagens and chips acquired via SEM.

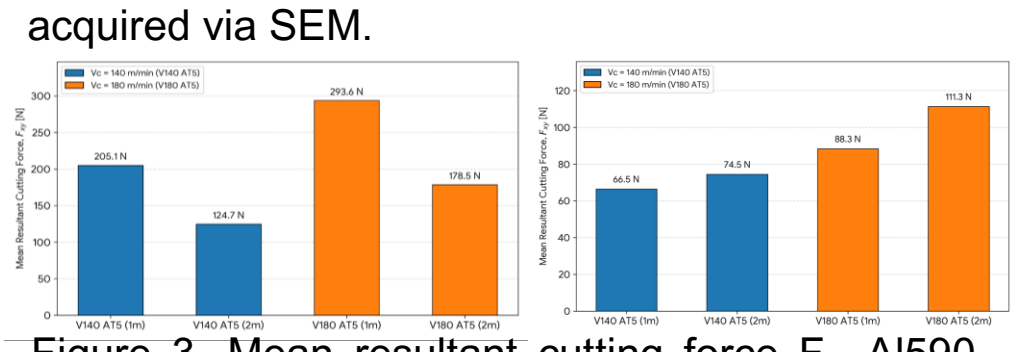


Figure 3. Mean resultant cutting force F_{xy} Al590 Tool and Al 2413 Tool (140m/mm and 180m/mm).

Conclusions

i. A cutting speed of 180 m/min increased F_{xy} forces, doubled RMS vibration, and intensified abrasive wear in both milling cutters.

ii. The AL2413 cutter outperformed the AL590, recording lower F_{xy} forces (66.5–111.3 N vs. 124.7–293.6 N), lower abrasive wear on SEM (0.61 vs. 2.57 mm), and later edge fracture (3 m vs. chipping at 1 m in the AL590).

iii. Chip morphology depended directly on cutter geometry: the trochoidal AL590 produced tubular chips with CFRP adhesion, whereas the AL2413 formed more fragmented chips with no CFRP adhesion.

References

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[2]Ozkan D, Panjan P, Gok MS, Karaoglanli AC. Experimental Study on Tool Wear and Delamination in Milling CFRPs with TiAlN- and TiN-Coated Tools. *Coatings*. 2020; 10(7):623

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Acknowlegdments

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