Journal of Chemical Technology and Metallurgy, 59, 3, 2024, 693-698

STUDY OF STEELS FOR THE PURPOSE OF COMPARISON IN TERMS OF QUALITY INDICATORS AND ENERGY EFFECT OF THEIR PRODUCTION

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Received: 10 July 2023
Accepted: 28 February 2024
DOI: 10.59957/jctm.v59.i3.2024.24

ABSTRACT

The main purpose of this work is to examine ingots of steel grades 35HGSL, GS-34CrMo4 and GS-42CrMo4 and to obtain data on the microstructure and mechanical properties in the cast state and after heat treatment.

Based on the results, it is necessary to evaluate the effectiveness of the heat treatment used and possibly prove its justification, since this type of additional treatment is usually recommended to improve the quality of materials, but it is not mandatory, as in the present case. The economic costs of the manufacturer for conducting heat treatment can be a good solution only in the case of achieved better performance indicators of the materials, and the energy efficiency of the applied processes is essential. For all these reasons, as a result of researches will be created databases, which will give the opportunity to definite opinion on the problem.

Keywords: engineering steels, heat treatment, microstructures, hardness.

INTRODUCTION

Steel 35HGSL responded to GOST 977-88. This is engineering low-alloyed steel used to manufacture of gear wheels, shafts, and parts, which are required to high wear hardness. Both of steels, GS-34CrMo4 (1.7220) and GS-42CrMo4 (1.7225) must respond to DIN for chemical composition (there are not requirements for the mechanical properties), and they both are constructive carbon steels. GS-34CrMo4 used to manufacture of plates, blocks, profiled bars, cylinders, discs, rings, ets.

Steel grade GS-42CrMo4 is used for manufacture of shafts, tubes, pie-shapes, rings, modules, etc.

EXPERIMENTAL

Studied of the alloys in cast condition

The mould equipment and technology for casting are produced according to BSS 3492-86 in "Metakom SCW Invest AD". To producing are used scrap metal with addition of elements Cr, Mn and Mo, melted in an induction furnace. Five tone ladles for the casting is used. The ingots are cooling in the sand moulds about 12 hours. Chemical compositions of cast alloys are shown on Table 1.

Annealing regimes preparing after casting

Figs. 1 to 3 present the annealing regimes after casting. The differences in heating temperatures are chosen because of chromium content in alloys compositions.

- 35HGSL - Heating with 80°C h^{-1} to 880°C and soaking (25 mm thickness of the wall/hour +1 hour); cooling with 50°C h^{-1} in furnace to 350°C, cooling on air.
- GS-34CrMo4 - Heating with 80°C h^{-1} to 870°C and soaking (25 mm thickness of the wall/hour +1 hour); cooling with 50°C h^{-1} in furnace to 350°C, cooling on air.
- GS-42CrMo4 - Heating with 80°C h^{-1} to 845°C and soaking (25 mm thickness of the wall/hour +1 hour); cooling with 50°C h^{-1} in furnace to 350°C, cooling on air.

Table 1. Chemical composition of alloys.

Alloys / Elements, %	C	Si	Mn	P	S	Cr	Ni	Cu	Mo	Al/Mg
35HGSL Specimen 1	0.34	0.57	1.22	0.025	0.024	0.69	0.11	0.16		0.044
35HGSL Specimen 2	0.34	0.9	1.44	0.024	0.028	0.75	0.07	0.09		0.069
GS-34CrMo4 Specimen 1	0.33	0.37	0.74	0.021	0.019	1.0	0.21	0.14	0.26	0.085
GS-34CrMo4 Specimen 2	0.3	0.34	0.78	0.022	0.02	0.86	0.12	0.12	0.2	0.07
GS-42CrMo4 Specimen 1	0.25	0.41	0.9	0.021	0.18	0.2	0.07	0.17	0.22	0.47
GS-42CrMo4 Specimen 2	0.24	0.42	0.92	0.020	0.18	0.22	0.07	0.16	0.218	0.477

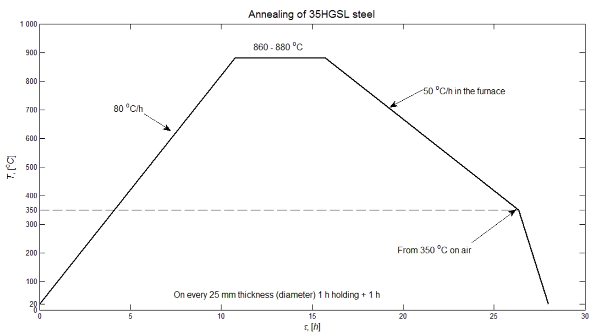

Fig. 1. Annealing of 35HGSL alloy.

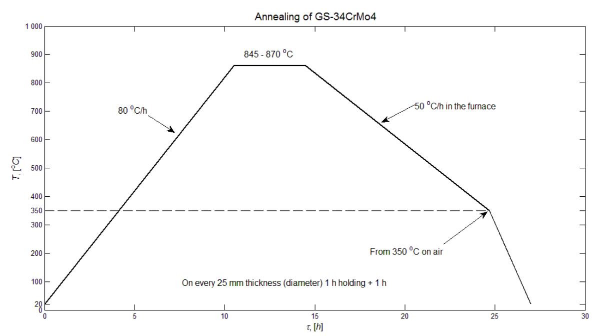

Fig. 2. Annealing of GS-34CrMo4 alloy.

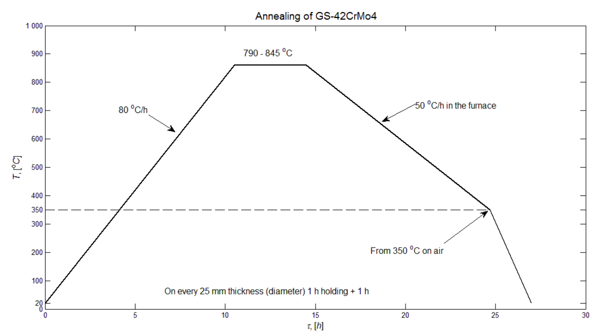

Fig. 3. Annealing of GS-42CrMo4 alloy.

Preparing the specimens

A standard methodology is applied to samples, cutting from selected alloys [1, 6, 8]. The shape and sizes of specimens as well as their cutting schemes are presented on Fig. 4. Dashed line shows the areas of the body of the ingot from which sample units are cut. Configuration and annotations of trials and sketch of cutting of trial samples are showing. In principle, specimens with No1 are taken under the feeder head of the ingot; specimens with No 2 are taken from the bottom of the ingot for all of steel ingots.

Structure in cast condition

All specimens are grinded, polished and etched with Nital, (3 % solution of H_2NO_3 in ethanol), [2, 3]. The microstructures are observed with light metallographic microscope, pictures are taken from the all-accessible surface of specimens - Specimen No1 (under the feeder head of the ingots); Specimen No2 (from the bottom of the ingots). Follows a detail monitoring of all specimens with magnification levels 100x and 500x and micrographs are taken. The result from observation shows, that:

In steel grade 35HGSL the structure is homogenous, composed from well-formed sub-eutectoid grains (ferrite-pearlite), Fig. 5.

With those compositions of the alloy, in steel grade GS-34CrMo4 a ferrite-pearlite microstructure is obtained too. The lighter areas contain fine ferrite; the darker areas are probably secondary cementite that primarily raised from the austenite grain-boundaries and appeared before annealing, Fig. 6.

The analysis of microphotographs of steel grade GS-42CrMo4 for each section showed that the structure volume is built from austenite and ferrite-carbide mixture. Coarse carbides are also observed (or probably

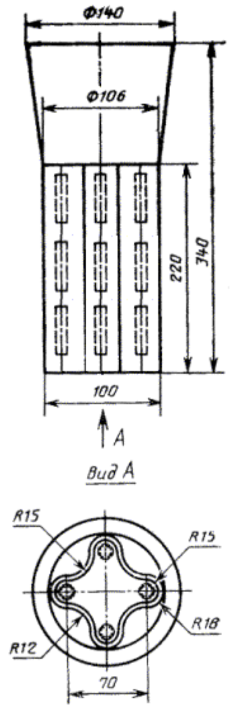

Fig. 4. Scheme of mould with feeder head (a), cast ingots and example of specimen`s view (b).

carbon-supersaturated ferrite platelets, or a high density of dislocations and twin boundaries), Fig. 7.

Studied of the alloys after additional heat treatment regimes

Selected heat treatment regimes, including Normalization and Tempering applied to the alloys, are presented from Fig. 8 to Fig.10, [1, 5 - 9]. They are:

For 35HGSL steel grade - Heating to 890^{o}C h^{-1}, cooling in air to 40^{o}C h^{-1}; heating to 600^{o}C h^{-1}, cooling in water.

For GS-34CrMo4 steel grade - Heating to 900^{o}C h^{-1}, cooling in oil to 40^{o}C h^{-1}; heating to 600^{o}C h^{-1}, cooling in furnace.

For GS-42CrMo4 steel grade - Heating to 880^{o}C h^{-1}, cooling in air to 40^{o}C and soaking 1 hour; heating to 600^{o}C h^{-1}, cooling in water.

Different post-tempering cooling rates are chosen due to the chromium content of the alloys to prevent the chromium carbide coarsening and secondary cementite precipitates.

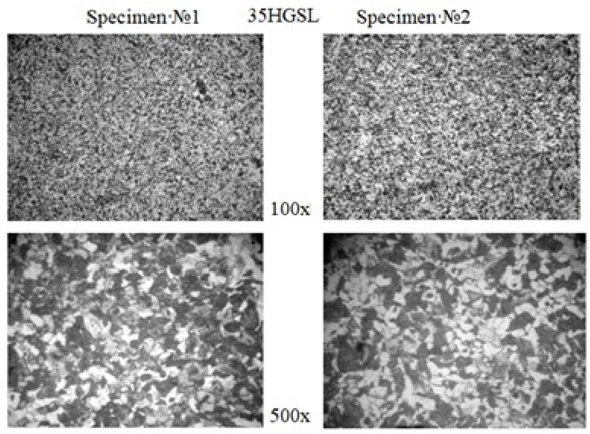

Fig. 5. Microphotographs of steel grade 35HGSL.

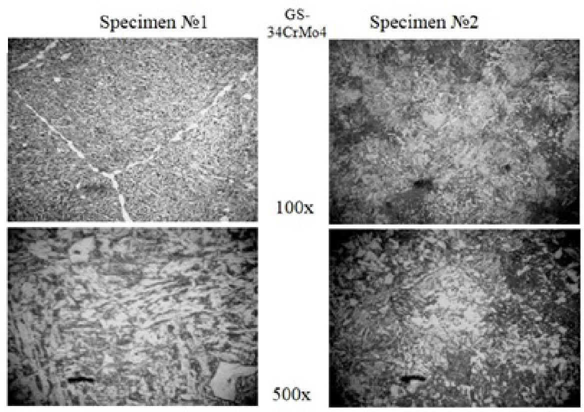

Fig. 6. Microphotographs of steel grade GS-34CrMo4.

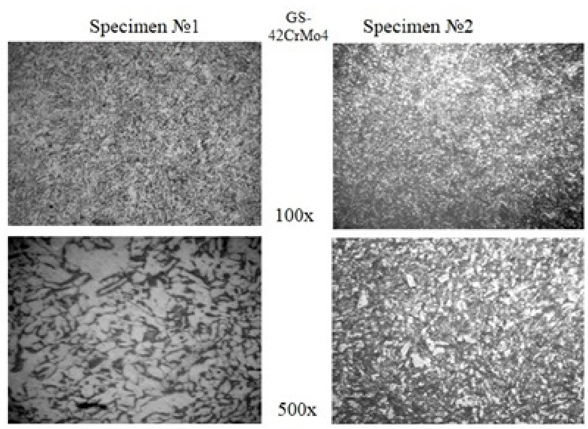

Fig. 7. Microphotographs of steel grade GS-42CrMo4.

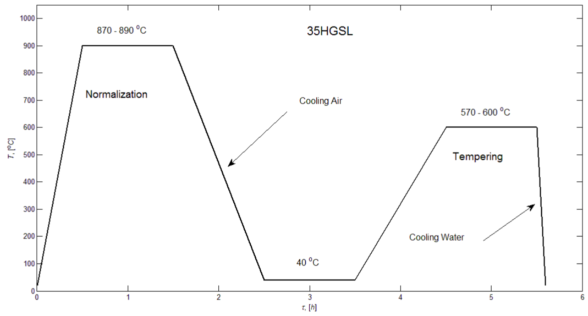

Fig. 8. Normalization and tempering of 35HGSL.

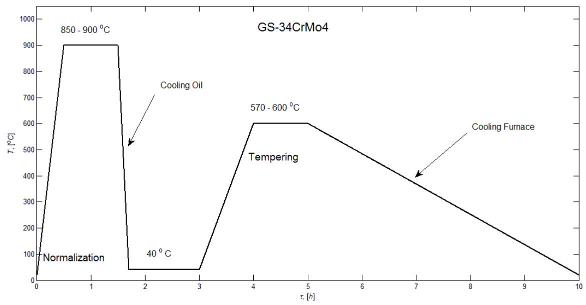

Fig. 9. Normalization and tempering of GS-34CrMo4.

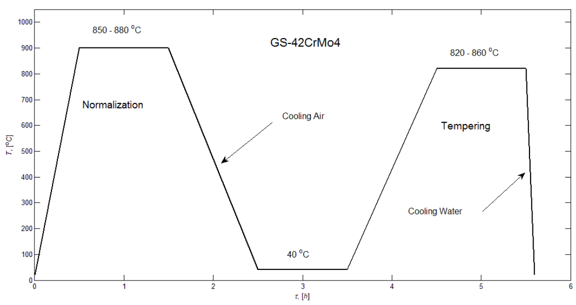

Fig. 10. Normalization and tempering of GS-42CrMo4.

Structures after heat treatment

All specimens are heat treated at regimes including Normalization and Tempering [2, 3]. The microstructures are observed with magnification levels 100x and 500x and micrographs are taken. The results from observation (Fig. 11 - 13) shows, that:

In steel grade 35HGSL microstructure contains fine, acicular ferrite (light constituent), pearlite (dark), and particles of cementite. There are no differences between grain sizes of the specimens taken from different places of the ingot body (Fig. 11).

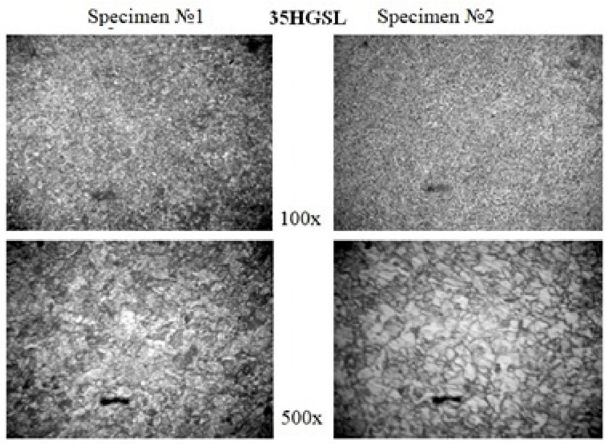

Fig.11. Microphotographs of the structure - steel grade 35HGSL obtained after heat treatment.

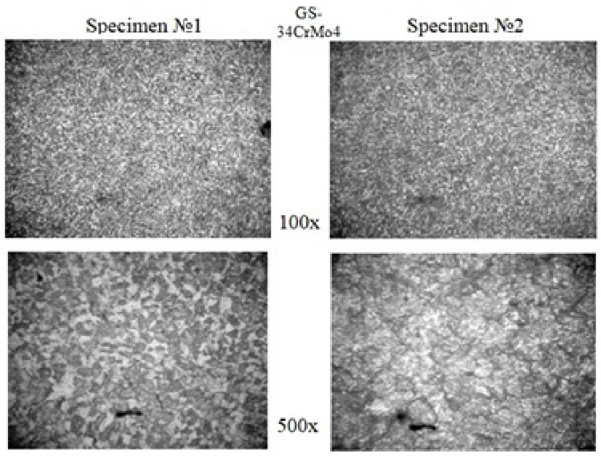

Fig. 12. Microphotographs of the structure - steel grade GS-34CrMo4 obtained after thermal treatment.

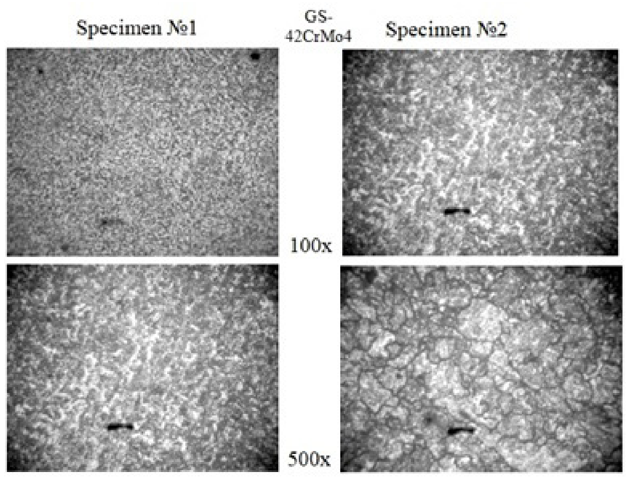

Fig. 13. Micro-photographs of the steel GS-42CrMo4 obtained after thermal treatment.

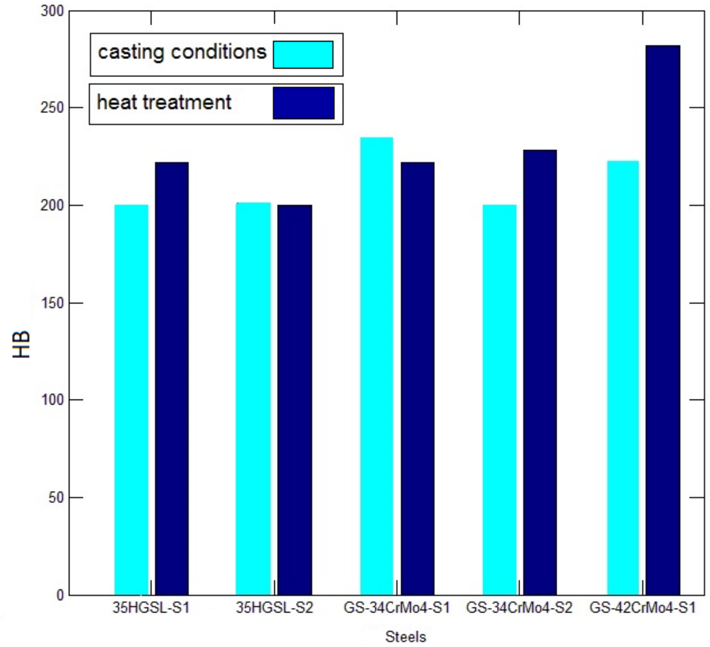

Fig. 14. Influence of the additional heat treatment on the hardness of alloys 35HGSL, GS-34CrMo4 and GS-42CrMo4.

As a result of heat treatment in steel grade GS-34CrMo4 (with an increase of cooling rate), upper bainite microstructure is obtained (ferrite platelets are separated by austenite or carbides). The structures seems uniformly and fine-grained (Fig. 12).

As a result of heat treatment in steel grade GS-42CrMo4 is observed carbide inclusions, dispersed, and regularly distribute in volume of metal specimens, (Fig. 13). At this grade of steel is observed differences in grain size of specimens taken from different places of the ingot body. After additional heat treatment the structure seems uniformly and fine-grained (see the next microphotographs for comparison).

RESULTS AND DISCUSSION

Mechanical indicators in casting condition and after heat treatment

The hardness was determined to Brinell method (BS ISO 6506). Graphically, on Fig. 14 are presented measurements of the hardness in cast condition and for different regimes of heat treatment of investigated alloys. The analysis shows that hardness tends to increasing with the influence of additional heat treatment. For each specimen obtained values after casting and after heat treatment are present in Fig. 14.

CONCLUSIONS

Structures prior heat treatment and after that are identified by metallographic examinations. To serve the aim of this work data on the microstructure and mechanical properties of the selected steel grades are obtained and analyzed.

As a result of heat treatment there are changes in the structure of specimens - it seems dispersed in the volume below the feeder head, while in the bottom part of metal block there are coarse grains with clearly defined boundaries.

By methodology for hardness testing are obtained data as a function of height of the ingots. The average values of Brinell Hardness are greater after the implemented thermal treatment.

Based on the results presented above (regarding Brinell Hardness, measured in casting conditions and after heat treatment) a conclusion is made, that if the energy costs, the duration and more complicated process management are taken in to account, the applcation of the additional heat treatment is justified for the selected alloys.

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