Surface Treatment of WC-Co dies with Low Energy High Current Electron Beam Irradiation Preparation

S.V. Grigoryev, N.N. Koval, K.V. Shalnov*, K. Uemura**

Institute of High Current Electronics, 4 Akademichesky Ave. Tomsk 634055 Russia
**ITAC Ltd. 8-2 Kamisuwa, Tsubame City Niigata 959-0181 Japan*
*** Tomsk Polytechnic Univ, ITAC Ltd*

Abstract – High hardness dies are used for, as an example, metal powder compression forming before high temperature and atmospheric controlled sintering. These dies are normally made with WC-Co alloys then shaped with Electric Discharged Machine (EDM).

Final finishing of the said dies is done with man-hands with diamonds paste, and the polishing with hands less are demanded in the industries.

Electron beam irradiation were tried to polish the WC-Co dies surface without hand polishing, however, we met many failures to create the craters and the cracks on the surface with electron beam irradiation. This derives from the multiphases alloy nature and the difference of thermal expansion ratio in each metallic component. And also owing to the big thermal gradient on border the modified layer-substrate.

We use the Low Energy High Current Electron Beam Irradiation to smooth and polish the WC-Co dies surface. It is known that WC-Co alloy are crack-recovered in the temperature range of 873–1173 K. Using the nature, Electron Beam Irradiation was done in two stages regime of high frequency low energy pre-heating and stronger energy irradiation.

In the paper, it is disclosed the surface smoothing and polishing of WC-Co dies with Low Energy High Current Electron Beam irradiation with it characterization result

1. Introduction

Recently as finishing treatment (polishing and hardening of a surface layer for steels and alloys) intensively develops rather new technology of a surface treatment of materials by concentrated flows of energy (lasers, pulse ion and electron beams, flows of the accelerated plasma). Such influence leads to melting of surface layer and modification of material properties on depth up to several tens micrometers. Now in Japan the technology of pulse electron beam treatment is applied to polishing a surface of complicated shape profile dies and the moulds produced by a method of Electric Discharge Machining (EDM).

At the same time at use of electron beam treatment for moulds and dies made from carbide alloys based on WC-Co there was a problem of formation of surface microcracks. Formation of microcracks essentially reduces quality of a surface and does not allow using such technology as finishing.

The probable reasons of microcracks formation are the big gradient of temperature on border of melted layer and a bulk material, and also various coefficients of thermal expansion of a material of a matrix and a cohesive material.

In the present work results of experiments on hard carbide alloys on the basis of WC-Co by high current, low-energy electron beam with pulse duration 150–200 microseconds are presented. For reduction of a thermal gradient by border the modified layer-substrate has been offered double-modes method of treatment consisting of preliminary volumetric heating of the sample up to 900–1000 °C by low-current pulses at frequency up to 17 Hz and the subsequent treatment by several powerful pulses on frequency of 1 Hz.

2. Experimental set up

Experiments were done on an electronic gun with the plasma cathode SOLO. [1]. Feature of the this source is the opportunity of independent smooth regulation and computer control of main parameters of an electron beam in a wide range (pulse duration 50–200 μs; a current of a beam 20–250 A; accelerating voltage 5–25 kV; frequency of pulses 0,3–20 Hz).

Experimental set up is presented in a Fig. 1.

Subjects of investigations were hard carbide alloys WC - 11 %Co and WC - 6 %Co. The main goal of researches was decrease in a roughness of a surface at preservation or increase in surface hardness of a material. As samples were used plates 10×10×5 mm, and also real dies with sizes 22×26×5 mm with a complicated shape of a surface. Samples have been produced by a method of electroerosive discharge machining (EDM). The initial roughness of samples made R_a=0.36 μm.

For achievement of energy density that necessary for melting of surfaces WC-Co samples, the beam was focused till diameter 1–2 cm. Treatment of industrial dies was done in a mode of scanning of a surface.

The irradiation of samples was done in duble-modes regime. At the first stage heat-insulated the sample fixed on thin strips of a tantalum foil (the Fig. 1.), heated up to high temperature

(1000±100 °C). The control of temperature was carried out as visually, on a luminescence of the sample, and by means of an optical pyrometer.

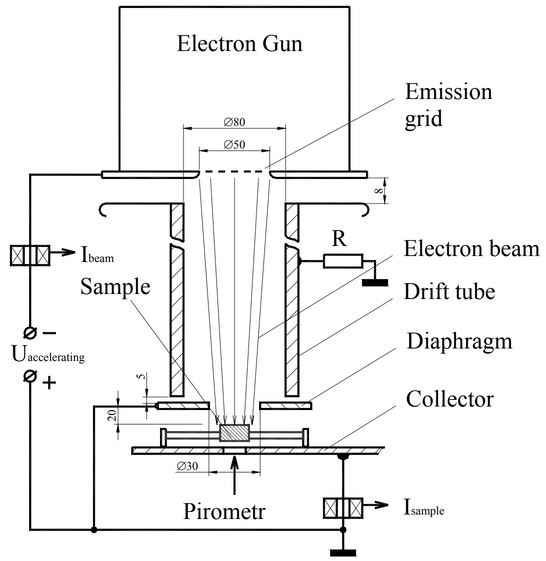


Fig. 1. Experimental set up

The amplitude of pulses of the beam current was set at the level completely excluding an opportunity of melting of the sample surface during influence of single impulses (20–40 A, 15 kV), and necessary for heating of the sample average power in a beam was reached by transition to increased (10–17 Hz) frequency of pulses. In the second stage frequency of pulses of the current of the beam decreased up to 1Hz, the amplitude of pulses of current and size of an accelerating voltage increased up to 200 A, and 20 kV accordingly. Thus, the energy density of beam on the sample increased in some times, achieving values (70 J/cm^2), providing surface melting of sample. Several pulses were act to sample that led to surface melting of preliminary heated sample to some micrometers of depth.

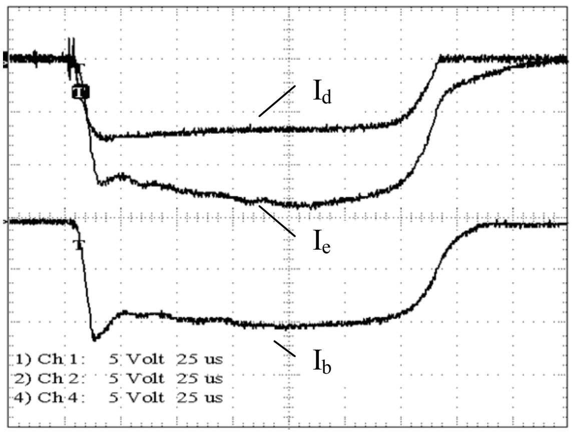


Fig. 2. Typical oscillograms of pulses of a current (100 A/div, 25 ms/div). I_d – discharge current; I_e – emission current; I_b – a current of a beam on the sample (the measured current passed through the diaphragm with diameter of an aperture of 30 mm)

Pulse duration of a current of beam varied in a range 150–200 μs. On Fig 2. typical oscillograms are presented.

For the analysis of the modified layer methods SEM were used (JEOL JSM 5510), measurements of a roughness of a surface were on atomic force microscope NANOPICS 1000 and laser microscope KEYENCE VK-8510, measurements of microhardness on Vickers scale were carried out on hardness testing machine AKASHI HM 114.

3. Results and analysis

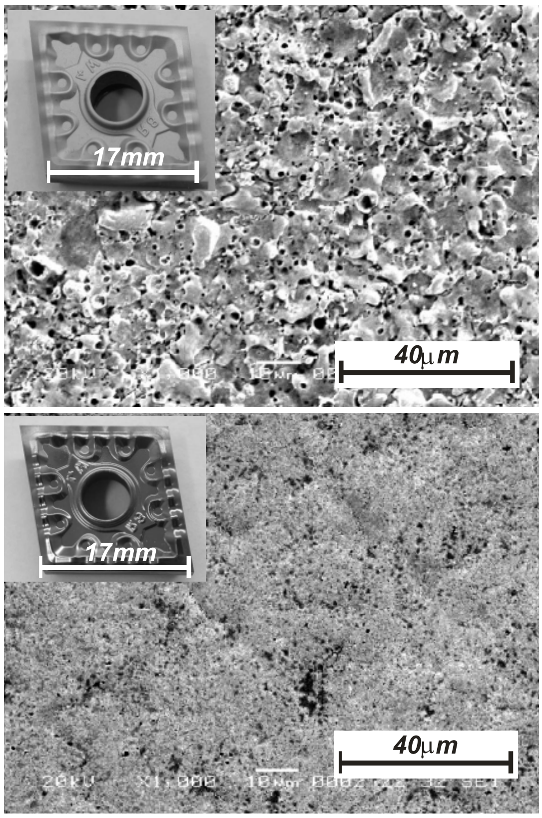
At the initial stage modes of treatment without preliminary heating samples have been tested in order to optimize parameters of high current pulses for surface melting. By means of calorimetric measurements it has been certain, that for melting of WC-Co surface on 150–200 μs pulse duration the energy density of not less than 60 J/cm^2 is necessary. On all samples treated without preliminary heating surface microcracks were observed.

In total 30 samples have been investigated. Measurements of a roughness have shown, that after processing the roughness has improved on the average in 5–6 times and has made R_a=0.06–0.07 μm. The surface looked shining. Typical SEM photos of surface and 3D view of die surface before and after treatment are shown in a Fig 3, *a*, *b*. It is visible, that on an initial surface microdefects are present in the form of microporosity and microcracks growing out during electroerosive processing.

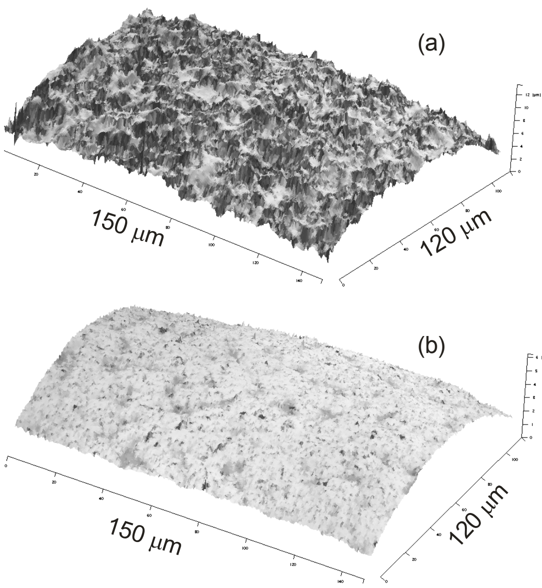
After irradiation by an electron beam initial microcracks is healed, and the quantity of microporosity is essentially reduced, thus their average size decreases. For alloys WC – 11 %Co and WC – 6 %Co a surface before processing had similar structure. Besides by results of SEM the analysis it has been revealed, that as a result of an irradiation considerably (approximately in 10 times) the average size of carbide grains decreases. Before of irradiation 1–5 microns and after an irradiation 0.2–0.5 microns.

Measurements of microhardness were carried out depending on loading. The dependences of microhardness is shown in a Fig. 4. It is visible that, some increase in microhardness in comparison with initial remains even on indenter loading in 200 g, that testifies, about significant depth of a layer with the increased microhardness. The maximum measured values were 2700–2800 kgf/mm^2. For alloys WC – 11 %Co and WC – 6 %Co dependences of microhardness are similar.

At the same time time the maximal values of microhardness for alloy WC – 6 %Co were above and for some samples achieved 3000 kgf/mm^2 In a SEM-photo of cross-section of the flat sample of a Fig. 5 it is visible, that depth structurally-modified a layer is 15 microns.



a



b

Fig. 3, *a*) Typical SEM photos of a surface: initial (top picture), after of e-beam irradiation (bottom picture); *b*) 3D view of the surface of die: (a) initial (top picture), (b) after of e-beam irradiation (bottom picture)

4. Conclusion

Double-modes regime of electron beam treatment (with preliminary heating of samples up to 900–1000 °C) for hard carbide alloys on the basis of WC-Co allows to carry out polishing of a surface with melting surface layer without formation of microcracks. The roughness of a surface decreases in 5–6 times in comparison with initial and makes R_a=0.06–0.07 μm

Irradiation leads to crushing of carbide grains and as consequence to increase in microhardness of a surface up to 2800 kgf/mm^2.

The investigated method of treatment can be recommended for finishing polishing of WC-Co industrial dies.

It is necessary to continue experiments on WC-Co treatment at temperature of preliminary heating less than 900 °C.

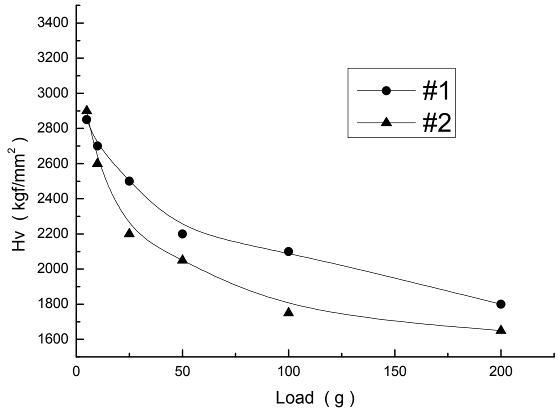


Fig. 4. The dependences of microhardness depending on indenter loading : #1 – WC – 11 %Co, #2 – WC – 6 %Co

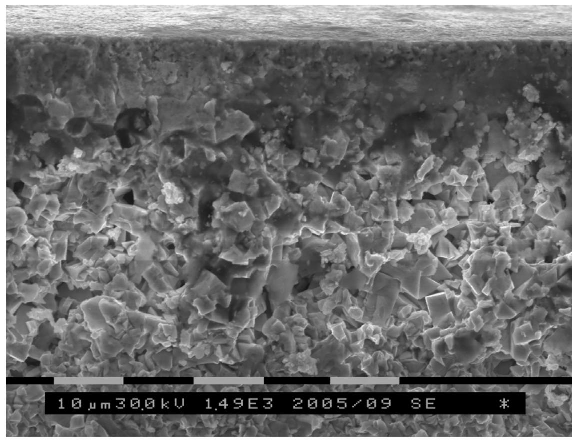


Fig. 5. SEM-photos of cross-section of plate sample WC – 11 %Co

References

[1] V.N. Devjatkov, N.N.Koval, et all. *7th Int.l Conf. on Modification of Materials with Particle Beams and Plasma Flows*, Tomsk Russia, 2004, pp. 43–46.