Coatings for Milling

Subjects: Materials Science, Coatings & Films
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This entry talks a little about the development and application of PVD and CVD coatings on machining tools.

Keywords: Coated tools, Wear, PVD, CVD.

1. Introduction

The milling process is one of the most used process in the manufacturing industry. The process as evolved with new machines and methods being employed, in order to obtain the best results in a consistent manner. Also seeing tremendous evolution are the machining tools used for milling, as the performance of the tool is deeply tied with the ovearll efficiency of the machining process, this is, the better the tool performance is, the smoother the process is. The milling tools that are used for machining are usually coated, with roughly 80% of all the tools used for this machining process (and turning as well) being coated tools or inserts. The advantage of the coatings are undeniable, with improvements being registered regarding tool performance (i.e. material removal rate), and tool-life. Enabling the machining of hard-to-machine materials, and the improvement/optimization of machining processes. In this entry some recent developments for coated milling tools are going to be presented, also, the various coating types and deposition methods are going to be mentioned.

2. Recent developments for coated milling tools

Accompanying the development of new and better machines for the milling process, there has been an evolution regarding cutting milling tools, from solid tools with varied geometries and multiple cutting edges, to the more recent coated insert milling tools with lubrication channels that enable the conduction of lubricant to the cutting area in a more efficient manner. For example, a study carried out by Lakner et al. [1], focused on a traditional manufactured milling tool with straight internal coolant channels, which was compared to an additively manufactured milling tool, with a concentrated cutting fluid supply. The authors reported that the additively manufactured milling tool had shown less tool wear and reached a 67% longer feed travel path, when compared to the traditional milling tool. This milling tool achieved overall longer tool life than the traditional milling tool; additionally, there were no great influences on chip morphology and size. As stated before, coated cemented carbide tools make up for roughly 80% of machining cutting tools. These coated tools, have improved the machining processes greatly, by permitting the machining of certain materials at higher speeds, when compared to regular uncoated tool inserts [2][3]. The coatings are deposited on the surface of the tool in order to confer to the tool a higher wear resistance and have less friction during the machining process. In summary, these coatings improve: tool-life, and overall surface finish quality and they reduce: cutting forces, cutting temperature and tool wear, making them a very appealing choice for the machining industry. There have been recent developments in cemented carbide tools, where these tools are fabricated by having a gradient, where, for example, the outer layers are harder than the substrate [4]. The fabrication of these gradient composite tools will provide tools with more versatility, as the desired properties can be applied on the base tool and improved on the surface, thus increasing their performance. Studies have been conducted, directed to the analysis of the influence of the thickness of these gradient layers, and how this affects the properties of these tools [5]. A study carried out by Xiangkui et al. [6] tested different gradient cemented carbides, with layers of differing thicknesses, and they tested these with different coatings in the high-speed cutting of a titanium alloy. The authors found that the thickness of the gradient layers influenced cutting performance, and these could be controlled by altering the cobalt and cubic carbonitride content of the cemented carbide.

3. Coating types and deposition method

The coatings can be obtained using two different processes, either by Chemical Vapor Deposition (CVD), or by Physical Vapor Deposition (PVD). CVD films are achieved by having a precursor pumped inside a reactor, and the flux is regulated by control valves. The precursor molecules pass by the substrate and are deposited on its surface, achieving a thin hard coating. This process runs at a temperature range from 300 to 900 °C. Additionally, the film thickness is usually uniform throughout the substrate surface [7][8]. PVD consists of different methods, such as, evaporation, sputtering and molecular beam epitaxy (MBE), where DC (direct current) magnetron sputtering is being the most used technique. The PVD process, when compared to CVD, runs at a lower temperature (under 500 °C), and is more environmentally safe due to the type of materials that CVD uses. Additionally, the PVD process is more energy efficient when compared to CVD [9][10][11][12]. When selecting the type of coating desired for a tool, the machining process that is being implemented must be taken into consideration. For example, CVD coatings are usually thicker and better for roughing operations; however, they can only be applied to cemented carbide cutting tools due to the good behavior of these materials under elevated temperatures. Whereas, due to the overall low temperature of the PVD process, it means that this method can be used to coat steel tools, with some studies made on the preparation and evaluation of these coatings [13]. The study performed by Silva et al. [14] evaluates the wear resistance of TiAlSiN coatings deposited by PVD on a steel substrate; the coating was evaluated, including the adhesion of the coating. The authors reported that a good adhesion of the coating to the tool steel was achieved. PVD, being a line of sight process, cannot be applied to substrates with very complex geometries. Moreover, the coating thickness is harder to control throughout the substrate surface. Thus, PVD coatings are usually used for finishing operations due to their overall thickness, these being thinner than their CVD counterpart. PVD is often used for applications requiring a better surface finish on the workpiece due to the sharp edges that this method confers on the tool [15].

Coatings provide the tool with the properties that best fit the machining appication, such as wear resistance, thermal dissipation, or low friction coefficient. These coatings have a variety of different desings, meaning that they can have multiple layers, providing the tool with enhanced properties, for example, the outer layer has a high wear resistance and the layer underneath has the main function of thermal dissipatio. This versatility makes coated tools very appealing. The various desings are:

- single-layer coating;
- double-layer coating;
- gradient coating;
- multilayer coating;
- nanolayered coating;
- nanocomposite coating.

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