FATIGUE BEHAVIOR OF COATED AND UNCOATED CEMENTED CARBIDE INSERTS INVESTIGATED BY IMPACT TEST AT THE CUTTING EDGE VICINITY

K.-D. Bouzakis, M. Batsiolas, G. Skordaris, N. Michailidis, F. Stergioudi

Aristoteles University of Thessaloniki, Thessaloniki, Greece.

Fraunhofer Project Center for Coatings in Manufacturing, Aachen , Germany and Aristoteles University of Thessaloniki, Laboratory for Machine Tools and Manufacturing Engineering, Thessaloniki, Greece

Introduction

The cutting edge wear due to fatigue affects directly the overall coated tool performance. In the present work, a quick assessment of the cutting edge fatigue behavior of uncoated and coated cemented carbide inserts is investigated by impact tests near the cutting edge. Substrates with various grain sizes, surface roughness and heat treatment were tested concerning the cutting edge fatigue endurance load. The FEM simulation of the test procedure at various distances from the inserts' cutting edge provided insight in the occurring stress fields. The developed test method facilitates a rapid quality control of both coated and uncoated cutting inserts at loading conditions, close to those encountered during their cutting operation.

Development of the experimental setup

In order to examine the fatigue failure of cemented carbide inserts' cutting edges, an appropriate feature was integrated into an existing impact tester [1, 2]. The developed arrangement controls accurately the positioning of the coated insert to the ball indenter spindle. This procedure is supervised by the impact tester control unit. In this way, the fixed specimen on a 2-axis linear guide system can be accurately displaced for attaining impact imprints at a certain distance from the cutting edge. The specimen movement to the impact tester spindle axis is monitored, as it is presented in figure 1. An appropriate graphical user interface, based on the platform of LabVIEW v.8.6 software, supports this procedure. In this way, the application of repetitive impacts at predetermined distances from the specimens' cutting edge was enabled.

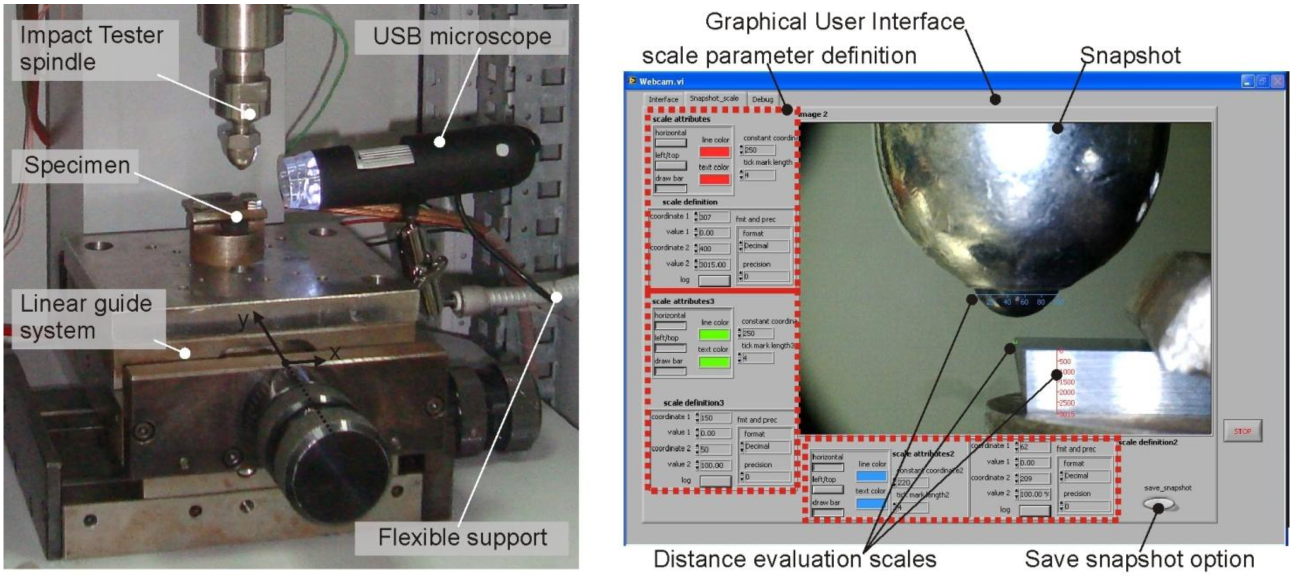

Figure 1: The developed experimental setup and graphical user interface.

The developed FEM model for describing the experimental procedure

The geometry of the specimen's edge affects significantly the stress distribution and failure initiation in the cutting wedge region. A 3-dimensional, plane-symmetric simulation model of the ball indenter penetration into the substrate was developed with appropriate boundary conditions and finite element discretization (see upper part of figure 2). This FEM model was modified accordingly, for calculating the related deformations and stress fields at various loading distances from the cutting edge. The plane symmetry that was exploited for restricting computational time and the meshing network for a penetration at a distance of 50 μm from the cutting edge are displayed. In the diagram at the lower figure part, the imprint load and the corresponding distances from the cutting edge for achieving a constant maximum stress of 5.3 GPa in the cutting edge region are exhibited. At this stress level, cutting edge breakages occur at distances lower than 100 μm after one million or less impacts. The photos illustrate the developed craters. These results indicate that loading proximity to the cutting edge leads to edge failure at lower loads for the same equivalent stress levels. Based on calculation results, this was attributed to tensile principal stress components that facilitate crack propagation under dynamic loading. The loading distance of 100 μm from the cutting edge does not lead to cutting edge fracture at a force of 27.5 daN after one million impacts for the fine-grained substrate with ground rake surface.

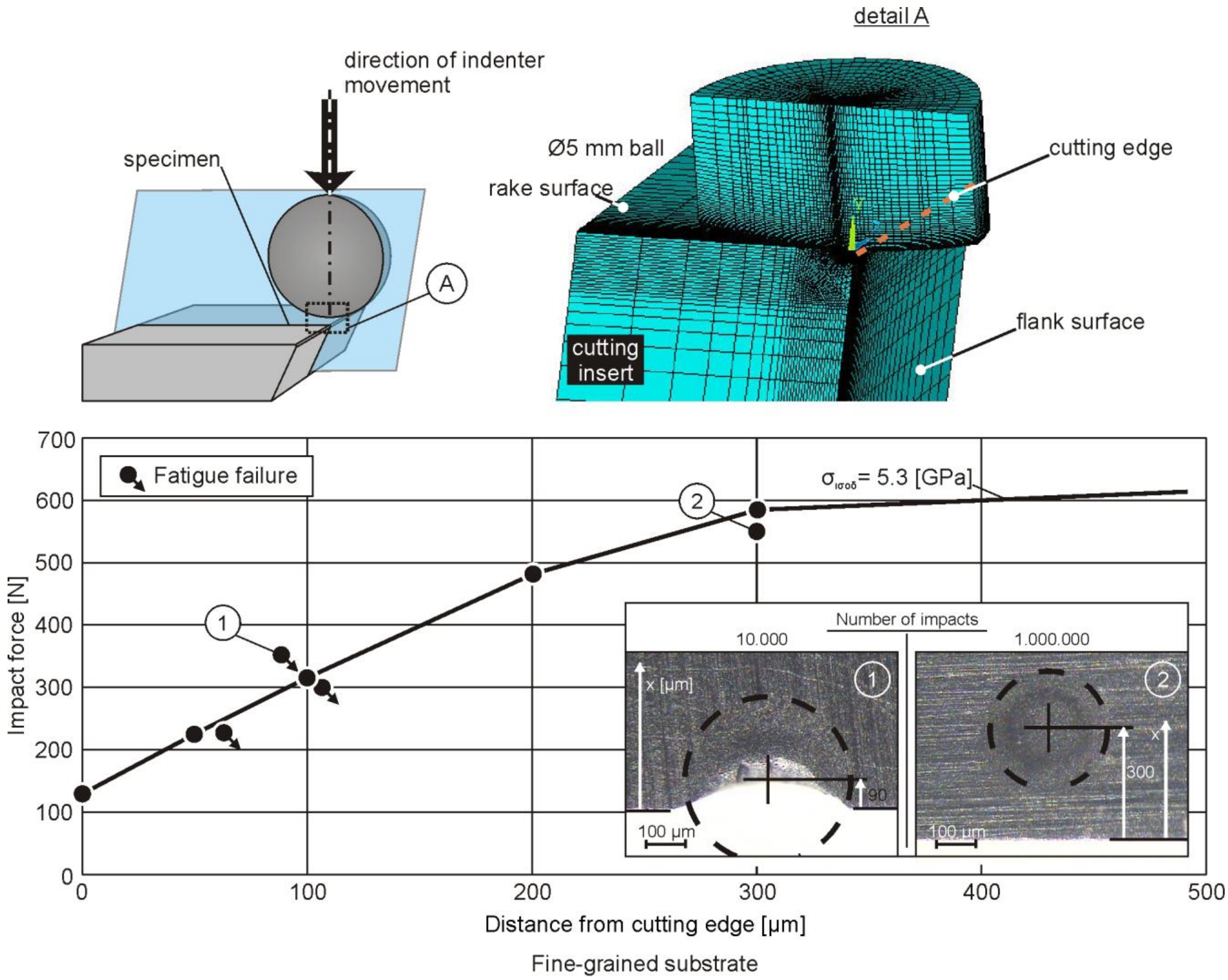

Figure 2: 3D-FEM model and selected experimental results for corresponding equivalent von Mises stress levels.

Effect of grain size, surface roughness and annealing temperature on experimental fracture load

In the described investigations, among others, fine-grained and ultrafine grained substrate grades were examined in relation to their fatigue endurance load, keeping the imprint distance from the cutting center constant and equal to 100 µm (see figure 3). The diminishing of substrate grain size increases the load for avoiding cutting edge fatigue failure after one million impacts. Moreover, the effect of heat treatment, for 4 h at various temperature levels in vacuum, on the maximum fracture load was also examined. A diminishing trend was revealed regarding the load that the substrate can withstand for one million impacts, with the annealing temperature augmentation.

By the introduced impact test procedure, the fatigue endurance of cutting edges can be effectively evaluated at various coated and uncoated specimens data.

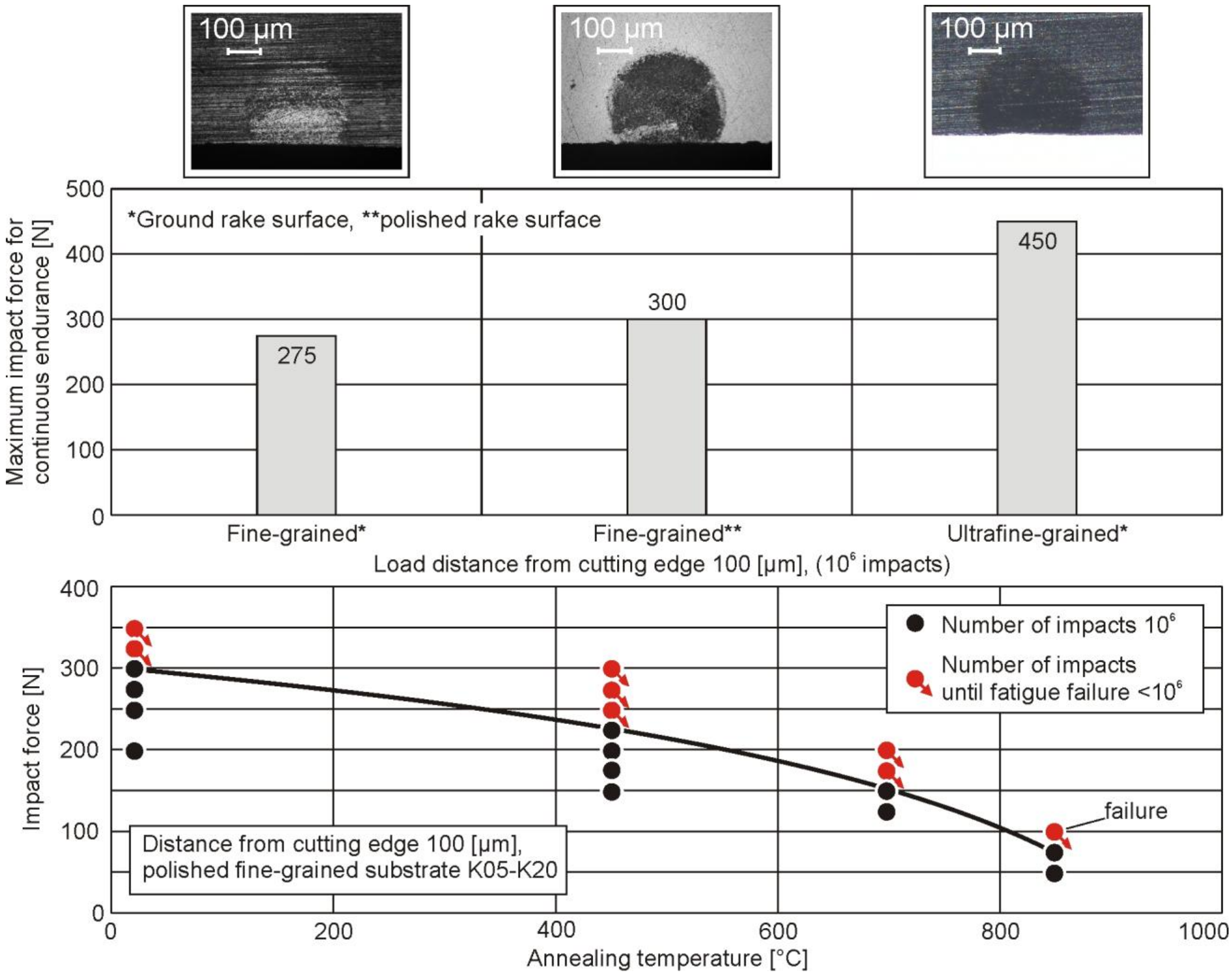

Figure 3: Comparison between experimental and FEM-calculated imprint depths versus the number of impacts

References

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[2] Batsiolas M., Development of experimental arrangements and methodologies for the characterization of fatigue and cohesion properties of thin hard coatings at various temperatures, Aristotle University of Thessaloniki, Thessaloniki, 2012, PhD Thesis.