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Technical, Economic and Environmental Review of the Lubrication/Cooling Systems used in Machining Processes

E.Benedicto[a,b], D. Carou[c,d], E.M. Rubio[a*]

[a]*Dept. of Manufacturing Engineering, Universidad Nacional de Educación a Distancia (UNED), C/Juan del Rosal, 12, E28040 Madrid, Spain*
[b]*Departmentof Tribology and Metal Processing, Leitat Technological Center, C/ Innovació, 2, E08225 Terrassa, Spain*
[c]*Schoolof Mechanical and Materials Engineering, University College Dublin, Belfield, Dublin 4, Dublin, Ireland*
[d]*Centre for Mechanical Technology and Automation (TEMA), University of Aveiro, Campus Santiago, 3810-193, Aveiro, Portugal*

Abstract

The use of cutting fluids in machining processes is a serious concern because their cost, and environmental and health effects. In the last decades, efforts have been developed to come up with alternatives to overcome their main drawbacks. The ultimate goal is the complete suppression of cutting fluids. However, because of the demanding requirements of the machining processes, in some cases it is not possible to use dry machining conditions. Reasons can be found in the excessive heat generated in the process, the increase of the friction between the tool and the workpiece or the need to evacuate the chips generated. The pull for sustainable products is also encouraging the developing of new cutting fluid formulations. In the present paper, a comprehensive analysis of the use of cutting fluids and main alternatives in machining is carried out. Particularly, the analysis was done focusing on the economic, environmental and technical points.

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*Keywords:*cost; cryogenic machining; dry machining; environmental impact; machining; MQL system; solid lubricants

1. Introduction

The global lubricant demand was 39.4 million tons in 2015 [1] and it is expected to reach 43.9 million tons in 2022. The industrial lubricant market can be segmented into several categories taking into account their applications. Some of the most used lubricants are gear oils, hydraulic lubricants and engine oils. Cutting fluids represent about

*Corresponding author. Tel.:+34 91 398 82 26; Fax: +34 91 398 60 42.
E-mail address: erubio@ind.uned.es

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5% of the global lubricant market, with Asia as the largest consumer [2]. Approximately, 85% of the cutting fluids used are mineral based. However, the estimated values deviate significantly because of the processes diversity [3].

Cutting fluids are widely used in machining processes. The main cutting fluid roles are cooling, reducing friction, removing metal particles, and protecting the workpiece, the tool and the machine tool from corrosion [4]. However, the use of cutting fluids has also associated some disadvantages such as their cost, environmental impact and health hazards to workers (Fig.1) [5]. In machining processes, sustainable manufacturing can be addressed for example, by reducing the consume of electric energy [6], improving the tool life and the surface quality of the workpiece [7].

In the last decades, new alternatives have been developed to overcome the main drawbacks of cutting fluids. The main alternatives include dry machining, minimum quantity lubrication (MQL), solid lubrication, cryogenic cooling, gaseous cooling, sustainable cutting fluids and nanofluids. Some of these alternatives, such as dry machining and minimum quantity lubrication, have been widely evaluated from the technical point of view. However, the study of other alternatives such as gaseous cooling has received less attention. Besides, further efforts in the analysis of these alternatives in both economic and environmental aspects are clearly needed.

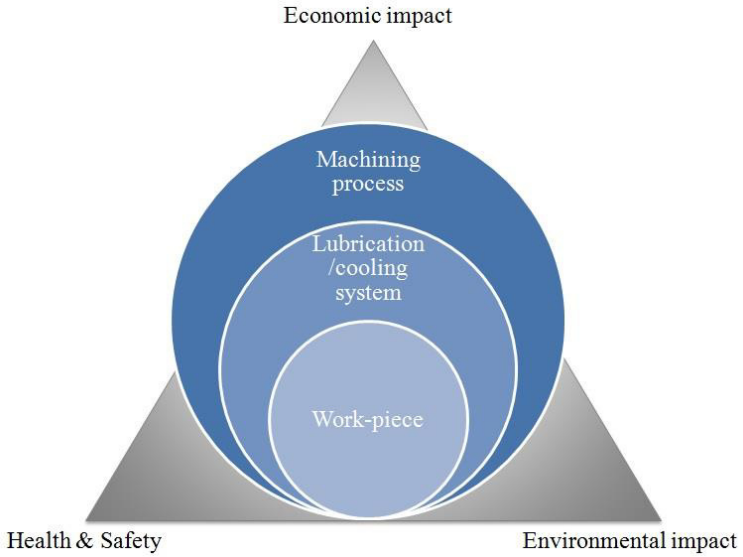

Fig.1. Economic, environmental, and health & safety impacts in sustainable manufacturing.

2. Technical review

2.1. Conventional lubrication/cooling systems

Cutting fluids are mixtures formulated with oil (base) and additives to enhance various properties depending on the machining process. They have been commonly used to enhance productivity and quality in the machining processes. They play an important role in the machining along with machining parameters such as cutting speed, depth of cut and feed rate [8]. The main function of the cutting fluids is to cool and lubricate. So, the use of cutting fluids helps reducing power consumption and protecting from corrosion the machined surface as well as tools and machine tools parts [9]. Moreover, cutting fluids cool down and transport the chips out of the cutting area, carrying away contaminants and debris in liquid instead of being suspended in the air. The ability to evacuate the chips will strongly depend on the viscosity and surface tension [10]. They allow increasing the cutting speed, prolonging the tool life, reducing the workpiece damage, improving the surface quality and meeting with the dimensional specifications. Therefore, cutting fluids increase productivity, improve efficiency by reducing the number of defects, help to ensure the process safety and guarantee and enhance the machining quality [11].