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# RESEARCH REGARDING THE SUPERFICIAL HARDENING OF TOOLS THROUGH NEW HASTY TREATMENT WITH BORON-CARBON-VANADIUM

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***Abstract:*** *The proposed technology presents a level of complexity and novelty represented by the following considerations. The manufacturing of the cold forming tools and the wearing machine parts will be done by replacing the existing classical tools made of carbon steel type OSC10 and alloyed steel type 90VMn20, 205Cr115, with quality carbon steel type OLC 15, and alloyed steel for machines manufacturing type 15Cr9, and 21MoMnCr12. The complexity results from the correlation of the results obtained in accordance with the process entry data (the by-product chemical composition, granular mixture chemical composition, boron-carbon-vanadium paste chemical composition, the determined ratio between the granular mixture weight in the kiln) and the piece weight as also determined thermo-physically parameters as: temperature, time, electrical resistance, current density, fuel speed and the recordings obtained at the end of the process (mechanical and structural properties obtained after the thermo-chemical process in comparison with the cold forming tools and wearing machine parts obtained as a result of the classical method).*

***Key words:*** *superficial hardening, boron, carbon, vanadium.*

## 1. INTRODUCTION

The general direction on global level regarding light auto components manufacturing with high physical-mechanical properties is to manufacture this type of items of multi-layers which combine the following properties: fatigue durability, elasticity and hardness (the capacity to resist to the required efforts) [1]. The international improvements had succeeded in an increased fatigue durability for forming tools and wearing parts and a increased exploitation time, with a high elasticity that is capable to take the tensions in the exploitation process [2, 3, 5].

In Romania, the cold forming tools like stamps, dyes, poansons, pulling mandrels, tools for cold rolling and wearing machine parts are made of carbon steel for tools and alloyed steel as blocks as one can see in Table 1.

The manufacturing of the cold forming tools and the wearing machine parts will be done by replacing the existing classical tools made of carbon steel type OSC10 and alloyed steel type 90VMn20, 205Cr115 , with quality carbon steel type OLC 15 and alloyed steel for machines manufacturing type 15Cr9 and 21MoMnCr12. The complexity results from the correlation of the results obtained in accordance with the process entry data.

Machine parts that are subject of stress (like axes, shafts, pressure valves,) are made of tool carbon steel and alloyed steels for thermal resistance.

The main considered activities are the following:

- the parts obtained using this new technology will have the same quality with the items produced all over the world and with more simple and cheaper installations, that will be more easy implemented on the existing technological lines;

*Table 1*

**Material and technological procedure for cold forming tools**

| No. art | Tools for cold forming | Material- Mechanical properties | Technological procedure |
|---|---|---|---|
| 1. | Polling mandrels and bung, removing mandrels, cold forming dyes, tools for extrusion | OSC 10<br>HB: 197daN/mm$^2$<br>HRC: 58–62 | Steel manufactured in electric kiln, + rolled, annealed, mechanical machining, quenched + low tempered |
| 2. | Poansons, tools for wire | OSC 13<br>HB: 217daN/mm$^2$,<br>HRC: 56–64 | Steel manufactured in electric kiln, + rolled, annealed, mechanical machining, quenched + low tempered |
| 3. | Stamps, dyes, tools for threading | 90VMn20<br>HB: 220 daN/mm$^2$<br>HRC: 57–62 | Steel manufactured in electric kiln, + rolled /Forged, annealed, mechanical machining, quenched + low tempered |
| 4. | Dyes, puncheon, pooling mandrels, tools for cold rolling, extrusion | 205Cr115<br>HB: 248 daN/mm$^2$<br>HRC: 58–64 | Steel manufactured in electric kiln, + rolled /Forged, annealed, mechanical machining, quenched + low tempered |

*Table 2*

**Material and technological procedure for machine parts**

| Nr. crt | Machine parts that are subject of stress | Material - mechanical properties | Technological procedure |
|---|---|---|---|
| 1. | axes, shafts, pressure valves | 40Cr10<br>$R_C$: 780 N/mm$^2$,<br>Rm: 980 N/mm$^2$<br>$A_5$: 10%,<br>KCU: 53 J/cm$^2$,<br>HB: 217 daN/mm$^2$ | Steel manufactured in electric kiln, + rolled/ forged, quenched + annealed, mechanical machining, quenched + high tempered |
| 2. | Pins, shafts, axes | 21MoMnCr12<br>$R_C$: 880 N/mm$^2$,<br>Rm: 1080 N/mm$^2$<br>$A_5$: 8%,<br>KCU: 68 J/cm$^2$,<br>HB: 217 daN/mm$^2$ | Steel manufactured in electric kiln, + rolled/ forged, annealed, mechanical machining, quenched + low tempered |
| 3. | Planetary axes, nuts, | 34MoCr11<br>$R_C$: 830 N/mm$^2$,<br>Rm: 1000–1200 N/mm$^2$<br>$A_5$: 11%,<br>HB: 223 daN/mm$^2$ | Steel manufactured in electric kiln, + rolled/ forged, annealed, mechanical machining, quenched + low tempered |
| 4. | Axes, nuts | 42MoCr11<br>$R_C$:780 N/mm$^2$,<br>Rm: 1100–1300 N/mm$^2$<br>$A_5$: 10%,<br>HB: 241 daN/mm$^2$ | Steel manufactured in electric kiln, + rolled/ forged, quenched + tempered annealed, mechanical machining, quenched + low tempered |

- establishing of the complex technologies with industrial applications for obtaining the boron-carbon-vanadium layers of the hard carbon and light alloyed steel;
- behavior analysis of the cold forming tools: contact pressure, compression, weariness usage, fatigue, mechanic–thermal shocks;
- thermal treatment action on material mechanical proprieties - observing the remaining tension;
- solving the physical-chemical phenomena that appear between the heating electrodes, heating granular mixture and metallic part that lead to the forming of the diffusion layer;
- study of the thermo–physical parameters of the kiln heating process;
- determination of the concentration;
- determination of the primary and secondary heat treatment influence;
- determination of the ratio between the part weight and granular mixture weight for every item, for a best heating efficiency [4];
- determination of the correlation between the X penetration of diffusion element and the heating time *t*;
- study of the dimension characteristics, possible geometric deformation that may occur during the heating and the tension study for the correlation with heating thermo–physic parameters;
- distribution of the components in the layer treated with boron-carbon-vanadium;
- manufacturing of the installation for testing and applying of this technology.

## 2. RESEARCH AND OBTAINED RESULTS

The proposed technology should replace the classical manufacturing variants of cold forming tools and wearing machine parts made of alloyed steel blocks with a simplified technological variant as number of phases and technological operations in the alloyed and superficial hardening variant for carbon-steel and light alloyed, that can be done with minimal investments on the existing technological lines in the specialized company.

A boron-carbon-vanadium paste will be applied on the surface of steel parts. These parts will be packed in a carbon-electric conductor granular graphite mixture, in the cubical interior of the experimental kiln and coupling the system to an electrical circuit powered by a converter with a secondary tension between 50 and 100 V and intensity between 250 and 1000 A.

The direct heating of the material in the kiln and keeping the required temperature for the thermo-chemical

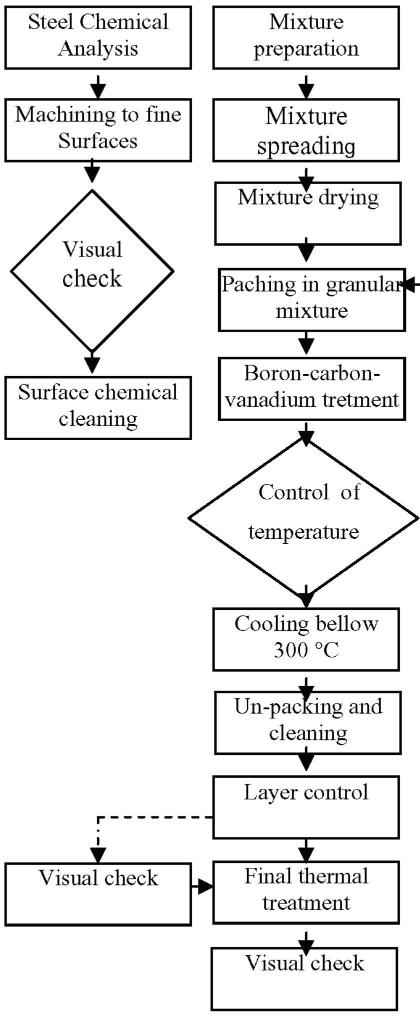


**Fig 1.** Technologic production line for new hasty treatment with boron-carbon-vanadium.

treatment for a period of 1–4 hours, which will ensure an superficial alloyed and hardened layer through structural finishing with a secondary thermal treatment (quenching + tempering) [8].

The technical solution principle consists of the following main phases:

- chemical analyses of the steel;
- mechanical machining (for a very delicate surface);
- appearance, dimensional check;
- chemical cleaning of the item surfaces;
- mixture preparing (BOVACONTROL paste);
- spreading the mixture on item surfaces;
- drying the mixture on item surfaces;
- preparing the carbon granular conductive mixture;
- preparing the thermo-chemical treatment chamber;
- packing the items in the granular mixture;
- electro-thermal BOVACONTROL in the granular environment;
- control of electrical, time and temperature parameters;
- items that were subject of BOVACONTROL will be cooled to 300°C;
- unpacking and cleaning;
- technical control of the items that were subject of BOVACONTROL;
- final thermal treatment;
- technical control, appearance, dimensions, mechanical properties.

The basic technological parameters were:

- surface roughness $Ra$ = 0.4 μm;
- paste layer thickness will be 6 to 8 times bigger than the depth of superficial hardened layer (approx. 5 mm).
- percentage of alloy elements (boron, vanadium) is maximum 10% [7].
- accelerators $BaCO_3$, $Na_2CO_3$ and aluminum oxide from granular environment is maximum 8%;
- protection against carbon will be done with protective paste (composition: quartz = max. 45%, the rest : metallic oxides;

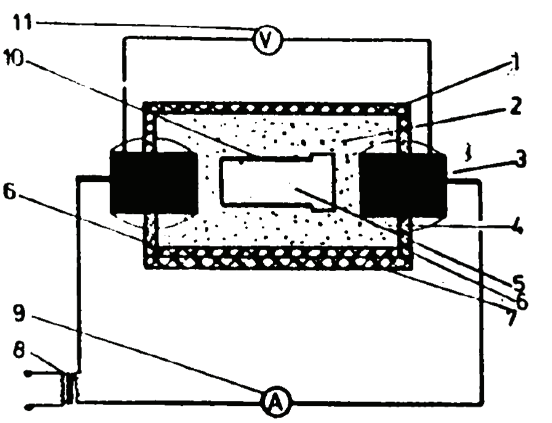


**Fig. 2.** Necessary equipment list [6]: 1, 2, 3, 6, and 7 – thermo-chemical treatment kiln with direct heating in granular environment – minimum volume: 1000 × 300 × × 270 mm; 8, 9 – transformer with adjustable command RSAR 1000-1200; 5, 10 – special materials for thermal treatment, iron-alloy Fe-B, Fe-V, borax, boron, metallic oxide, organic binding material); 11– thermocouples Pt – Rh – Pt, regulator micro-voltmeter, precision class: 1.

- for carbon steel the quenching will be done at 780–800°C;
- for alloyed steel the quenching will be done at 850–900°C for the core and 760–820°C for the layer;
- for alloyed steel and carbon steel the low tempering will be done at 180–210°C for an increasing bending resistance.

Micrograph of piece superficial hardening with boron-carbon-vanadium: 1 – superficial layer (martensite structure with complex carbides, acicular cementite); homogeneous layer with adequate depth; 2 – transition zone (transition sorbite-pearlite structure); 3 – core (gross ferrite + pearlite).

The following instruments and equipment are required: measure and control of temperature and chemical composition devices, laboratory instruments required for studying the structure and material mechanical properties.

## 3. MEASURABLE OBJECTIVES

The main measurable objective of this theme is the establishing of the correlation between the following technological and thermo-physical parameters of the thermo-chemical process in such a manner that the elements dispersion will be done atom by atom:

- granule-metric conductive mixture dimension – $0.1 < d < 0.4$ mm;
- piece weight – mixture weight, depending on the weights: 2/1 and 1/3;
- heating temperature between 950°C to 1 130°C – melting temperature;
- secondary tension: 50 to 150 V;
- current intensity : 250 to 1 000 A;
- current density $I = 0.2 \div 0.6$ A/cm$^2$;
- feeding speed 0.2÷1 mm/h;
- maintaining time $t = 0.5 \div 4$ h ;
- increased tensile strength with 10–15% above the average (900 N/mm$^2$ );
- ensure of the existing phases α and ά; $Fe_2B$ spherical iron margins, vanadium components in the superficial layer.

## 4. CONCLUSIONS

The complexity results from the correlation of the results obtained in accordance with the entry data of the process (base material chemical composition, granular environment chemical composition, alloy paste chemical composition, heating temperature, heating and maintaining time, cooling condition) and the exit data of the process (mechanical and structural proprieties obtained by the metal piece after fabrication process, the behavior in testing).

The parts will combine the hardness, elasticity, resistance at wearing properties in the same manner as the item manufactured from a block (classical variant).

This is a complex technological process, assisted and conducted by computer following the correlation: by-product structure, technological parameters (chemical composition, granular environment, paste for alloying, temperature and time of thermal and chemical process), surface alloyed layer structure – transition area – core structure – mechanical properties obtained on item.

The estimated results are:

- tensile strength: min. 780 N/mm$^2$;
- impact (flow): min. 53 J/cm$^2$;
- elongation: min. 8 %;
- surface hardness: min. 770–800 HV;
- low alloyed core hardness: 40–45 daN/mm$^2$;
- carbon steel core hardness: 30–35 daN/mm$^2$;
- structure characteristics: carbon steel remaining compression tension: max. 650 MPa, low alloyed remaining compression tension: max. 750 MPa;
- volume: constant of Fe$\alpha$ (martensite) after quenching surface layer micro structure characteristics: cca. 0.2% in the processed by-product.

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