THE RESULT OF THE QUALITY ANALYSES OF SG TYPE ROLLED
SECTIONS FOR THE METAL SUPPORT OF UNDERGROUND
EXCAVATIONS

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Abstract: The quality issues of rolled sections type SG for the metal sliding fittings of supporting was and remains a matter of real concern, having in mind that the type of steels for machining and lamination processes to which they are subject, are the causes of obtaining, whether or not the optimal technical conditions, both during subsequent processing of the metal elements (cutting and curving) as well, especially during the mounting and operation of service for underground. In the spirit of the promotion and adoption of suitable steels, this paper discusses the quality conditions which must be met, and how these factors influence the quality of the steel, and the quality of SG rolled sections manufactured in our country in terms of the elements and chemical analysis of a mechanical characteristics.

Key words: rolled sections, metal support, alloy steel/carbon steel, ferrite-pearlite structure cristal pearl, nital, pearl draft, thermal treatment, non-metallic inclusions.

1. INTRODUCTION

Deficiencies noted on the metal support, used for the underground work, noticed the improve of constructive and functional parameters of these types of constructions. As a result, in such a context, it was considered appropriate to address to the issues of laminates quality for construction of metal elements, specifically, the steel quality for machining the rolled sections.

Rolled sections used for the construction of metal sliding support, i.e. SG type laminates manufactured in the country, have been obtained from hot rolled steel, alloy steel carbon-type manganese (C-Mn), or low alloyed steels, including the chemical composition therefor reduced in alloying elements, i.e. under 0.19% vanadium, niobium, titanium and aluminium or that, in our country, were used until 1980 for machining the products type SG-18 and SG-23, and until 1988 for laminate SG-29 (OPM steel type). At that time, from economic reasons, lamination of profiles has been branded from SG (18 and 23) and 31Mn 4 for SG.29 section, both types being characterised without alloying elements content, these being replaced by carbon content increases up to 70%, favoring the maintenance of mechanical characteristics of resistance to upper limit values, on account of the reduction and deformation properties, under the minimum allowable limits of efficiency, dilatation, contraction, resilience.
The machining use of 31Mn 4 steel, was upheld for the SG.23 laminate, the only type of rolled section made current in the country and used for metallic support.

This type of steel, 31Mn 4, is used for machining the profiles of TH series, common abroad, but which, unlike our country, is delivered as prescribed under the German rule DIN 21544-85, which provides for the implementation of the suppliers of heat treatments for improvement, with the purpose of recrystallization and mixing the crystalline structure, in order to obtain higher deformation properties and toughness of the steel.

2. TERMS OF STEEL QUALITY USED FOR LAMINATES

General requirements to which the used steel must respond to execution of rolled steel are [4]:

- to ensure high mechanical strength values for breaking the material to be produced at greatest tasks;
- to ensure the upper values of fluidity limit, in order to print a load capacity to profiles as possible in the elastic field;
- to provide high values of tenacity, elongation and contraction, so the rolled steel can withstand large deformations after overrunning elasticity, without fragile breaking during bending by cold plastic deformation, or during operation of underground support;
- to enable re-use of support components through cold straightening, without applying any treatments, however, to improve the operation of bending previously.

Basically, the quality of steels is influenced by a number of factors, including:

- chemical composition, i.e. the nature and content of chemical elements;
- the size and distribution of granulation in the formation of crystalline structure of steel;
- the quantity and distribution of non-metallic inclusions in the structure of steel;
- nature and application of heat treatments on the profiles after machining operations and as finished products, after curving.

In terms of chemical composition, compared to stainless steels used abroad for mechanical treatment of profiles, the situation indicates for steels of our country, including in terms of the size of the mechanical properties, sensitive values, what gives them their location at the level of the best steels of worldwide [3], [4] [5].

Corresponding to technical machining requirements provided for under the recent norms existing in the country for the laminating of profiles (OPM 1/31Mn 4/STAS 9531-91 for SG-18, 23 and 29, respectively 31Mn 4/SF 3-93 for machining of SG-18 and SG-23) it is found that, in the absence of alloying elements, in order to improve the quality and chemical composition of steel, the new regulations provide for provider the application of thermal processes of improvement, i.e. normalization, but non-compliant with the actual practice in our country. In this case, for non-alloy steel of OPM mark 1 and 31Mn 4, untreated, reducing the deformation properties of tenacity, respectively, due to the presence of a high concentration of cementite – Fe3C in the pearlitic steel structure, with upward trend with increasing content of C, giving it a high hardness and brittleness, with negative consequences
on the processing primers that occur later during the bending by cold plastic deformation of the profiles (cracks, checks and material braking), including deficiencies of mounting support in underground (getting to merge beam apertures with the pillars of support, as a result of the use of elements with different radius and lengths).

On the other hand, the characteristics of resistance, bending and tenacity of steel are crucial influenced of the grain size, respectively of the degree of finish of its crystalline structure. In turn, the size of the granulation is influenced, among others, of: chemical composition, degree of deoxidation, quality of machining process (temperature, duration of heating and cooling rate of blooming).

Concerning the participation of chemical elements on the degree of structure completion, it is noticed that aluminum, carbon and vanadium print a finishing bearing to steel structure, while silicon, manganese and phosphorus contributes to the achievement of gross structures, leading to increased fragility, on account of the reduction in capacity and tenacity of deformation.

Thus, due to the lack of vanadium and the presence of aluminum in a low proportion in chemical composition, carbon steels compared to those alloy, have high structures with great grains(large) whose distribution is not uniform, but in the strings.

As regards the influence of degree of deoxidation of steel quality, the results obtained from tests carried out highlight that alloy steels have a high degree of deoxidation, according to which, through the formation of crystalline grains of oxidic type (Al2O3, V2O5, TiO2), resulting in a fine grain structure, which prevents the growth and arrangement of rows of grain size. Unlike the referred situation, in the case of carbon steels there is no forming of oxide inclusions, lack of alloying elements resulting in reduction of degree of deoxidation and increase of grain size of crystalline lenses.

In terms of the influence of rolling temperature and cooling rate, observations and analyses of quality made, showed that non-compliance with adequate conditions, particularly in the case of carbon steels with higher content of 0.25% C, determines the appearance of so-called “structural hardening”, in cold weather, when sudden cooling occurs, resulting in self-hardening of the steel and increasing the rigidity and fragility of braking account of the reduction of flexibility and resilience.

Appreciation of quality steels from the point of view of grains, is done according to the number and size of crystalline grains presented in the pearlitic steel structure of the material. In this context, corresponding to the existing classifications, the results obtained in the laboratory for metallographic analyses and the action of laminates, have confirmed the possibility of obtaining an appropriate plasticity and tenacity under the conditions of a number of crystalline grains size 9 to 15, characterized as having medium to fine size (table 1).

<table>
<thead>
<tr>
<th>Crt. no.</th>
<th>Number of crossed grains</th>
<th>Size of grains</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>over 15</td>
<td>very fine grains</td>
</tr>
<tr>
<td>2.</td>
<td>12 - 15</td>
<td>fine grains</td>
</tr>
<tr>
<td>3.</td>
<td>9 - 11</td>
<td>medium grains</td>
</tr>
<tr>
<td>4.</td>
<td>up to 8</td>
<td>large grains</td>
</tr>
</tbody>
</table>

Table 1 Classification of size for crystalline grains from the pearlitic steel structure for supporting rolled sections
In terms of the influence of non-metallic inclusions on the quality of steel (oxides, sulfides, silicates, nitrates and phosphates), this is determined by quantity, geometric shape and inclusions dispersion in crystalline structure, representing points of primer of internal tensions, with negative effects in case of large quantities and non-uniform distributions, producing the appearance of a study on the structure of the material. Non-metallic inclusions dispersion can be uniform or non-uniform, individual or grouped, in or out of pearlitic steel structure, stating that plastic deformation at hot rolling process of profiles lamination, encouraging their breakdown in strings, over sliding planes (Figure 1, a and b).

![Fig.1 Heterogeneous pearlitic steel structure (not re-crystallized) with pearlitic grains, grain score 5-7 (nital attack, X 100): a - SG-23 laminate sample; b - SG-29 laminate sample](image)

The layout of the rows of steel structure, as a result of uneven distribution and the concentration of large quantities of non-metallic inclusions, go to increase the rigidity and fragility of the material breaking, on account of the reduction of plasticity and deformation capacity of cold-rolled products, including tenacity.

Influence of heat treatments on the steel quality, results from the effect of easing which prints to the internal structure of the material, for the purpose of recrystallization and homogenization of obtained structure from the lamination of profiles.

In order to ensure the subsequent deformation capacity of cold-rolled profiles (required for bending the support elements), elongation and contraction, as well as the tenacity of exploitation, worldwide, it is applied, after profiles machining, heat treatment of normalization, which means the phase transformation process, i.e. heating the material at temperatures of up to 900° C, followed by cooling to the temperature of the atmosphere. In this way, in the case of non-alloyed steels is removing the rows arrangement and homogenization of pearlitic structure of steel.

Also, in order to obtain the appropriate properties of laminates exploitation, resistance and tenacity as well, after trimming (cutting and curving) it is applied the hardening heat treatment of the material, i.e. the heating and cooling in water or oil, followed by a high return. In this way, the pearlite which represents the basic constituent of the re-heated steel (normal state), it turns into sorbite or pearlitic sorbite, giving an optimal correspondence to the treated steel between the plasticity properties, tenacity and the mechanical resistance.

In the case of alloy steels, with content under 0.25% C, lack of tension set that forms after cold bending of the support elements, with re-crystallization and re-homogenization of the material structure, is achieved through the application of heat treatment of stress relieving.
3. QUALITY SITUATION OF STEELS USED IN OUR COUNTRY FOR MACHINING THE ROLLED PROFILES

Although, by the existing norms, chemical composition and mechanical properties of the steel used in our country shows close quantum as worldwide, however, by the lack of alloying elements and non-heat treatments to improve quality, laminated profiles recorded more imperfections, resulting in the production of primers to the curving operation and exploitation of the underground support. Edifying are the results of the analyses carried out on samples of historically rolled pieces machined from different steel types, taken directly from the machining or after bending or underground operation of the profiles [1], [4], [5], [6].

Thus, the comparative chemical analyses of cuttings carried out on samples from non-steel with vanadium (OPM 1 brands and 31 Mn 4 types) have highlighted the following aspects:

- carbon levels were generally higher than those provided by the regulations, placing it in the range 0.32-0.39% beside 0.24-0.30%, as provided for OPM 1 steel type and 0.36%-0.48 for 31 Mn 4 type, beside the allowable of 0.28%-0.36;  
- as the carbon, manganese content was framed as a rule within the ranges of 0.84-1.1% for OPM 1 type and 0.81-1.31% for 31 Mn 4 type, in both situations it was over the content prescribed by normative, i.e. up to 0.8% Mn for OPM 1 and up to 1.1% Mn for the 31 Mn 4 type;  
- silicon levels were also in ranges greater than those laid down, registering up to 0.35%, to a maximum of 0.25%. Like carbon, manganese and silicon recorded maximum levels permitted, what has awarded the first indications of increasing grain size of crystalline grains from pearlitic steel structure of the material, with getting heterogeneous structures;  
- aluminum levels as alloying element with utmost importance after vanadium, were present in a ratio lower than that provided for by regulations, namely 0.006-0.015% Al, compared to the minimum of 0.02% Al (Figure 2).

![Fig. 2 The distribution of the content of aluminum from steel structure, OPM 1 type](image)

In addition to favoring the reduction of steel resilience, the performed analyses showed that the presence of aluminum in the low proportion of non-metallic inclusions influenced the structure of the steel, which have amplified the homogenization of structure, because the lack of heat treatment, production of breaking the structure, with its passage from breaking to the fragile phase (Figure 3, a and b).
Fig. 3 The rupture of the material in the case of laminated-profile SG-23 taken from underground (X 600):- the appearance of fatigue fracture in the starting area of priming fracture; b-aspect of fragile breaking recorded in time of touching the structure.

The metallographic analyses have shown, in the case of non-alloyed steels (not heat treated), the presence of heterogeneous pearlitic steel structures, with content in the non-metallic elements over the maximum allowable limit, having coarsely crystalline lenses in parallel rows with the stratification planes (Figure 4, a and b).

Fig. 4 Samples of SG-18 (a) and SG-23 rolled steels (b) machined from not alloyed steel, OPM type. Heterogeneous pearlitic steel coarsely crystalline lenses of pearlite, grain size of 4 and 6 (nital attack X 100)

On the contrary, but positive results on samples from alloyed and non-alloyed steels, heat-treated (normalized), have highlighted more uniform pearlitic steel structures and more uniform distribution of crystalline grain (Figure 5, a and b), occasion, when, in order to obtain the maximum resilience in aging condition of material (kCU), has been established the optimal temperature for homogenization and re-crystallization of steel structure at 850 ± 10°C (table 2).

Table 2 The result of applying the normalization heat treatment to improve the quality of non-alloyed steels

<table>
<thead>
<tr>
<th>Normalization temperature, °C</th>
<th>830</th>
<th>840</th>
<th>850</th>
<th>860</th>
<th>870</th>
<th>880</th>
</tr>
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<tbody>
<tr>
<td>Resilience in improved state, J/cm²</td>
<td>61.7</td>
<td>76.4</td>
<td>74</td>
<td>74</td>
<td>64.7</td>
<td>64</td>
</tr>
</tbody>
</table>
Verification of mechanical properties, tests performed on samples of material from non-steel and not heat treated, have highlighted the less resistance to breakage (Rm) and flow (Rp 0.2) in admissible limits, these being, as a rule, in the much larger intervals, i.e. up to 850 N/mm² (Rm case) and 590 N/mm² (Rp 0.2 case). To get the mechanical resistance to high limits, much more above the required sizes, even towards improved steels were the consequence of the existence of the steel composition of carbon and manganese surpluses, which have generated the self heated of profiles in the lamination process, in cold time, when heating and cooling temperatures of blooms were applied with reticence [1], [4], [6].

By the advantage of re-homogenization and finishing of alloy steels structure (OPM type) and the non-allied but heat-treated (OPM 1 and 31 Mn 4 type), the result of carried out tests have shown a mechanical resistance much more affordable Rm = 635-640 N/mm² and Rp (0.2) = 415-422 N/mm².

As a consequence of higher levels of C and Mn in the crystalline structure of non-alloyed and not normalize, breaking elongation values (A5) were located in large limits, placing it, under the minimum acceptable norms (under 19%), except for a part of the OPM 1 steel specimens with relatively low levels of Carbon, where the elongations were classified in the range of 10.5-21.6% in case of the SG-29 laminate on account of the considerable reduction of breaking. As elongation, resilience values obtained from tests on samples subjected to artificial ageing, have shown less than the minimum values required by the regulations, respectively min. 70 J/cm² for both OPM 1 steel type and 31 Mn 4 type.

Compared to the described situation, in case of alloy steel and non-alloyed steels, but heat treated, the resilience have higher values, fitted to the requirements laid down in the regulations, for both states.

4. CONCLUSIONS

Now, for the execution of metal sliding support applied to the underground excavations, in a totalitarian share of works in the underground mining sector, it is used the laminate SG. 23, whose production does not involve alloying elements in the chemical composition of steel, but imperative for ensuring that processing and operation qualities of support for the application of the heat treatment, the improvement of the treatment of normalization.
In such circumstances, the result of the analyses carried out on quality and performance in service, highlight the compromising of the general requirements of the machining steels should be, resulting in alteration of the internal structure of the material, with primers appear to the next operations of cutting cold bending of profiles, as well as the adverse repercussions on the installation and operation of underground support.

In relation to the level of disruption of the current quality of SG 23 rolled steel, the supplier should apply heat treatment conditions for normalization of the flow/laminating technology as required to achieve the optimum technology of this process. As an alternative to the non-application of this measure, it is proposed to continue the purchase of imported rolled steel similar in shape, dimensions and sizes of static characteristics and resistance made of alloy steel or manganese in accordance with DIN 21544/85, but which are delivered in enhanced internal cutting conditions and cold-bending of the support elements.

REFERENCES