Bimetallic Light Automotive Parts Obtained From Liquid Phase

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Abstract: - Technology for manufacturing light automotive parts (bearings, bearing boxes, spindle, bushings etc.) of bimetallic semiproduct parts obtained from liquid phase, replaces the classical manufacturing options for light automotive single cast parts made of alloyed steel or non-ferrous materials, with a technological version in which phases and operations rely on parts made of different materials in multilayer version, and which can be realized with minimum investments using technological flows existing in companies working in field [1]. The proposed technology can be realized on an automatic line, thus, a strict control of the final product technological parameters and characteristics being achieved. This technology presents opportunities to widen the technical concept in executing light automotive parts and it can be applied to other fields, such as: aeronautics, military technique and shipbuildings.

Key-Words: - bimetallic light automotive parts.

1 Introduction

By centrifugal casting on machines with horizontal axis, hollow cylindrical pieces are obtained, bushings and bimetallic bearing boxes type, of medium length and tubes of different diameters, with lengths varying between 50 and 1000 mm [2]. As in centrifugal casting on machines with a vertical spindle, the exterior profile of the cast pieces is determined by the interior configuration of the shape of the base material.

The main objective of this technology is to increase reliability and performances of the light automotive parts, taking into account that during the manufacturing process, an execution technology at an european level is applied, which includes obtaining of automotive parts that can ensure – through their structure and properties optimization – an improved thermal fatigue strenght, an increased durability and dimensional stability [3,5].

2 Main Experimental Technological Phases

The manufacture of the bimetallic bushings for automobiles obtained from liquid phase supposes the achievement of the following experimental technological steps, conforming to those presented in [Fig.1.]

F 1 - Choice and establishment of base material; F 1.1– Control of chemical composition; F 1.2 – Mechanical tests.

Fig. 1. Main experimental technological phases of obtaining the bimetallic half-products from the liquid phase by spin casting.
3. Experimental Installation

The main economic objectives of realizing and implementing the manufacturing technology for bimetallic automotive parts [Fig.2] are: to raise the competitiveness of the internal manufacturers of light automotive parts, through an improved price/quality ratio. To create collaboration opportunities which can incentivize technological restructuring at a regional level, through sectorial applications; to obtain the needed premises for technological transfer and for new products to be developed, with special features and defined destination [4]. In [Fig.3] is shown the installation diagram for bimetallic light automotive parts obtained through horizontal centrifugal casting – a method used within industrial experiments.
4. Experimental Research on Bimetallic Layers

The bronze layer deposited by vertical spin casting, being in treated condition, has been submitted to the analysis of the structure by spectrometry by extraction of ions with laser micro-probe [6]. The LMA 10 apparatus disposes of an optical microscope for the selection of the investigation zone and a laser device with ruby, with the radiation wavelength of 694 nm. The micro-plasma generated by the action of the laser radiation on the sample is analyzed by the spectrograph PGS 2, with a spectral interval comprised between 2.000 ÷ 10.000 Å.

The specters obtained are registered on a photographic plate and then interpreted with the help a specters projector and a micro-dens meter, with a view to obtaining the specters specific to the elements from the sample. The determinations have been made on metallographic samples taken from alloys of deposited bronze, of type CuNiAl on supports of steel in heat treated condition – salt hardening + ageing (485 ºC/1,5h/water), the visualization of the structure being possible due to the attack of the surface with copper ammonia chloride. The laser excitation has been made on the precipitates present in the microstructure of the samples, the excitation energy being selected in such a way that the crater produced by the laser pencil rays by the local vaporization of the material is smaller than the precipitate’s diameter [7]. By the analysis performed four types of precipitates have been visualized. Their chemical composition obtained by spectrometry with laser is shown in the table 1 below.

Table 1. Precipitates determined by spectral analysis with laser

<table>
<thead>
<tr>
<th>Crr. nr.</th>
<th>Precipitate size</th>
<th>Chemical composition of the precipitate, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Cu</td>
</tr>
<tr>
<td>1</td>
<td>Big</td>
<td>28,5</td>
</tr>
<tr>
<td>2</td>
<td>Average</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Average</td>
<td>79</td>
</tr>
<tr>
<td>4</td>
<td>Small</td>
<td>3</td>
</tr>
</tbody>
</table>

Depending on the chemical composition of the 4 types of precipitates (percentages of chemical elements) and the size optically visualized, the probable chemical formula of the precipitated components are the followings:
- pos.1 – big precipitates, formula Al\(_2\)Cu → average hardness, leads to a variation of the hardness with an average intensity;
- pos.2 – average precipitates, formula Ni\(_3\)Al → leads to a variation of the hardness with a big intensity;
- pos.3 – average precipitates, formula Cu\(_3\)Al → average hardness, leads to a variation of the hardness with a high hardness, leads to a variation of the hardness with a high intensity.

CuNiAl alloy, following the heat treatment (salt hardening + ageing), obtains a hardening due to the precipitation from the solid over-saturated solution of the chemical components Al\(_2\)Cu, Ni\(_2\)Al, Cu\(_3\)Al and Ni\(_2\)Si that determines an important increase of the wearing resistance of the deposited layer and of the bimetallic component elements of the auto-vehicles in assembly.

The specific adherence characterizes the bimetallic component parts for automobiles from a qualitative point of view. For the calculation of the specific adherence the resistance of detachment by shearing is necessary to be determined.

![Fig. 5. Bronze alloy type CuNiAl treated (salt hardening + ageing 484ºC/1,5 h/water). Electronic microscopy(x2500)- big density of non-coherent precipitations in the base matrix](image)

![Fig. 6. Proposed modalities of determination of the detachment resistance by shearing](image)

- a – determination of the detachment resistance with linear test bar; 1 – linear test bar; 2 – guiding stocks;
- g – structure of base support of hypoeutectoid carbon steel;
- b – determination of the detachment resistance with circular test bar; 3 – circular test bar type bushing-disc; 4 – matrix; 5 – superior support;
- D – inner diameter of base support of the bimetallic bushing for automobiles;
- d – inner diameter of the bimetallic bushing for automobiles
The specific adherence (q) is determined with the formula:

\[ q = \frac{F}{A} \quad [\text{N/mm}^2] \quad (1) \]

where: \( F \) – pressing or tensile force, [N] ; \( A \) – aria of the surface submitted to the detachment, [mm\(^2\)].

Depending on the specific adherence value \( q \), we can have:
- Soft joint: \( q < 70 \text{ N/mm}^2 \);
- Average joint: \( q = 70-170 \text{ N/mm}^2 \);
- Strong joint: \( q > 170 \text{ N/mm}^2 \).

The heat treatment of salt hardening has in view [2]:
- Conservation at ambient temperature, in a metastable supersaturated condition, of the solid solution existent at high temperature;
- The supersaturated solid solution is obtained by rash cooling from the temperature of meting in solution (the transformation by precipitation of certain components from the solid solution cannot take place), the deposited layer (bronze with aluminium) conserving its mono-phase structure of the high temperature;
- The technological parameters of the salt hardening have been established experimentally. The temperature and time of maintaining at salt hardening must ensure the dissolving of the inter-metallic components in solid solution, the homogeneity of the solid solution, the obtaining of a proper size of the crystalline grain.

Bimetal hypo-eutectoid carbon steel – bronze with aluminium: \( T_{\text{salt hard}} = 850-900^\circ\text{C}, t_{\text{maintain}} \sim 0.5\text{h}, \) water-cooling.

- The effect of this treatment on the base material MB hypo-eutectoid carbon steel does not present big shortcomings because the cooling of the bimetallic bushing in water from 850°C does not have the effect of a hardening in its self due to the low content of C of the base material MB- hypo-eutectoid carbon steel;
- The size of the heating speed is conditioned only by the capacity of the deposited layer SD of non-cracking at sudden temperature variations (for the bronzes with aluminium this variation of temperature can be maximum \( \rightarrow \) the bushings can be introduced in the furnace directly at the treatment temperature);
- Following the salt hardening, the deposited layer presents a mono-phase structure constituted of a metastable supersaturated solid solution \( \alpha \) (alloying elements substitute the Cu atoms or penetrate in the net interstices) having low physical and mechanical properties.

Structural analysis of bimetallic automotive bushings of hypo-eutectoid steel alloy CuNiAl is shown in table 2.

<table>
<thead>
<tr>
<th>Automatic part name</th>
<th>Bimetallic material</th>
<th>Bimetallic structure bimetal</th>
<th>D_{sp} [%]</th>
<th>q [N/mm²]</th>
<th>Notes.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic bushing</td>
<td>Hypoeutectoid steel alloy CuNiAl</td>
<td>MB= F+P, SD=ssa+Cu3Sn (x400, ammonium persulphate attack 10%)</td>
<td>51</td>
<td>52</td>
<td>D_{sp}&gt;30%, improper. q&lt;90 mild, improper</td>
</tr>
<tr>
<td>Automatic bushing</td>
<td>Hypoeutectoid steel alloy CuNiAl</td>
<td>MB= F+P, SD=ssa+cc Cu3Sn (x100, ammonium persulphate attack 10%)</td>
<td>52</td>
<td>61</td>
<td>D_{sp}&gt;30%, improper. q&lt;90 mild, improper</td>
</tr>
<tr>
<td>Automatic bushing</td>
<td>Hypoeutectoid steel alloy CuNiAl</td>
<td>MB= F+P homogeneous, SD=ssa polyhedral (x100, ammonium persulphate attack 10%)</td>
<td>29</td>
<td>190</td>
<td>D_{sp}&lt;30%, proper composition. q&gt;170 hard joint</td>
</tr>
<tr>
<td>Automatic bushing</td>
<td>Hypoeutectoid steel alloy CuNiAl</td>
<td>MB= F+P, SD=ssa (x200, ammonium persulphate attack 10%)</td>
<td>25</td>
<td>218</td>
<td>D_{sp}&lt;30%, proper composition. q&gt;170 hard joint</td>
</tr>
<tr>
<td>Automatic bushing</td>
<td>Hypoeutectoid steel alloy CuNiAl</td>
<td>MB= F+P, SD=ssa (x400, ammonium persulphate attack 10%)</td>
<td>25</td>
<td>220</td>
<td>D_{sp}&lt;30%, proper composition. q&gt;170 hard joint</td>
</tr>
</tbody>
</table>
Joint area was characterized by cross-bending testing of bimetallic samples, thus defining the unbinding by percent and the shearing test which makes evident the specific adherence in N/mm².

5. Industrial Applications and Economical Aspects

The use of the bimetals carbon steel-bronze has as main purposes the followings:
- the improvement of the electrical, thermal and anti-friction properties;
- the improvement of the sticking, adherence possibilities and surface appearance;
- bronze saving.

Bimetallic bushings carbon steel low alloyed – bronze obtained by special procedures of deposition are used especially for:
- connection bushings, connection couplings for feeding ducts; - casings, contact points;
- motors sealing gaskets; - connection bushings of the tanks for auto-vehicles radiators; - tightening bushings for immersible boilers and heat changers; - bushings and bearings for the containers under pressure and bearings for containers under pressure and condensers; - the manufacture of the gearshifts, disks of the hydrodynamic converters, disk brakes, synchronizing cones, clutches with multiple disks;
- bushings for crude oil refining installations; - air-coolers at the converters with oxygen for the cooling of the blowing lances and converters hoods;
- half-bearings for tractor and truck motors; - bearings at Diesel motors and tractors on caterpillars; - busings for the manufacture of big turning machines;
- bearings of the shake out machines compressors.

By the utilization of the half-products and bushings with bimetallic layers the following aspects are had in view:
- saving of the expensive and critical materials and implicitly the imports reducing;
- obtaining a product that combine various properties, unreachable by using of a single metal:

| MB= F+P homogeneous SD=ssα+cc Cu3Sn (x100 ammonium persulphate attack 10%) |
| Automotive bushing |
| Hypoeutectoid steel alloy CuNiAl |
| D_p<30%, proper composition q>170 hard joint |
| 22 |
| 205 |

a – the good thermal conductivity of the base steel with the corrosion-proof of the deposited steel;
b – high strength of the base steel with anti-friction good properties of the deposited alloy;
c – high mechanical properties and thermal dilatation coefficients different between component metals of the thermo-bimetal;
d – high technological properties of the base steel with distinct appearance of the deposited materials.

The thickness of the half-products and bimetallic bushings most utilized in the whole world is comprised between 0,5 – 5 mm, the proportion of the deposited layer SD being of 10 – 30%.

Using the half-products and the bimetallic bushings low alloyed carbon steel – bronze, the percentage savings presented in table 3 are obtained.

In [Fig.6] the percentage savings (%) are indicatively synthesized in the presented curves, that are achievable by using a ton of bimetalic half-products of low alloyed carbon-steel – stainless steel and of a ton of half-products and of a ton of bimetalic half-products and bushings of low alloyed carbon steel - bronze → instead of a ton of half-products of stainless steel, respectively bronze.

The savings represented in the ordinate have been established depending on the ratio K from the in the abscissa (K= ratio between the surface of the cross section of the carbon steel half-products and the surface of the deposited layer section). As much bigger is K as the obtained savings are higher. In the building machines, energetic and automobile industry the bimetallic half products and bushings of low alloyed steel – anti-friction material are used on a large scale and they have superior characteristics: high and stable friction coefficient at different temperatures, low wearing and long service time, resistance at high temperatures and good thermal conductibility, high resistance at corrosion, ensurence of a slow braking.

Table 3. Average savings achieved by the obtaining and utilization of the bimetals low alloyed carbon steel- bronze

<table>
<thead>
<tr>
<th>Savings resulted by the utilization of the bimetals low alloyed carbon steel - bronze</th>
<th>Proportion of deposited layer SD, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value savings</td>
<td>39</td>
</tr>
<tr>
<td>Quantitative savings regarding the alloy of deposited layer SD</td>
<td>81</td>
</tr>
<tr>
<td>Minimum ratio between the price of the deposited alloy SD and the price of the base material MB in order to achieve value savings</td>
<td>4</td>
</tr>
</tbody>
</table>
The utilization of the bimetallic half-products and bushings of steel bronze achieve a 60-70% average of savings of Cu alloys; in the case of apparatus and machines manufacture (products with a high incorporated intelligence degree) the savings can reach even up to 90% scanty metals and alloys (in which case they are used as thin layers deposited and tight joined by MB of carbon or low alloyed steel).

The economic efficiency is as much bigger as the geometrical dimension on the products are bigger and the proportion of the deposited layer SD is reduced at minimum values.

6. Conclusions

Following the thermal treatment (solution hardening + ageing), the CuNiAl alloy acquires a hardening due to precipitation of the chemical compounds $\text{Al}_2\text{Cu}$, $\text{Ni}_2\text{Al}$, $\text{Cu}_3\text{Al}$ și $\text{Ni}_2\text{Si}$ in the oversaturated solid solution which determines an important growing of the hardness and wearing resistance of the deposited layer and of the bimetallic automotive parts in their entirety.

Generally, the structure of the bimetallic automotive bushings of hypo-eutectoid steel alloy CuNiAl, whose metallurgical joint was considered hard, $q>170$ N/mm$^2$, presented the following metallographic structure:

- SD = ssα polyhedral or ssα or ssα + isolated chemical compounds; MB = fine pearlite-ferrite structure or a homogeneous pearlite-ferrite structure;
- ZI = transit area on the entire surface, dissolved oxides, presence of the chemical compounds, reciprocal diffusion of the elements in MB or SD or transit area on the entire surface, dissolved oxides, presence of the chemical compounds.

Hard metallurgical joint is characterized from a structural point of view, by a jointing area with transit portions on the entire surface, the density of the joint knots on wide portions being extremely high.

At joining temperatures $\text{Timb} = \text{T}_{\text{top1}} + 100$, the specific adherence reaches values $q > 170$ N/mm$^2$ corresponding to the strong joints. At joining temperatures $\text{Timb} > \text{T}_{\text{top1}} + 100$, the specific adherence decreases towards values of 150 N/mm$^2$ corresponding to the average joints.

Ageing leads to the evolution of metastable layers obtained by salt hardening to physical-chemical stability. If the metastable structure is of type supersaturated solid solution then the ageing hardens and if the metastable structure is of martensite type then the ageing softens the layers deposited on the base material.

Gradual increasing of the geometrical dimensions bushings leads to the increasing of the economical advantages in the case of the utilization for welded constructions of big dimensions..

References:


