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Near Dry Machining - A way to Sustainable Manufacturing Process

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Abstract

Many scientists are working in the field of machining fluids to reduce its usage while machining for economic and environmental benefits. Near Dry Machining (NDM) is a new machining technique in which an oil mist in a compressed air stream, rather than a flood coolant is applied to the machining interface. There are three types of NDM systems exist today internal, external and single channels. Mist is supplied to the machining area according to machining operation. However, there is no proper approach to this technique. Some studies have stated that NDM results in zero airborne mist levels since the oil mist vaporizes. In this review, an effort is made to study the NDM advantage over the conventional dry and flooded machining application.

Keywords: NDM; Oil mist; Compressed air stream

Introduction

However financially viable, ecological and technological reasons currently it is a need to reduce the use of machining fluids in various metal cutting processes [1-3]. The first preference is for dry machining, but in many cases, this is not possible due to the properties of the workpiece materials. Machining of hardened material generates high temperatures in the cutting zone [4]. Such high-temperature causes change in dimensional and wear in cutting tools. It also affects the surface finish of the product by inducing tensile stresses and micro-cracks in the workpiece surface and in addition to corrosion [5]. In such a case, there is a need of machining fluids for cooling and lubricating the machining process the conventional flooded or wet machining, but in this state supply of machining fluids are more, it directly affects the production economy and causes health hazards to the machine tool operator [6,7]. A study stated that the total manufacturing cost would be lower to the cost of traditional flooded cooling machining using large amounts of water-miscible metalworking fluids [8]. Dry machining operations are now of great popular and they meet with success in the field of eco-friendly manufacturing. In reality, however, they are less effective when higher machining efficiency for better surface finish and severe cutting conditions are required. To overcome the deficits of dry and flooded machining scientists and practitioners have introduced Near Dry Machining [9].

Near Dry Machining is based on the principle that supplying the very small quantity of machining fluid made of either mineral oil or vegetable oil with high-pressure air to the machining interface [10,11]. The consumptions of machining fluid in NDM are in the range of 10ml/hr-100ml/hr approximately. In conventional machining, machining fluid application fails to penetrate the chip-tool interface and thus cannot remove heat produced in the workpiece effectively [12,13]. But in case of NDM the flow of high pressure of machining fluid, when sprayed at the chip-tool interface, could reduce cutting temperature and improve tool life. Near Dry Machining, in particular, has been accepted as a successful semidry application because of its stated to be eco-friendly, so far, many good results have been obtained with this technique. By using this technique in the reaming process of gray cast iron and aluminium alloy with coated carbide tools, there was a reduction of tool wear when compared with the completely dry machining. NDM is also called as 'Micro Lubrication'; it is the latest technique of machining fluid applied to the tool-work interface. Using this technology, a small amount of fluid supplied properly and sprayed to the tool-chip interface, it could prevent the tool wear. In conventional operations using flooded coolant, machining fluids are selected mainly based on their cutting performance. This is important because the lubricant must be compatible with the environment and resistant to long term usage with low consumption [14-16].

Industries are looking for ways to reduce the amount of machining fluid in metal removing operations due to the environmental hazards, economical and most importantly occupational pressure [17,18]. Further, NDM reduces induced thermal effects and helps to increase the workpiece surface finish in situations of high tool pressure. NDM has been suggested since a few years ago for the issues of environmental effects and operators' health hazards with the airborne machining fluid particles on factory shop floors. The minimization of coolant also leads to economic benefits by way of saving lubrication costs and tools, workpiece, machine cleaning cycle time [9]. NDM combines to provide cooling and lubricating to the tool and workpiece surfaces with low consumption of machining fluid [19]. High-speed machining (HSM) not only exhibits a higher metal removal rate but also results in lower cutting force for the better surface finish [20].

There are serious environmental pollution and waste disposal problems when flooded coolants are used [21]. The goal of the new international global standard is to support environmental protection and prevention of pollution in the environment to balance with socio-economic needs [22]. A study reveals that skin and respiration problems were the main side effects. According to the National Institute of Occupational, Safety, and Health, it is estimated that 1.2 million workers are potentially exposed to the hazardous and chronic toxicology effects of machining fluid [23-25].

A recent survey conducted on the production of the European automotive industry revealed that the expense of machining fluid comprises nearly 20% of the total manufacturing cost [17]. In comparison to cutting tools, the machining fluid cost is significantly higher. As a result, there needs to reduce machining fluids consumption [26]. Furthermore, the permissible exposure level for machining fluid aerosol concentration is 5mg/m3, according to the Occupational Safety and Health Administration, and is 0.5mg/m3 according to the National Institute for Occupational Safety and Health (NIOSH) [27].

Industries are looking to reduce the amount of machining fluid in metal removing operations due to the environmental, economic and most importantly occupational pressure [9]. A study revealed that skin and respiration problems were health hazards [28,29]. The machining fluid applied in the machining process is considered to act as a coolant and lubricating agent, hence the cutting temperature can be reduced workpiece surface finish and the tool life can be improved [30]. The intermittent cutting such as milling operation, especially in high-speed cutting, the large undulation of cutting temperature could cause micro-cracks on the cutting edge which leads to failure of a cutting tool due to edge fracture [31].

Machining fluid

Machining fluid is a lubricant and coolant which is used for metalworking and machining processes to reduce the excess heat generated during machining and provide proper lubrication to the tool-workpiece interface [1,32]. The use of machining fluids in machining operation was first reported in 1894 by Taylor, who observed that machining fluid could be increased up to 33% without reducing tool life by applying large amounts of water in the chip tool interface. There are various types of machining fluids such as straight oils, soluble oils, synthetic and semi-synthetic. Straight oils are non-emulsifiable are used in machining operations in a concentrated form. It composes of base mineral or vegetable oil and often contains lubricant agent such as fats and esters as well as additives such as chlorine sulphur and phosphorus. Straight oils provide better lubrication and the poorest cooling characteristics among machining fluids. Soluble oil fluids form a compound, when mixed with water. The concentrate consists of basic mineral oil and emulsifiers to help produce a stable compound. They are generally used in a concentration of about 3% to 10% and provide better lubrication and heat transfer rate. Synthetic fluids contain no petroleum or mineral oil base and instead are formulated from alkaline inorganic and organic compounds along with additives for corrosion restriction. Synthetic fluids often provide better cooling performance among all machining fluids. It is widely used in industry and is less expensive among all machining fluids. Semi-synthetic fluids are essentially a combination of synthetic and soluble oil fluids and have characteristics common to both types. The cost and heat transfer performance of semi-synthetic fluids is between those of synthetic and soluble oil fluids. Most machining processes can benefit from the use of machining fluid, depending on the workpiece material. Common exceptions to this are machining brass and cast iron, which can be machined dry. The main advantage of machining fluid is increasing tool life, act as coolant and lubrication, better surface finish, it removes the chippings, dust and its consumption less energy, etc [33,34].

Area of NDM application

Several studies on the application of NDM in the machining of workpiece had been conducted. It was demonstrated that NDM could be utilized in the drilling and turning processes, whereas its application in the drilling process, especially in high-speed machining of hardened steel, has rarely been studied [12,16].

NDM is also applied to machining operations like turning, milling, high-speed milling, boring, deep drilling, tapping, grinding, drill finishing with single and multiple edge cutting tools. NDM is given internally and externally, depending on the manufacturing process [8,35].

Conclusion

In high-speed machining, conventional machining fluid application fails to penetrate the chip-tool interface and hence it cannot remove heat effectively. Minimum quality lubrication (NDM) machining, in particular, has been accepted as a successful semidry application because of its environmentally friendly activities and good heat removal from the tool and workpiece surfaces. Using this technology, a small amount of fluid supplied properly and sprayed in tool wear. Machining of hardened material generates high temperatures in the cutting zone. Such high-temperature causes change in dimensional and wear in cutting tools [36]. It also affects the surface finish of the product by including tensile stresses and micro-cracks in the workpiece surface and in addition to corrosion. NDM combines to provide cooling and lubricating to the tool and workpiece surfaces with low consumption of machining fluid. High-speed machining (HSM) not only exhibits a higher metal removal rate but also results in lower cutting force for better surface finish. To avoid micro-cracks on the cutting edge and failure of cutting tool more research on Micro Lubricant is needed.

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