UDC 620.186.4 DOI: 10.17580/cisisr.2018.02.10

ASSESSMENT OF CENTRAL HETEROGENEITY IN SLAB TO FORECAST CENTERLINE SEGREGATION IN PLATE STEEL

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Key words:

central heterogeneity, cast slabs, plate steels, centerline segregation, asymmetric macrostructure, solidification, etching, image analyzing.

ABSTRACT

Continuous cast slabs obtained on curvilinear casting machine have an asymmetric macrostructure with reference to their wide faces. This asymmetry is associated with a different coefficient of heat transfer when feeding water from above and from below to wide faces with a small and large radius, respectively. In such complex asymmetric thermo-physical and hydrodynamic conditions of solidification, a centerline segregation of the slab is formed. Slab centerline segregation may be narrow or wide dependent upon the development of the above-mentioned processes. To reveal the slab centerline segregation, the samples were etched with a 15 % aqueous solution of ammonium persulphate for 10–30 minutes. The images of the slab centerline segregation structure and their evaluation were obtained using the Thixomet Pro image analyzer. A wide segregation zone in a slab always leads to a high class of centerline segregation in the plate at any volume fraction of segregation spots in the slab central zone. In the absence of a wide slab centerline segregation, the class of plate centerline segregation is linearly increased with an increase of the volume fraction of segregation spots in the narrow slab centerline segregation.

Introduction

The quality of the plate steel is determined by the structural and chemical heterogeneity of the slab from which it is made in many respects. Continuous cast slabs obtained on curvilinear casting machine have an asymmetric macrostructure with reference to their wide faces. Zone of column crystals on a small radius can be twice as long as on a large radius. This asymmetry is associated with a different coefficient of heat transfer when feeding water from above and from below to wide faces with a small and large radius, respectively [1, 2]. The asymmetry is amplified by the gravitational sedimentation of fragments of dendrites come off from the crystallization front from a small radius when a slab moves to a horizontal position [1, 3]. Because of a difference of temperatures on wide faces on a large and small radius there are closed thermal streams of the melt on perimeter of a solidifying slab [4]. Solidified skin is expanded between the rollers and presses up on them while moving in the secondary cooling zone [5–10]. Various shrinkage processes develop [5, 8]. In such complex asymmetric thermo-physical and hydrodynamic conditions of solidification, a centerline segregation of the slab is formed. Slab centerline segregation may be narrow or wide dependent upon the development of the above-mentioned processes. During hot rolling the narrow or wide slab centerline segregation is transformed into a centerline segregation in the plate so the purpose of this paper is to find the correlation between them.

Materials and Methods

Samples from the centerline zone of industrial slabs 300-mm thick, as well as from the 25-mm thick plates produced from these slabs were examined. To reveal the slab centerline segregation, the samples were etched with a 15% aqueous solution of ammonium persulphate for 10–30 minutes. The images of the slab centerline segregation structure and their evaluation were obtained using the Thixomet Pro image analyzer [11]. Areas limited to 2-cm for the narrow and 10-cm for the wide slab centerline segregation zones were studied. In each area the total volume fraction of the segregation spots V^W for the wide slab centerline segregation and V^N for the narrow one, as well as the average size of the segregate spots were measured. To assess centerline segregation in the plates, the technique provides ratings of centerline segregation in accordance with standard charts using a magnification of ×200, was used [12]. Additionally, structure is evaluated at magnification ×500 to assess the non-metallic inclusions that are decorating the band. Such inclusions or wide single band can be the basis for an assignment of additional 0.5 class penalty. Class 1 means the structure with slightly visible discontinuous bands in the field of view, class 2 is assigned in the cases when number of such bands is not more than 3, class 3 is for the structure with more than 3 bands, class 4 means 3 bands located close to each other and uniformly.

Results and Discussion

The narrow centerline segregation of slab No. 1 is a poorly resolved region of segregation spots (**Fig. 1, *a***), the size of which (620±86 μm) varies within narrow limits, and the fraction (V^N) does not exceed 0.21 vol. % (**Fig. 1, *b***).

The narrow centerline segregation in slab No. 2 is strongly marked (**Fig. 1, *d***), the size of each spot varies considerably (**Fig. 1, *e***). The volume fraction of segregation spots in slab No. 2 (V^N =3.23 vol. %) is 16 times

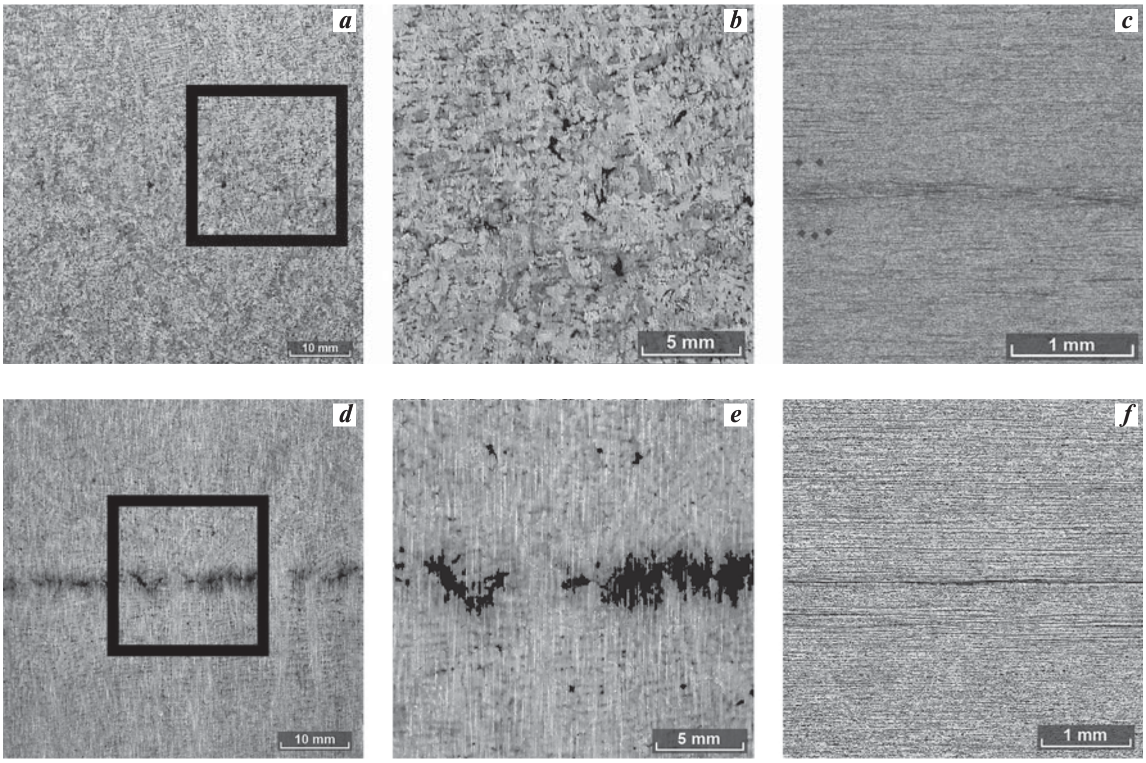

Fig. 1. Narrow Slab Centerline Segregation and Centerline Segregation in the Plate Produced from this Slab:

- Etched segregation spots, slab No. 1 (*a*) and slab No. 2 (*d*);
- Measured segregation spots, slab No. 1 (*b*) and slab No. 2 (*e*);
- Plate No. 1, class 2.5 (*c*); Plate No. 2, class 4.5 (*f*)

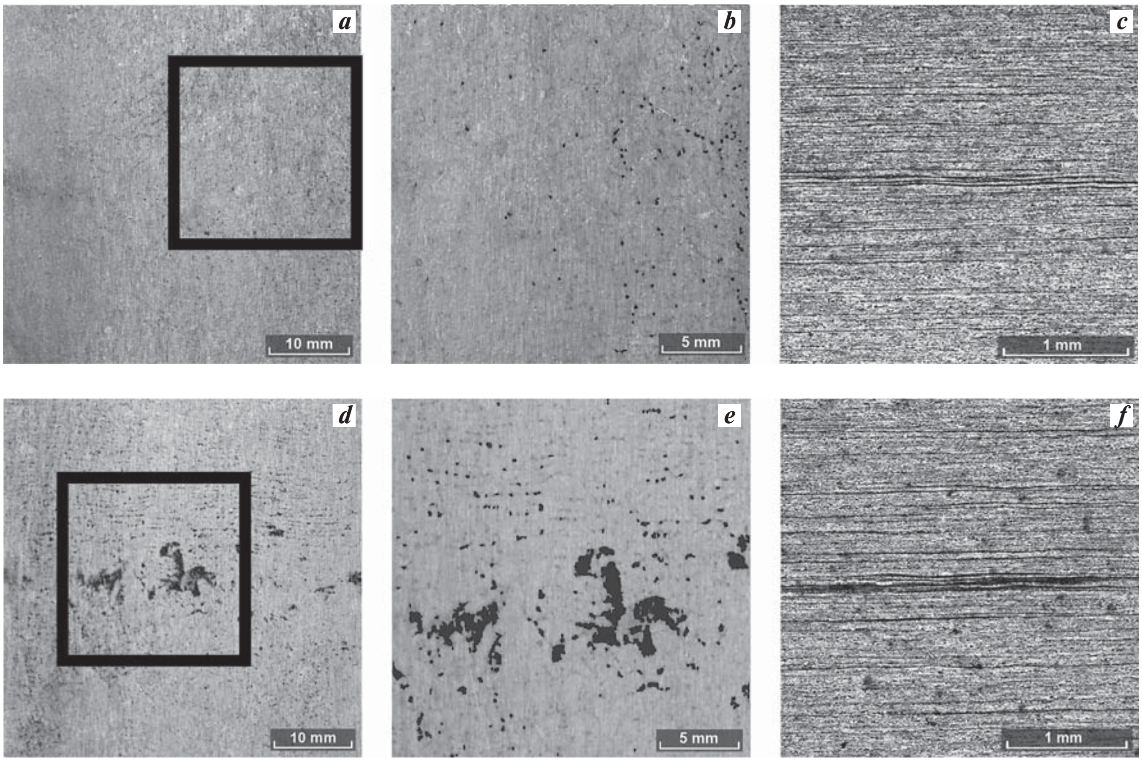

Fig. 2. Wide Slab Centerline Segregation and Centerline Segregation in the Plate Produced from this Slab:

- Etched segregation spots, slab No. 3 (*a*) and slab No. 4 (*d*);
- Measured segregation spots, slab No. 3 (*b*) and slab No. 4 (*e*);
- Plate No. 3, class 4.0 (*c*); Plate No. 4, class 4.5 (*f*)

Table 1. **Volume fraction of the segregation spots for a wide (V^W) and for a narrow (V^N) slab centerline segregation**

Heat	1						2								3					
Slab	1	2	3	4	5	6	1	2	3	4	5	6	7	8	1	2	3	4	5	6
V^W %	–	–	–	–	–	0.17	–	–	–	–	–	–	–	–	–	–	–	–	–	0.25
V^N %	0.01	0.11	0.31	0.34	0.39	0.21	0.14	0.15	0.17	0.24	0.27	0.34	0.76	1.39	0.08	0.1	0.15	0.16	1.85	0.55
V^N % ±s	0.23 ± 0.16						0.43 ± 0.44								0.47 ± 0.77					

greater and the average size (978±315 μm) in 1.5 times more than in slab No.1 (Fig. 1, *b* and *e*).

There is a poorly resolved wide centerline segregation with fine spots (212±15 μm) and with low volume fraction ($V^W = 0.1\%$) in slab No. 3 (**Fig. 2, *a* and *b***). The wide centerline segregation in slab No.4 is much more obvious with big segregation spots 1070±86 μm in size and with a volume fraction $V^W = 0.89$ % (**Fig. 2, *d* and *e***).

Wide or narrow slab centerline segregation can be found in samples with high volume fractions of the segregation spots (0.65 % and 0.89 %), respectively for slab No. 2 and No. 4 on Fig. 1, *e* and Fig. 2, *e* and in samples with low volume fractions of the segregation spots (0.04% and 0.1 %), respectively for slab No. 1 and No. 3 on Fig. 1, *b* and Fig. 2, *b*.

Two sets of samples were examined. The first set consisted of slabs and plates obtained from these slabs (Fig. 1 — Fig. 2). The wide slab centerline segregation always leads to a high class of the centerline segregation in plate and it is independent of the volume fraction of the segregation spots in the wide slab centerline segregation (**Fig. 3, *b***).

In the absence of a wide slab centerline segregation, the class of plate centerline segregation is linearly increased with an increase of the volume fraction of segregation spots in the narrow slab centerline segregation (**Fig. 3, *a***).

The second set consisted only of slabs without plates. All slabs of the second set can be ranged by the average volume fraction of segregation spots (**Table 1**).

In one slab of heat No.1, despite the lowest average fraction of segregation (0.23±0.16), a wide centerline segregation was found. The volume fractions of segregation in two other heats were approximately the same and twice as large as in heat No. 1. A wide centerline segregation zone was found only in one slab from heat No.3, where the spread of V^N was twice as great as in heat No. 2.

Conclusions

Correlation between centerline segregation class in the plate steel and the character of the slab centerline segregation was revealed. A wide segregation zone in a slab always leads to a high class of centerline segregation in the plate at any volume fraction of segregation spots in the slab central zone. In the absence of a wide slab centerline segregation, the class of plate centerline segregation is linearly increased with an increase of the volume fraction of segregation spots in the narrow slab centerline segregation.

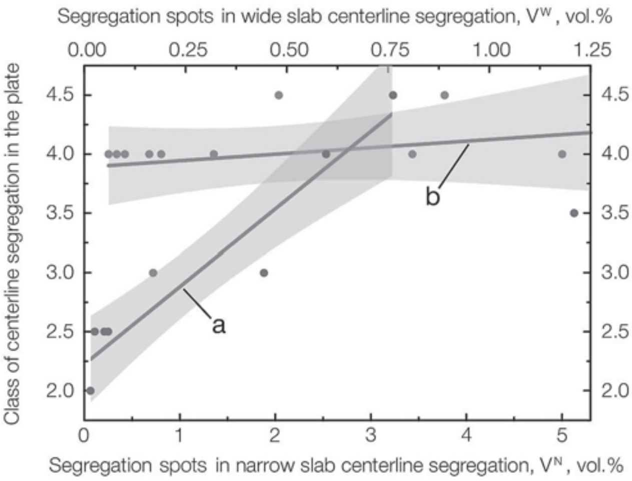

Fig. 3. Centerline segregation class in the plate steel vs. character of the slab centerline segregation:
a — narrow; *b* — wide

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UDC 678.012

DOI: 10.17580/cisisr.2018.02.11

THE STUDY OF THE EFFECT OF CHROMIUM BORON (CrB_2) HARDENING ADDITIVE ON THE DEVELOPED PG-Zh40 SURFACING POWDER*

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Key words:

self-fluxing alloy, gas powder surfacing, durability, mechanochemical technology, attritor, granulation.

ABSTRACT

Powders of Fe, Ni, Cr, Si, Cu, B, C and hardening additive CrB_2 ligature were used as initial reagents for creating self-fluxing surfacing powder. The synthesis of the composite material was carried out by mechanochemical method using an attritor. Optimization of the composition of new composite alloys with the addition of a chromium boron ligature was carried out and the conditions for the formation of the alloy were determined. The conditions of phase formation and the structure of a new composite filler with boride hardening under mechanical alloying were also studied. The following rational composition of powder alloy was obtained : Fe = 32–40 %; C = 1.1–1.4 %; Cr = 14–15 %; Si = 2–3 %; B = 2.0–2.9 %; Ni = 30–32 %, Cu = 2–3 % with a hardness of 30–44 HRC. The analysis of structure in blankets of surfacing alloy on the basis of iron is carried out it was carried out by means of the metallographic analysis.

Introduction

The world economy annually loses approximately 80 billion USD due to wear and corrosion, but adequate proactive wear protection can help to avoid these losses. This protection involves surfacing of new parts as well as reconditioning and return of worn ones to economic circulation. Surfacing with materials with high performance characteristics is an effective method of machinery parts surfaces hardening. This method is cost-effective, because surfacing is applied only to the surfaces functioning in an aggressive wear environments, and as a rule, the weight of deposited material is very low in comparison with the total weight of a part. Durability of hardened parts is determined by the characteristics of deposited material, and for this reason, the materials or alloys used for surfacing are selected on the basis of the part's operational environment and the surfacing method. Also, alloying elements used for powder deposition and affecting the structure and properties of surfacing materials are selected. Powder alloys based on Fe–Cr–Ni and Fe–Co–Ni are used as the base material. Based on their composition, features of the structure of the surfacing layer, which has a crystalline dendritic structure, are revealed. The influence of alloying elements on the formation of the microstructure of surfacing, which affects the processes of structure formation during crystallization, is established. The features of the phase composition during doping are revealed, its positive effect on the mechanical properties of the weld deposition is evaluated [1]. One of the most promising areas for the development of materials science is powder metallurgy. New possibilities for obtaining products from powder of different chemical composition are opened up by the creation and testing of synthesis technology, as well as the formation of coatings on surfaces of parts with enhanced performance properties [2].

The new self-fluxing surfacing ferrous powder material with hardening additive developed by our team will be used for the reconditioning of components of equipment and machinery operating in abrasion wear, corrosion, high temperature or aggressive environment exposure conditions.

Currently, there are many self-fluxing surfacing powder nickel- and copper-based alloys produced under various methodologies. These alloys have started to take the lead among the materials commercially produced by the world's leading companies such as NACA, JNCO, Battelle, Cabot, BBC, Vienna, KRUPP etc. Alloys with hardness specified in the range from 35 to 55 HRC (such as PSR-2, PSR-3, PSR-4 etc. (GOST 21.448-75)) were developed to create coating of different hardness. All these

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