Tribological Performance of MoS$_2$-Filled Microtextured Cutting Tools During Dry Sliding Test

Kishor Kumar Gajrani
Department of Mechanical Engineering, Indian Institute of Technology Guwahati, Guwahati 781 039, India

Mamilla Ravi Sankar
Department of Mechanical Engineering, Indian Institute of Technology Guwahati, Guwahati 781 039, India
e-mail: evrnss@iitg.ernet.in

Uday Shanker Dixit
Department of Mechanical Engineering, Indian Institute of Technology Guwahati, Guwahati 781 039, India

1 Introduction

During machining, cutting fluids are mainly used to remove the heat generated, improve tribological properties, and flush the chip and debris. Cutting fluids reduce machining forces, coefficient of friction (COF) at the tool–chip interface, and tool wear, thus increasing the tool life [1]. However, they have various detrimental effects due to harmful chemical constituents, causing harm to health of the operator and environment [2,3]. Researchers are trying to develop alternate methodologies to reduce or eliminate cutting fluids during machining [4]. Dry machining attempts to eliminate cutting fluids completely [5]. It reduces the costs of machining, post component cleaning, and chip disposal apart from avoiding pollution and health hazard [6,7]. However, dry machining causes severe crater and flank wear of cutting tool due to high temperature in the machining region.

To reduce crater wear in dry machining, techniques have been developed for reducing the rake face temperature [8–13]. One of the techniques is surface texturing, which includes fabricating an array of indents, dimples, linear grooves, or any engineered pattern on the surface [14]. Surface texturing is an established method for enhancing the tribological properties [15]. Surface textures consisting of micro-indents have the ability to store lubricant [16,17], reduce sliding contact area [18], entrap wear debris [19], and increase the load carrying capacity of lubricated sliding surface [20]. Surface textures also have the ability to enhance the efficiency of hydraulic lubrication [21].

Researchers used a wide range of processes to fabricate surface textures, such as laser-based texturing [14,15,22,23], focused ion beam [24], electrical discharge machining [25], photolithography, and photochemical texturing [26]. Most of these processes are thermal energy- and chemical-based texturing methods. These processes produce recast layer, heat-affected zone, residual stresses, chemically affected layers, and cracks. Texturing can also be fabricated by inexpensive mechanical methods, avoiding the above-mentioned defects.

In self-lubricating composites, solid lubricants are applied either as fillers or as surface coatings [27]. Filling of solid lubricants is easy and they do not alter characteristics of the parent material. Molybdenum disulphide (MoS$_2$) has various advantages such as low volatility, non-toxic, nonradioactive, chemical inertness, strong adhering ability, good load bearing capacity, and resistance against wear [28].

It is important to correlate machining with tribology of sliding interface for the better understanding of friction and wear at tool–chip interfaces. In this study, a mechanical texturing process was used to create micro-indents on the surface of the plasma nitrided high-speed steel (HSS) workpiece by indenting using Vickers hardness tester. Micro-indents were filled with MoS$_2$ in a grease base. Objective of this study is to study the effect of texture area density (2%–14%) on the COF, pin surface temperature, wear, weight loss of the pin, and wear rate. Friction and wear tests were carried out using pin-on-disk tribometer on both types of pins (with and without MoS$_2$-filled pins). For comparison purpose, experiments were also carried out on untextured (UT) pin. Temperature, cutting force, feed force, and centerline average (CLA) surface roughness ($R_a$) of the machined surface were also assessed during machining test with 10% area density of unfilled textured (UFT) and MoS$_2$-filled textured (FT) cutting tools. For comparison purpose, machining tests are also carried out with a plain, i.e., untextured cutting tool (UT).

2 Details of Experiments

Plasma nitrided HSS was chosen as work material in the form of pins for this study due to its number of application in sliding