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Analysis of Performance and Surface Integrity in Milling of Ti-6Al-4V Titanium Alloy

Rita C. M. Sales-Contini[1,2*]; Naiara P. V. Sebbe[2]; Pedro H. M. de Carvalho[1]; Rafael R. Lucas[3]; Heide H. Bernardi[2]; Jorge T. Matsushima[2,4]; Francisco J. G. da Silva[1,5]

1. FATEC São José dos Campos – Prof. Jessen Vidal (CPS), SP, Brazil; 2. CIDEM, ISEP – Polytechnic of Porto, Portugal; 3. UNESP – School of Engineering and Sciences, Guaratinguetá, SP, Brazil; 4. INPE – São José dos Campos, SP, Brazil; 5. LAETA-INEGI, Porto, Portugal. *Corresponding author: rcmsc@isep.ipp.pt

Introduction

Titanium alloys (Ti-6Al-4V, Ti-555, Ti6242S) are widely used in critical structural parts (compressor blades, discs, castings, gas turbines, and pylons on Boeing 787 and Airbus A380) due to their strength-to-weight ratio, creep resistance, and corrosion resistance[1].

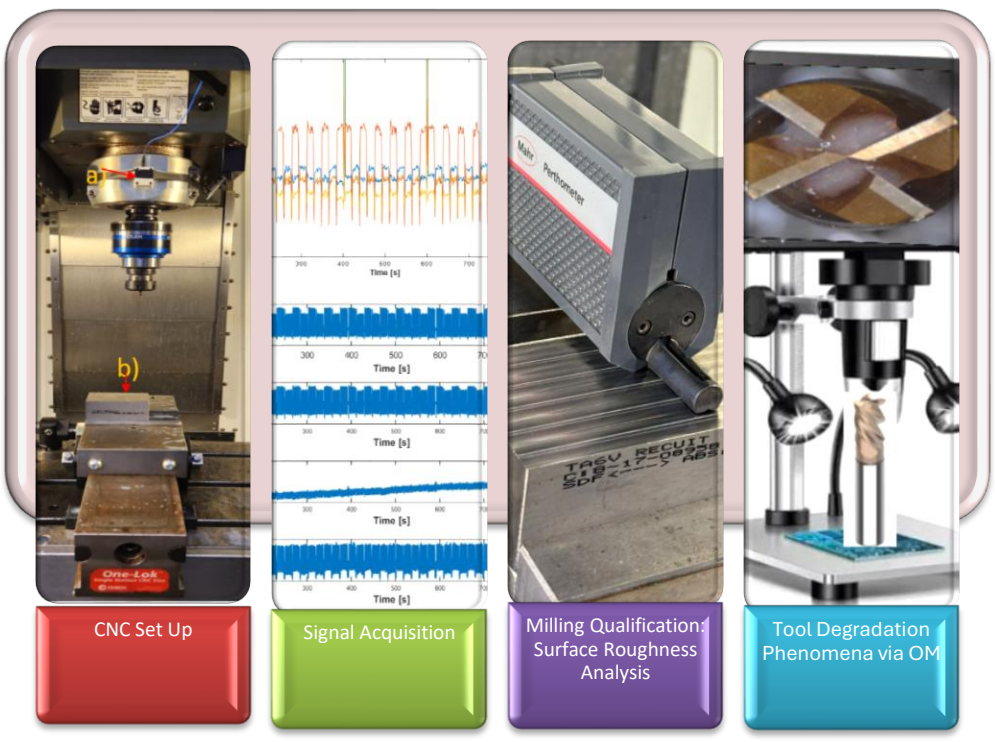
Low thermal conductivity concentrates heat at the tool–workpiece interface, while high hot strength and low elastic modulus generate strong compressive edge stresses, built-up edge (BUE), burrs, and premature tool failure[2].

Selecting appropriate coatings and cutting parameters alongside vibration analysis enables early wear detection, extends tool life, and reduces scrap, aligning with UN Agenda 2030 (SDG 12) for sustainable manufacturing[3].

Objectives

i. Correlate triaxial RMS vibration and shear forces with the initial wear of milling cutters.
ii. Quantify surface roughness (Ra) at three cutting speeds (Vc) and feed rates (fz).
iii. Identify wear (ISO 8688-2) to optimize productivity and surface finish.

Methodology



Results and Discussion

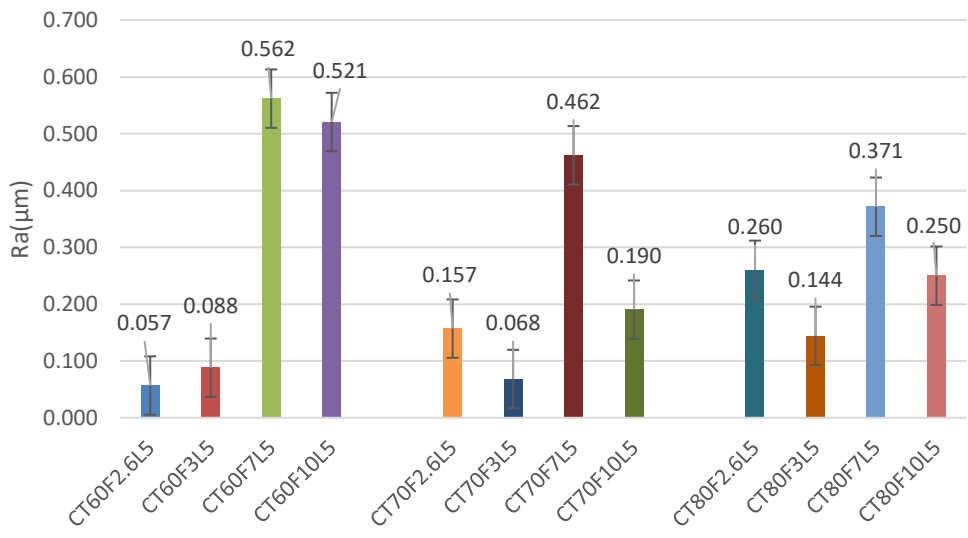


Figure 1. Ra average values of Annealed Ti 6Al 4V alloy after the milling process using the cutting speed of a) 60 m/min, b) 70 m/min, and c) 80 m/min.

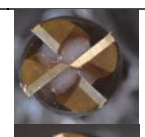
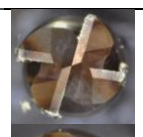
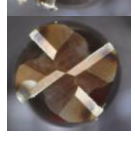
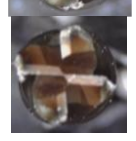
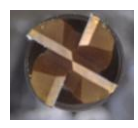
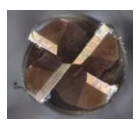
Tool Designation	Fz 0.03	Fz 0.07	Fz 0.10	Tool Deterioration Phenomena
CT60				Fz 0.03= Scratches on the coating surface Fz 0.07= Localized flank wear Fz 0.10=Localized chipping
CT70				Fz 0.03= Scratches on the coating surface Fz 0.07= Irregular cracks Fz 0.10=Non uniform flank wear
CT80				Fz 0.03=Irregular cracks Fz 0.07= Localized flank wear Fz 0.10= Non-uniform flank wear and BUE

Figure 2. Tool deterioration imagens acquired via optical microscope.

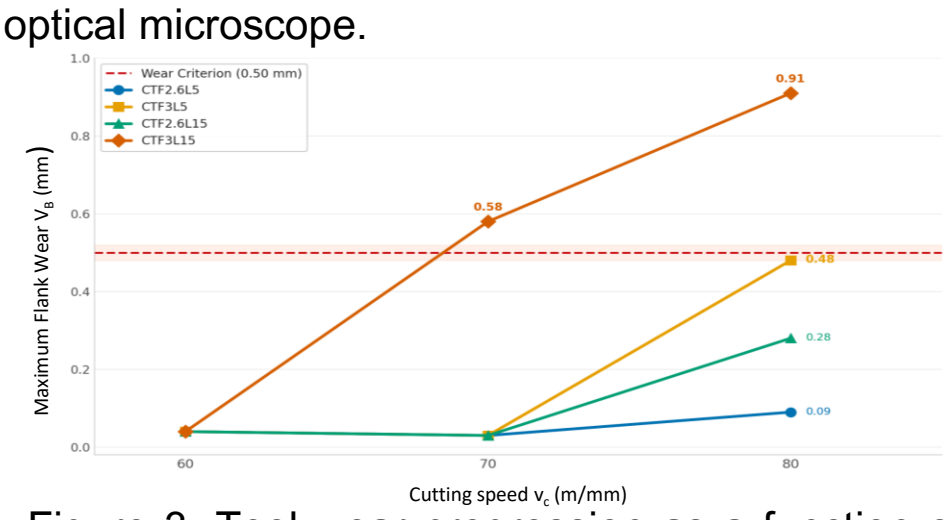


Figure 3. Tool wear progression as a function of cutting speed.

Conclusions

i. The axial force Fz increased with cutting speed, reaching 710 N at 80 m/min.
ii. At fz = 0.03 mm/tooth, the Fx, Fy, and Mz signals remained stable throughout the cut.
iii. In CT70 (fz 0.07 and 0.10), sudden spikes in Fx, Fy, and Mz indicate rapid instability.
iv. At 60 m/min, VB3 wear was ≤0.14 mm; however, CTF3L15 exceeded 0.50 mm at 70–80 m/min.
v. Even at 80 m/min, CTF2.6L5 (0.09 mm) and CTF2.6L15 (0.28 mm) maintained low wear.

References

[1] Kumar D., Gururaja S., Jawahir I.S. Machinability and surface integrity of adhesively bonded Ti/CFRP/Ti hybrid composite laminates under dry and cryogenic conditions, J. of Manufact. Proc., 58 (2020) 1075-1087.

[2] Pawar O.A., Gaikhe Y.S. , Tewari A., et al. Analysis of hole quality in drilling GLARE fiber metal laminates, Compos. Struct., 123 (2015) 350-365 [3] ONU, 2015 Transforming our world: the 2030 Agenda for Sustainable Development, 2015/2018

Acknowlegdments:

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