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Micro-geometrical characteristics of the cutting edge as the intersection of two rough surfaces

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ABSTRACT

The sharpness of the cutting edge plays an important role in the cutting process, but is not well-defined because of a variety of possible cutting process applications. The edge sharpness strongly depends on the geometrical characteristics of the edge, as well as other important factors: the tool and work (target) materials, the cutting edge dimensions (linear and angular), and the kinematics of the process. Considering the cutting edge as the intersection of two flank roughnesses, it is possible to evaluate the 3D distribution of the actual edge knowing only both flank profiles and edge angles. This may support decisions concerning the sharpening technology. The proposed metric of the edge rectilinearity is the dimensionless edge length ratio. Such an approach was applied for the assessment of the micro-geometrical properties of surgical scalpel blades. Analyses demonstrated the suitability of the edge length ratio for the evaluation of the cutting edge micro-geometry.

1. Introduction

The term "perfect cutting edge" has not, as yet, been defined from a technical point of view. The problem arises from the variety of tools and work-materials and cutting kinematics. Cutting is an important operation in many different applications: medical [1,2], meat [3–5] and plastics [6,7] processing as well as in other areas [8–11] and the metal and wood-cutting industries. In some applications, where the cut material reveals internal pressure (live biological tissues, fresh fruit, etc.) or for elastic, soft materials [12] (foodstuffs, elastomers) serrated blades demonstrate the beneficial effect of initial contact providing local incisions or cracks which facilitate the propagation of the material cut. Hard work-materials require cutting edges which provide greater contact area and thus smaller contact pressure to reduce tool wear. This can be obtained by increased cutting edge radii [13,14]; however, such a solution also increases the cutting forces [7], and the final result of rounded cutting edges, considering both cutting energy and wear, is not obvious. The simplest cutting kinematics consist in indentation (guillotining) where the relative movement is more or less perpendicular to the edge. This relates to most machine cutting methods applied in metal and wood-cutting technology. Some cutting techniques use additional movement tangential to the edge and similar to sawing. All these factors (material; kinematics; edge shape) usually depend on the edge angle as well (varying from about 15 to 90 degrees), which complicates the problem of the definition of the perfect cutting edge.

"Sharpness", describing the performance of a cutting instrument, is another important term which is difficult to define defined [11,15–17]. McCarthy et al. [16,17] reported two general approaches to the definition of edge sharpness: (i) the level of force exerted by the cutting instrument during a cutting trial; (ii) the radius of the cutting edge. The first approach requires standardized material and cutting kinematics to empirically evaluate the cutting performance of the edge. McGorry et al. [3–5,18,19] in several studies related to the food processing industry as well as other authors [6,7,11,12,20,21] followed this concept. McCarthy et al. [17] developed a quantitative dimensionless metric, the blade sharpness index (BSI), for the sharpness of a straight edged blade. This relates the energy required to initiate a cut in a substrate to the fracture toughness and thickness of the particular substrate and to the indentation depth required to penetrate the substrate. The second approach, related to edge radii as the metric of the sharpness, has limited applications since there are cutting edges having near zero radii directly after they are fabricated. This refers, particularly, to the cutting edges for soft materials and low-speed cutting where the wear is not so important—examples of such edges are presented in Section 3. In other cases, however, the intentionally made radius of the cutting edge is an important element of the geometrical characteristics of the edge [13,14,22–27] as well as a symptom of edge wear [10,28,29]. Outeiro and Astakhov [27] found that tool sharpness cannot be defined as an absolute parameter characterized only by a particular value of the cutting edge radius. They proposed characterising tool sharpness by the dimensionless relative tool

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