Journal of Achievements in Materials and Manufacturing Engineering

International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

Chemical-heat treatment of materials used for fabrication of tools and effects of this treatment to durability of tools

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Received 28.12.2013; published in revised form 01.02.2014

ABSTRACT

Purpose: The aim of the presented researches is development and design of fluid bed mixed by hot gas. The fluid bed is designed to the chemical-heat treatment with thermo-active powders. This treatment is used for tools and mechanical parts.

Design/methodology/approach: Contribution is focused on increasing of the cutting property of tools made from high speed steel by chemical-heat treatment. Precisely nitrocarburizing at a fluid mixture of a thermo-active powder was used. Possibilities of this method of nitrocarburizing are described in the contribution, especially advantages, disadvantages and effects on the durability of the tools and mechanical parts.

Findings: The material test have showed that the surface layer made by fluid process have better properties than layers made by classical method. But the verification test of the tools with nitrocarburizing did not show increasing of durability.

Research limitations/implications: Layer of nitrocarburizing was evaluated by material tests as nanoindentation and scratch-test. Moreover working test of the tools and parts was made for detection of the effect of the fluid-nitrocarburizing to the durability of the tools and properties of the parts.

Originality/value: The chemical-heat treatment with fluid bed extends durability of thermo-active powders against treatments without fluidization. Other advantage of the treatment with fluidization is reducing of the energy consumption of the technological process.

Keywords: High speed steel; Cutting property; Durability of tool; Nitrocarburizing; Fluidization; Fluidized bed; Thermo-active powder

Reference to this paper should be given in the following way:

J. Němec, J. Fajt, Chemical-heat treatment of materials used for fabrication of tools and effects of this treatment to durability of tools, Journal of Achievements in Materials and Manufacturing Engineering 62/2 (2014) 88-92.

MANUFACTURING AND PROCESSING

1. Introduction

The issue of improving the properties of cutting tools by chemical-heat treatment is solved at project „Development of method of heat-chemical treatment of tool steels using a fluid bed with thermo-active micropowder“. This project is solved by three companies: COMTES FHT a.s., PILSEN TOOLS s.r.o. and IMP Warsaw.

The aim of the project is development and design of fluid bed mixed by hot gas. The fluid bed is designed to the chemical-heat treatment with thermo-active powders. This treatment is used for tools and mechanical parts. The shape of fluid bed, layout of nozzles and gas pressure are designed by numerical simulation of flow. The fluid bed is designed for a homogenous heating of part and homogenous mixing of powder. The chemical-heat treatment with fluid bed extends durability of thermo-active powders against treatments without fluidization. Other advantage of the treatment with fluidization is reducing of the energy consumption of the technological process.

Partial objective of the project is development of technological procedures of chemical-heat treatment of tools and mechanical parts in the new furnace with fluid bed and detection of an impact of these procedures to the properties of the cutting tools. The developed procedures will reduce the total costs of the treatment.

2. Nitrocarburizing with fluidization

Nitrocarburizing is type of chemical-heat treatment and this process is based on diffusion saturation of surface with nitrogen and carbon. Carbon facilitates diffusion of nitrogen into steel in nitrocarburizing process. The surface layer of nitrocarburizing is thicker than surface layer of nitriding. Over more nitrocarburizing layer is created in shorter time. Temperature range of nitrocarburizing is from 520°C to 620°C. These temperatures are close to a tempering temperature of tool steels so using of this chemical-heat treatment should not cause reduction of hardness of the cutting tool from HSS. Low temperatures are also associated with smaller deformations compared to other heat treatments. The surface layer created by the nitrocarburizing is wear resistant and corrosion resistant. Both these properties are important for tools made from HSS. Nitrocarburizing is divided to four main classes by used medium. Nitrocarburizing use gas, salt bath, plasma or fluidized medium.

Fluidized medium is created by fluid bed and gas, which flows through nozzles in fluid bed. Further the gas is swirling thermo-active powder. An advantage of fluidized medium is faster heat transfer from medium to a part. Faster heat transfer allows reducing the time of chemical-heat treatment. It means lower energy costs and longer life of thermo-active powder (powder can be used for more cycles of treatment).

A disadvantage of fluidized medium is increased abrasion wear of furnace parts.

3. Evaluation of surface layers

Material institute IMP Warsaw already has a device with fluid bed for chemical-heat treatment. So the PILSEN TOOLS has fabricated turning knives from HSS 19 830.4 (Fig. 1), which have been modified by nitrocarburizing in chemical active powder with fluidization and without fluidization.

Fig. 1. The turning knives for verification test

Chemical-heat treatment was done at 540°C for 30 minutes. Further oxidation was carried out for 60 minutes. The knives marked 30-2 and 30-3 were treated without fluidization, the knives marked 30-4 and 30-5 were treated with fluidization and the knife marked 30-1 was hardened only. Material properties of these tools were tested on the University of West Bohemia on the Department of Material and Metallurgy. The behaviour of the layers was tested by scratch test using a Rockwell's diamond tip 0.2.

The samples in the picture (Fig. 2) are 30-2, 30-3, 30-4, 30-5 from upper side. The best resistance against scratch test has the sample 30-4. Friction breach is appeared about a third of scratch. Breach of edges is appeared little bit later and it was small. Dimension of breach gradually increases, but finally breach of the sample 30-4 is smaller than branches of other samples.

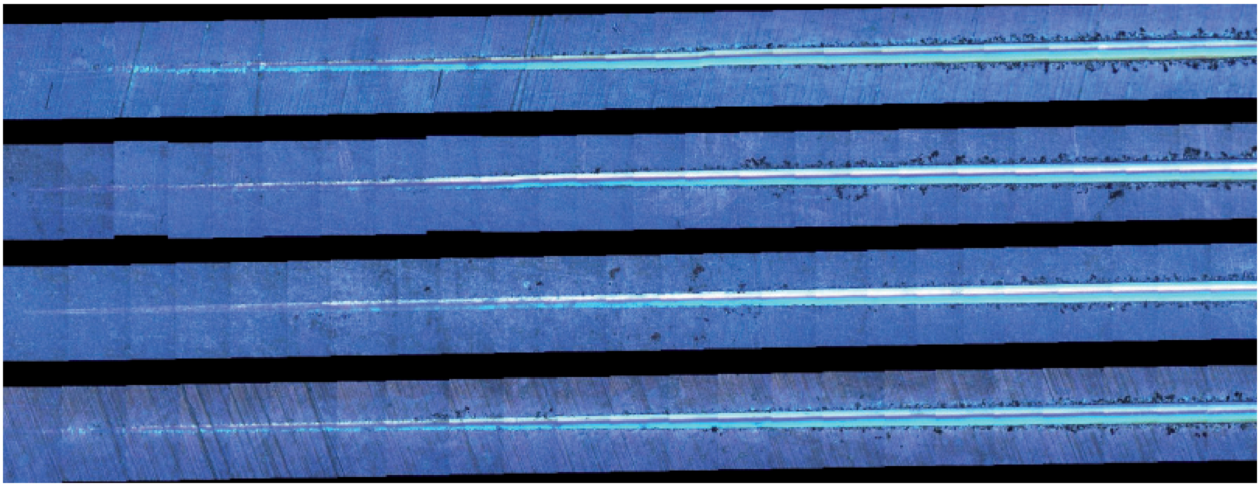

Fig. 2. Result of the scratch test

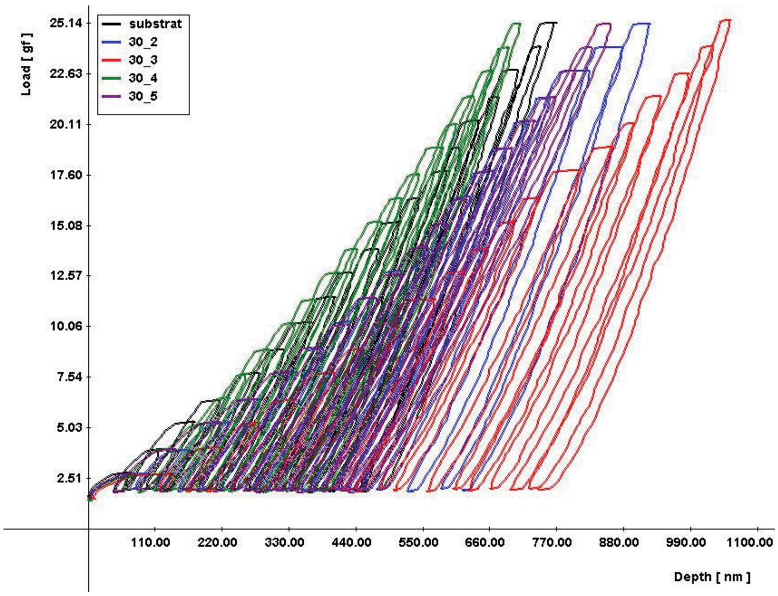

Fig. 3. Summary graph of indentation measuring

The small breach on the scratch of the sample 30-5 is appeared earlier than breaches on the samples 30-2 and 30-3, but it was caused by rougher surface of the sample. The expansion of the breach is not so great at higher axial force as breaches of samples 30-2 and 30-3. The lowest resistance against scratch test has the sample 30-3. The sample 30-2 has bigger breach at small axial force, but the expansion of the breach on the sample 30-3 is more significant. Behaviour of both samples (30-2, 30-3) about maximal axial force is comparable. Conclusions from the scratch test were confirmed by results from measuring of acoustic emission and measuring of progress of friction coefficient.

Other the indentation measuring was used. Load of indenter was chosen 5 g, 25 g and 200 g. Every load investigated different behaviour of surface layer, substrate and interface between layer and substrate (Fig. 3).

The samples 30-5 and 30-4 have bigger reinforcement of the surface, because the maximum depth of penetration is smaller and indentation curves are denser.

4. Verification test of durability of the turning knives with chemical-heat treatment

The verification test was done at the University of West Bohemia on the Department of Machining Technology and this test is a part of diploma thesis of Mr. Černohorský.

Experiment was done on the CNC lathe MAS Masturn 50, workpiece material was carbon steel 11 523.0. The cutting parameters were: cutting speed v_C = 56 m/min, feed per revolution f_o = 0.12 mm, depth of cut a_p = 2 mm and cutting process was cooled by oil emulsion. The criteria dimension of wear for evaluation of durability of the tools was chosen 0.2 mm and dimensions of wear were measured on the microscope Multicheck PC 500 (Table 1) [1].

The tools with chemical-heat treatment reached criteria wear about 20 minutes. But reference tool 30-1 did not reach the criteria wear after 26 minutes. The experiment did not show positive impact of this chemical-heat treatment to the durability of cutting tools.

5. Conclusion

The material test have showed that the surface layer made by fluid process have better properties than layers made by classical method. But the verification test of the tools with nitrocarburizing did not show increasing of durability. Possible cause of failure of nitrocarburizing tools could be inappropriately selected cutting parameters, especially high cutting speed. Priority will be to find suitable cutting parameters for tools with this type of treatment. The chemical-heat treatment of cutting tools in fluidized medium could be used for fabricating of pull or push broaches, because this type of cutting tool works with lower cutting speed.

Furthermore is contemplated to use chemical-heat treatment with fluidization on the highly stressed mechanical parts for energy industry and machine components. Threaded material will be for example 17 134.6 (1.4923), 15 340.7 (1.8507), 34CrAlNi7 (1.8550), 17CrNiMo6 (1.6587) and 14 220.4 (1.7131).

Table 1.
Data from measuring of wear [1]

Tool	Measurement	1	2	3	4	5
30-1	t, min	0:08:00	0:16:00	0:20:05	0:26:05	
	VB, mm	0.041	0.074	0.108	0.146	
	VB krit.	0.141	0.195	0.235	0.289	
	R_a, μm	2.04	1.95	1.96	2.17	
	R_z, μm	11.08	11.40	11.52	12.49	
30-2	t, min	0:08:00	0:11:36	0:14:36	0:17:36	0:21:36
	VB, mm	0.131	0.145	0.162	0.184	0.213
	VB krit.	x	x	0.189	0.209	0.229
	R_a, μm	2.08	1.96	1.90	1.80	1.70
	R_z, μm	11.70	11.50	10.70	10.78	10.60
30-3	t, min	0:04:00	0:17:12	0:23:12		
	VB, mm	0.045	0.158	0.201		
	VB krit.	0.075	0.212	0.244		
	R_a, μm	1.95	1.80	1.66		
	R_z, μm	10.70	10.90	9.66		
30-4	t, min	0:08:00	0:11:00	0:14:30	0:18:30	
	VB, mm	0.135	0.157	0.184	0.219	
	VB krit.	0.295	0.296	0.321	0.340	
	R_a, μm	1.70	2.07	2.04	1.81	
	R_z, μm	9.80	11.05	11.24	9.93	
30-5	t, min	0:04:00	0:17:56	0:23:56		
	VB, mm	0.092	0.189	0.222		
	VB krit.	0.128	0.257	0.280		
	R_a, μm	1.60	1.70	1.80		
	R_z, μm	8.97	9.50	10.69		

Acknowledgements

This project is funded with support from the state budget through the Ministry of Education, LF 13032 TAMPFLU from the program EUREKA CZ.

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[1] J. Černohorský, Possibilities of increasing the cutting power of the tools from HSS, Diploma thesis. University of West Bohemia, Pilsen, 2014.