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THE FATIGUE BEHAVIOUR, RESIDUAL STRESSES AND MICROSTRUCTURE OF CARBURIZED AND SHOT PEENED LAYERS

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ABSTRACT

The investigations were made with steel Cr-Ni-Mn, used for carburizing.The steel was carburized with various parameters of the process and the different thickness of diffusion layer were obtained. The carburized layers were shot peened and the time of exposition of shot-peened surface was a changing ratio.Value and distribution of residual stresses in carburized layers, carburized and shot-peened ones and the fatigue characteristic of chosen parameters were determined.It was proved that improve of fatigue behaviour is the result of changes of value and distribution of residual stresses caused by shot peening and structural changes in diffusion layer in result of shot peening. The results of investigations of structural changes, observed by the electron microscope, are enclosed.

KEYWORDS

Carburizing, shot peening, fatigue behaviour, residual stresses,structural changes.

INTRODUCTION

The extremely loaded parts of machines such as gear wheels, cams, bolts, working in complex conditions of mechanical, fatigue-volume, fatigue-contact loads and abrasive wear require hardening of surface. This surface hardening has its technical and economical reason. The hardening can appear as a result of structural transformation or dispersion process which occurs in materials in process of heat treatment. In practice all heat treatment methods have been already used up (1). The plastic strain, done by means of mechanical surface plastic treatment eg. shot-peening, results also in hardening of surface layer of machine parts (2). The effects of combining both heat and mechanical processes of hardening are very interesting (3).
In the paper below there are described phenomena, appearing in carburized layers, caused by additional plastic treatment - shot peening, and their influence on fatigue behaviour.

THE PURPOSE AND SCOPE OF INVESTIGATIONS

The purpose of the investigation was to define the influence of shot peening of carburized layers on the changes of features of surface layer (residual stress, structure and fatigue behaviour). The tests, made with Cr-Ni-Mn steel, covered measurements of distribution of residual stresses of the different thickness of diffusion layer before and after shot-peening. Two versions of shot-peening were applied, differing with time of exposure. For one chosen thickness of diffusion layer the fatigue strength limits of carburized specimens as well as carburized and shot peened ones were determined. The results of fatigue tests are shown as Smith's diagram.

MATERIALS FOR INVESTIGATIONS

Tests were made with specimens of Cr-Ni-Mn steel which chemical constitution is in Table 1

Chemical constitution of Cr-Ni-Mn steel Table 1

C	S	Mn	Si	P	Cr	Ni	Mo
0,215	0,017	0,81	0,56	0,021	0,57	0,74	0,16

The form and sizes of specimens were matched to the methodology of each test. All specimens were after heat chemical treatment - carburizing.
Carburizing by gaseous method was done in endothermic atmosphere at temperature 920°C. The specimens for measurement of residual stresses distribution were carburized in various time length to obtain three different thicknesses of diffusion layer: $g_1 = 0,6$ mm, $g_2 = 1,0$ mm, $g_3 = 1,3$ mm. The test pieces for measurements of fatigue strength and static strength were carburized to the depth $g_2 = 1,0$ mm. After carburizing they were quenched and tempered in temp. 170 °C within 1 h. The thickness of diffusion layer was determined by measuring of distribution of hardness. The given values are the conventional thicknesses of diffusion layer HV 550. The chosen part of carburized specimens assigned for investigations, was shot peened. Shot peening was done by pneumatic method where steel round shot (hardness 400-450HRC, granulation 0,6-1,0 mm) was uses. Air pressure was 0.6 MPa. The length of time of exposure of the surface was decided from the diagram of curve of saturation (Fig.1) and equals
$t_1=5$ s (f=0,35 A), $t_2=10$ s (f=0,37A).

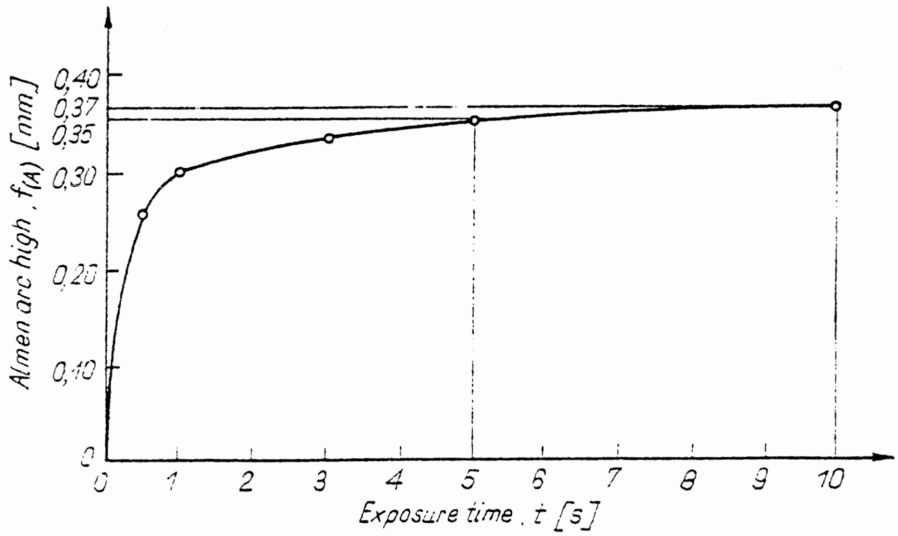

Fig. 1 Shot peening saturation curve.

RESULTS OF INVESTIGATIONS AND THEIR ANALYZE.

Measurement of residual stresses.

The value of residual stresses in function of distance from the surface were measured on the flat specimens (Fig.2) by means of modified Weismann & Philips methods (4,5).

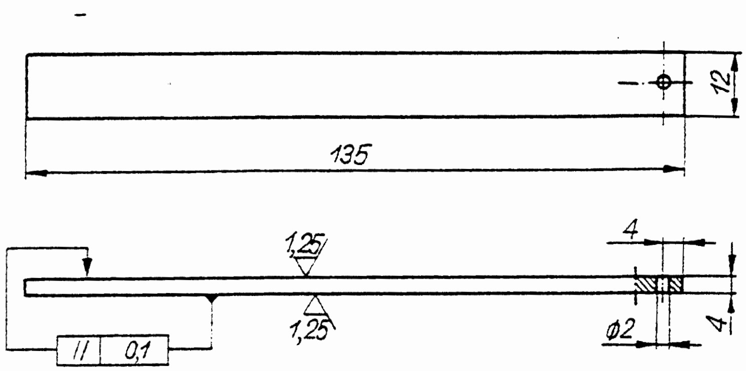

Fig. 2 Specimen for measurement of value and distribution of residual stresses.

The calculation of value of residual stresses in each layer was done basing on the results of measurement of changes of deflection of tested pieces in function of thickness of the removed layer of material. The measurement of pattern of residual stresses value were done on carburized specimens with diffusion layer g_1 =0,6 mm, g_2 =1,00 mm, g_3 =1,3 mm and on carburized specimens with layers of the above thickness and shot peened in time t_1 = 5 s and t_2 = 10 s. The results of measurements of residual stresses value in function of distance from the surface are shown as diagrams:

The influence of thickness of carburized layer on value and distribution of stresses is shown in Fig.3

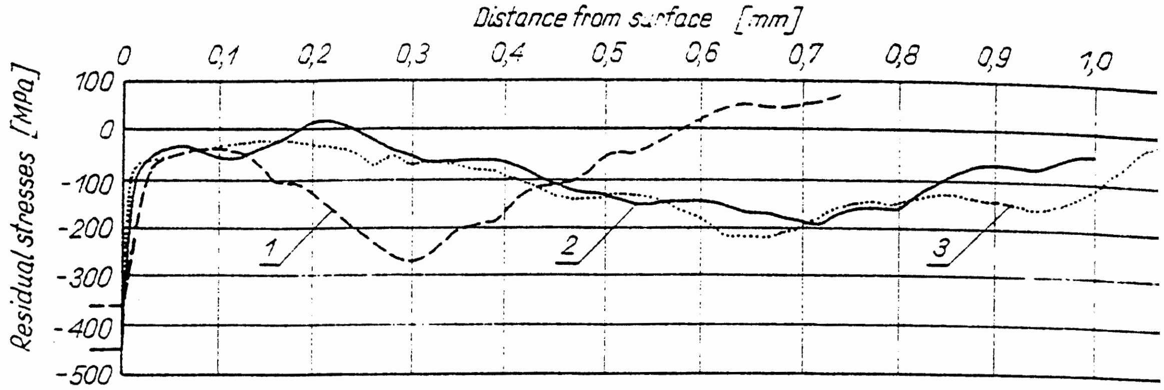

Fig. 3 The influence of thickness of carburized layer on value and distribution of residual stresses.

1 - g_1 = 0,6 mm; 2 - g_2 = 1,0 mm; 3 - g_3 = 1,3 mm.

The influence of time of shot peening on value and distribution of residual stresses in carburized layer 1,0 mm are shown in Fig. 4

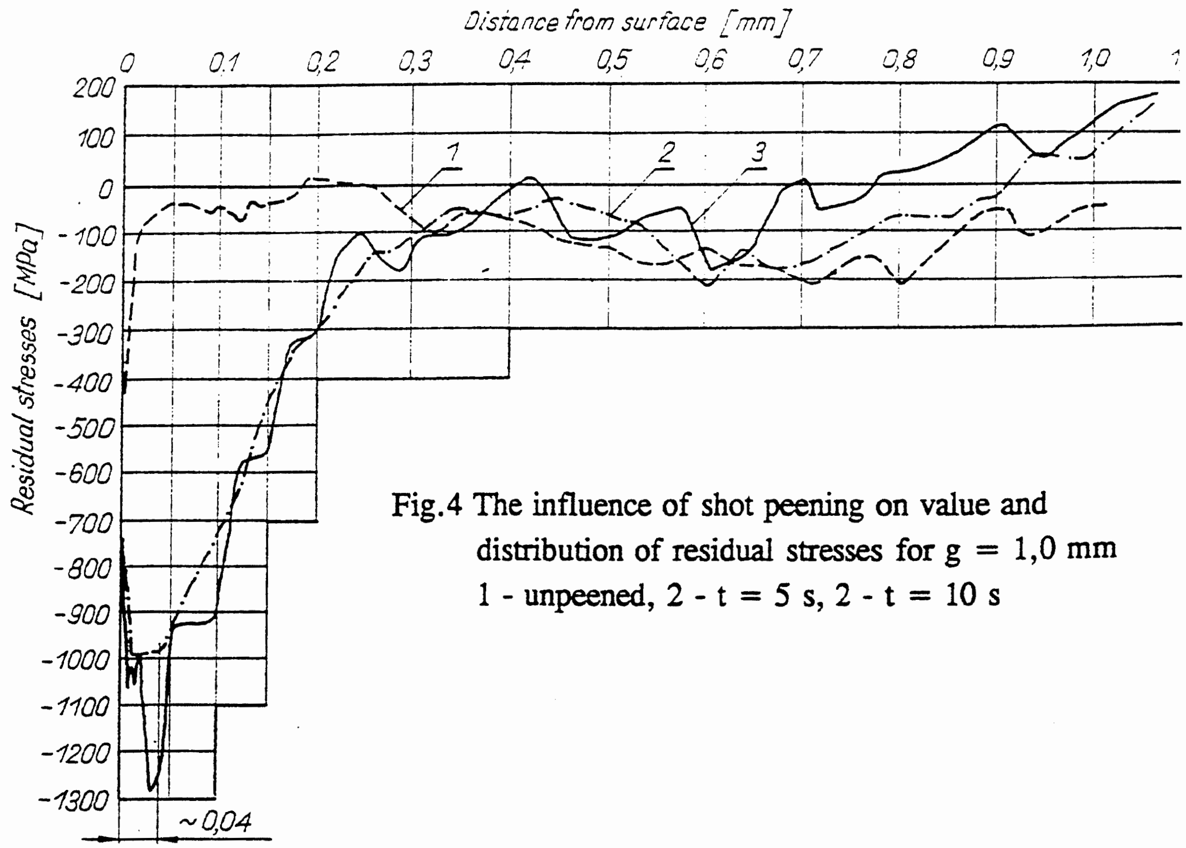

Fig.4 The influence of shot peening on value and distribution of residual stresses for g = 1,0 mm
1 - unpeened, 2 - t = 5 s, 2 - t = 10 s

The influence of thickness of carburized layer on value and distribution of residual stresses after shot peening is shown on Fig. 5.

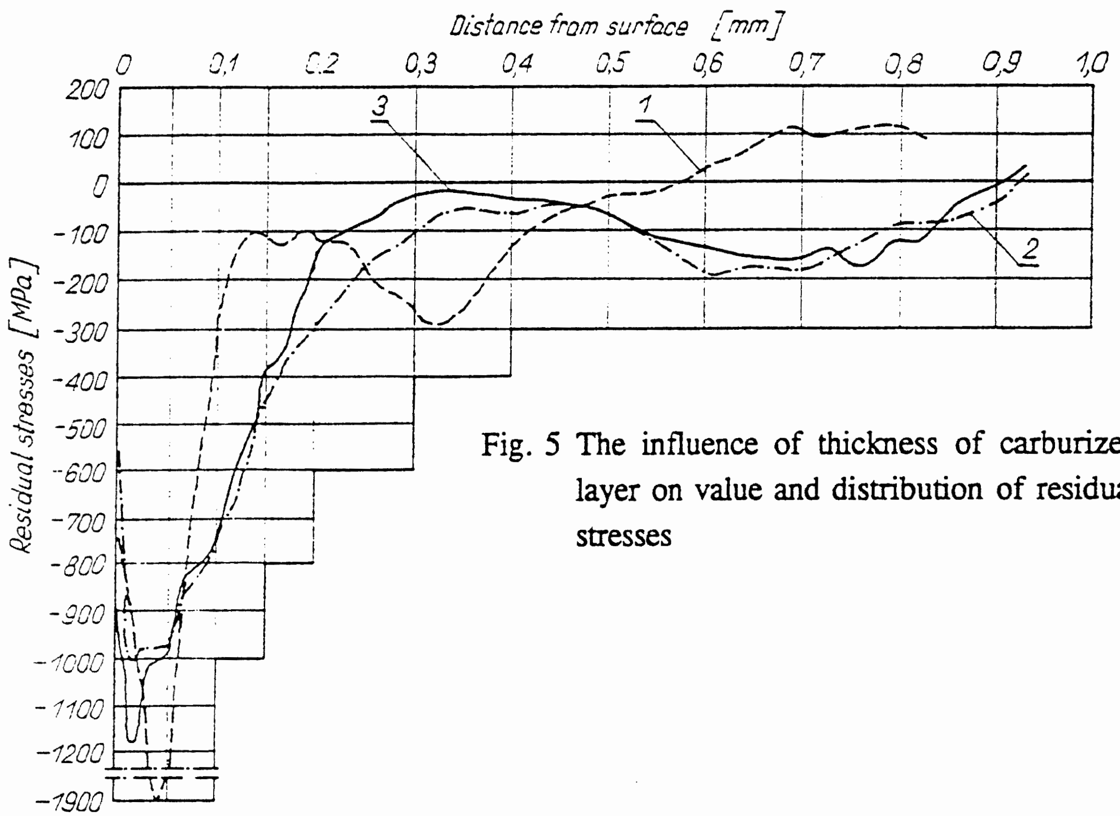

Fig. 5 The influence of thickness of carburized layer on value and distribution of residual stresses

The results of measurements of residual stresses value allow to say that shot peening of carburized surface causes the considerable increase of gradient and maximal values of compressive stresses, which move down from the surface inside the material to the depth 30 - 40 μ. Shot peening causes also the growth of thickness of the layer in which compressive stresses appear. This thickness depends in the variable way on the thickness of diffusion layer. The extension of shot peening time causes the further increase of values of maximal compressive stresses with their very small movement into the depth of material (6). The highest values of maximal compressive stresses σ=1800 MPa appears in specimens carburized to the depth of 0,6 mm and shot peened in time t = 10 s.

Testing of fatigue strength

Testings of fatigue strength were done on specimens which size and dimensions are shown in Fig.6 (stress concentration factor α=1,02).

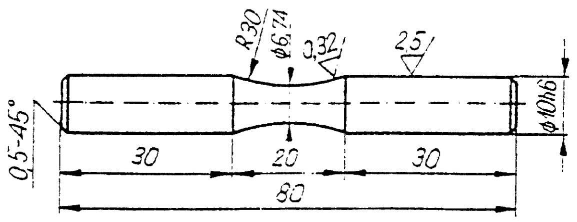

Fig. 6 Specimen for testing fatigue strength

The specimens, carburized to the depth 1,0 mm were tested. The percentage of carbon on the surface of carburized layer = 0,8%, hardness 62HRC. There were also tested specimens carburized as above and additionally shot peened in time t=5 s with intensity f=0,35 A (7).The investigations were made in condition of one-size, four-point bending on the testing machine 10HFP-422 manuf. by Amsler with reciprocating movement of the element loading the specimen. To obtain the effect of bending a special attachment which allow to obtain a constant bending moment on the gauge length of the specimen was used. The assumes base of testing $N_G = 10^7$ cycles.Medium value of stress cycles σ_m was taken as a fatigue strength limit. Tests were made for various values of stress ratio R=0,1, R=0,3, R=0,6. The received values of safe fatigue life for Cr-Ni-Mn steel carburized as well as carburized and shot peened are shown in Table 2 and as a diagram in Fig.7.

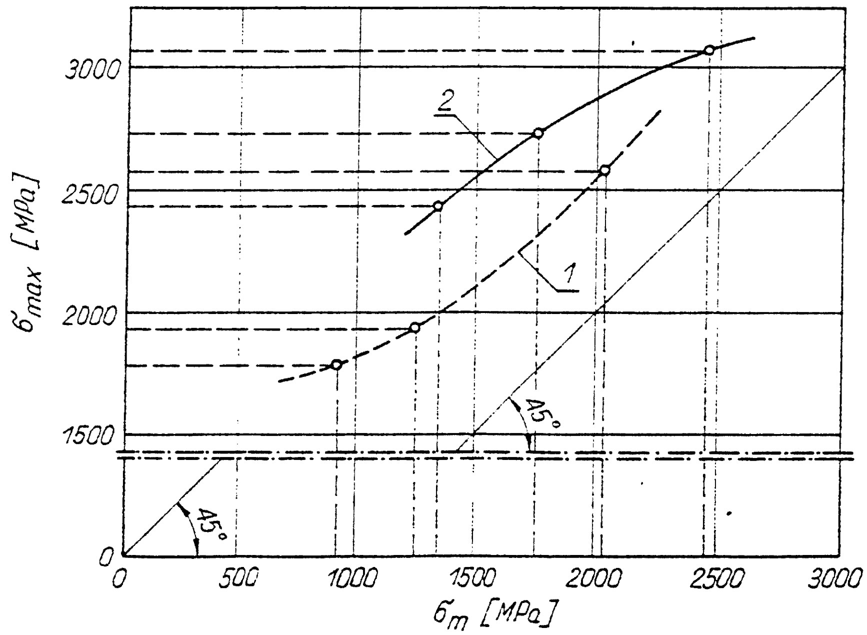

Fig.7 Fatigue strength of steel Cr-Ni-Mn

The value of fatigue strength limit for carburized steel depends on values of stress ratio and at R=0,1 equals σ_m=976 MPa and at R=0,6 σ_m=2057MPa. The process of shot peening caused the increase of fatigue strength limit from 13,7% to 50% depending on stress factor R.

Value of fatigue strength limit

Table 2

	Stress ratio R = 0,1		R = 0,3		R = 0,6	
Stress MPa	Carb.	Carburized and shot peened	Carb.	Carburized and shot peened	Carb.	Carburized and shot peened
σ_{max}	1775	2449	1918	2734	2571	3061
σ_{min}	178	245	575	820	1543	1836
σ_m	976	1347	1247	1777	2057	2449

Structural investigations

The influence of surface plastic treatment on the changes of structure in carburized layer were tested. The tests were made on specimens with dimensions 0,5 x 5 x 20 mm. From these test pieces the disc-shape leafs, dia. 3 mm, thickness 100 μ were taken. Electron microscope JEM 1000 C was used for testing.
The structure of carburized layer before plastic strain is shown in Fig.8. The structure of tempered martensite with numerous dispersions of cementite is well seen.

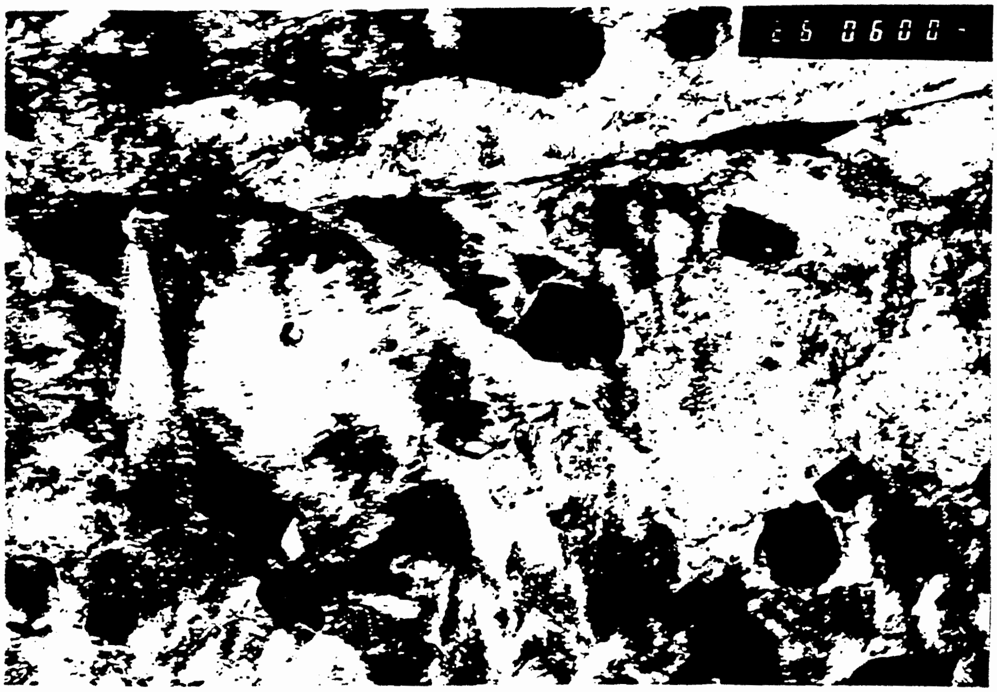

Fig. 8 Structure of steel before plastic strain - austenite aeries well seen multipl. x 42 000

As a result of plastic strain in the areas where cementite has appeared the martensite phase (Fig.9) and dispersive separations in martensite phase (Fig.10) are seen.

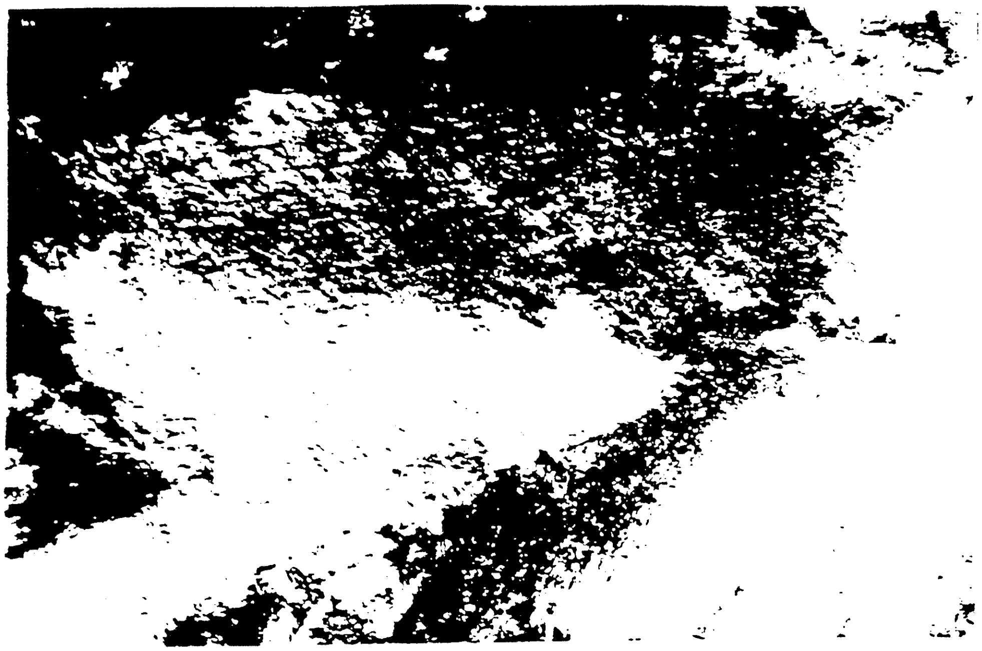

Fig. 9 Structure of steel after plastic strain - martensite aeries with dispersive separations of phase ϵ. multip. 50 000 x.

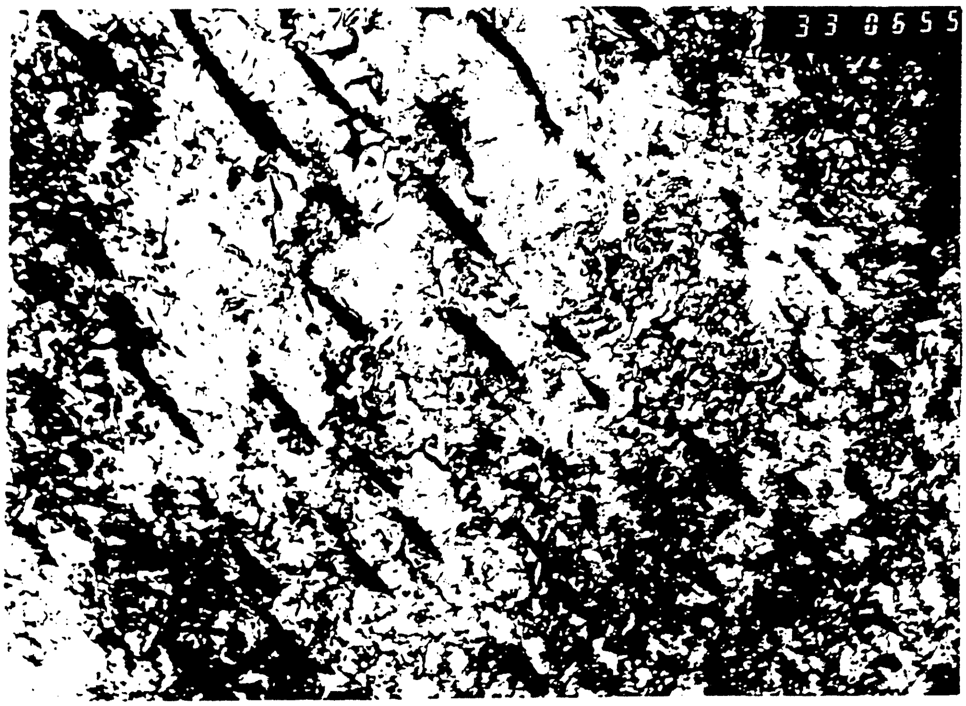

Fig 10 Structure of steel after plastic strain - structure of martensite with dispersive separations - multipl. 50 000 x

Diffractomerical tests have shown that phase ϵ (Fe_2C and Fe_3C) occurs (8).
The testing of changed of structure in carburized layer caused by surface plastic treatment show the reason of its hardening defined as the increase of compressive residual stresses. As the result of plastic strains, the plastic changes - destruction of austenite, arising of martensite and appearing of new phases type ϵ - are observed

CONCLUSIONS

The described above process of global influence of heat treatment and mechanical surface plastic determination on the hardening of surface layer has a great practical meaning. It allows to increase the fatigue strength even by 50% comparing to processes without surface plastic determination. It comes out from the above investigations tat the global technological process of forming features of surface layer is not a simple additive one but is requires optimization at processes of heat treatment - volumetric and surface one and at process of plastic determination.

REFERENCES

1. Dahl W, *Verhalten von Stahl bei Schwingen der Beanspruchung*, Verlag Stahleisen M.B.H,., Dusseldorf p.103-113

2. Nakonieczy A, *Umocnienie przez kulowanie*, Materiały konferencyjne *Techniki wytwarzania warstw powierzchniowych metali*, Rzeszów, 1988

3. Nakonieczny A, *Podwyższenie wytrzymałości zmęczeniowej części maszyn przez obróbkę cieplną i powierchniową obróbkę plastyczną*. Materiały XXIV Seminarium IMP, Warszawa, 1984.

4. Weismann I L, Philips A. *Simplified measurement of residual stresses*. Proc. of the Society Experimental Stress Analysis. t.XI p.29, 1954

5. Szyrle W, Janowski St, *Stanowisko do pomiarów rozkładów napręźeń własnych w elementach o postaci płaskich pretów.* MOC, nr 37, p,42, 1979.

6. Szyrle W, Maziewski A, Kamowicz S, *Określenie optymalnych parametrów części maszyn po nawęglaniu.* Sprawozdanie IMP nr 114.00.0127, Archiwum IMP, not published.

7. Nakonieczny A, Cichowicz L, Babul T, *Określenie własności mechanicznych uzyskiwanych w kombinowanych procesach obróbki cieplnej i plastycznej*. Sprawozdanie IMP nr. 114.00.0001, Archiwum IMP, not published.

8. Nakonieczny A, *Ocena i podwyższenie efektywności metod powierzchniowego umacniania części maszyn.* Praca habilitacyjna, Moskwa, 1991.