Available online at www.sciencedirect.com
ScienceDirect
Procedia CIRP 46 (2016) 360 – 363
www.elsevier.com/locate/procedia

7th HPC 2016 – CIRP Conference on High Performance Cutting

Development of a cutting tool for high-performance cutting of railway rolling components

A.A. Vereschaka[a,*], A.Yu. Popov[b], A.S. Vereschaka[a], A. D. Batako[c], N.N. Sitnikov[d] and A.S. Tverdokhlebov[e]

[a] *Moscow State Technological University (STANKIN), Russia;*
[b] *Moscow State University of Railway Engineering (MIIT), Russia;*
[c] *Liverpool John Moores University (LJMU), UK;*
[d] *National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Russia;*
[e] *Moscow State Engineering University (MAMI), Russia.*

* Corresponding author. Tel.: +7 499 972-95-21; fax: + 7 499 972-95-21. *E-mail address:* ecotech@rambler.ru

Abstract

High performance cutting (HPC) is used in machining railway parts like wheel sets or axes with large depth of cut and high feeds~~).~~ The process is accompanied by increased thermal loads causing high concentration of stresses in the contact areas with the tool. This paper presents a set of methods to reduce thermal stress in machining zone in HPC conditions through the use of a special tool system, consisting of carbide cutting inserts with nano-structured multilayer composite coatings and a special scheme for mounting such inserts on tool holder with the use of high heat-conducting ceramic-polymer pads. The study has revealed that the developed tool system can significantly accelerate heat transfer from the insert and increase efficiency. Production tests show that the tool and the new coating in machining rolling stock (of railway) components can improve performance by 80-100%.

Peer-review under responsibility of the International Scientific Committee of 7th HPC 2016 in the person of the Conference Chair Prof. Matthias Putz

Keywords: wheel sets; PVD-coating; physical vapour deposition (pvd); hard machining; thermal effects;

1. Introduction

The process of manufacturing critical parts of railway rolling stock (turning of wheel sets, boring of wheel bands, turning of axes, etc.) is accompanied by:

- high removal of withdrawn allowance at cutting depth a_p = 5-20 mm, feed f = 0.8-1.5 mm/rev and cutting speed V = 30-50 m/min;
- high variation of cutting allowance (radial runout may reach up to 15 mm);
- inclusion of non-metallic particles with increased abrasive properties on the machined surface of forged slab [1- 3].

Edge machining of workpieces under the above conditions produces elevated heating of the cutting area (up to 800-1000°C), which results in high concentration of thermal stresses directly at the contact areas of carbide inserts (for example, inserts of LNMX ISO shape) used in this process of manufacturing products for rail transport [1-5]. The studies of wear mechanisms of cutting carbide inserts with coatings of various compositions have shown [8-15] that the process of wear of inserts under conditions of the high thermal stresses is accompanied by thermoplastic deformation of a cutting edge. This in turn is connected with the subsequent intense failure of coating and high adhesion and fatigue wear, which is accompanied by chipping of cutting edges or complete failure of fragile cutting part of a tool [8-10, 13-15].

In this regard, the decrease of thermal stress of the cutting area by the deposition of nanoscale multilayer composite coatings (NMCCs) on the working surfaces of the tool, which reduce friction and capacity of heat sources, as well as the general improvement of the conditions of heat transfer out of the cutting area improves the tool life and the efficiency of the HPC processes. The studies of the effect of

Peer-review under responsibility of the International Scientific Committee of 7th HPC 2016 in the person of the Conference Chair Prof. Matthias Putz
doi:10.1016/j.procir.2016.04.009

wear-resistant coatings on the thermal state of the cutting system under severe cutting conditions [10-12] have shown that they reduce thermal and mechanical loads on the tool and increase its efficiency.

The standard method for reducing thermal stress of the cutting process includes the use of cutting fluids. However, under heavy conditions of machining, the efficiency of cutting fluids decreases significantly. Besides, specialized machine equipment (including wheel turning machines and vertical turning machines), intended for manufacturing of products (wheel sets, wheel bands, axles, etc.) used in rail transport, does not use the systems of supply of liquid fluids because of high probability of their intense damage. Thus, the main objective of this study was to develop a tool system improving the efficiency of the technology of heavy machining of workpieces of rail rolling stock products by reducing the thermal stress of the cutting process and cutting tools.

2. Methodology

2.1 Cutting tool.

The study mainly focused on testing carbide inserts, which were mounted in tool holders of the cutting tool assemblies. The selection of the shapes of two-way inserts was justified by the extensive use of such inserts in machining rail rolling stock products. Because of large rake angles (γ = 12-15°) and wide chip-breaking grooves, at rake face of carbide inserts (width 2.5-3.5 mm), large air cavities are formed in the contact area of bearing surfaces of the inserts and the tool holder, and the total area of their actual contact can reach up to 50-65% of the total contact area. The above fact results in significant deterioration of heat transfer from carbide insert to holder body, which is a massive heat absorber, since the air thermal conductivity is 3000 times lower than the thermal conductivity of metal of the tool holder (Fig. 1). With this in mind, during the development of a tool system with improved heat transfer from carbide insert to bearing surface of tool holder, elastic pads of ceramic-polymeric sheet reinforced material with high thermal conductivity were mounted on. In shape and thickness, the above elastic pads corresponded to the sizes of the chip-breaking grooves of carbide inserts [7]. The used ceramic-polymer pads are characterized by high elasticity (at least 50%) and thermal conductivity of about 0.8-1.4 W/(m K), which provided a significant increase in heat transfer along the entire bearing surface of the insert by reducing air gaps between bearing surfaces of the carbide insert and the tool holder (Fig. 1b). Due to fibre glass reinforcement, ceramic-polymer pads withstand compression of up to 40 MPa, and that guarantees reliable mounting of carbide insert. With the change of bearing surface of carbide insert, when the previous bearing surface of the insert became the rake face, the remains of the pads appearing in the cutting area were easily removed by chips cut off.

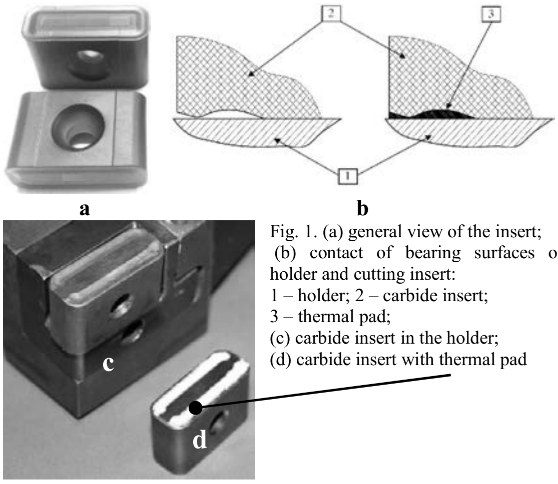

Fig. 1. (a) general view of the insert;
(b) contact of bearing surfaces of holder and cutting insert:
1 – holder; 2 – carbide insert;
3 – thermal pad;
(c) carbide insert in the holder;
(d) carbide insert with thermal pad

2.2 Deposition of nanoscale composite multilayer coatings (NMCC).

Nanoscale composite multilayer coatings were deposited on carbide inserts using filtered cathodic vacuum arc deposition (FCVAD) with the vacuum-arc unit VIT-2 [8-9, 11-12]. The study used a three-component NMCC system, comprising outer (wear-resistant) layer, intermediate layer, and adhesive layer. The developed three-component NMCCs meet at best the dual nature of coatings as an intermediate process medium between the tool material and the material being machined. The coating should at the same time increase the physical and mechanical properties of the cutting tool (hardness, heat resistance, wear resistance) and reduce thermal and mechanical effect on the contact pads, resulting in their wear. The analysis of the influence of the synthesis process parameters on various properties of composite coatings (e.g. Ti-TiN-TiCrAlN) has shown that the most important parameters are as follows: current of titanium cathode arc I_{Ti}, nitrogen pressure in vacuum chamber p_N, and bias potential on the substrate (tool) during condensation of wear-resistant layer U_k. These parameters were taken as major ones for the deposition of NMCCs.

The investigation into the microstructure of NMCCs were carried out on a Jeol electron scanning microscope JSM-6480LV. The macroscopic properties of NMCCs, such as thickness, hardness, friction coefficient, and strength of coating adhesion to substrate, were determined by standard methods.

Using a portable computer tomography UPUC-2000, the temperature gradient of the developed tool system was obtained as shown in Fig. 2. Here a reduction in the intensity of the heat source in the NMCC can be seen with a better heat dissipation through the thermal pad.

The certification (industrial confirmation) tests of the developed tool system were carried out in turning of running surfaces of wheel sets. The tests were conducted with T14K8 carbide inserts (14% TiC; 8% Co; 78% WC) without coatings, and with inserts coated with the developed Ti-TiN-TiCrAlN NMCCs. Tests were performed on the heavy machines of Rafamet UCB-125 bUBB112, the criterion of insert failure was flank wear VB_{max}=0.5 mm.