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THE VOLUMETRIC SURFACE HARDENING OF HOLLOW AXISYMMETRIC PARTS BY ROLL STAMPING METHOD

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ABSTRACT

The article provides information on how to hardening treatment hollow rotationally symmetric parts by severe plastic deformation, which is based on the method of roll forming. The information about planning and analysis of the results of experimental research has been considered. It was established that the method allows getting combination of gradient hardening from processed surface and significant thickness of hardened layer.

Keywords: hardening, roll stamping, intensive plastic deformation, gradient hardening.

INTRODUCTION

At present time the demand on machines parts production, having higher mechanic and service properties grows. It is caused by the fact that the given products are maintained under tough terms of alternating and impulse loadings, high and changing temperature, heightened deterioration and hostile environment.

Also to the same parts the demand of clearance minimization and limitation is raised and in some cases a limitation on used materials is imposed. For solving same class of problems constructors adhere to a principle of maintenance of optimum values of strength properties at minimization of expenses for manufacture.

The traditional solution of this problem is the application of one or another method of hardening processing.

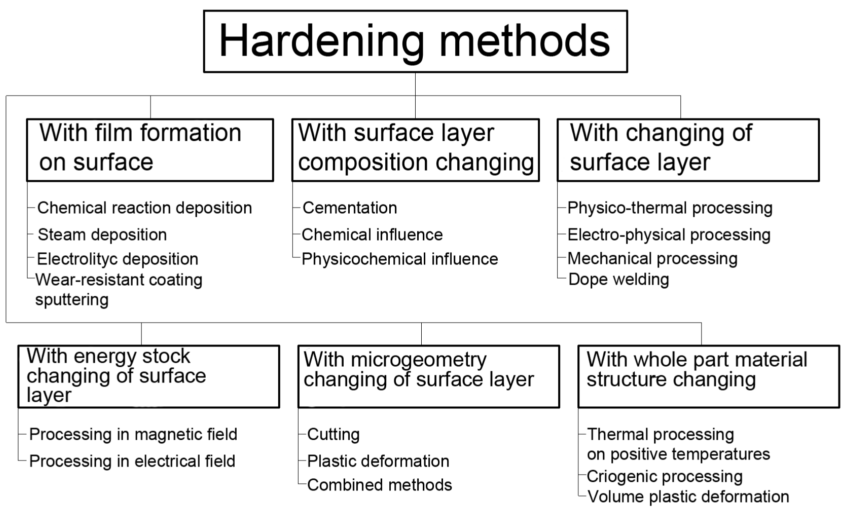

Fig. 1. Methods of hardening processing.

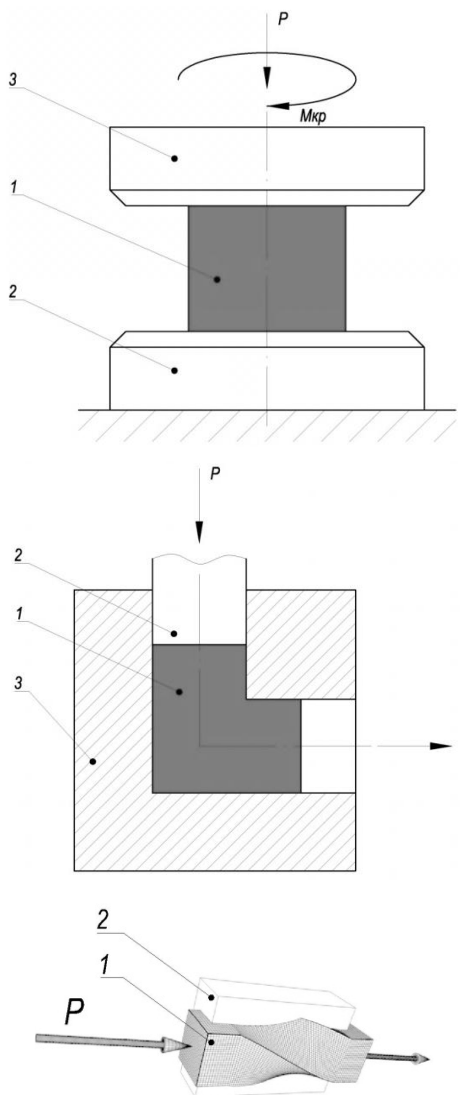

Fig. 2. Intensive plastic deformation (IPD) processing schemes: high pressure torsion: 1 – part; 2 – anvil; 3 – die; b) equal-channel angular pressing (ECA pressing): 1 – part; 2 – male die part; 3 – female die; c) spiral extrusion: 1 – part; 2 – spiral female die.

At present time there are most extended methods of hardening processing, presented on Fig. 1 [1 - 5].

The groups from the first to the fifth methods of surface hardening are composed and they have the following lacks:

- significant interfacial stresses, bound rises between the hardened and not hardened zones;
- sharp edge of transition from hardened zone to not hardened;
- small depth of hardening;
- high required power and related expenses on thermal, thermo-chemical and current processing.

Most fully to these requirements observed at the beginning satisfy methods of the sixth group, particularly - the volumetric deformation methods (Fig. 2).

The classic example of high pressure torsion (Fig. 2a) is the Bridgman anvil. Processing implementing by upsetting of the part, placed between die and anvil, with simultaneous torsion. Such kind of processing allows to obtain high deformation ratio and as consequence considerable hardening of the processing part. However important limitation on parts assortment, produced by these method exists - non hollow axisymmetric, cylindrical and disk form parts.

ECA pressing (Fig. 2b) consists in part pushing, usually the rod, through profile female die path by means of male die part. On the each next processing iteration the part rotates to certain angle and processing repeats. As high pressure torsion this method allows to obtain considerable cold hardening degree, also ability of not only cylindrical parts production, but also profile parts production presents. To the lacks of this method the distortion of original geometry chargeable to the account (Fig. 3), whole part hardening and considerable required processing power.

Spiral extrusion [6] (SE) consists of part pushing through spiral female die path which profile corresponds to the part profile. To the lack of this method one can mention the loss of the original geometry and whole part hardening chargeable to the account.

Summarizing aforesaid the lacks of volume plastic deformation methods can be picked out:

- whole part hardening, that not required in most cases and leads to its embrittlement;
- requirement in high coast and as a rule power-

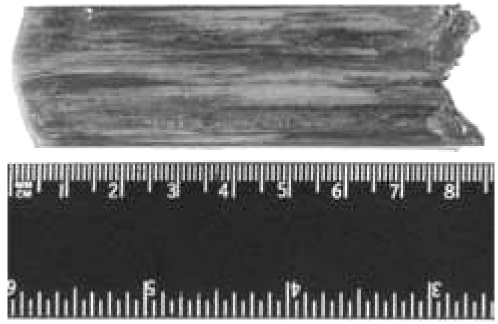

Fig. 3. The rod after ECA pressing [6].

consuming equipment, since at volume plastic methods realization the processing connected with whole part loading that leads to high requirement deformation strengths.

One of perspective methods based on intensive plastic deformation (IPD) is the modification of roll stamping (RS) method [1] consisting in combination of complex monotonous whole part loading by means of male die part or clench crossbeam and periodic local loading of deformation zone by rotary driven rollers or wheels.

It is necessary to carry of the advantages of the given method: low required processing strengths that is a consequence of partially complex-local loading character.

In its original form the RS method used for required form axisymmetric parts obtaining i.e. result is the ultimate forming.

TECHNOLOGY

On the base of RS the hardening processing method was developed by composite author of State University – Education-Science-Production Complex [7, 8], allows gradient hardening of processed surface in aggregate with high cold hardening degrees obtaining.

Advantages of this methods concerns low required processing strengths and the ability to obtain gradient of processed surface hardening.

But in spite of the advantages these methods have lacks. The method in [7] allows outer surface processing but as aforesaid the working surface of bush like parts is the inner, for example - sliding bearings. The method in [8] allows inner surface processing but the lack consists of original geometry distortion on the strength of metal spreading towards end faces.

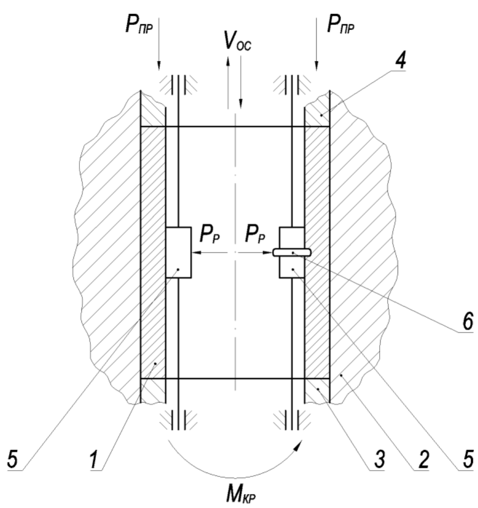

Fig. 4. The inner surface hardening method of bush type parts by roller running [9]: 1 - part; 2 - container; 3 - hold-down tool; 4 - abut; 5 - rollers; 6 - deformation rib.

Thus, actual becomes the development of the hardening method, summarising the advantages of methods [7, 8],namely:

– inner surface processing possibility of bush type parts;

– the processing must realize in terms of rolling friction otherwise sliding friction.

Following aforesaid the hardening method [9] was developed (Fig. 4).

The method can be described as follows: Part 1 puts into container 2 thereby it fixes. Axial limiters are hold-down tool 3 and abut 4. After that the process tool, consists of rollers 5, some of those are smooth but one or more have deformation rid 6, bringing into part cavity. Rollers pressed to the part 1 with the force P_p. To the processing tool relays twisting moment M_{kp} and axial move with constant speed V_{oc} [9].

At processing in part rises local dispensing deformation zone near dispensing rib on deforming roller. Since deformation rib has chamfered form the metal dispensing aside of it and axial tensile deformation at uniform compression conditions arises. At contact place of part inner surface with smooth rollers the limited by contact spot wringing out zones arises i.e. deformation zones of reversed sign, besides stressed state defines by essential negative hydrostatic component and dispensed metal returns to its original place.

Such character of the part deformation leads to alternating strain accumulation in processing material and as consequence the part material hardening goes with original geometry conservation and gradient of inner surface micro- and nanocrystaline structure formation to the given depth which defines by rollers pressing force to processing part.

EXPERIMENTAL

Experimental research [10] of method [9] executes using the original equipment, shown on Fig. 5.

The bush processing by shown method is realized by the next way. On lathe machine tool support bar the container (Fig. 5b) places by tail piece 1. Then part places into it and fixes by abut 5. Required pressing force cre-

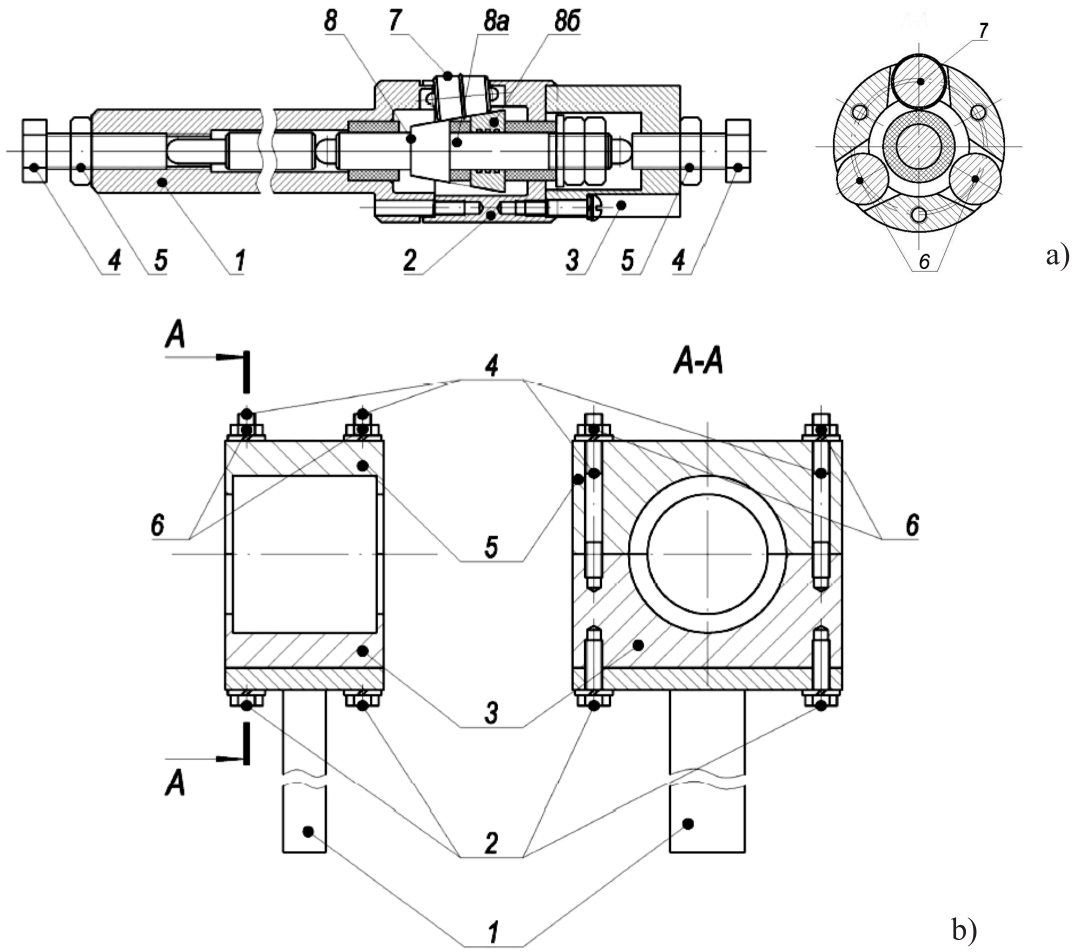

Fig. 5. Scheme of developed experimental equipment: a) burnisher: 1 - body; 2 - cage; 3 - hold-down tool; 4 - setting screw; 5 - lock nuts; 6 - smooth rollers; 7 - deforming rollers; 8 - abut; 8a - the abut part that active about body; 8b - the part that active about part 8a; b) container: 1 - tail piece; 2 - fastening bolt; 3 - hold-down tool; 4 - double-end bolt; 5 - abut; 6 - draw nut.

ates by nuts 6. Into three-jaw chuck by tail piece 1 (Fig. 5) the burnisher places. Then on lathe machine sets up required technological parameters, angular motion impacts to mainspindel and sliding feed to tool support bar.

The processing consists of a number of back-and-forth axial motions of container with the part relative to spinning burnisher.

The deform rollers 7 (Fig. 5a) depth tuning realizes by setting screw 4 rotating. Rollers 6 and 7, moves on conic abut, mounted into body 1 and cage 2 tunes to required diameter. After that setting screw fixation of radial torsion realizes by lock nuts 5, i.e. in that case the form-closure scheme realized this allows us do not control the rollers 6 and 7 pressure force to processed surface, which is required at force-closure scheme.

On experimental research holding the n - number of processing cycles and S - tool axial move step was accepted as scaleable parameters.

HV_{max} – maximum cold hardening degree and h_{max} – maximum depth of hardened zone was accepted as controlled parameters.

Also the hypothesis was putted forward about:

– number of processing cycles n have more influence on cold hardening degree while axial move step S have minimum influence;

– axial move step S have more influence on hardened zone depth while number of processing cycles n have minimum influence;

For hypothesis checked up the Table 1 of experiment parameters that contains the parameters used to

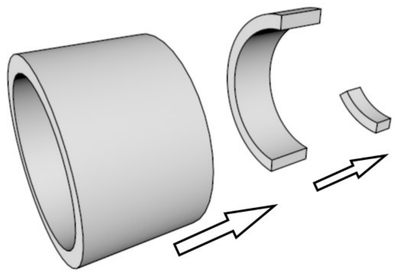

Fig. 6. The specimen piece obtaining for microstructure and cold hardening degree research.

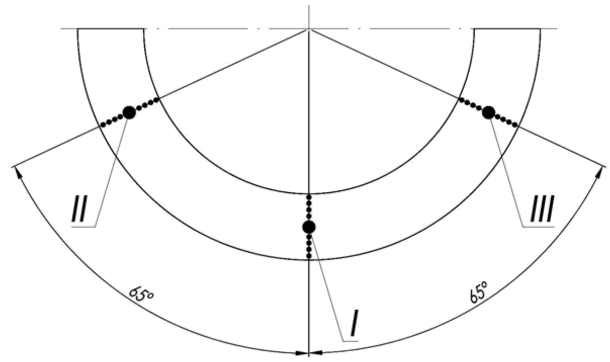

Fig. 7. The spread of microhardness measurement scheme I, II, III – microhardness measurement ways

experimental equipment has been made.

The processed parts preparation to microstructure and cold hardening degree research was realized in few steps.

At the beginning the piece of cylindrical specimen was obtained (Fig.6).

The spread of microhardness measurement was carried out on radial way (Fig. 7).

In compliance with presented scheme half of part radial middle section divides on three ways along which the series of picks by microhardness gage was executed. It should be remembered that according to state standard specification (SSS) № 9450–76 "Measurements microhardness by diamond instruments indention" distance of specimen edge to imprint center must be not less than double imprint size and distance between imprint centers marked on one surface should be more than three imprint sizes.

Researches conducts with "Center of collaborate usage by control instrumentation" equipment that was created at State University – Education-Science-Production Complex, in particular with microscope AXIOSCOPE MAT-2 with microhardness gage MHT-10 mounted on it.

On the diagrams, shown on Fig. 8, [10, 11], presents microhardness spread for maximum reached durability values - microhardness HV_{max} = 282 and hardened zone depth h = 5 mm with processing parameters: n = 30, S = 0.5 mm.

Analyzing the shown diagram it is possible to conclude that hardening of processed material have a gradient character with no pronounced transition of hardened to non-hardened zone bound. To maximum hardening degree the number of processing cycles has more influence and tool axial move step has minimum influence since on more numbers of processing cycles we can obtain more accumu-

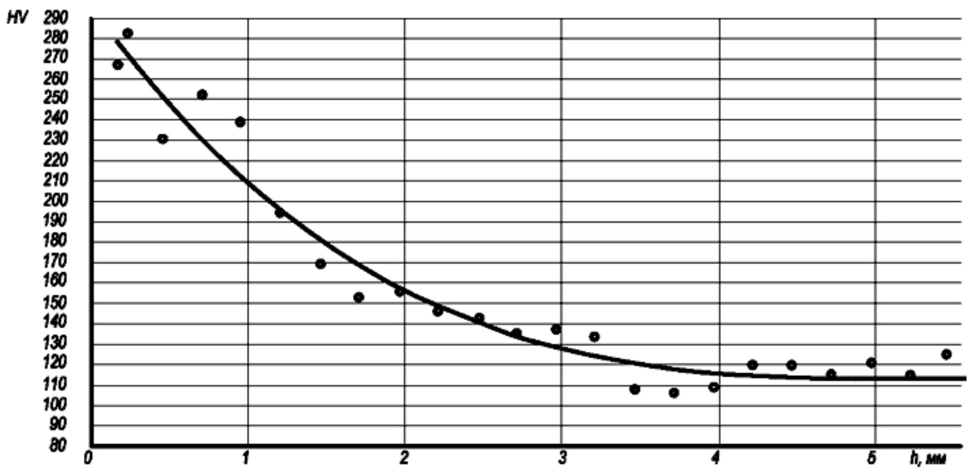

Fig. 8. Specimen microhardness spread diagram at n = 30, S = 0.5 mm as a function of the hardened zone depth.

Table 1. Experiment parameters.

Parameters	Value			
The part				
Material	БрОЦС 5-5-5			
Outer diameter *D, mm*	70			
Inner diameter *d, mm*	50			
Length *L*, mm	50			
The tool				
Deformation rib width R_{rib}, *mm*	1			
Processing				
Number of processing cycles *n*	15	20	25	30
Axial move step $h = x \cdot R_{rib}$		0.25		
	0.5			
		0.7		
		1		

lated deformation degrees than with the axial move step value variation. To maximum hardened zone depth axial move step has main influence and number of processing cycles has minimum influence. Such effect explained by minimization of overlapped cold hardening zones, created by deform roller on neighboring coils at greater axial move step value. In that case cold hardening of surface layer goes less intensive that creates more favorable conditions for plastic deformation penetration deep down.

Also geometry parameters study was carried out - inner diameter and circular deviation measurement (EFK). For example the parts with beginning parameters d_0 = 50 mm и EFK_0 = 10.98 µm after processing with controlled parameters n = 15, S = 0.5 become d = 50 mm и EFK = 18.66 µm. Hence ascertained that the inner diameter value does not change and circular deviation value changes insignificantly. However it is necessary to note that the changes includes into after processing tolerance that is not a lack.

On Figs. 9 and 10 are shown the processed surface condition photos at different processing parameters.

Fig. 9. Processed surface condition of the specimens at $S = 0.5 \cdot H_{rib}$: a) $15 < n < 25$; b) $n \geq 30$.

It is necessary to remember that before critical number of processing cycles achievement the processed surface condition is satisfactory – without visible processing defects (Fig. 9.a) and on achievement of critical number of cycles further hardening becomes unreasonable since surface layers achieves maximum cold hardening degrees and peels and crumbles appear (Fig. 9b).

The axial tool move step value variation also has an effect on surface condition:

– with it increasing the screw line of deform roller

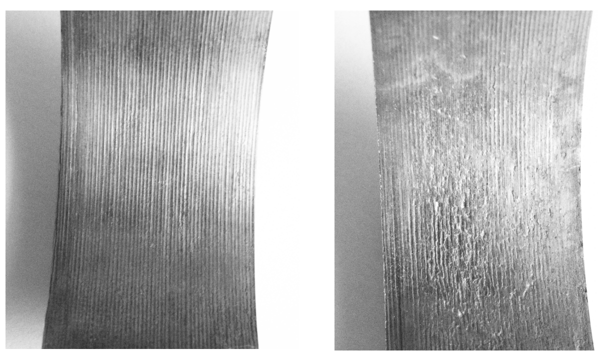

Fig. 9. Processed surface condition of the specimens at $S = 0.5 \cdot H_{rib}$: a) $15 < n < 25$; b) $n \geq 30$.

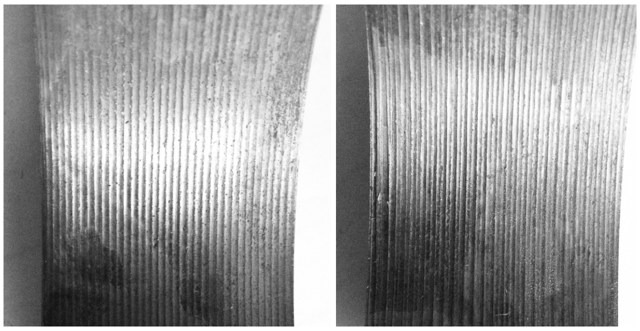

Fig. 10. Processed surface condition of the specimens on axial move step variation at: a) $S = 0.7 \cdot H_{rib}$; b) $S = 1.0 \cdot H_{rib.}$

rib becomes apparent more clearly ($S > 0.5 \cdot H_{rib}$) (Fig. 10a and 10b);

– on $S < 0.5 \cdot H_{rib}$ processing surface material cut off occurs that makes further deformation impossible.

The microstructure research also has been carried out at "Center of collaborate usage by control instrumentation".

For microstructure research specimens has been sawed up to 4 pieces and after that the small segment was sliced of it (Fig. 6).

The specimen preparation undergoes three phases:

The specimens has been subjected to grinding by abrasive paper with abrasive grain gradually decreasing from big (400 - 500 µm) to small (14 - 20 µm);

The grinding surface polish with special polisher and polish paste on base of green rouge III;

Polished surface has been etched by 5% trivalent chloric iron solution on 10% hydrochloric acid;

As relevant to cast alloy [12 - 14] the non-processed part has dendrite structure (Fig. 11). According to [14] this type of structure leads to material mechanical characteristic irregularity. On this photo the dendrite grain seen clearly (dark areas) and the solid solution (light areas) takes up the space between them besides the classical grained structure is absent. That proved by Fig. 12.

On Fig. 13 and 14 the microstructure of hardened

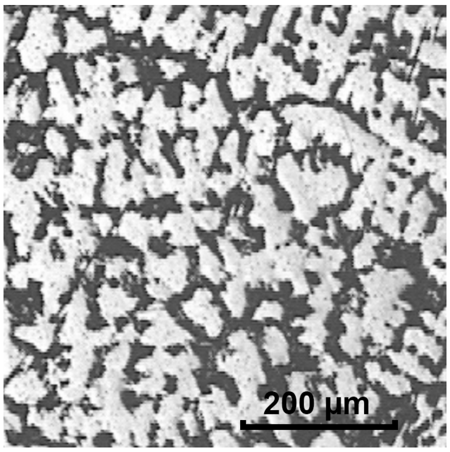

Fig. 11. Non-processed part microstructure at 50x.

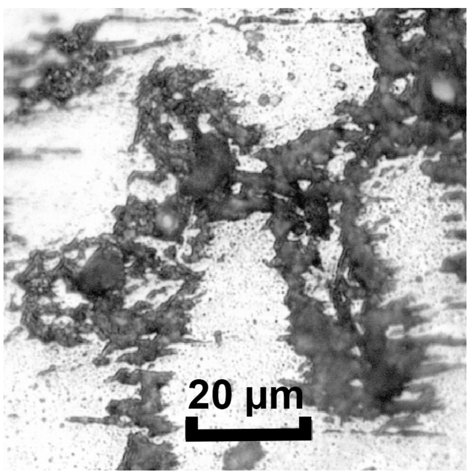

Fig. 12. Non-processed part microstructure at 1000x.

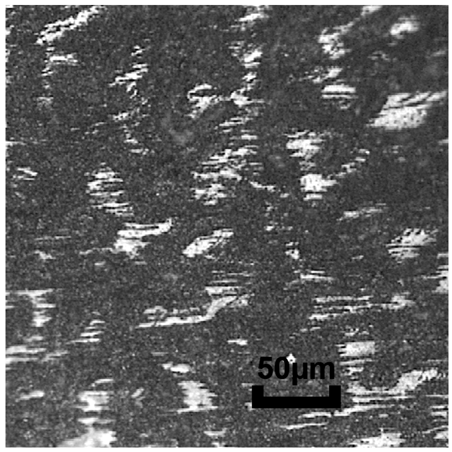

Fig. 13. Hardened zone middle at 200x.

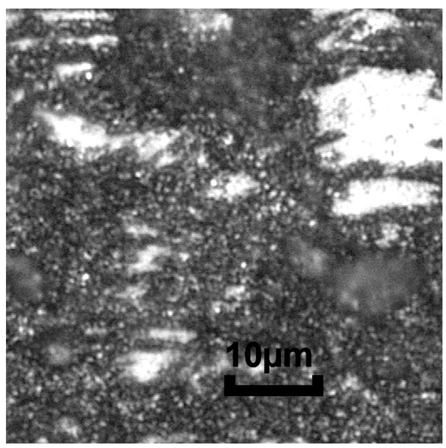

Fig. 14. Hardened zone middle at 1250x.

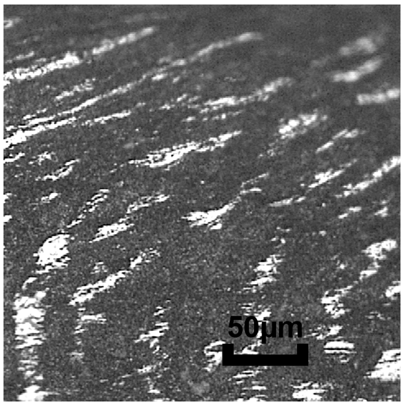

Fig. 15. Maximum hardening zone microstructure at 200x.

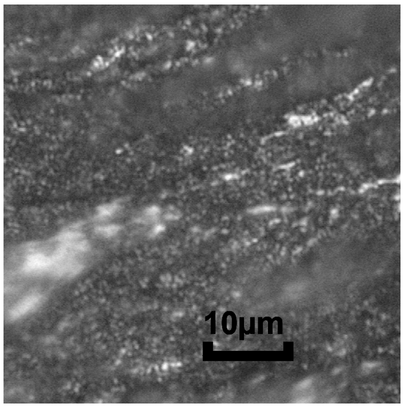

Fig. 16. Maximum hardening zone microstructure at 1250x.

middle zone has been shown. Crumbling of structure elements is scoping in comparison with non-hardened zone. The specimen areas with that structure type has the microhardness parameter value about 120 - 130 HV.

On Figs. 15 and 16 the maximum hardening zone microstructure is shown. The further subdivision and texturing of microstructure - extending to tool rotation way is noticeable. Averaged size of structure elements of this area is about 100 - 200 nm. The specimen segments with that structure has microhardness parameter value about 160 - 170 HV (for processing parameters that has been considered).

It is important to notice that in processed area the dendrite structure that relevant to cast alloys has been disappeared that promotes smoothing mechanical characteristics of processing parts.

CONCLUSIONS

Hence, on the base of aforesaid established:

- The actuality of new hardening methods has been explained. Advantages of hardening methods by pressure processing has been shown;
- New technology which excludes lacks of existing hardening methods has been described;
- It is established that the hardening has gradient character. Parameters considered in this article were: maximum microhardness parameter value HV_{max} = 282 and maximum hardened zone depth h_{max} = 7mm. It should be noted that strong boundary between hardened and non-hardened zones is absent, that favorise the performance characteristics;
- In compliance with hardening gradient character the microstructure changes of relevant to cast alloys dendrite type to highly dispersed structure as far as hardening degree grows. The grain size on maximum hardening area is about 100 - 200 nm.

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