

The critical analysis of austenitic manganese steel T130Mn135 used for castings in the mining industry

A Josan¹, C Pinca Bretotean¹ and V Putan¹

¹Politehnica” University of Timisoara, Department of Engineering and Management, 5 Revolution Street, 331128 Hunedoara, Romania

E-mail: ana.josan@fih.upt.ro

Abstract. This paper presents the critical analysis of making technology of austenitic manganese steel *T130Mn135*, used for castings of the type *Mills hammer* at a Romanian foundry. Are analyzed 11 charges of steel for castings and is determined the diagram of the heat treatment. After the applying of the heat treatment results a single-phase structure, consisting of homogeneous austenite. For all the 11 charges is presented the variation of chemical composition.

1. Introduction

Austenitic manganese steels are part of the alloyed steel, to which the manganese is the main alloying element. The main particular physical property of high alloyed manganese steel (known as Hadfield steel) is its exceptional wear resistance (highest in comparison with all other known steel grades). Moreover, this steel, having an austenitic structure (is called austenitic manganese steel), is not magnetic, what determines also other uses for this steel. The austenitic structure of the steel is obtained after hardening at a temperature of 1000...1150 °C in water [1].

This steel is used to making castings that have a high wear resistance, combined with mechanical shock, but with no special conditions with regard to maintaining the exterior dimensions, of the type: Mill Hammer, jaw crusher, balls for mill, elements for tractors and tanks tracks, buckets for excavator etc., being used in the same time as the non-magnetic material [1], [2].

The mechanical properties of the Hadfield steel hardened are characterized by the following values [1], [3]:

- tensile strength: 800...1000 N/mm²;
- flow limit: 225...400 N/mm²;
- elongation: $A_5 = 40...55\%$;
- necking: $z = 35...45\%$;
- resilience: 20...30 daN/cm²;
- Brinell Hardness: HB = 180...220.

Also, the austenitic structure of this steel determines the relatively low hardness (of approximately 200 HB) but however the Hadfield steel can not be mechanically processed with tools of common special steel (high speed steel-HSS). Only the carbide alloys (such as Widea) can process, to same extent (with low speed) this grade of steel. Therefore, *Hadfield steel parts are obtained only by casting* [1], [2], [3].



2. The analysis of technology for obtaining the parts of type *Mill Hammer*

The casting is the process of obtaining the manganese steel pieces. If the castings have internal hollows, these can be achieved only by cores, made separately, in core boxes. In this context, it is advantageous to obtain the pieces by casting, when it is necessary to obtain the pieces with complicated shape, in conditions of certain easy and economical making technologies. Properties of the material have, often, a decisive influence on the making process of the casting [4], [5].

In order to perform the analysis of the causes leading to rejection of pieces of Mill Hammer type in industrial practice, was performed a study on a sample of rejected pieces, casting of steel T130Mn135 [5], [6]. The situation registered in the rejected castings is as follows (Figure 1):

- 56% of the castings presented crack, porosities, void holes;
- 24 % of the castings presented nonmetallic inclusions;
- 20% of the castings presented unhomogeneous structures.

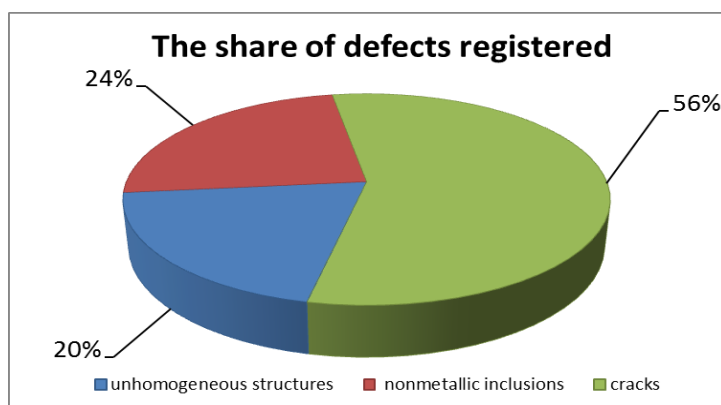


Figure 1. The share of defects registered

Following this study, were put in evidence causes for rejection of their [6], [7]:

- Failure to comply with prescribed parameters of thermal treatment, the castings studied presented a unhomogeneous austenitic structure, with carbides between austenite crystals;
- An example of structure by austenite, with carbides remaining undissolved at the grain-boundary, inclusions and micro-void holes is presented in Figure 2. This defect are due to non-compliance with the prescribed casting temperature and the oxidation of the steel during casting and thus forming MnO inclusions, which determines the occurrence of the hot cracking in the castings.

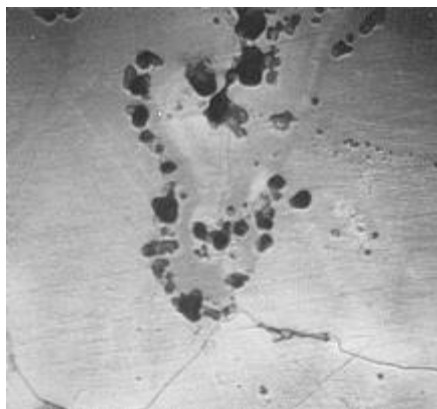


Figure 2. Austenitic structure 200X; Nital attack 2%

- Failure to comply with the casting parameters (temperature and speed casting), the castings presented a columnar primary structure with advanced transcrystallization who was not eliminated by the thermal treatment of hardening, causing the occurrence of the hot cracking in the castings; at occurrence of this serious defect of casting (hot and cold cracking) can contribute both the steel itself and the mould or casting process parameters and thermal treatment parameters of castings;
- The castings presented a large quantity of non-metallic inclusions, due to inadequate quality of the moulding mixture but also because the deoxidation process, which has been insufficiently completed.

Thus, a particularly important role is assigned to elaborated process of the liquid alloy, because it must to consider both the pouring properties of this alloy and moulding technology of piece to be obtaining. A particularly important role is assigned of the mould and positioning of core inside it.

3. The analysis of steel making technology (steel grade *T 130 Mn 135*)

In order to analyze regarding the establishment of measures that lead to improved physical and mechanical characteristics of manganese steel, were analyzed **11 charges** for the steel grade *T 130 Mn 135*. This steel was elaborated in order to obtain pieces of *Mill Hammer* type (Figure 3), used in mining, for coal grinding [2].

According to standard, for cast steel *T 130 Mn 135*, chemical composition must be within the following limits [3], [4]:

Table 1. Chemical composition of the steel *T 130 Mn 135*

Chemical composition, in %						
C	Mn	Si	P	S	Ni	O ₂
1,25...1,4	12,5...14,5	0,3...1,0	max 0,11	max 0,05	max 0,8	max 1,2

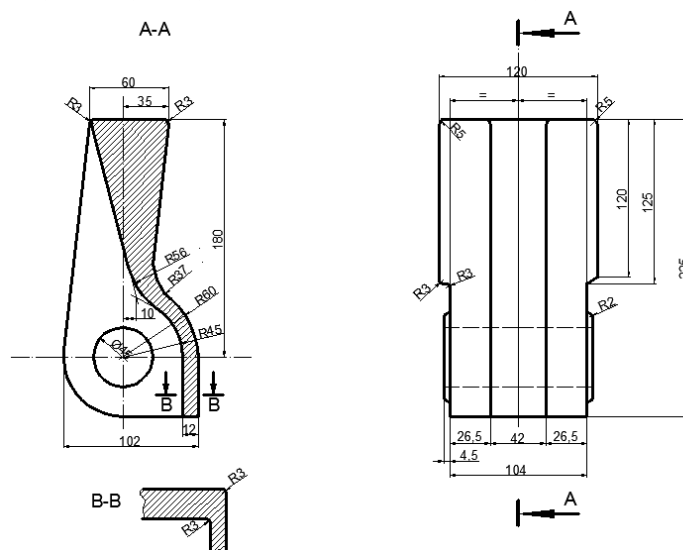


Figure 3. Drawing the piece *Mill Hammer*

The charges of steel were elaborated in electric arc furnace DSN-3 type, with basic lining, with a nominal capacity of 3500 kg. The length of time required to elaboration charges was 200...215 minute/charge.

The metal charge of the furnace consisted, for all charges studied, of the following materials [1], [4], [8]:

- pure scrap iron: 1000 kg;

- waste manganese steel: 2350 kg;
- ferro-manganese FeMn 75: 260 kg;
- ferro-manganese FeMn 82: 70 kg;
- ferro-silicon FeSi 75: 20 kg.

In Table 2 are presented the chemical composition of the charges studied.

Table 2. The chemical composition of the charges studied

No.	Chemical composition, %							
	C	Mn	Si	S	P	Ni	Cr	Mn/C
Charge 1	1,34	14,37	0,36	0,02	0,07	0,33	0,54	10,72
Charge 2	1,38	13,60	0,20	0,01	0,18	0,20	0,61	9,85
Charge 3	1,45	12,61	1,08	0,01	0,09	0,11	0,85	8,83
Charge 4	1,28	11,62	0,55	0,03	0,08	0,55	0,51	8,68
Charge 5	1,23	12,4	0,42	0,04	0,09	0,62	0,52	10,08
Charge 6	1,32	12,82	0,48	0,01	0,09	0,32	0,54	9,71
Charge 7	1,42	13,2	1,02	0,04	0,10	0,59	0,92	9,29
Charge 8	1,33	14,36	0,35	0,02	0,07	0,32	0,53	10,79
Charge 9	1,35	13,59	0,20	0,02	0,07	0,19	0,60	10,06
Charge 10	1,27	11,61	0,54	0,02	0,07	0,53	0,50	9,14
Charge 11	1,43	12,59	1,06	0,02	0,06	0,09	0,83	8,80

Using the data registered in Table 2, was performed the critical analysis of the chemical composition of the 11 charges studied. Thus, conclusions were as follows:

- According to standard, the carbon content must be between 1,25...1,4% [3].

Of the diagram presented in Figure 4 follows that to charge No. 5, the carbon content is below the limit prescribed in standard, and to charge No.3 is registered a value above the maximum of carbon

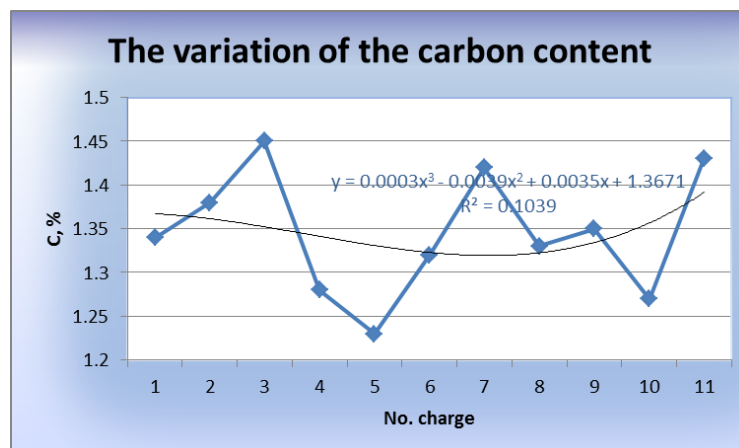


Figure 4. The carbon content of the charges elaborated

The increase over the acceptable limits of carbon content (1,4 % maximum), at a content of manganese in normal limits, has a negative influence of the quantity of carbides and their fineness in the basic metallic mass, resulting in a decrease of the mechanical properties of the steel.

- According to standard, the manganese content must be between 12,5...14,5% [3].

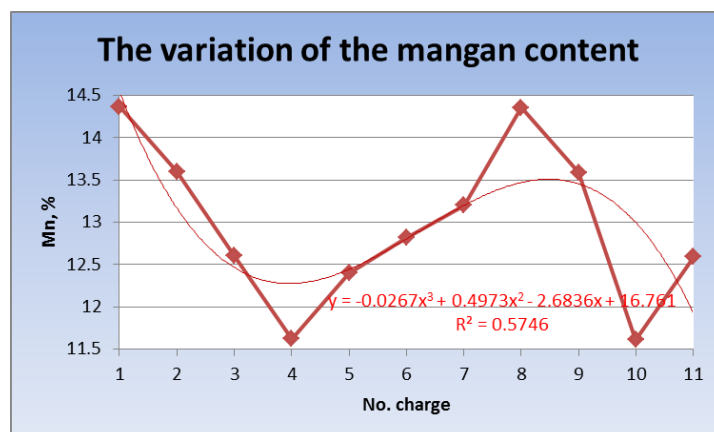


Figure 5. The manganese content of charges elaborated

Of the diagram presented in Figure 5 follows that only to charge No. 4 is recorded a manganese content slightly lower than the standardised value. This deviation causes a deterioration of physical and mechanical properties of steel.

- According to standard, the silicon content must be between 0,3...1,0% [3]. The diagram presented in Figure 6, indicates that, for charges 2 and 9, the silicon content is less than the admissible value, and for charges 3,7,11 is slightly than the maximum admissible value.

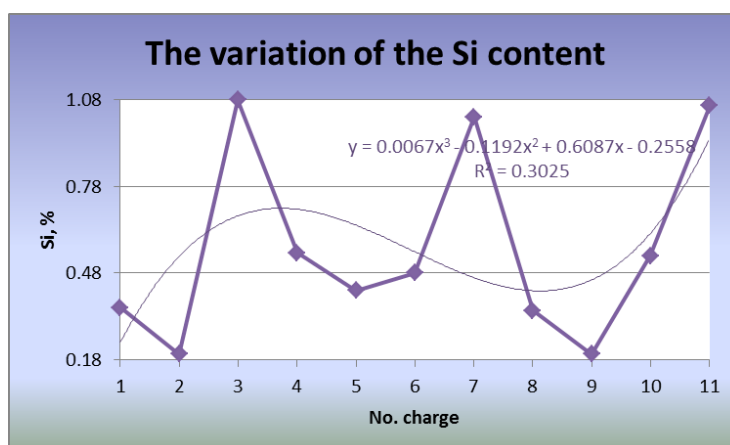


Figure 6. The silicon content of charges elaborated

- According to standard, the sulphur content must be max.0,05%, and the phosphor - max.0,11% [3].

Of the diagram presented in Figure 7, follows that to charge no.2 are registered an increase of the phosphor content above the admissible limits (max. 0,11%), which leads to an increase of britleness of the steel, simultaneously with the decrease its plasticity and toughness.

In all cases, the sulphur content is within the limits recommended, due to the high content of manganese in the steel.

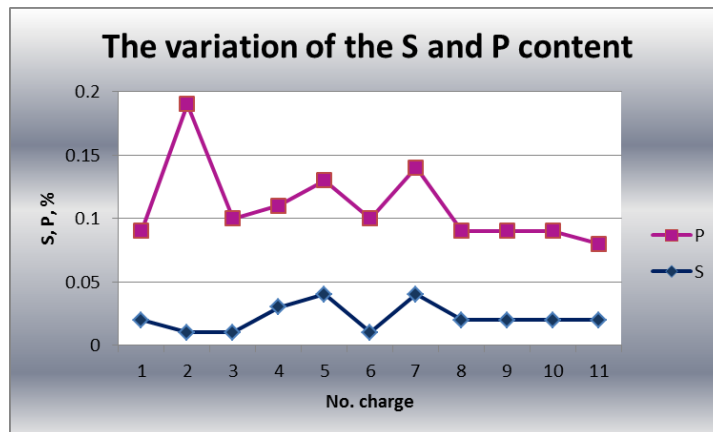


Figure 7. The sulphur and phosphor contents of charges elaborated

- According to standard, the nickel content must be max. 0,8% and the chrome content - max. 1,2% [3]. The diagram presented in Figure 8, indicate that the two elements correspond, in the case of all charges, with the limits recommended in the literature.

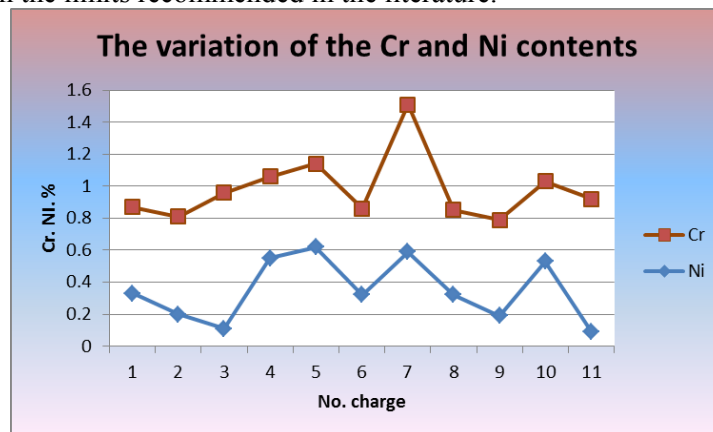


Figure 8. The chrome and nickel contents of charges elaborated

Following the analysis these results, is found that the best properties for austenitic manganese steel are obtained when the ratio $Mn/C \geq 10$ (when the quantity of carbon is the smallest possible, i.e. is towards the lower limit admissible and quantity of manganese is towards the upper limit admissible) [1], [3], [4], [8]. Figure 9 presents the report Mn/C for all 11 charges analyzed.

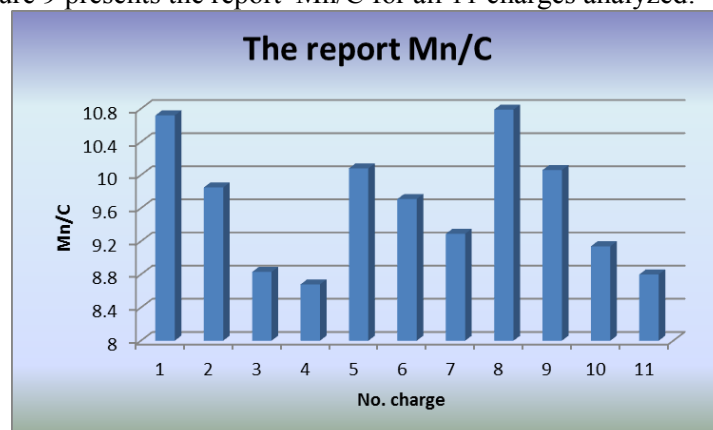


Figure 9. The report Mn/C of charges elaborated

Thus, can be mentioned that, in the case of charge no.1, the contents of elements are within the limits recommended for these steels. Is observed the report $Mn/C = 10,72$, which gives the castings the best physical and mechanical properties. Similary, also for charges 5,8,9 for which the report $Mn/C > 10$ (i.e 10,8; 10,79; respectively 10,06).

The parameters of the thermal treatment (heating temperature, heating time and maintaining, the speed of heating, the speed of cooling and medium cooling) must ensure the obtaining a uniform structure on the section of piece, obtaining a hardness which be within the recommended values and preserving the integrity of the metallic material (absence of cracks and internal and external microcracks) [1].

6. Conclusions

Obtaining the castings of the manganese steel, without defects, requires to know the casting properties of this type of alloy. Then, must be establish the alloy elaborating technology and moulding-casting tehnology, taking into account of all factors that influence the quality of the castings.

Thus, to reduce losses and rejects, should take the following measures:

- At the steel making, to strictly observe the chemical composition in order to obtain the mechanical characteristics established by the standard and the beneficiary; it is necessary to give high priority to Mn and C content, so the ratio $Mn/C \geq 10$;
- At the steel making should be carry out a advanced dezoxidation, due to the formation of the manganese oxide inclusions; to observe, if possible, the steel temperature to elaboration, the fluidity of the steel, the chemical composition;
- To increase the wear resistance of the castings, can be make a supplementary alloying with cromium (max. 2,5%) and molibdenum (max. 2%)
- At casting of steel into the mould to respect the parameters of the casting process, respectively the casting temperature (has the greatest influence on concerning the formation of hot crack), the casting speed and corectly pouring of the liquid alloy;

An important role in obtaining of quality castings is the correct positioning of the core into the mould [2], [5], [9], [10] (figures 10-12), so the mould to take over the stresses that appear during pouring and solidification of steel; thus, can be avoid the appearance of the cracks into the castings;

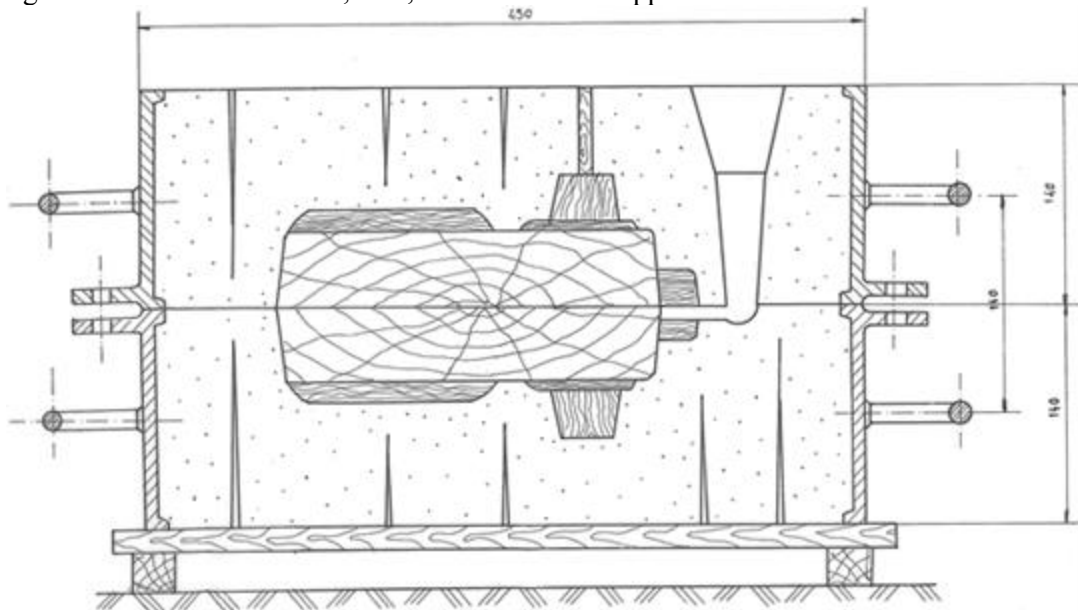


Figure 10. Making the mould parts

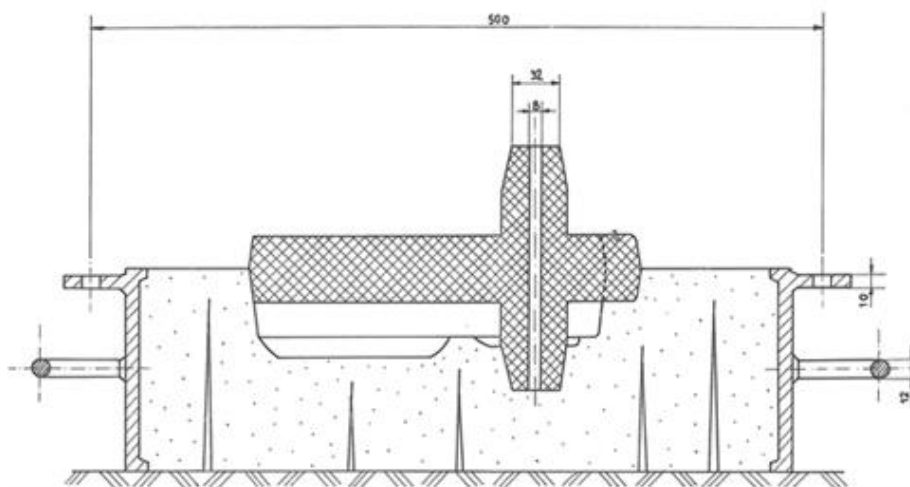


Figure 11. The positioning of the core in the lower mould part

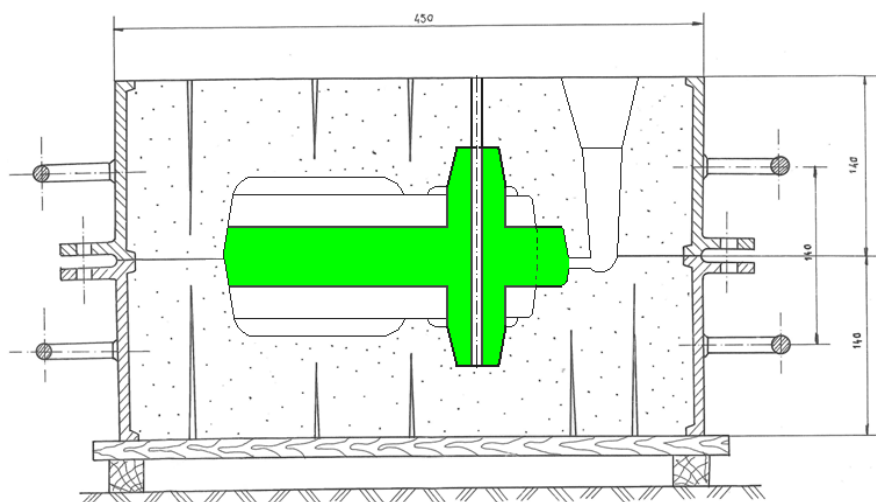


Figure 12. The mould reading of casting

- To respect the prescribed parameters of the hardening thermal treatment (Figure 13):

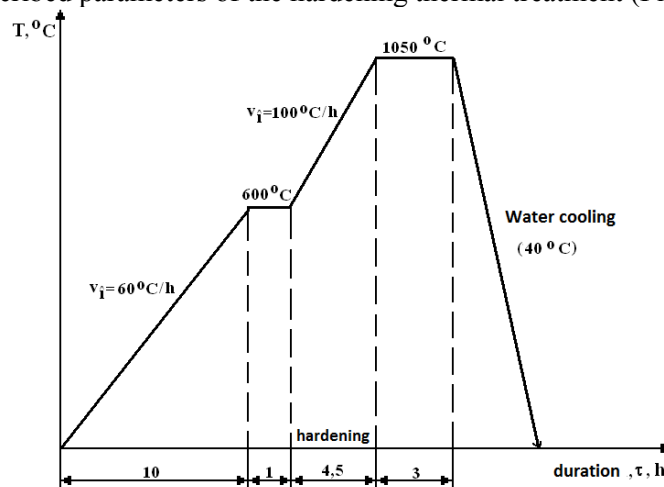


Figure 13. The diagram of the thermal treatment for castings of the steel *T 130 Mn 135*

References

- [1] Sofroni L 1975 *The elaboration and pouring of alloys*, Publishing House Didactic and Pedagogical, Bucharest, Romania
- [2] Josan A, Pinca Bretotean C and Pauca A 2012 *The Use of Regenerated Mold Mixtures in Manganese Steel Piece Casting* Proceedings of the 3-rd International Conference on Energy, Environment, Devices, Systems, Communications, computers (INEEE '12), Mathematical Modelling and Simulation in Applied Sciences, Rovaniemi, Finland, pp 162-164
- [3] ***The Standard *STAS 3718-88 - Manganese austenitic steel castings. Grades and general technical requirements for quality ASTM A128 / A128M - 93(2012) - Standard Specification for Steel Castings, Austenitic Manganese*
- [4] Stefanescu C and Cazacu I 1980 *Technologies of realization of the parts by casting*, Technical Publishing, Bucharest, Romania
- [5] Josan A 2012 *Casting and moulding technologies of metal parts – the project guide-book*, Publishing Polytechnic, Timișoara, Romania
- [6] Josan A 2010 *The analysis of casting defects recorded in the metallurgical enterprises*, International Symposium on Advanced Engineering & Applied Management - 40th Anniversary in Higher Education (1970-2010), Hunedoara, Romania (CD)
- [7] ***1977 *International Atlas of casting defects* Technical Publishing, București, Romania
- [8] Socalici A, Popa E, Hepuț T and Vilceanu L 2014 Contributions related to the control of steel ingot solidification, *IOP Conf. Ser.: Mater. Sci. Eng.* **57** 012004
- [9] Josan A, Pinca Bretotean C, Ardelean E and Ardelean M 2015 Using lateral cores to casting of carbon steel parts, of drive wheel tyle in a metallurgical enterprise, *IOP Conf. Ser.: Mater. Sci. Eng.* **85** 012016
- [10] Josan A and Pinca Bretotean C 2015 Using special additions to preparation of the moulding mixture for casting steel parts of drive wheel type, *IOP Conf. Ser.: Mater. Sci. Eng.* **85** 012017