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REVIEW ARTICLE

A comprehensive exploration of minimum quantity lubrication in machining process

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ABSTRACT - Minimal Quantity Lubrication (MQL) has received a lot of interest in the machining processes because of its potential and environmental benefits. Transitioning from traditional flood cooling technologies to MQL has various advantages, including lower heat generation and better chip evacuation. The MQL approach has shown to be effective since it conforms with "green machining" criteria. The current study reviews significant research publications on the usage of cutting fluids and fluids based on nanofluids, as well as mineral and vegetable oils for various machining operations, including drilling, turning, milling and grinding. The suitability of the MQL technique has been demonstrated as it aligns with the requirements of environmentally friendly machining. The paper elucidates the mechanism behind the MQL technique and systematically explores its impact on the performance parameters of diverse machining processes. The study gives a detailed investigation of MQL in terms of its impact on cutting performance, tool life, and surface finish. Numerous experimental studies indicate that employing MQL results in surface quality superior to dry machining and comparable to that achieved with wet machining. Furthermore, the application of MQL reduces cutting forces, cutting zone temperature, tool wear, and friction coefficient when compared to both dry and wet machining. Consequently, the MQL technique has demonstrated its viability as a feasible alternative to flood lubrication under similar performance parameters.

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1. INTRODUCTION

Metal cutting operations are associated with huge amount of energy consumption. Significant portion of energy is converted into heat at tool-chip interface and tool-workpiece interface leading to tool wear, which ultimately reduces tool life and causes changes in material properties [1]. Lubricants play a critical role in taking away heat from heat zone areas. In past, many traditional machining processes used different types of lubricants and cutting fluids in order to reduce friction, dissipate heat and enhance machining processes [2]. These lubricants often contained chemicals and compounds and they were applied in many forms including oils, emulsions and pastes [3]. Although theses lubricants served the purpose of aiding the machining, they also had some negative consequences for workers and the environment. Moreover, the conventional lubrication technique was associated with large dose of fluids which in turn causes high costs to the process [4]. Using cutting fluids improperly has adverse impact on both human health and the environment. Due to concerns about the economy and the environment, industrial companies are searching for a method that minimises the use of lubricants during the metal cutting process. Protecting environmental instability through socioeconomic precondition is the primary goal of the ISO 14000 standards [5, 6]. In order to enhance cooling techniques and reduce environment associated problems, traditional flood cooling was replaced by MQL technique. MQL is an environmental friendly lubrication method that involves directly applying lubricant to the cutting zone in a minimal amount, typically 500 mLh-1 or less, which is around 10000 times less than that of standard cutting fluids [7]. The objective of this study is to examine how the utilization of various nano-fluids and traditional cutting fluids in diverse machining processes impacts the outcome.

MQL, also known as "Micro Lubrication" or "Small Quantity Lubrication," is the best way to apply cutting fluid to the tool-workpiece interface [8-11]. Several researchers have proposed MQL theory for dealing with biological safety problems. One aspect of biological safety concerns in machining is the potential health risks associated with exposure to cutting fluids, which often contain hazardous chemicals. These fluids can generate mists or aerosols during machining operations, which can be inhaled by workers, leading to respiratory issues or skin irritations. Additionally, the disposal of large volumes of used cutting fluids can pose environmental hazards if not managed properly [12]. Wet cooling is less effective than MQL technique due to improved evaporative and convective heat transfer. In a study it was found that at high-velocity, the fluid droplets pierced the vapour blanket, reached the tool-workpiece interface and increases heat transmission as compared to moist lubrication. Actually, the oil droplets reduce the amount of friction between the tool

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