Environmental friendly hard machining performance of uncoated and MoS$_2$ coated mechanical micro-textured tungsten carbide cutting tools

Kishor Kumar Gajrani$^a$, Sompalli Suresh$^b$, Mamilla Ravi Sankara$^{a,\ast}$

$^a$ Department of Mechanical Engineering, Indian Institute of Technology Guwahati, Guwahati, 781039, India  
$^b$ Department of Mechanical Engineering, Rajiv Gandhi University of Knowledge and Technology, RK Valley, 516330, India

ARTICLE INFO

Keywords:  
Mechanical micro-textures (M$_T$Ts)  
Hard turning  
Dry machining  
Cutting tools

ABSTRACT

Nowadays dry machining is favored due to various detrimental environmental effects and health hazards to operator by use of cutting fluids. Surface texturing on the cutting tool is one of the viable solutions to enhance tribological properties in dry hard machining. In present paper, performances of six different mechanical micro-textured (M$_T$T) cutting tools are compared. At first, three different types of M$_T$Ts are fabricated on the cutting tool rake face using Vickers hardness and micro-scratch testers. Furthermore, a set of M$_T$T tools are coated with molybdenum disulphide (MoS$_2$). Dry machining experiments are carried out and found that MoS$_2$ coated perpendicular M$_T$T tool performs better among all. Thus, M$_T$T tools can be a viable alternative to the cutting fluids in machining.

1. Introduction

Severe friction occurs at the tool-chip interface during dry machining resulting in high heat generation [1]. Thus, tool-chip interface temperature rises resulting in crater wear i.e., shorter tool life [2]. Cutting fluids are used to reduce friction and heat in machining as well as to flush wear debris. They have the ability to enhance tribological conditions between two sliding surfaces. However, cutting fluids are detrimental to the environment and are hazardous to operator's health [3,4]. Therefore, the recent trend is associated to remove or minimise the use of cutting fluids to improve the environmentally friendliness and sustainability during machining [5]. Dry machining is a best possible alternate to reduce environmental pollution, health hazard, treatment and cleaning cost, etc. [6].

In dry machining, due to severe friction and adhesion between tool-workpiece interfaces high heat generates resulting in high cutting temperature. Thus, tools life reduces. Therefore, advanced cutting tools, which are able to reduce friction between sliding surfaces are needed. Tool coatings, addition of solid lubricants with tool materials, advanced tool materials are few alternatives to enhance dry machining performance [7]. TiN/TiAlN coatings on the tool surface have the ability to enhance their tribological properties during dry machining of nickel-based super alloy [8]. Addition of calcium fluoride (CaF$_2$) solid lubricant in tungsten carbide/ceramic material or filling of solid lubricant in micro-textures is another promising way to reduce friction [9–11]. Abrasive and adhesive wear between sliding surface also reduces as compared to tungsten carbide material without solid lubricant [9]. Schultheiss et al. proposed increasing the cutting tool utilization for sustainable machining [12]. Minimum quantity cutting fluid (MQCF) is also widely used for cooling and lubrication [13–15].

As per conventional tribological perspective, smoother friction pairs show milder wear. However, several researchers work shows that micro-textured surfaces might perform better in reducing friction and enhancing dry machining capabilities under certain conditions [16–18]. Different processes are used for surface texturing such as electrical discharge machining to laser [19–21]. Cutting tool inserts with micro-textured rake face were fabricated using a laser to enhance tribological properties during drilling of Ti-6Al-4V [22]. They reported reduction of friction upto 16.33% and 14.29% while using micro-grooved and micro-dimpled surface as compare to conventional surface. Jayal et al. employed uncoated cemented tungsten carbide tools with rake face ground to different tolerance levels during production [23]. Results show that several surface texture parameters for the tools rake face have significant effects on the tool-chip interface temperature and cutting force during machining of AISI 1020 steel. Four micro-holes were fabricated on the cutting tool rake and flank face using micro-electrical discharge. Molybdenum disulphide (MoS$_2$) powders were burnedished in the micro-holes. Results show that a thin self-lubricated solid lubricant film formed in between tool-chip interface. During turning of H-13 steel, tool-chip interface friction and cutting forces were reduced as compared to the un-textured cutting tool [24]. Although surface texturing has several merits, however, it is also reported...