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An Analysis of Green Manufacturing Environments for Challenging Materials †

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Abstract: Industry wants materials of the highest competence that are strong and precise in their dimensions. Due to their strength even at high temperatures, these high-grade, high-strength materials are difficult to machine. The traditional methods of cooling and lubricating have been shown to be ineffective and are harming the environment and human health. Researchers have created green machining environments that can lower cutting pressures and temperatures while improving surface quality and tool life to solve this issue. An attempt has been made in this work to compile every alternate approach that may be used to manufacture materials that are challenging to cut, like titanium, toughened steels, and nickel super alloys. The results of diverse machining conditions will undoubtedly be shown in our assessment. The best green settings, according to current research, are nano fluid minimum quantity cutting fluid (NFMQL) and minimal quantity cutting fluid (MQL).

Keywords: green environment; difficult-to-cut material; MQL; NFMQL

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1. Introduction

Every day, there is a greater need for high-quality materials that may be used in a variety of engineering applications. Titanium alloys, stainless steel alloys, toughened steels, and nickel-based super alloys are acceptable materials that can be used to meet the demands of diverse applications. The machining process constantly produces heat, which has a negative impact on product quality and the life of the cutting tool [1]. Heat is produced as a result of the friction between the workpiece–tool contact and the tool–chip interface. Due to the greater cutting pressures used, this effect is even more severe in the case of difficult-to-cut materials. There are numerous strategies designed to extend tool life as much as possible. Bio cutting fluids should take the place of petroleum-based cutting fluids since they significantly lower the danger of environmental pollution. Cutting fluids need to be non-toxic, odourless, less viscous, capable of conveying a lot of heat, and inexpensive [2].

2. Effects of Cutting Fluid Application Strategies

The search is underway for safer, pollution-free cutting techniques that use safer, more potent lubricants and coolants. Mineral or synthetic substances are frequently used as cutting fluids. These hazardous cutting fluids end up in rivers as waste or as an emulsion, endangering the ecosystem significantly. Utilizing Minimum Quantity Lubrication (MQL), which involves spraying biodegradable oil micro particles into the cutting zone, is another option for creating an environmentally friendly cutting environment [3,4]. It has been concluded that using cooling air is advantageous for green machining. Cutting tool nose wear curves for various cutting mediums are depicted in Figure 1.

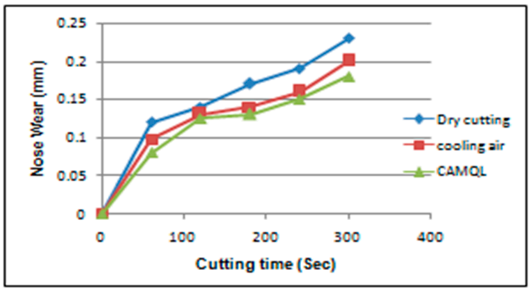
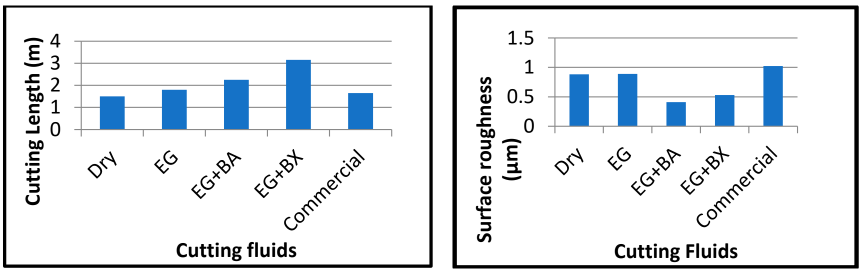


Figure 1. Cutting tool nose wear curves for various cutting mediums [5].

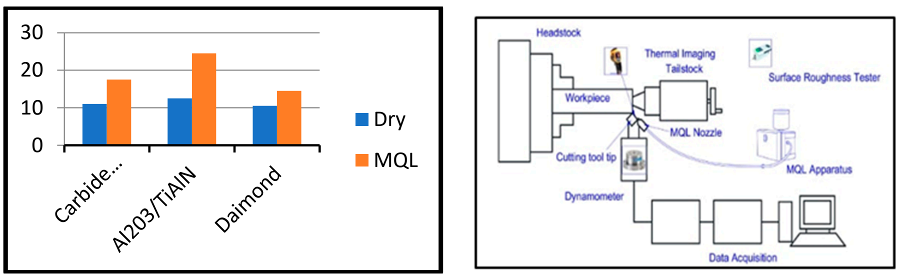
In their research, ref. [6] endeavoured to boost milling productivity for Inconel 718, a difficult-to-cut alloy. Figures 2–4 depict the arrangement employed in their investigation and tool life using three dissimilar tools in dry and MQL conditions, respectively, along with their parameters.

Figure 2. Cryo-MQL experimental configuration [6].



(**a**) (**b**)

Figure 3. (**a**) Effect of coolants on tool life; (**b**) effect of coolants on surface quality.



(**a**) (**b**)

Figure 4. (**a**) Cutting tool durability and (**b**) surface roughness and tool temperature in dry and MQL environments were measured experimentally.

3. Impact of Adding Nanoparticles to Cutting Fluids (NFMQL)

Recent research recommends using nano particles in cutting fluids because they are effective at producing a good cooling effect. These nanoparticles, when combined with the base fluids, change their thermo-physical characteristics. Because of the increased effective surface area for virtually the same volume and the cutting fluid's remarkable wettability, it has high heat conductivity. Figure 5 depicts how varying cutting conditions affect tool temperatures (a) and attrition (b). Adding nanoparticles of Al_2O_3 to the initial cutting fluid increased its ability to transfer heat by about 22% [7]. With more nanoparticles and smaller particles, the cutting fluid's thermal conductivity was enhanced [8]. To create nano lubricants, the cutting fluid was mixed with naturally occurring and affordable Montmorillonite Clay (MMT) nano additions at 0.2 and 0.3 weight percent. In the hard-milling of AISI 1018 steel, these nano fluids containing 0.2 and 0.3% nano additive demonstrated good tribological performance in comparison to the base lubricant [9].

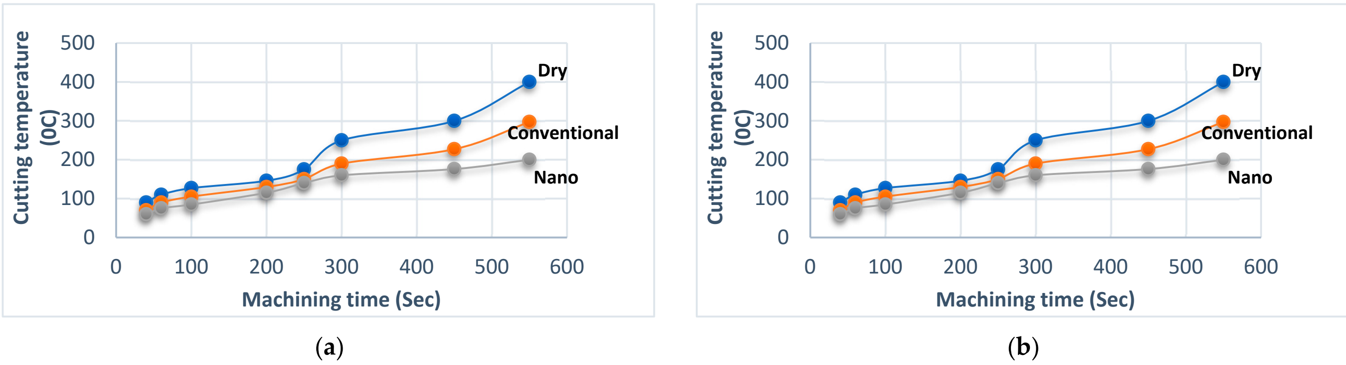


Figure 5. (**a**) Machining time vs. cutting temperature [7]; (**b**) machining time vs. flank wear [7].

Figure 6 shows the tool flank wear in three nano cutting fluids operating at various speeds. The primary benefits, drawbacks, possibilities, and various cooling method optimization methods are also displayed.

The drawbacks and potential directions of these techniques for machining titanium and related alloys are highlighted [10–13]. It follows that further study is obviously ongoing to determine the best ways to machine hard-to-cut materials in an ecological manner.

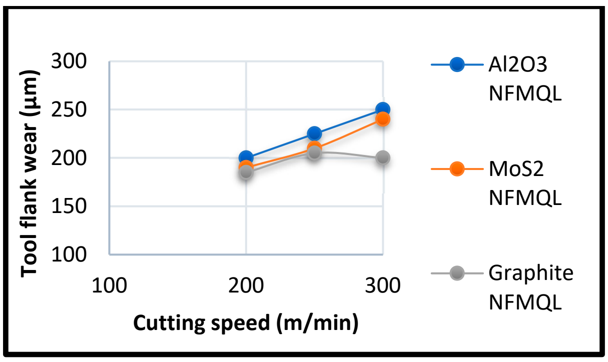


Figure 6. Tool flank wear in three nano cutting fluids [11].

4. Conclusions

The coating treatment of tools is limited to the processing of specific materials, which is an expensive activity, according to a compilation of all previously reported studies on the processing of challenging-to-cut materials. Despite cryogenics appearing to be effective, it is costly and pollutes the cutting environment. Although dry cutting is less expensive, the results are ineffective, particularly for surface polishing. The use of MQL, which creates an ecological processing environment and exhibits good outcomes, is a perfect solution. The addition of nanoparticles can improve the thermo-physical and tribological attributes of base fluids. The use of small nanoparticles can improve the surface quality and thermal conductivity of machining. Nanoparticles or NFMQL can increase surface quality and tool life by reducing wear rates, friction, and, as a result, heat in the cutting zone.

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