Development of FEM-based digital twins for machining difficult-to-cut materials: A roadmap for sustainability

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According to the united nations sustainable development goals, by 2030, the member states are expected to make significant advances towards sustainable manufacturing by applying of clean technologies and environmentally friendly processes. As machining is widely employed across various industries, stakeholders in the sector must promote sustainable and efficient practices. The goal is to effectively manage resources, including cutting tools, energy, and metalworking fluids (MWFs), while maintaining quality to avoid waste-related costs.

This work reports how MWFs have been used for machining difficult-to-cut alloys. Moreover, it emphasizes the need for shifting away from flood cooling with mineral oil based emulsions towards sustainable alternatives such as cryogenic machining and minimum quantity lubrication (MQL), as both use lower flow rates of MWFs with lower environmental impact.

It also highlights the worth of the finite element method (FEM) as a valuable tool for optimizing machining conditions and studying the thermo-mechanical response without the need for time-consuming experiments. On the other hand, it addresses how the lack of MWFs-assisted machining simulations is an obstacle when dealing with difficult-to-cut alloys, as MWFs play a crucial role in controlling surface integrity and tool life.

Meaningful questions such as, how to convert the MWFs and delivery systems into suitable variables for numerical simulation? How computational methods such as FEM and CFD (computational fluid dynamics) contribute to the sustainable use of MWFS in machining? What efforts have been made to increase the accuracy of MWFs-assisted FEM models? where answered in this work. Moreover, it was found that advanced cooling techniques, such as cryogenic MQL, electrostatic MQL, nanofluid MQL have been used, with promising results in difficult-to-cut alloys. All these efforts will contribute for building a society with responsible consumption and production standards.

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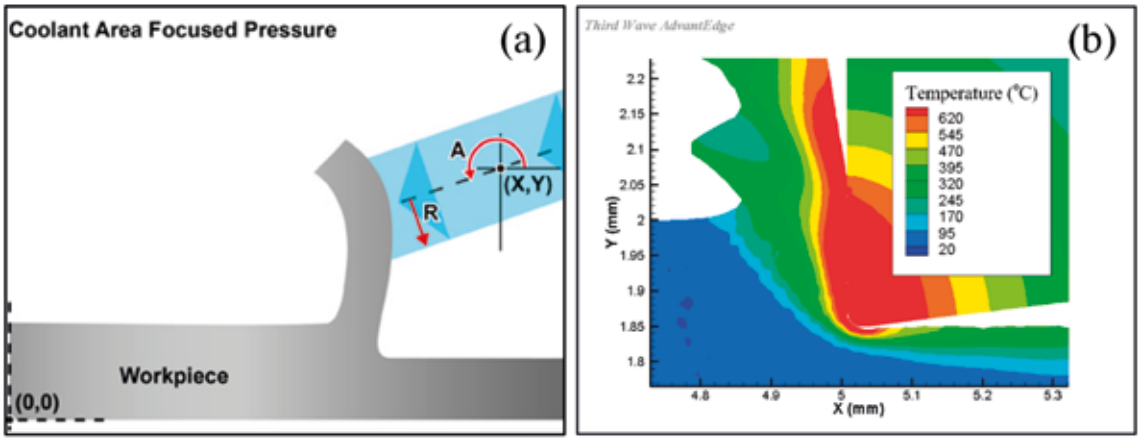

FIGURE 1
Development of metalworking fluid assisted simulations: (a) Method available in AdvantEdge for implementing a minimum quantity lubrication setup; (b) Temperature contour in machining simulation with FEM.