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TRIBOCORROSION RESISTANT CHROMIZED LAYERS PRODUCED ON TOOL STEEL BY MEANS OF THE PACK CEMENTATION PROCESS

WARSTWY CHROMOWANE WYTWARZANE NA STALI NARZĘDZIOWEJ METODĄ PROSZKOWĄ ODPORNE NA ZUŻYCIE TRIBOLOGICZNO-KOROZYJNE

Słowa kluczowe:

chromowanie dyfuzyjne, obróbka cieplno-chemiczna, metoda proszkowa, właściwości tribologiczne, korozja

Key words:

diffusion chromizing layers, thermochemical treatment, pack cementation, tribological properties, corrosion resistance

Abstract

Chromized carbide layers produced on a tool carbon steel surface by means of pack cementation process were investigated. Studies were carried out of layer thicknesses, their morphology, chromium, carbon and iron concentration depth profiles in the diffusion zone of chromized layers. The tribocorrosion resistance

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of chromized layers was determined. To determine the tribological properties, an Amsler machine of the A135 type was used. The friction unit was disk and plate. Lubrication was provided with a 50% water solution of physiological salt with drip feed of 60 drops/min. High tribocorrosion resistance of the investigated chromized layers was indicated.

INTRODUCTION

Diffusion chromizing is a thermochemical treatment employed today for improving properties of a steel surface such as wear and corrosion resistance. Diffusion chromizing processes are usually conducted at temperatures within the range from 900 to 1100°C for times of up to 10 h by different methods, i.e. powder pack cementation, gas, vacuum, and molten salt baths, as well as in fluidized beds and in pastes **[L. 1–5]**. There is considerable bibliographical data concerning the diffusion chromizing process, in particular, problems connected with hard chromium carbide layers are quite well detailed **[L. 6–9]**.

Carbon content plays an important role in the diffusion chromizing of steels, since its diffusion to the surface (uphill diffusion) during the process leads to its combination with chromium to form carbides. At high carbon content in steels, the obtained diffusion layers are composed of chromium carbides. Such layers are hard and wear resistant.

In this paper, the results of tribological investigation of chromized layers obtained on carbon steel by the pack-powder method are presented. The diffusion layers of chromium carbides were tested in conditions of sliding friction and concentrated contact.

EXPERIMENTAL

A carbon tool steel C120U (PN-EN ISO 4957-2004) containing 1.21%C were selected for experiments. Chromizing of this steel was carried out in a furnace at the temperature of 900°C (10 h) with the utilization of boxes made from heat resistant steel in which steel samples are placed together with the powder mixture, composed of ferrochromium (60 wt.%), ammonium chloride activator (1 wt. %) and filler – kaolin (39 wt. %). The design of the boxes enables their hermetic sealing during the process by means of an enamel that melts at temperatures above 600˚C.

The layers obtained were investigated by performing an X-ray structural analysis and a spectral line analysis with a micro-analyser. Metallographic examinations and thickness measurements of the layers were carried out with an optical microscope. The layer microstructure was revealed by nital etching.

An Amsler type machine was used for determining of the tribological properties and the friction unit was disk and plate **[L. 10, 11]**. In this method, the plate is rubbed against a rotating disk **[L. 11]**. The steel samples used for experiments were machined to the following dimensions for tribological test: The disk was 40 mm in diameter x 10 mm, and the plate was 30 x 10 x 4 mm. The samples were prepared by grinding to the Ra = 0.32 μm. The testing parameters were as follows: the speed of disk sample was n = 200 rpm; the average sliding friction speed was v = 0.42 m/s; the load of frictional system by concentrated contact was P = 25 daN; and, the total friction time was t = 2 h. Lubrication was provided with a 50% water solution of physiological salt with a drip feed of 60 drops/min. Microscopic measurement of linear wear was used to estimate tribocorrosion damage. The coefficient of sliding friction was defined as follows **[L. 10]:**

$$\mu_{śr} = \frac{A}{\pi P D n_c}$$

Where: A – the work of the friction [N·m],
P – load of frictional system [N],
D – the nominal diameter of disk [m],
n_c – the number of turns.

RESULTS

Layer constitution

An X-ray surface structure analysis of chromized carbon tool steel revealed the presence of $(Cr, Fe)_7C_3$ carbide and some $(Cr, Fe)_2(C, N)$ carbonitrides. A metallographic cross-section of carbide layer is shown in **Figure 1**. The layer is unetched, as opposed to the steel base. Concentration depth profiles of Cr, Fe, and C in the layer diffusion zone are shown in **Figure 2**.

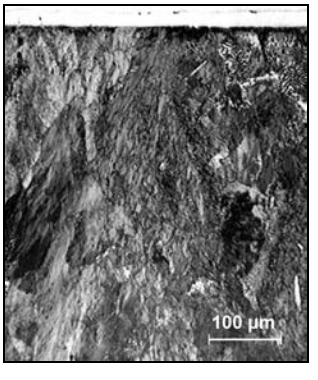

Fig 1. Microstructure of chromized carbide layer on the tool steel surface. Etched 2% HNO_3

Rys. 1. Mikrostruktura węglikowej warstwy chromowanej na powierzchni stali narzędziowej. Traw. 2% HNO_3

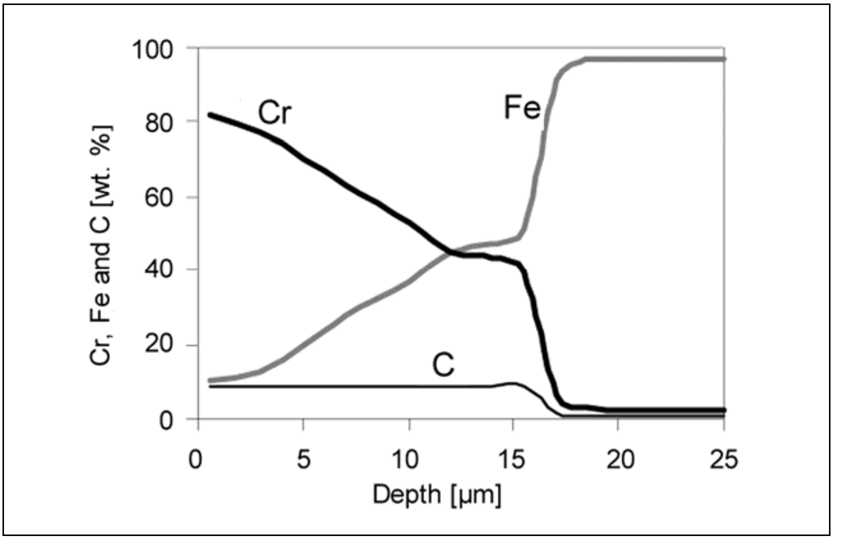

Fig. 2. Chromium, iron, and carbon depth profiles in chromized carbide layer formed on tool steel surface

Rys. 2. Rozkłady stężenia chromu, żelaza i węgla w warstwie chromowanej wytworzonej na powierzchni stali narzędziowej

The surface concentration of chromium in the layer was about 80 wt. % and dropped gradually with the distance from surface to about 50 wt. % at the boundary zone between the layer and steel core. The reduction of chromium concentration in the layer was associated with the simultaneous increase of iron concentration, while the concentration of carbon remained at the same level of about 9 wt. %. Layer hardness was about 1600 HV 0.02.

Tribological properties

Results of the resistance of the chromized layer subjected to tribocorrosion damage are presented in **Fig. 3**, which show a linear wear as a function of friction time. For comparison, the tribological characteristic obtained for toughened (to 62 HRC) steel is also given. The coefficient of friction of tempered and chromized steel was 0.25 and 0.16, respectively **(Table 1)**.

The high wear resistance of the investigated chromized carbide layers has been proved. The results obtained show a very high wear resistance of chromized tool steel in conditions of sliding friction by concentrated contact in the presence of a corrosion medium.

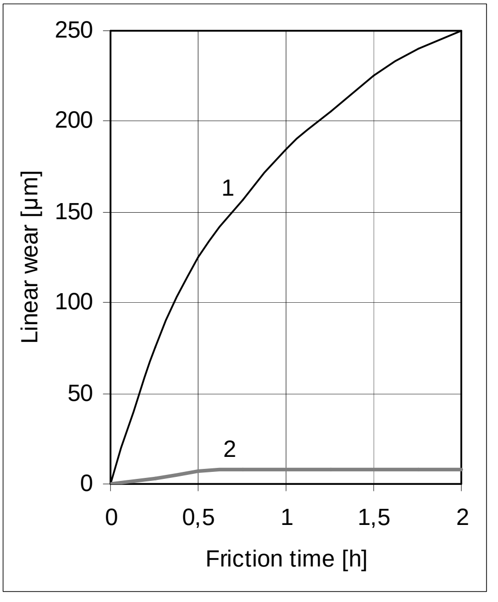

Fig. 3. Run of linear wear of tempered (1) and diffusion chromized steel (2) subjected to the tribocorrosion damage

Rys. 3. Przebieg zużycia liniowego stali ulepszonej cieplnie (1) i chromowanej (2) narażonej na zużycie tribologiczne i korozyjne

Table 1. Coefficient of sliding friction of tempered and chromized tool steel

Tabela 1. Współczynnik tarcia ślizgowego stali narzędziowej ulepszanej cieplnie i chromowanej

Sample	Coefficient of sliding friction
Tempered steel	0,25
Chromizing steel	0,16

CONCLUSIONS

On the basis of the received results, we can formulate the following conclusions:

1. Application of the pack cementation chromizing enables a formation of carbide layers on the surface of C120U tool steel, consisting of $(Cr, Fe)_7C_3$ carbide and some $(Cr, Fe)_2(C, N)$ carbonitrides, with a hardness of about 1600 HV 0.02.
2. The carbide layer thickness reached about 20 μm in 10 hours at a temperature of 900^{o}C. Surface chromium concentration in the carbide layer was about 80 wt. %. The average carbon concentration in this layer was about 9 wt. %.
3. This diffusion layer, produced in the chromizing process, was characterized by high tribocorrosion resistance and a respectively low coefficient of sliding friction by concentrated contact.

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Streszczenie

W pracy omówiono wyniki badań dotyczących węglikowych warstw chromowanych na stali narzędziowej nanoszonych metodą proszkową. Przeprowadzono badania grubości warstw, ich morfologii, składu fazowego, twardości oraz rozkładów stężenia chromu, węgla i żelaza w strefie dyfuzyjnej. Określono odporność warstw chromowanych na zużycie tribologiczno-korozyjne. Dla określenia właściwości tribologicznych użyto urządzenia Amsler typu A 135. Badanie odporności na zużycie przez tarcie wykonano metodą krążek–płytka, stosując smarowanie 50% roztworem soli fizjologicznej podawanym kroplowo ze stałym wydatkiem 60 kropli/min. Udowodniono bardzo dobrą odporność na zużycie tribologiczno-korozyjne warstw chromowanych.