Experimental Evaluation of Flank Wear in Dry Turning from Accelerometer Data

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This paper presents an experimental evaluation of cutting tool wear based on vibration signals to study the wear development of the cutting tool insert in order to increase machining performance. To achieve this purpose, tool life tests according to ISO standard 3685 have been performed in turning operation under dry cutting conditions. The wear development was studied for thirty cutting tool inserts selected from the same production batch, and used in strictly identical experimental conditions for a statistical study. The vibration signatures acquired during cutting processes have been analysed and contrasted using three signal processing techniques: statistical, temporal and spectral analysis. Results have shown that the dynamic characteristics of tool vibration changed with cutting tool wear development. Furthermore, this vibration analysis exhibited a strong correlation, during machining, between the evolution of flank wear land and vibration responses.

1. INTRODUCTION

In the machining process, the quality of the workpiece, like dimensional accuracy and surface roughness, depends mainly on the state of the cutting tool. Monitoring of the cutting tool condition therefore plays a significant role in achieving consistent quality and controlling the overall cost of manufacturing. High performance machining consequently requires a good evaluation of the cutting tool wear.[1] A wide variety of sensors, modelling, and data analysis techniques have been developed for this purpose.[2–4] In general, the cutting tool wears on the two contact zones, and the wear phenomenon appears in several forms, such as flank wear, crater wear, chipping, etc.[5] These forms depend essentially on cutting tool characteristics, workpiece material, cutting conditions, and types of machining.[6] Crater wear occurs on the rake face of the tool (see Fig. 1) where the chip moves with a frictional force under heavy loads and high temperatures, leading to wear. Crater wear is usually avoided or minimized by selecting cutting conditions and a cutting tool that does not have an affinity for diffusion with the workpiece material. Flank wear is caused by friction between the flank face of the cutting tool (see Fig. 1) and the machined workpiece surface. At the tools flank-workpiece interface, tool particles adhere to the workpiece surface and are periodically sheared off. This leads to the loss of cutting edge and affects the dimensional accuracy and surface finish quality. An established industrial standard on tool wear is ISO 3685 (1993).[7] Figure 1 shows the typical tool wear profile according to this standard. In this figure, the wear of the major cutting edges of the tool can be divided into four regions:

- Region C is the curved part of the cutting edge at the tool corner, which marks the outer end of the wear land;
- Region B is the remaining straight part of the cutting edge between Region C (consisting of uniform wear land);
- Region A is the quarter of the worn cutting edge length farthest away from tool corner;
- Region N extends beyond the area of mutual contact between the tool workpiece for approximately 1 to 2 mm along the major cutting edge. The wear in this region is of the notch type and contributes significantly to surface roughness.

Under normal machining conditions, flank wear is regarded as the most preponderant. According to ISO 3685 (1993), measurement of the width of flank wear land (VB) is the most commonly used parameter to evaluate cutting tool lifespan.[5,6] If the profile is uniform, the tool can be used unless the average value of VB is greater than 0.3 mm. For uneven wear, the maximum wear land width (VBmax) should be less than 0.6 mm.

The development of this wear form on the cutting tool is not a random phenomenon. A typical evolution of flank wear land (VB) with cutting time for different cutting velocities is shown in Fig. 2.[5] The curve can be divided into three zones during its lifetime:

- Initial wear zone, where the initial flank wear land is established (primary wear zone);
- Steady wear zone, where wear progresses at a uniform rate (secondary wear zone);
- Accelerated wear zone, where wear occurs at a gradually increasing rate (tertiary wear zone).

Generally, the evaluation of cutting tool wear can be made in two ways: direct and indirect methods. The direct methods involve measuring the state of tool wear by the classical vision or optical systems such as CCD-based cameras, equipped optical microscopes, and/or white light interferometers.[8,9] These methods have an advantage of measuring exact