Proceedings of WTC2005
World Tribology Congress III
September 12-16, 2005, Washington, D.C., USA

WTC2005-63538

TRIBOLOGICAL CHARACTERIZATION OF STEELS FOR CUTLERY: A NEW METHODOLOGY TO ACCESS CUTTING EDGE SHARPNESS

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ABSTRACT

In this work, the tribological behaviour of stainless steel used in cutlery is analysed. Professional knives were tested in well-controlled field conditions and the mechanism of cutting edge loss of sharpness was determined by using Scanning Electron Microscopy. It was determined that the mechanism which causes loss of sharpness in the cutting edge is plastic deformation whereas the edge life itself is mainly affected by abrasive wear during the resharpening process and the sliding wear that occurs while the knife is being used. A new methodology based on the energy that causes plastic deformation is proposed in order to access the bending resistance of the cutting edge. The proposed technique is very simple and cost effective. It reproduces to a great extent the field mechanisms that cause the loss of sharpness in the cutting edge and allows the ranking of different stainless steels usually used by the cutlery industry. Additionally, abrasive and sliding wear tests were carried out on martensitic and ferritic stainless steels. Although the chemical composition and heat treatment considerably modified the microstructure and hardness of the steels, they had no significant effect on abrasion resistance and friction coefficient. On the other hand the sliding wear rate was greatly affected by the chemical composition of the steel.

INTRODUCTION

The materials for use in cutlery should have a high hardness cutting edge and good wear and corrosion resistance.

In general, different grades of steels are used for hand held and machine knives and blades. Among them, stainless steel, in particular 420A grade is the most used material combining corrosion resistance, high hardness and easiness of production. In general, these properties are suitable for the great majority of the cutlery applications. However, when sharp edge retention is an important issue, such as in professional applications, in particular in the meat processing/food industry, the 420A stainless steel is defective and other steel grades should be used.

For the industrial knives the material should additionally present high corrosion resistance associated with high resistance against the sliding wear that occurs while the knife is being used and against the abrasive wear that occurs during the resharpening process.

Nowadays, the sharpness and edge retention of cutlery are evaluated by a specific sharp edge tester subject to the recently approved international standard BS EN ISO 8442-5.2005. In this test, the blade cuts, in very well controlled conditions, a pack of specially developed manila cards containing 5% SiO_2 as an abrasive media. The blade oscillates back and forth progressively cutting into the card pack; the depth of the cut being the measurement of sharpness. Plotting the depth of the cut against the number of cycles, it is possible to obtain a measure of the initial sharpness and subsequent wear rate, generally quoted as initial cutting performance (ICP) and total card cut (TCC) [1].

The literature in this area is very scarce, in particular, concerning wear mechanisms acting on the real application of industrial knives. The present work aims to investigate, in a comprehensive way, the tribological behaviour of professional knives, in particular in the meat processing/food industry.

EXPERIMENTAL TECHNIQUES

Professional knives were tested in well-controlled real field conditions in three different meat-processing units: two meat-processing plants (bovine and poultry respectively) and a butchery. The knives were produced in P498A stainless steel and purchased in retail outlets.

The mechanism of cutting edge loss of sharpness was determined by using Scanning Electron Microscopy. Before tests, the blades were cut and ultrasonically cleaned. For the transversal section analysis, the cutting edge was protected by an eletrolitically deposited Nickel layer.

For the laboratorial tests according to the proposed methodology, specially designed blades were industrially produced using P498, P 420A e P420D stainless steel. These blades presented the same cutting edge transversal geometry and were used to generate, by electro discharge machining, the specimens for the impact tests.

Abrasive wear tests were carried out in a “free ball” micro abrasion tester. The determination of the permanent wear regime and wear coefficient is described in another paper [2]. Sliding wear tests were conducted in a reciprocating device and were well described in a recent paper [3].

The microstructure, chemical composition and detailed tribological results were recently published [4].

RESULTS AND DISCUSSION

Figure 1 shows typical aspects of the cutting edge after field tests.

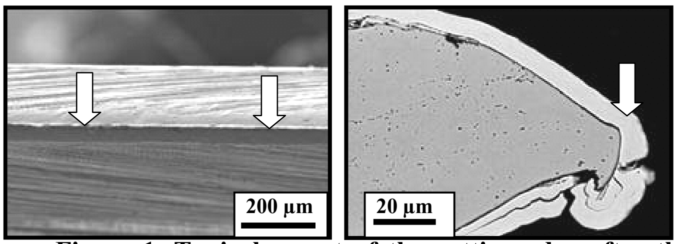

Figure 1. Typical aspect of the cutting edge after the first loss of sharpness while processing bovine meat. a- Overhead view. b- Transversal view.

It was clearly determined that the mechanism which causes loss of sharpness in the cutting edge is plastic deformation, (arrows in figure 1) whereas the edge life itself is mainly affected by abrasive wear during the resharpening process and the sliding wear that occurs while the knife is being used.

From these results, a new methodology based on the energy that causes plastic deformation is proposed in order to access the bending resistance of the cutting edge. The bending energy is determined by the variation of potential energy associated with the impact of a special pendulum against a specimen which was cut from a real knife as schematized in figure 2.

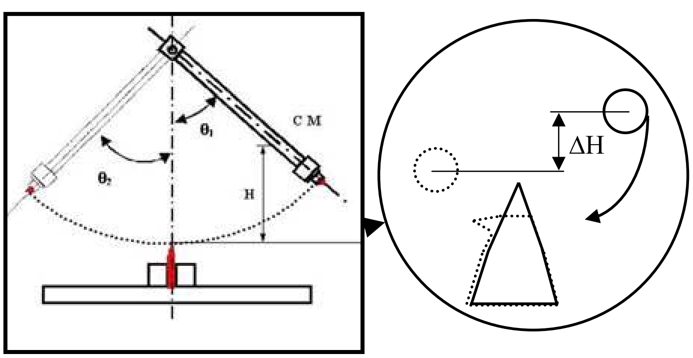

Figure 2. Principle of the proposed test.

The effect of the impact depth on the bending resistance of the cutting edge, quoted as angular difference is shown in figure3. 498A stainless steel presented the higher bending resistance while the performance of 420A and 420D steels was lower and quite similar.

The morphology of the plastic deformation produced by the proposed technique (typical aspects shown in figure 4) reproduces to a great extent the field mechanisms that cause the loss of sharpness in the cutting edge, figure1, and allows the ranking of different stainless steels usually used in the cutlery industry

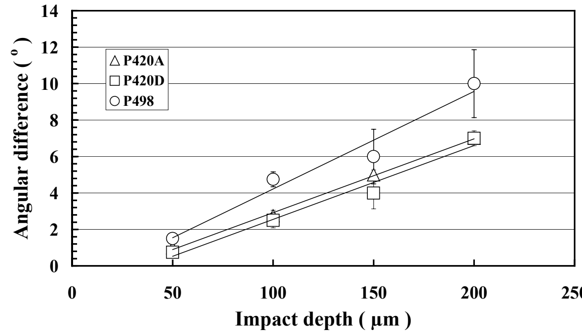

Figure 3. Influence of impact depth on the bending resistance of the cutting edge.

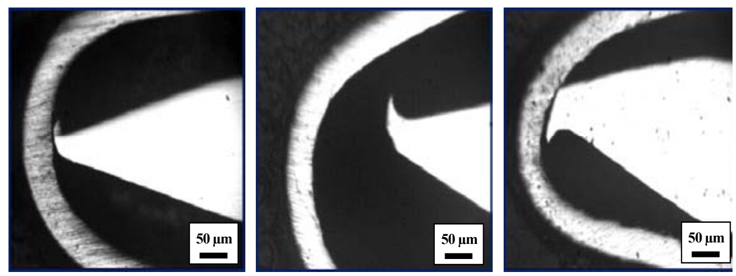

Figure 4. Typical aspect of the cutting edge after impact test. Optical microscopy, Impact depth: 200 µm. a- 498A. b- 420A. c- 420D.

The main tribological properties of the studied steels have recently been repported by De Mello and Bálsamo [4]. Chemical composition and heat treatment had no significant effect on abrasion resistance and friction coefficient. On the other hand, the sliding wear rate was greatly affected by the chemical composition of the steel.

CONCLUSIONS

The proposed technique is very simple and cost effective. It reproduces to a great extent the field mechanisms that causes the loss of sharpness in the cutting edge and allows the ranking of different stainless steels usually used in the cutlery industry

Chemical composition and heat treatment had no significant effect on abrasion resistance and friction coefficient. On the other hand, the sliding wear rate was greatly affected by the chemical composition of the steel.

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