Materials and Design 32 (2011) 706–715

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Influence of nickel content on machinability of a hot-work tool steel in prehardened condition

A. Medvedeva [a,*], J. Bergström [b], S. Gunnarsson [a], P. Krakhmalev [b], L.G. Nordh [a]

[a] Research and Development, Uddeholms AB, SE-683 85 Hagfors, Sweden
[b] Karlstad University, Department of Mechanical and Materials Engineering, SE-651 88 Karlstad, Sweden

ARTICLE INFO

Article history:
Received 6 May 2010
Accepted 30 July 2010
Available online 4 August 2010

Keywords:
A. Tool steel
E. Machinability
F. Nickel content

ABSTRACT

In the present study, the influence of nickel content on the machinability of a prehardened hot-work tool steel was investigated. The machinability with varying nickel content from 1 to 5 wt.% was characterized in end milling and drilling by evaluating tool life, cutting forces, and tool/chip interface temperature.

Nickel content showed to have a positive effect on the machinability of the hot-work tool steel; with increasing nickel content in the steel, the longer tool life was reached in end milling and drilling operations. Machining the higher nickel containing steels generated lower cutting forces and tool/workpiece interface temperature. In addition, less adhesive wear and built-up edge formation were observed on the tools.

The difference in the steel machinability was discussed in terms of their microstructure and mechanical properties. Increasing nickel content tends to decrease the carbon in the martensite and to retain a fine distribution of small primary carbides. It resulted in a reduction in yield strength with increasing nickel content related to the cutting force reduction and machinability improvement.

1. Introduction

Modern demands on cutting tool performance have increased as progress in material development has lead to the appearance of new materials with enhanced properties but usually of poor machinability. Moreover, the components trend to be machined at higher hardness, at high speed and in dry condition, raises the cutting forces and tool temperature. As a consequence, this has led to a shift in material choice for indexable insert cutting tool bodies from low-alloyed to higher-alloyed steels with enhanced high-temperature properties. Machinability of such steels is of great economic importance as well. The cutting tool body has a complex shape with flutes and insert pockets as well as small and deep holes for cooling channels, where machining is time-consuming and requires advanced machining operations [1]. Because of demands on the dimensional accuracy, the cutting tool bodies are also preferred to be machined in the prehardened condition.

Machinability has several definitions and may be assessed by one or more of the following characteristics: tool life, limiting rate of material removal, cutting forces, machined surface and chip breaking [2]. It depends on many factors such as the machining operation, cutting conditions and cutting tool. The machinability of prehardened steel is influenced by non-metallic inclusions, mechanical properties, chemical composition and microstructure.

Among the different ways of improving machinability, increasing sulphur content in steel is, by far, the most common due to the good deformability of sulphides inclusions under machining [3–5]. Calcium treatment is also a well known metallurgical method to improve machinability by producing easier deformable compound inclusions in steels [2,3,6]. Unfortunately, the deleterious effect of inclusions on material toughness and fatigue strength is well known.

Steels with higher strength, higher ductility, higher work hardening rate and lower thermal conductivity are generally difficult to machine. Materials with high strength and ductility require more deformation energy to create a chip, which increases heat and cutting forces. The ductile steel tends to stick to the tool and form a built-up edge, which, in turn, promotes chipping of the cutting edge [2,3,7,8]. However, some researchers did not find a direct relationship between the toughness and machinability of the steels [9,10]. Thermal conductivity has a strong effect on the cutting temperature by increasing the ability of the steel to dissipate the generated heat, and thus reducing the cutting edge temperature [7,8].

In general, alloying elements in steels (carbon, manganese, chromium, etc.), which increase the steel's strength, during cutting of the steel raise the stresses acting on the tool and the temperature generated and, in this way, reduce the tool life [2]. Carbide-rich steels, highly alloyed with Cr, V, Mo, etc. are usually difficult

* Corresponding author. Tel.: +46 563 17574; fax: +46 563 17460.
E-mail address: anna.medvedeva@uddeholm.se (A. Medvedeva).

0261-3069/$ - see front matter
doi:10.1016/j.matdes.2010.07.037