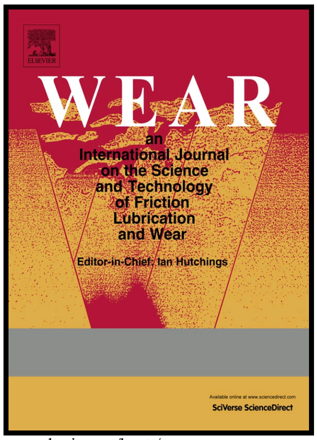
Author's Accepted Manuscript



www.elsevier.com/locate/wear

Tool wear and machining dynamics when turning high chromium white cast iron with pcBN tools

Oleksandr Gutnichenko, Volodymyr Bushlya, Jinming Zhou, Jan-Eric Ståhl

PII: S0043-1648(16)30815-8
DOI: http://dx.doi.org/10.1016/j.wear.2017.08.005
Reference: WEA102225

To appear in: *Wear*

Received date: 18 January 2017
Revised date: 16 August 2017
Accepted date: 18 August 2017

Cite this article as: Oleksandr Gutnichenko, Volodymyr Bushlya, Jinming Zhou and Jan-Eric Ståhl, Tool wear and machining dynamics when turning high chromium white cast iron with pcBN tools, *Wear,* http://dx.doi.org/10.1016/j.wear.2017.08.005

Tool wear and machining dynamics when turning high chromium white cast iron with pcBN tools

Oleksandr Gutnichenko*, Volodymyr Bushlya, Jinming Zhou, Jan-Eric Ståhl

Division of Production and Materials Engineering, Lund University, Ole Römers väg 1, SE-221 00 Lund, Sweden

*Corresponding author, Tel. +46 70 2205694, *Oleksandr.Gutnichenko@iprod.lth.se* (O. Gutnichenko)

Abstract

High chromium white cast irons (HCCI) with high hardness and abrasiveness owing to a particular combination of hard primary and eutectic carbides were used as workpiece materials for longitudinal turning with binderless cBN (bcBN) and high cBN (hcBN) tools. The materials with low and high Si content were used in as-cast and quenched states. Binderless cBN is prone to cratering and flank wear, while hcBN is more prone to significant cutting edge rounding. Atypical behavior was found when machining high-Si material where the increase in cutting forces was accompanied by suppression of vibrations. The observed formation of a tool protection layer (TPL) on the tool–chip interface was found to be responsible for the improved dynamic stability. Electron microscopy and EDX analysis revealed that the TPL consists of nanocrystalline Al_2O_3 with SiO_2 inclusions, both present in the workpiece materials. The stability of TPL was found to depend on both workpiece and tool materials. The absence or removal of the layer resulted in the development of self-excited vibrations with a frequency of 380 Hz, which affected the machined surface.

Keywords

pcBN, tool protection layer (TPL), high chromium white cast iron (HCCI), self-excited vibrations

1. Introduction

The superior wear resistance of high chromium white cast irons (HCCI) makes these materials attractive in applications in aggressive environments where high resistance to abrasion, erosion, and erosion-corrosion is required. Example applications include slurry pump casings and impellers, crushers, breaker screens, gravel and dredge pumps. According to multiple studies of the microstructure and properties of HCCI performed over the last decade [1–5], its high wear resistance is attributed to a combination of hard primary and eutectic carbides of M_7C_3 type, where M includes Fe, Cr, and other carbide-forming alloying elements in relatively ductile ferrous matrixes. The hardness of M_7C_3 is in the range of 1200–1800 HV and depends on the carbide composition. Other carbides such as $M_{23}C_6$ can also be formed, depending mainly on the chemical composition of the cast iron and the heat treatment steps.

The large amount and extreme hardness of the carbides in the material microstructure puts HCCI into a group of difficult-to-machine materials [3–6]. The cutting process is, therefore, accompanied by severe tool wear and tool deterioration, which often leads to the generation of forced and self-excited vibrations in a broad frequency range. Already high cutting forces are further increased by tool wear and cutting edge rounding. If this occurs, the amplitude of vibrations may increase drastically, resulting in chatter. The generation and stability of the chatter is driven by a complex mix of tool–workpiece interactions and chip formation processes. These are reflected in such factors as temperature-dependent plasticity, temperature- and velocity-dependent friction, and nonlinear stiffness of machine tool components [6]. Two main types of chatter can be distinguished in machining [7, 8]. The first type is associated with a regenerative effect, where dynamics of the systems on the current tool pass depend on the workpiece geometry from the previous pass. The second type is related to the physics of the cutting process [8] and depends on the conditions in plastic deformation zones and friction interactions between tool, workpiece, and chip during machining. The friction conditions themselves are governed by the relative movements between tool and workpiece, cutting temperatures, and chemical interactions in the cutting zone. The large number of influencing parameters leaves significant uncertainty on this issue in spite of numerous studies of chatter [7–9]. In addition, friction conditions and their respective vibrations may change during machining due to factors such as tool wear, changes in temperature conditions, and tribological and chemical processes in the cutting zone.

The formation of an adherent or tribologic layer has been observed on pcBN tooling in machining hardened and other difficult-to-cut materials [10–15], including white cast irons [16, 17]. The formation and stability of this layer, and therefore friction conditions in the cutting zone and related process dynamics, have been found to change with workpiece composition [18] and cutting speed [19]. These studies do not address the dynamics of tool–workpiece interaction and focus only on post-mortem tool wear analysis.

The objective of the present study is to characterize the machining process of two types of HCCI in as-cast and hardened conditions with two grades of pcBN tools in terms of tool wear specifics and related dynamics of the machining process. The dynamic response study includes measurements of cutting forces and toolholder vibrations with further numerical analysis of the experimental data in frequency and time domains. The study aims to investigate the relationship between the dynamic characteristics of machining HCCI with pcBN tools and cutting and tool wear processes.