ISSN 1392-1134/ eISSN 2345-0371
Agricultural Engineering, Research Papers, 2015, Vol. 47, 1-5 p.

WEAR BY FRICTION ANALYSIS OF NITRIDED AND CARBURIZED CONSTRUCTIONAL STEELS

J.Senatorski, J.Tacikowski, P.Mączyński
Institute of Precision Mechanics, Warsaw, Poland

This work presented the results of tribological properties of constructional steels: 18HGT and 20MnCr5 after nitriding or carburizing. It was state directly proportional relation their wear resistance from value of their surface pressures. But wear – friction properties of carburized and nitrided layers were similar.
Keywords: constructional steels 18HGT and 20MnCr5, nitriding, carburizing, tribological properties

Received 2015-08-31, accepted 2015-12-16

INTRODUCTION

Gas nitriding is emerging as the significant surface – hardening process for today's and future industry, constituting a viable alternative to the well – established carburizing process. In the field of producing technological process of diffusion layers, the most attention was given to nitriding and carburizing [1], the most of such process, used in Polish industry was elaborated in Institute of Precision Mechanics (IPM) [2]. Mentioned diffusion layers are different towards their structure. The existing differences, in chemical composition, microstructure and frequent of phase composition, causing variations of proprieties in these particular zones. Not always the whole of generate layer is used during the exploitation the machine parts. It is related, on the one hand with the admissible wear and on the other hand, with the necessity of removal part of layer in consideration of correlation their dimensions, or requirement roughness of the surface.

Tribological properties of diffusion layers are depended on many factors, but specific influence for these properties makes temperature, which is the function of mechanical effects and determine factors i.e. input functions. Many articles are related to the problems of influence of such input functions, but not many referred to the diffusion layers [3]. Towards of a little number of such articles, in Institute of Precision Mechanics (IPM) such investigations were undertaken. Their objects were two types of diffusion layers: carburized and nitrided.

DESCRIPTION OF REALIZED EXPERIMENTS

Diffusion layers generation. Two structural steels grade 18HGT and 20MnCr5 were selected for the thermo–chemical processes to generate the equivalent carburized and nitrided layers.

Their chemical composition presents table 1. Generation conditions of layers and their thermal treatment before and after chemical treatment are given in table 2.

Nitriding and carburizing processes are realized in controlled atmosphere enabled for create layers with specified surface concentration of nitrogen and carbon [4, 5].

Nitriding was precedence by the toughening, usually used before this process, with the aim to increase the strength properties of the substrate.

Carburizing was realized with the quenching, what enabled shortening the total time of process producing and hardening of the layer and reduction of their deformations.

Table 1. Chemical composition of investigated steels.

Steel Grade	Chemical composition [%]				
	C	Si	Mn	Cr	Ti
18HGT	0,20	0,30	0,95	1,15	0,08
20MnCr5	0,22	0,37	1,40	1,30	-

Table 2. Condition of cteating the diffusion layers and their thermal treatments

Kind of thermo – chemical treatment	Grade of steel	Process parameter			Thermal treatment
		Temperature T[°C]	Time T [h]	Medium	
Nitriding	18HGT	530	6	Controlled atmosphere with type NH_3-N_2	Previous hardening 860°C and tempering 600°C, 3h
Carburizing		930	6	Controlled atmosphere with coal potential 0,85%	Quenching and tempering 180°C, 2h
Nitriding	20MnCr5	570	24	Controlled atmosphere with type NH_3-air	Previous normalizing
Carburizing		930	5	Controlled atmosphere with coal potential 0,85%	Hardening with precooling to 840°C, tempering 200°C, 2h

Diffusion layers characteristic. Layers generated for the experiments, from the point of view on structure and hardness usually are recommended in industry practice. Modified layers characteristics given in table 3. The thickest layers were achieved after carburizing. Hardened to martensitic structure, they had relatively modest surface hardness. Nitrided layers, obtained in short duration time, were several times thinner. They had a little higher surface hardness, that was related with existing thin zone (NSZ) near the surface of ferro-carbonitrides and nitrides ε + γ' which hardness is about 1200 HV 0,02.

Table 3. Description of diffusion layers

Kind of layer	Grade of steel	Process parameter T[°C]/t[h]	Process description	Thickness of layer [mm]	Hardness $HV_{0,5}$ surface/ core
Nitriding	18HGT	530/6	Near the surface zone of the carbonitrides and nitrides ε + γ' and zone of solid solution $Fe_α$ [N]	0,16	826/268
Carburizing		930/6	Martensite with the near the surface zone of retained austenite	0,95	745/460
Nitriding	20MnCr5	570/24	Near the surface zone of the carbonitrides and nitrides ε + γ' and zone of solid solution $Fe_α$ [N]	0,25	555/175
Carburizing		930/6	Martensite with the near the surface zone of retained austenite	0,80	606/480

Wear – frictional properties of diffusion layers. The wear–frictional experiments of diffusion layers were carried out by the cone-three-cylinder wear test [6]. The linear wear of nitrided and carburized layers were estimated. Wear tests were conducted by keeping the approximate constant unit loads. The total time of test was 100 min. Measurements of wear were made every 10 min, simultaneously increasing the load proportionately to the increase in worn surface, in order to maintain the nominal surface pressure. The parameters of wear investigations are given in table 4.

Table 4. Conditions of linear wear investigations

Pressure p [MPa]	Friction speed V [m/s]	Friction time t [min]	Kind of lubricant	Outlay of lubricant in [drop/min]
50 100 200 300 400 600	0,58	100	Lux - 10	30

Linear wear was characterized by the total wear during the test – z_l [μm]. Wear–frictional properties of nitrided and carburized layers were characterized using three dimensional graphs of the linear wear of investigated layers as a function of wear time and surface pressure and are shown in the figures 1 to 4.

Three dimensional graphs of the linear wear of nitrided layers as a function of wear time and surface pressures (50 ÷ 600 MPa) for different layer depths on steel 18HGT are shown in fig. 1. Specific feature for this layer is significant increase of wear as function of surface pressures. Up to 200 MPa rising wear was not observed. But, continuously increasing of wear volume or salutatory rising was seen in surface and subsurface zones at pressures of 400 and 600 MPa. Depth of wear tracks, for this layers (in except the test by pressure 50 MPa), was beyond the NSZ thickness and exceeds it 6 μm. Linear wear values by the pressures 50 ÷ 200 MPa was contained in the limits from 5,8 to 11,6 μm.

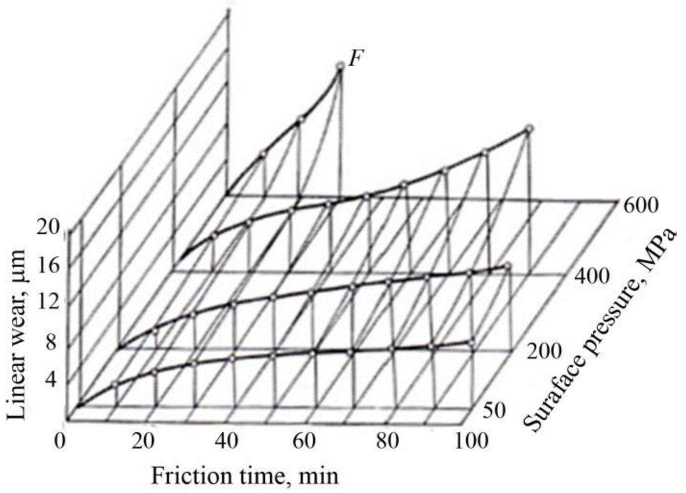

Fig. 1. Linear wear of nitrided layer of steel 18HGT in dependence on friction time and surface pressures. Here F means seizure

The linear wear of carburized layers against wear time and surface pressure for the steel 18HGT are shown in the form of three dimensional graphs in Fig. 2. Increasing the surface pressure above 200 MPa causes a distinct increase in wear, on both surfaces and subsurface zones, leading to accelerated wear or seizure at pressures above 400 MPa. Linear wear values by the pressures 50 ÷ 200 MPa are contained in the limits of 7,0 ÷ 9,2 μm.

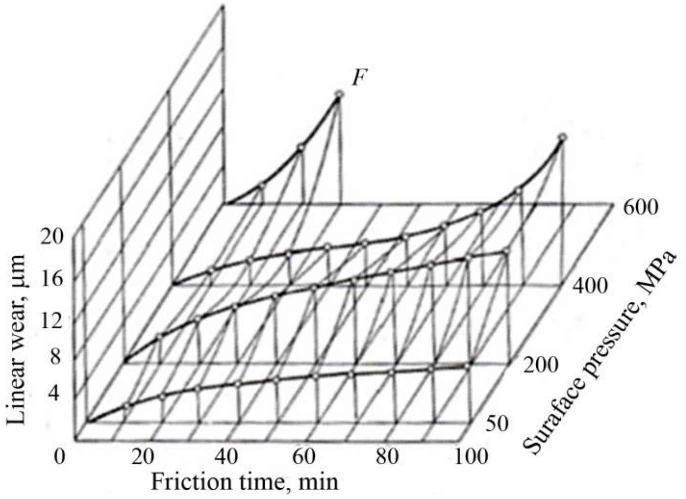

Fig. 2. Linear wear of carburized layer on steel 18HGT in dependence on friction time and surface pressures. Here F is seizure

Wear of long–term nitrided layer, generated on steel 20MnCr5 in the range of surface pressures 100 ÷ 400 MPa are given in fig. 3. This layer were characterized with greater linear wear directly NSZ, in spite of existing the carbonitrides and nitrides zone ε + γ' with great hardness. Applied values of surface pressures caused, that NSZ was wearing already during running–in period. Values of linear wear, by the applied pressures rise until 74,5 μm.

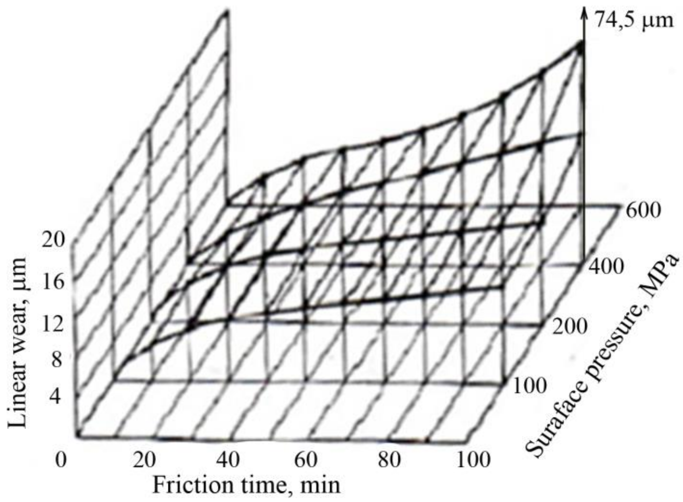

Fig. 3. Linear wear of nitrided layers of steel 20MnCr5 in dependence on friction time and surface pressures.

Wear of carburized layer on steel 20MnCr5, shown on fig. 4, was appointed in the range of surface pressures 100 ÷ 400 MPa. In this case linear wear directly by surface is greater than in deeper situated zone.

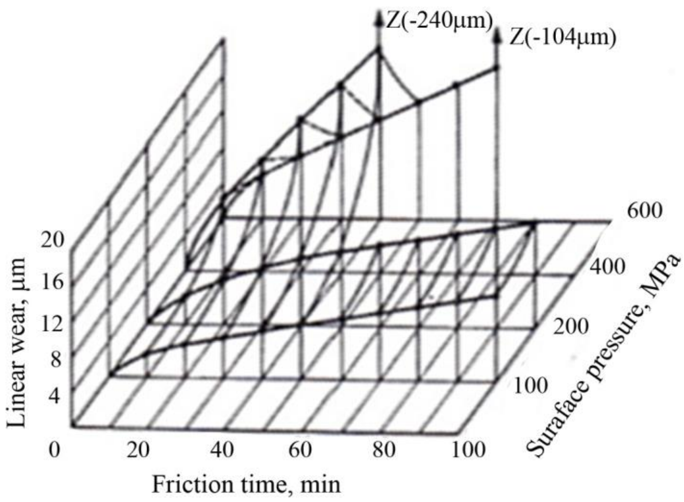

Fig. 4. Linear wear of carburized layers on steel 20MnCr5 in dependence from friction time and surface pressures. Z – seizure.

This fact is related with occurring the retained austenite near the surface zone. Minimum of wear occurs on depth about 0,1 mm. It was the big zones where the wear distinctly increases, showing the symptoms of seizure. That was related with decreasing of carbon concentration and falling the hardness.

CONCLUSIONS

1. The results of tribological investigations of diffusion layers created using nitriding and carburizing technological process shows distinct but directly proportional dependence of wear resistance on values of surface pressure.

2. The experiments shows, that tribological properties defined for carburized and nitrided layers on steels 18HGT and 20MnCr5 were similar, what give possibility for replacement of carburized machine elements, working in frictional conditions with nitrided elements [7].

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Author for contact:
Prof. Jan Senatorsky
Institute of Precision Mechanics, Duchnicka 3, 01-796 Warsaw, Poland
E-mail: jsen@imp.edu.pl