Modeling Surface Roughness and Tool Wear using Particle Methods

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Machining of metal parts involves two key challenges that have driven modeling research in recent decades: optimizing cutting strategies and parameters, and balancing productivity with tool longevity. From the perspective of the workpiece, industry seeks reliable predictions of process parameters that yield optimal surface finish while minimizing energy consumption and machining time. Simultaneously, attention must be given to tool performance, particularly in extending tool lifespan by reducing wear under optimal cutting conditions.

In this work, we present two numerical approaches to predict the surface roughness of the workpiece and the surface topography of the cutting tool. The objective is to characterize the final surface and the residual stresses induced in the material, enabling a more complete assessment of machining performance. This information supports the identification of optimal process conditions.

To address the complexity of machining, we combine fast search algorithms with the Particle Finite Element Method (PFEM) [1, 2], capturing both the geometrical aspects of the process and the thermo-mechanical behavior of the material [3].

The approach is applied to additively manufactured parts, which allow the production of complex geometries but often lack the required surface quality. Machining is used as a finishing step to achieve tighter tolerances and improved surface finishing, helping to reduce overall production time, material use, and energy consumption.

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[1] J.M. Carbonell, J.M. Rodríguez and E. Oñate. "Modelling 3D cutting problems with the Particle Finite Element Method", Computational Mechanics, 66, 603-624, (2020).
[2] Bakhshan, H., Oñate, E. and Carbonell, J.M. "Microstructure evolution modeling of Ti6Al4V alloy during cutting using the Particle Finite Element Method and homogeneous field distributions". Journal of Manufacturing Processes, pp.73-92. (2024).
[3] Bakhshan, H., Oñate, E. and Carbonell, J.M. "A Review of the Constitutive Modelling of Metals and Alloys in Machining Process". Arch Computat Methods Eng (2023).