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EFFECTS OF SHOT PEENING ON PROCESS OF CARBURIZATION AND SELECTED STRENGTH PROPERTIES OF STEEL 18 HGT

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ABSTRACT

The influence of shot peening before carburization and conditions of the process of carburization on the selected properties of 18 HGT steel specimens have been tested. The results show that the pre-strains of surface layer of the specimens provide for obtaining of the higher concentrations of carbon in the layer and, except fatigue contact strength, the obtained values of Z_{go}, R_g, R_m and $R_{0,2}$ on the level corresponding to the results of tests with unpeened specimens. In case of specimens with martensite structure containing small quantities of retained austenite, specimens quenched from the temperature of the process had better results of the tested properties than those which were quenched from the lowered temperature.

KEY WORDS:

Carburization, shot peening, surface layer.

1. INTRODUCTION

The state of carburized layer, containing significant quantities of retained austenite, is changed in result of micro and macro plastic strains. The changes consist in phasal changes of retained austenite to martenzite even up to seperation of carbides in martenzite spines [1]. The changes of structure of carburized layer cause the change of residual stresses and improvement of mechanic properties, especially fatigue strength, both volumetric and contact one [1]. This is the reason of common use of dynamic plastic treatment (shot peening) for working of carburized gears [2].

Of particular interest is the recognition of the effects of the earlier plastic strains of surface layer on the state and quality of the layer obtained after carburization. The carburization is a diffusion process, so the earlier plastic strains should have a substantial influence on it.

2. SPECIMENS AND EXPERIMENTAL PROCEDURE

2.1. Specimens

The effects of the state of surface layers peened and unpeened before carburization as well as conditions of this process on the selected properties of 18 HGT steel specimens have been tested. Diversified state of surface layer of specimens was obtained in result of peening and burnishing according to the following procedures:

The specimens were shot-peened pneumatically in self-made chamber equipped with peening nozzle type SB-4. The construction of peening stand allowed for constant flow of shot between chamber and the peening nozzle. A dust extractor kept the chamber clean and removed also too small shots.

The specimens were held by specially elaborated and self-made holders, which allowed to repeat the parameters of process for all specimens of the same kind. Those surfaces of specimens which because of technological conditions should not be peened were covered with thin sheet of rubber fixed with self-adhesive type. The specimens were rotated and nozzle was fixed perpendicularly to the axe of the specimen. The cast steel round shot type WS 2300 of 0,5 – 0,6 mm grain size, hardness about 470HV was used in the process. The distance between nozzle and peened surface was L = 300 mm. The diameter of nozzle was 4,3 mm, the air pressure $0{,}6^{+0{,}05}$ MPa. The intensity of peening was determined according to intensity curve obtained in process of peening of Almen strips type A strengthened in the same conditions as assumed for the tested specimens.

Shot-peening was carried out for total time 90 s which meat the same intensity f_A = 0,39mm for all specimens and ensured the coverage of surface > 100%.

The burnishing was carried out by means of burnishing roller diameter Φ = 10mm with force P = 1000N.

2.2 Treatment

Such prepared specimens were carburized, oil-quenched and tempered. The process (carburization and quenching) was carried out in two technological procedures:

Procedure I– boost-diffusion carburization with direct quenching after this process, according to the following parameters: carburization at 910° C in time t = 2 h at potential 0.95%C with diffusion annealing at potential 0.8%C in time t = 1 h and at potential 0.7%C in time t = 1h.

Procedure II – boost-diffusion carburization with quenching from lowered temperature according to the following parameters: carbirization at 910°C in time t = 4.5 h at potential 1%C with diffusion annealing at potential 0.8%C in time t = 1h at temperature of carburization and in time t = 1 h at potential 0.7%C while the temperature was lowered to 840°C.

Moreover single-stage carbirization of 18HGT steel metallographic specimens, initially shot peened or burnished, was carried out for time of 5 h at temperature 920°C.

3. EXPERIMENTAL RESULTS

3.1. Metalographic researches

The results of investigation of surface layer of specimens heat treated according to Procedure I are presented in Fig. 1 – 4. Distribution of carbon concentration in carburized specimen (peened and unpeened) are shown in Fig.1. Effect of the above procedure on distribution of hardness in surface layers is shown in Fig. 2

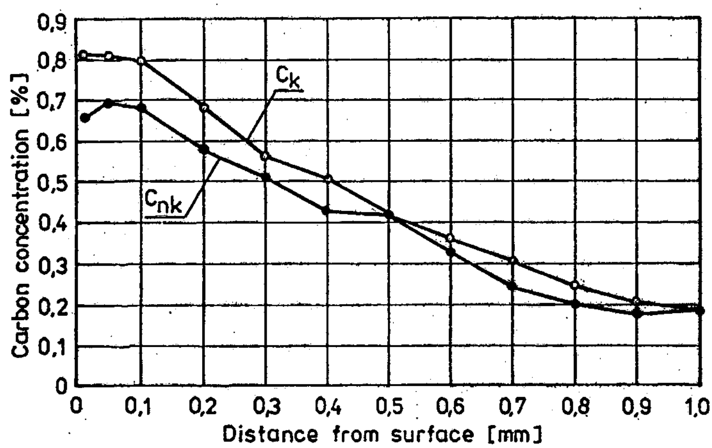

Fig.1 Distribution of carbon concentration in layers of 18HGT steel specimen carburized and hardened from the temperature of the process (procedure I);
k – surface initially peened before carburization.
nk – surface unpeened

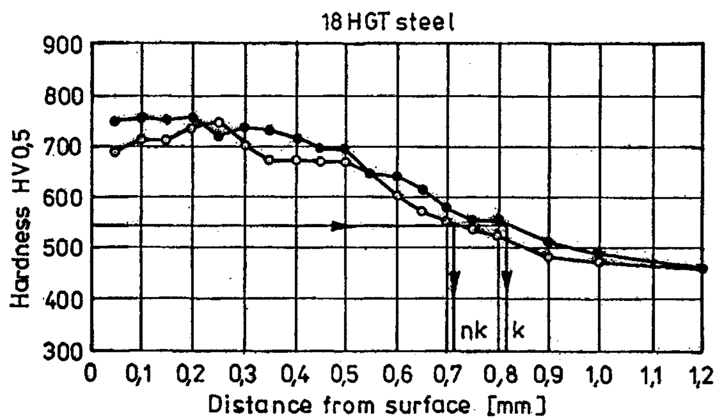

Fig. 2 Distribution of hardness in layers of 18HGT steel specimen carburized and hardened (procedure I);
k – surface initially peened before carburization
nk – surface unpeened

The obtained metallographic structures are presented in Fig. 3 and Fig 4. It was observed that they consist of fine-needled martenzite with uniformly situated fine carbides and small amount of retained austenite (Procedure 1).

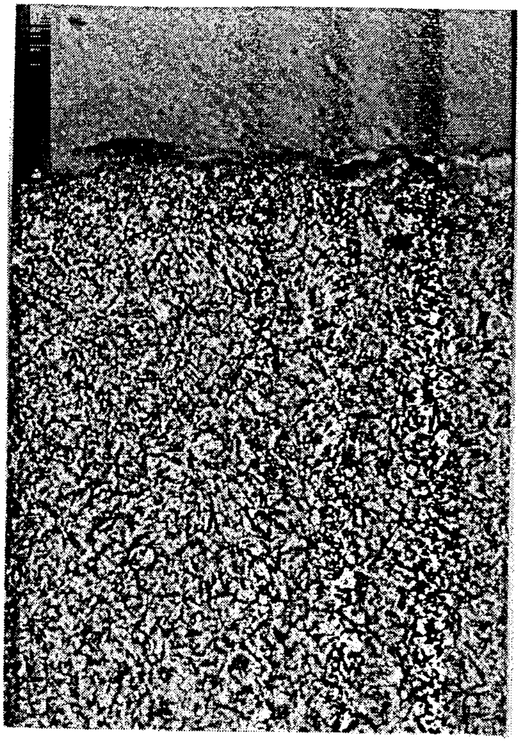

Fig. 3 Structure of unpeened surface layer of 18HGT steel specimen, carburized and hardened from the temperature of the process (procedure I), x500. Etched in 2% Nital

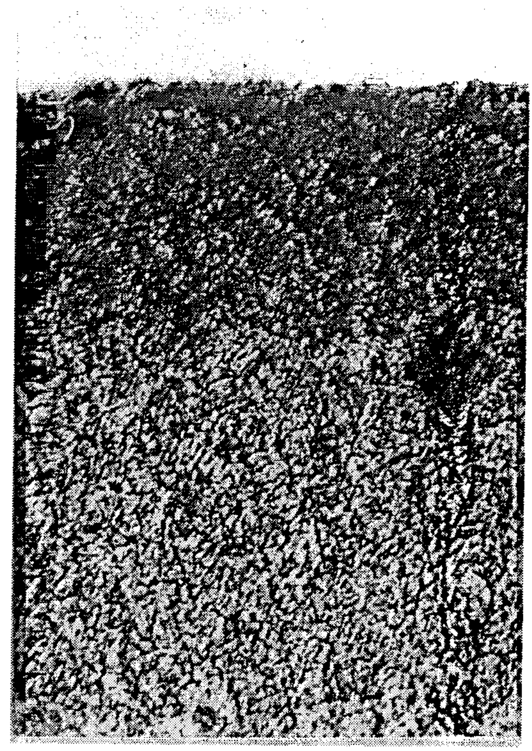

Fig. 4 Structure of peened surface layer of 18HGT steel specimen, carburized and hardened from the temperature of the process (procedure I), x500. Etched in 2% Nital

Concentration of carbon, hardness penetration pattern and structure of layer of 18HGT steel specimen, which was carburized in two steps and hardened from lowered temperature is presented in Fig. 5 – 7 (Procedure II). The structure of layer (Fig. 7) does not differ from the structure of not peened sample from Procedure 1 (Fig.3) and concentration of carbon shows the constant value in deeper layer (Fig.5) but this is the result of different choice of time and carbon potential in both stages of carburization.

The effect of shot-peening and burnishing on carbon concentration, hardness and structures of layers after single-stage carburization is shown in Figs. 8 – 15. Fig. 8 proves that during single-stage carburization of peened specimens there appears high concentration of carbon in surface layer on depth 20-30 μm which is much higher than carbon potential of atmosphere. It does not, however, influence the depth of the effective case, quenched after single-stage carburization (Fig.9).

The structures of layers illustrated in Figs. 10-11 differ with higher concentration of carbides and retained austenite when the sample was initially peened. In the specimens initially burnished the pattern of carbon concentration does not differ from that of unburnished ones (Fig. 12).It refers also to depth of hardened layers (Fig.13) and their structures (Fig.14-15)

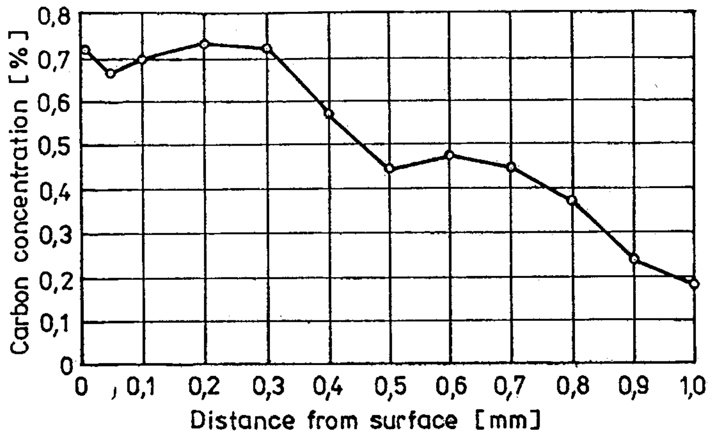

Fig. 5 Distribution of carbon concentration in layer of 18HGT steel specimen carburized and hardened from the lowered temperature (procedure II);

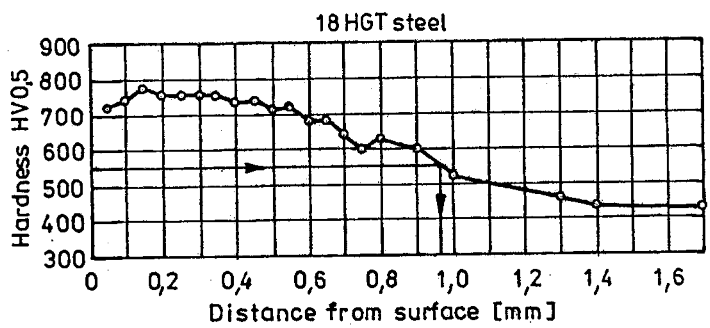

Fig. 6 Distribution of hardness in layer of 18HGT steel specimen carburized and hardened from the lowered temperature (procedure II);

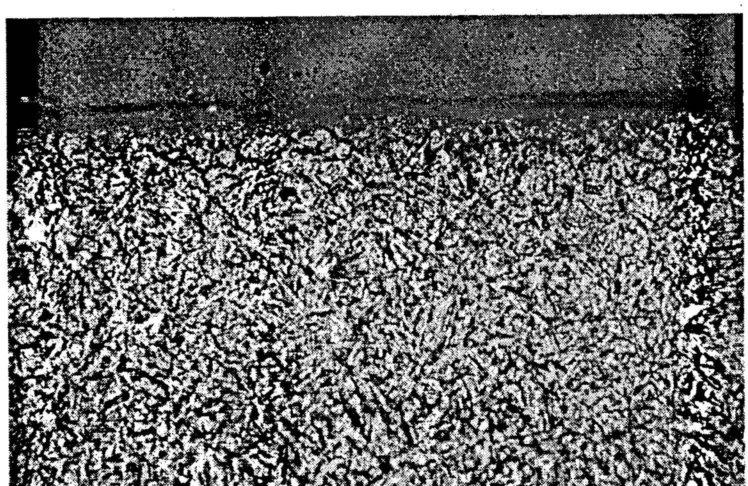

Fig. 7 Structure of surface layer of 18HGT steel specimen, carburized and hardened from the lowered temperature (procedure II), x500.

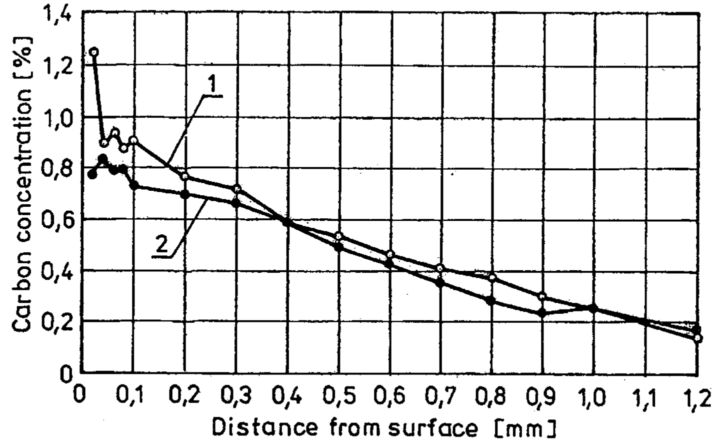

Fig. 8 The effect of state of a surface on carbon concentration in surface layers of 18HGT steel specimens after single-stage carburization at temp. 920°C/1h at potential 0,8-0,9%C and quenching in oil from the temperature of the process. 1 - peened surface, 2 - unpeened surface

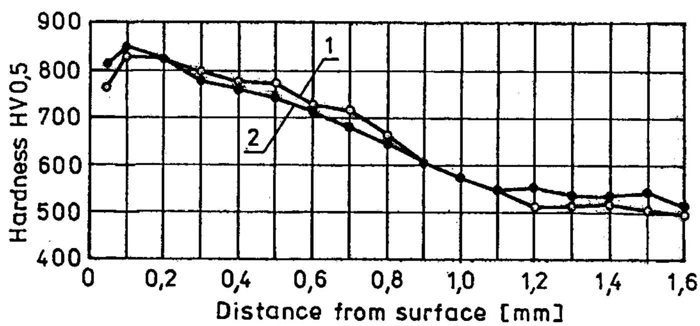

Fig. 9 Distribution of hardness in surface layers of 18HGT steel specimen peened and ground, then single-stage carburized at temp. 920°C/5h at potential 0,8-0,9%C and quenched in oil from the temperature of the process. 1 - peened surface, 2 - unpeened surface

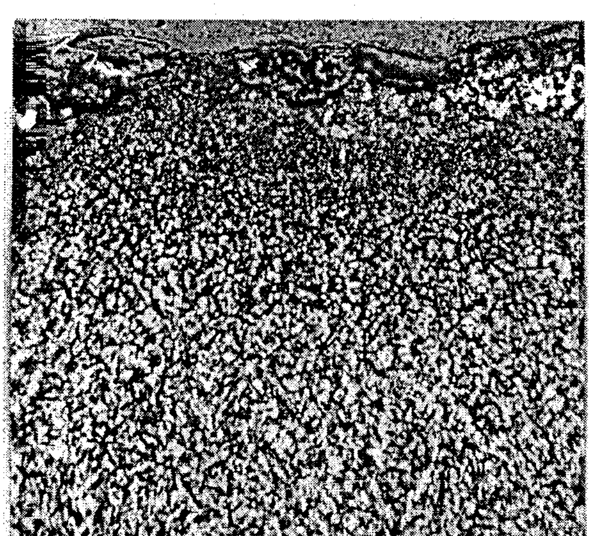

Fig. 10 Structure of surface layer of 18HGT steel specimen, peened after grinding, then single-stage carburized at temp. 920 C/5h at potential 0,8-09,%C and quenched in oil from the temperature of the process.

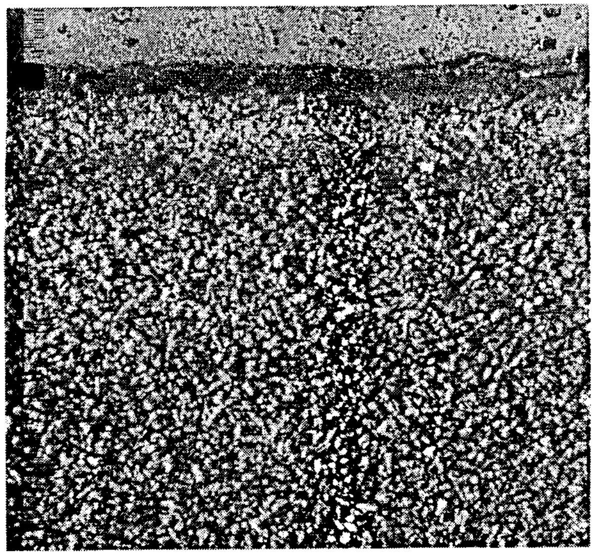

Fig. 11 Structure of surface layer of 18HGT steel specimen, ground then single-stage carburized at temp. 920°C/5h at potential 0,8-09,%C and quenched in oil from the temperature of the process

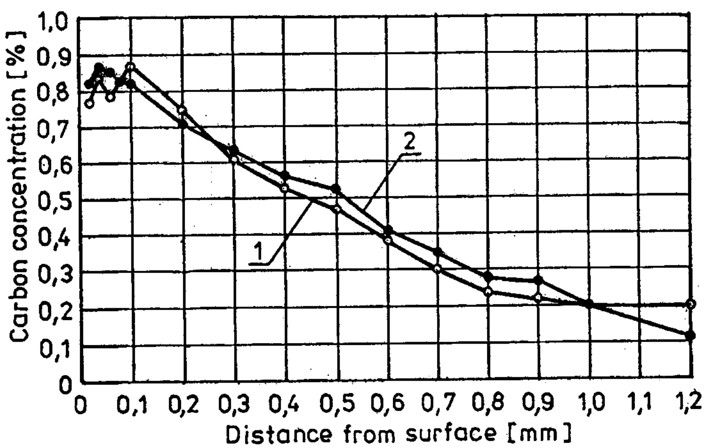

Fig. 12 The effect of state of a surface on carbon concentration in surface layers of 18HGT steel specimen after single-stage carburization at temp. 920°C/5h at potential 0,8-0,9%C and quenching in oil from the temperature of the process. 1 - burnished surface, 2 - unburnished surface

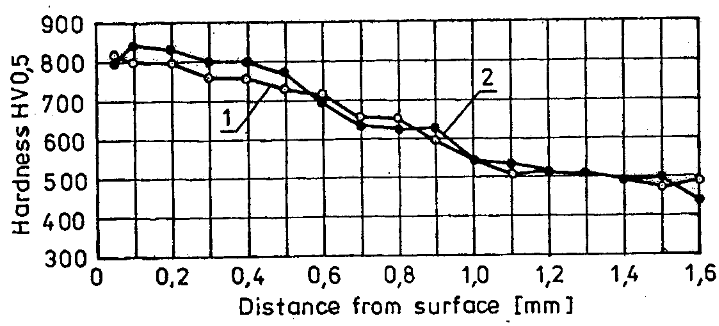

Fig. 13 Distribution of hardness in surface layers of 18HGT steel specimen burnished and ground, then single-stage carburized at temp. 920°C/5h at potential 0,8-0,9%C and quenched in oil from the temperature of the process. 1 - burnished surface, 2 - unburnished surface

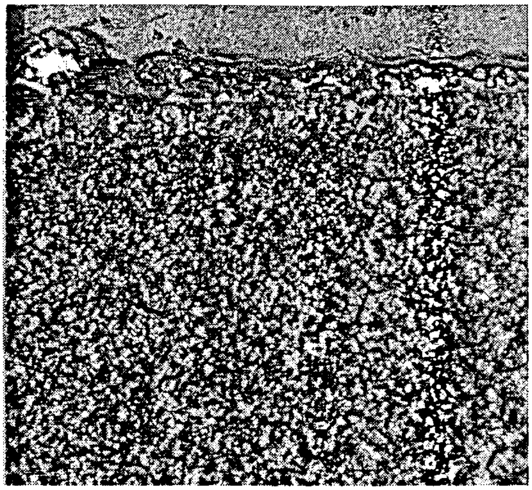

Fig. 14 Structure of surface layer of 18HGT steel specimen, burnished and then single-stage carburized at temp. 920°C/5h at potential 0,8-09,%C and quenched in oil from the temperature of the process

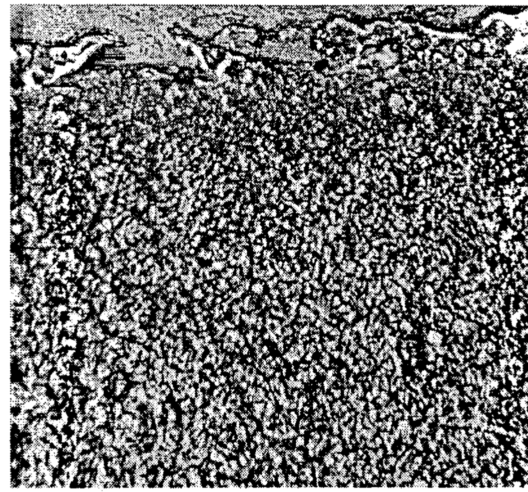

Fig. 15 Structure of surface layer of 18HGT steel specimen, ground and then single-stage carburized at temp. 920°C/5h at potential 0,8-09,%C and quenched in oil from the temperature of the process

It is necessary to draw attention to the fact that the character of burnishing is significant. In paper [6] it was proved that hardness of threaded part of bolt made of 45HN chromium-nickel steel in process of cold roll-threading after austenitizing in atmosphere of nitrogen and toluene was higher than hardness of unthreaded part of that bolt.

The results allowed to find out that the initial peening of specimens before carburization provide for increase of carbon concentration in surface layer during single- and two-stage process of carburization and that thickness of hardened layer grows up after two-stage carburization .

Table 1
Results of measurements of apparent thickness of hardened layer (HV550) for two procedures of two-stage carburization and single-stage carburization.

Item	State of specimen's surface before carburization	Thickness of hardened layer in mm		
		Two-stage carburization		Single-stage carburization
		Procedure I	Procedure II	
1	Ground	0,71	1,03	
2	Peened after grinding	0,82	1,18	
3	Ground			1,05
4	Peened after grinding			1,05
5	Ground			1,0
6	Burnished after grinding			1,0

3.2. Strength researches

Static and fatigue strength tests were carried out on specimens heat-treated according to procedure I and procedure II. In procedure I some series of specimens for test of static and fatigue strength were shot-peened before carburization as described above in item 2.

After procedures I and II all specimens were carburized and heat treated , then ground to remove layer about 0,1 mm. The results of mechanical properties tests are shown in Table 2.

Table 2
Mechanical properties of 18HGT steel specimens for two procedures.

Technological Procedure	Z_{go} [MPa]	R_m [Mpa]	$R_{0,2}$ [Mpa]	R_g [MPa]	T_s [MPa]
Peened and Carburized According to Procedure I	942	1471	1330	4057	2472
Unpeened and carburized According to Procedure I	942	1484	1326	4085	3315
Unpeened and carburized According to Procedure II	922	1482	1127	4476	3057

The compared results of fatigue investigations after procedure I for both types of carburized specimens (peened and unpeened) show that fatigue strength Z_{go} remains on the similar level. The inspection of fracture revealed that initiation of fatigue cracks has appeared on the surface of the tested specimens.

The value of contact fatigue strength T_s for specimens initially peened before carburization was lower comparing with unpeened specimens.

The metallurgy researches carried out till now and removing of 0,1 mm layer by grinding did not give the sufficient information to explain the reasons of lowering of contact fatigue strength on peened specimens comparing with unpeened ones. It requires further researches.

The obtained lower values of fatigue strength both volumetric and contact as well as the apparent yield point of specimens carburized in procedure II comparing with procedure I can be caused by the sma+ller fraction of retained austenite in surface layer in result of cooling down the specimens from the temperature of carburization to the temperature of quenching.

4. CONCLUSIONS

The presented data illustrate that hardening from the lowered temperature (Procedure II) gave the worse results (except R_m and R_g) than the direct hardening from the temperature of carburization (Procedure I).

The results of measurements of specimens peened and unpeened before carburization ascertained:

- the initial peening did not effect the values of Z_{go}, R_m, R_g, $R_{0,2}$;
- reduction of contact fatigue strength;
- higher concentration of carbon in surface layer;
- advantageous hardness distribution in surface layer.

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