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Technological Assessment of the Possibility of Making Light-section Castings of GX2CrNiMoN25-6-3 Cast Steel by the Centrifugal Casting Method

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Abstract

The paper presents the results of investigation into the technological possibility of making light-section castings of GX2CrNiMoN25-6-3 cast steel. For making castings with a wall thickness in the thinnest place as small as below 1 mm, the centrifugal casting technology was employed. The technology under consideration enables items with high surface quality to be obtained, while providing a reduced consumption of the charge materials and, as a result, a reduction in the costs of unit casting production.

Keywords: Duplex cast steel, Centrifugal casting technology

1. Introduction

The main area of application of ferritic-austenitic steels and cast steels, also called duplex cast steels, are structures and elements subjected to high loads and exposed to environments favouring stress, pitting or crevice corrosion. Under such conditions, ferritic-austenitic steels and cast steels with a comparable fraction of their basic phases, i.e. ferrite and cementite, exhibit a better set of mechanical properties, compared to traditionally used ferritic or austenitic steels. Their higher mechanical properties compared to austenitic cast steels and good resistance to general and pitting corrosion have caused steels and casting steels of the duplex family to become today irreplaceable

in the chemical industry for the construction of, e.g., the stores and tanks of ships transporting products with high chemical activity, such as phosphoric acid, concentrated sulphuric acid or strongly alkaline media, or for equipment to be used in the petrochemical, power and pulp and paper industries [1-7]. Owing to their high yield strength, they are used for the construction of heat exchangers (thin walls plus good thermal conductivity), heaters, coolers, condensers; or desalination, desulphurization and purification installations (e.g. in waste treatment plants). Their good resistance to fatigue corrosion makes them suitable for the construction of centrifuges, rotary vane driers and other dynamically loaded devices.

The centrifugal casting technology is most often used for producing castings in the form of bodies of revolution without

coremaking. The mould is set in rotating motion around the vertical, horizontal and inclined axes. It is also able to rotate simultaneously around mutually perpendicular axes, e.g. the vertical and horizontal ones [8-12]. Shape castings, on the other hand, are made in a mould or moulds arranged on the edges of the disc of the centrifugal pourer with a vertical axis of rotation. Castings with a mass ranging from several grams (micro-castings) to several tons are produced by the centrifugal casting technology, while in the case of using machines with a horizontal axis of rotation, light-section castings with a diameter of up to 700 mm and with a maximum mass of about 1 ton are made [8]. Gołowin gives an example of a 45-ton ingot casting made by the centrifugal method with a vertical axis of rotation [8].

In the centrifugal casting process, the filling of the mould cavity with metal or alloy takes place by the agency of the centrifugal force acting in the casting forming process. Generally, three methods of supplying the liquid alloy to the mould cavity are distinguished [8-12]:

- proper centrifugal casting – the axis of the casting coincides with the axis of rotation; the outer casting surface takes on the form of the mould cavity, while the inner free surface is formed by the action of the centrifugal force;
- semi-centrifugal casting – in this case, the inner surface is reproduced by means of cores used; the casting axis also coincides with the axis of rotation;
- casting under centrifugal pressure – the main gate is situated in the vertical axis of rotation; the casting alloy fills the mould cavity by the action of the centrifugal force, as it is fed to the gating system.

Due to its chemical composition, low carbon content and high chromium content (above 21%), nickel content normally not less than 3-6%, and an addition of elements, such as molybdenum and nitrogen, the alloy under investigation is characterized by poor casting properties. While for casting with a considerable wall thickness this does not pose any problem, in the case of light-section castings this makes a great obstacle. Basic drawbacks in those cases in the incorrect reproduction of the mould and casting contraction defects. A remedy for these problems can be increasing the casting module above the recommended 30% or producing an adequate metallostatic pressure inside the mould. Using an enlarged riser head will result in a very substantial waste of even up to 2/3 of the finished product. An alternative seems to be to employ the centrifugal casting technology; while, it is expected that by appropriately selecting the parameters it will be possible to obtain not only a higher efficiency, but also a good or even better surface with the simultaneous possibility of reproducing the wall with a thickness of up to 1 mm.

2. Research material and methodology

The subject of the research was cast steel in the GX2CrNiMoCuN25-6-3-3 and GX2CrNiMoCuN25-6-3 grades according to PN-EN 10283:2002. Chemical composition of the cast steel is summarized in Table 1.

Table 1.

Chemical composition of the examined cast steel grade

No.	C	Cr	Ni	Cu	Mo	Mn	Si	S	P	N
1	0.025	26.80	6.48	0.03	3.00	1.19	1.04	0.011	0.008	0.25

The aim of the investigation was to assess the possibility of using the centrifugal casting technology as an alternative to other casting techniques for duplex cast steels in order to produce light-section shape castings.

The study endeavoured to demonstrate that the change in technology would not have a negative effect on the quality of the casting. Tests were carried out on a casting representing a pump rotor produced on a commercial scale by a domestic manufacturer.

A rotor model (Fig. 1a) adapted to the centrifugal casting technology was produced by 3D printing. The model was characterized by a surface roughness of Ra 11.93 and Rz 61.1. On its basis, thin-walled ceramic mould were made according to the investment pattern technology in the solution with a support layer. So prepared mould, after the pattern fusing and baking process, was cooled down to a temperature of about 500°C. At this temperature, the mould was mounted on the vertical rotation axis centrifugal pouring stand. To establish the preliminary pouring process parameters, three series of castings were made with basic process parameters, as shown in Table 2.

Table 2.

The parameters of the casting process for cast steel GX2CrNiMoN25-6-3

Designation	Pouring temperature, °C	Rotation speed r/min	Pouring method
Series 1	1550	250	rotating mould
Series 2	1550	200	rotating mould
Series 3	1550	0	fixed mould
Series 4	1650	0	fixed mould

The "fixed mould" pouring method is understood here as the one, where as soon as the mould has been filled with the alloy, it is set in rotary motion at preset rotational speed. In contrast, the term "rotating mould" is used where the mould is filled with the alloy as it rotates. The rotation duration of castings during solidification was 2 minutes, and after about 5 minutes the castings were knocked out to allow them to solidify freely. The element marked as Series 4 is a gravity casting with an enlarged riser, which is derived from technological tests carried out in classic moulding sand. The castings were subject to quality assessment for dimensional conformity and surface roughness. The surface roughness measurement was taken using a DIAVITE DH-5 surface roughness tester to determine the Ra and Rz parameters. The structural examinations were performed with a Nikon Eclipse MA-200 optical microscope on specimens etched with the Mi21Fe reagent.

3. Research results and their discussion

The obtained castings of GX2CrNiMoN25-6-3 cast steel, in accordance with the adopted methodology, were subjected to surface quality assessment. Castings made according to the parameters for Series 1 and 2, as being free from defects, such as a misrun, were considered correct (Fig. 1b). Series 3 of gravity castings was characterized by repeatable defects in the form of misruns. Whereas, the increase in metallostatic pressure and pouring temperature for Series 4 allowed castings of a complex shape to be obtained (Fig. 1c). The obtained casting surface roughness results are summarized in Table 3.

Table 3.

Surface roughness results

series	1	2	3	4
Ra μm	4.65	4.39	7.34	12.79
Rz μm	19.1	20.0	40.9	59.2

The lowest surface roughness is exhibited by castings made by the centrifugal casting method. Compared to the castings made by the gravity casting method, they have a value of the Rz parameter smaller by two times and that of the Ra parameter also about twice as small.

The microstructural examination of all castings in a raw condition, made in the central working part of the rotor blade, showed the presence of a ferritic-austenitic structure (Fig. 2).

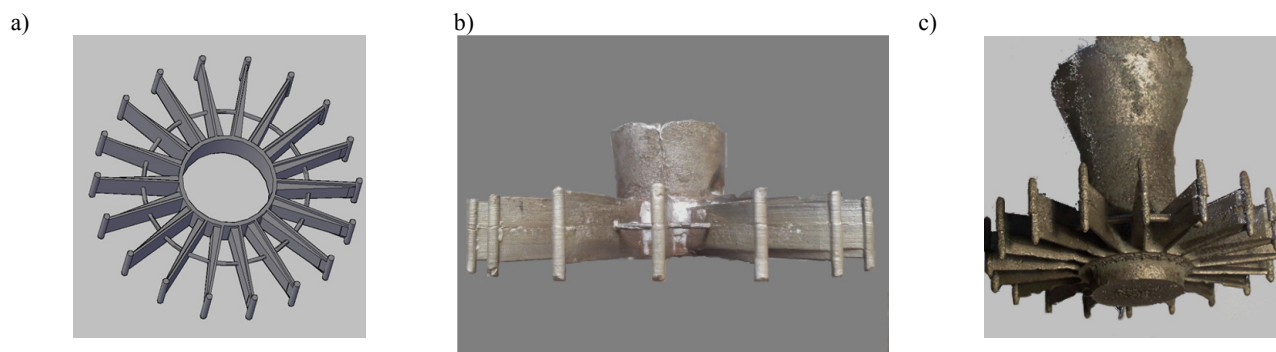
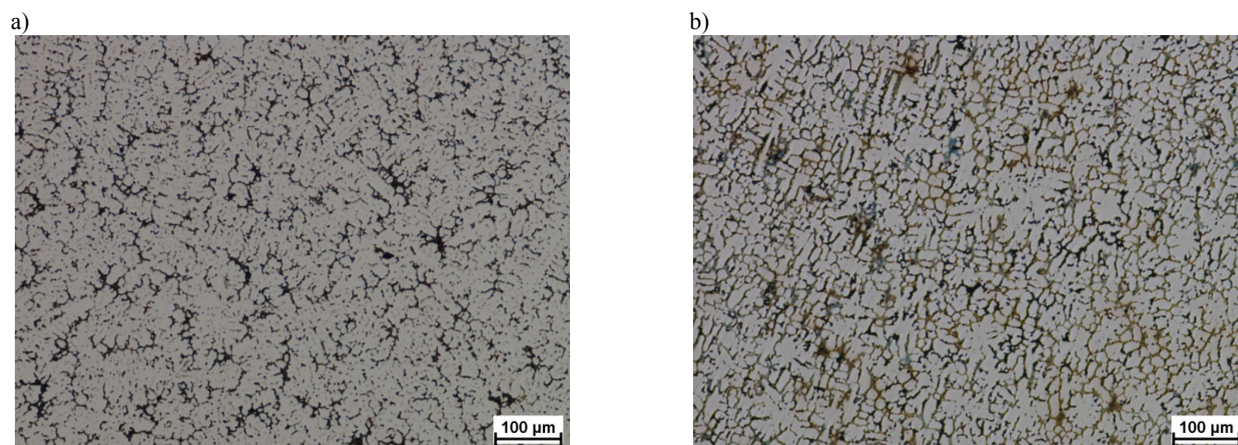


Fig. 1. Pump rotor a) 3D model, b) centrifugal casting, c) gravitational casting (series 4)



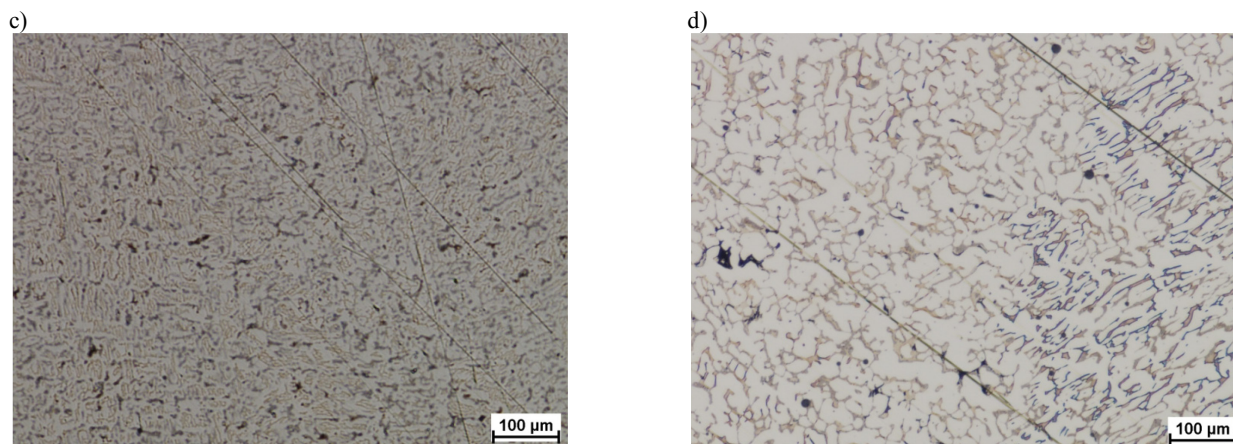


Fig. 2. The microstructure GX2CrNiMoCuN25-6-3 a) series 1, b) series 2, c) series 3. d) series 4 – magn. 100x

The results for Series 1 & 2 and Series 4 were characterized by a similar microstructure in terms of the grain size and the percentage fraction of basic phases. At the same time, small precipitations of the sigma phase, distributed uniformly within the entire volume, were observed. Such distribution [13] of this phase increases the erosion resistance, which is particularly important for parts exposed to aggressive working medium. For Series 1 & 2, the directional character of the structure is additionally observed, whose effect for the alloy under investigation would need to be determined in a separate study.

The comparison of the gravity cast structure has revealed that the casting of Series 3 exhibits an increased fraction of the sigma phase. The cause of the increased sigma phase fraction is seen in the slower heat removal from the solidifying casting, in spite of the lower pouring temperature.

4. Summary

The performed investigation into the possibility of employing the centrifugal casting technology to produce light-section shape castings of duplex cast steel has confirmed the authors' presumptions. The obtained centrifugal castings are distinguished by high quality of surface reproduction, lower surface roughness and a structure similar to that of castings made by gravity methods (Series 4). Moreover, in conformance with the literature reports describing the method of centrifugal casting of metals and alloys, it has been demonstrated that it is possible to produce light-section shape castings of duplex cast steel with an increased output and a reduced pouring temperature.

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