ТОРАЙҒЫРОВ УНИВЕРСИТЕТІНІҢ
ҒЫЛЫМИ ЖУРНАЛЫ

НАУЧНЫЙ ЖУРНАЛ
ТОРАЙГЫРОВ УНИВЕРСИТЕТА

ҚАЗАҚСТАН ҒЫЛЫМЫ МЕН ТЕХНИКАСЫ

2001 ЖЫЛДАН БАСТАП ШЫҒАДЫ

TORAIGHYROV UNIVERSITY

НАУКА И ТЕХНИКА КАЗАХСТАНА

ИЗДАЕТСЯ С 2001 ГОДА

ISSN 2788-8770

№ 3 (2023)

ПАВЛОДАР

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№ KZ51VPY00036165

выдано
Министерством информации и общественного развития
Республики Казахстан

Тематическая направленность
Публикация научных исследований по широкому спектру проблем
в области металлургии, машиностроения, транспорта, строительства,
химической и нефтегазовой инженерии, производства продуктов питания

Подписной индекс – 76129

https://doi.org/10.48081/GZVJ4547

Импакт-фактор РИНЦ – 0,189

SRSTI 53.47.01

https://doi.org/10.48081/PRBW4597

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MACROSTRUCTURE OF A HOLLOW BILLET FROM STEEL 25CRV UNDER DIFFERENT TEMPERATURE CONDITIONS OF CASTING

In this work, the influence of technological factors and the macrostructure of hollow cast billets made of 25CrV steel on the mechanical properties at various temperatures was studied. It has been established that the branched transcrystalline macrostructure of pipe billets is the most favorable. The temperature parameters of continuous casting are determined, which ensure the production of a branched transcrystalline macrostructure of pipe hollow billets. A comparative analysis of the mechanical properties of pipe billets obtained at different temperatures of casting the melt, which have a transcrystalline (columnar) macrostructure, is carried out, and with an increase in the degree of its dispersion, the strength and plastic properties increase. It is shown that the presence of a large temperature gradient promotes the formation of columnar crystals, the orientation of which is determined by the direction of the heat flow. To ensure high mechanical properties, it is necessary to obtain a finely branched transcrystalline macrostructure of the billets.

Keywords: 25CrV, hollow billet, macrostructure, mechanical properties, casting temperature.

Introduction

Pipe billets made of steel 25CrV obtained by continuous cast have a exceptionally columniform macrostructure with radially ordered crystals growth from the out aboveground to the center. Since there are a moderately comprehensive character of technological constituents that influence the crystallisation of these billets (overheating temperature and time, receptacle temperature, casting temperature, casting speed, cooling rate, metallic deoxidation, modification, etc.), sporadically there are predicaments related with a rock-bottom commensurate technological and machine-driven properties, the exploitation of situation constitution destruction, the embrittlement of steel, etc. There are furthermore contradictions related with the consequence of the macrostructure on the properties of continuously casting billets made of steel 25CrV. On the individual hand, it is recognized that pipes produced from billets with a columniform macrostructure have a higher semipermanent capability compared to billets with an equiaxed macrostructure [4–7]. On the over-the-counter hand, it has been accepted that the intergranular crispiness of these consequences is outstanding to the formal propinquity of a coarse columniform constitution and the exploitation of breakage on the frontiers of columniform dendrites. At the corresponding time, thither is a diversification of macro- and microstructures

of broadloom pipes made of steel 25CrV, outstanding to the consequence of the technological constituents mentioned above [8–10].

Materials and methods of research

In the process of obtaining billets, the influence of such a factor as the melt casting temperature was studied in the range from 1450 to 1600 °C. Billets with an outer diameter of 210 mm and an inner diameter of 127 mm were cast. The macrostructure of templates from pipe billets made of steel 25CrV, the chemical composition of which is given in Table 1, was studied. The determination of mechanical properties was determined by tensile testing.

Table 1 – Chemical composition of steel 25CrV

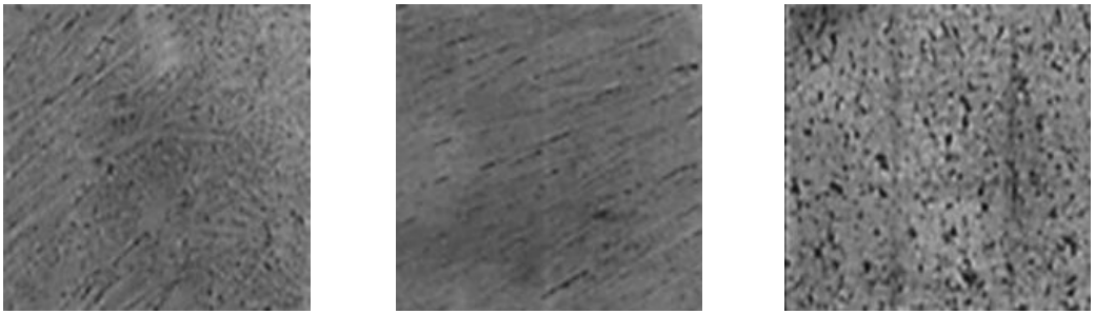
Steel	C	Si	Mn	Ni	S	P	Cr	Mo	V
25CrV	0.25	0.28	0.45	0.19	0.017	0.019	1.68	0.27	0.18

Results and discussion

The study of billets from steel 25CrV showed that it is possible to accomplish contradistinctive macrostructure and mechanical properties depending on the temperature of the liquidize casting. The nature of the crystallisation cognitive semantics which arbitrates the macrostructure of the pipe billet made of steel 25CrV, upon be contingent on the liquidize casting temperature and the conditions of its solidification.

By ever-changing the liquidize molding temperature, individual can importantly consequence the structure of the billet (Table 2). Lowering the cast temperature of the liquidize decrease the imagination to transcrystallization and encourages the formation of an equiaxed dendritic structure. During the experimentations in this work the values of steel casting temperature 1450, 1475, 1500, 1525, 1550, 1575 and 1600 °C were chosen. An analysis of the macrostructure of billet templets confirmed that with a diminution in the liquidize casting temperature, the imagination to transcrystallization decreases, and the zone of equiaxed crystals from the out surface of the casting billet increases (Figure 1).

Thus, in pipe billets from steel 25CrV, it is possible to obtain a completely transcrystalline (columnar) structure, a columnar structure with a small inclusion from the inner surface of equiaxed crystals up to 10 mm deep, a mixed structure with different levels of the length the zone of columnar crystals – 15–20 mm, 10–15 mm, 5–10 mm from the outer surface, as well as a completely equiaxed structure, although the latter structure is rarely obtained and always contains zones of columnar crystals near the walls of the billet. By changing the melt casting temperature, it is possible to vary the mechanical properties of the billets in a wide range.



a b c

Figure 1 – Macrostructure of billets

a – macrostructure at casting temperature 1450–1500 °C; b – macrostructure at casting temperature 1525–1550 °C; c – macrostructure at casting temperature 1575–1600 °C

Table 2 – Macrostructure and mechanical properties of billets

№	Casting temperature, °C	Macrostructure	Tensile strength, MPa	Yield strength, MPa	Elongation, %
1	1450	Zones of columnar and equiaxed crystals	490	305	14,3
2	1475	Zones of columnar and equiaxed crystals	507	325	16,1
3	1500	Zones of columnar and equiaxed crystals	537	358	17,9
4	1525	Columnar branched crystals	592	396	18,8
5	1550	Columnar branched crystals	588	381	18,5
6	1575	Coarse columnar crystals	522	330	21,8
7	1600	Coarse columnar crystals	530	341	22,3

A relative analysis of the pipe billets mechanical properties obtained at different liquidize casting temperatures, which have a transcrystalline (columnar) macrostructure, showed that with an increase in the measure of its dispersion, the capability and impressionable properties, as advantageously as impact strength at extension temperature, increase. This relatively contradicts the information obtained in the works of additional authors, where it is explicit that the plastic properties and impact strength of billets with a transcrystalline macrostructure increase with an accumulation in the casting temperature of the melt. The results obtained in this work can be explained by the positive chain reaction on the all-inclusive heterogeneous of mechanical characteristics the devastating of columniform crystals and an increase in the commensurate of their branching. The transcrystalline macrostructure of castings, formed at a melt casting temperature of 1550–1600 °C, has an average cross section of dendritic branches of 4.6 mm^2, and formed at a melt casting temperature of 1500 °C, 2.3 mm^2.

Billets with a cross-bred macrostructure have a mark down commensurate of strength, malleability and toughness, determined by a different correspondence of the breadth of districts with different shapes of dendrites. The heterogeneous nature of the macrostructure of the billetrs fix up with provision a non-uniform apportionment

of stresses during testing, which occasions a decrease in the mechanical properties of billets made of steel 25CrV. An analysis of the representatives mechanical properties showed that the beyond compare compounding of mechanical properties is exhibited by pipe billets made of steel 25CrV with columniform crystals obtained at a liquidize molding temperature of 1525°C. It is this liquidize molding temperature that make sure the creation of a transcrystalline macrostructure consisting of thin branched columniform crystals. These results are in concordance with exhortations with reference to the superiorities of obtaining a transcrystalline macrostructure, on the other hand in the contemporaneous studies, it was constitute that in progression to increase the commensurate of mechanical characteristics, it is all-important to accomplish a homogeneous transcrystalline macrostructure of pipe billets, consisting of thin branched columniform crystals. It should be anticipated that much a macrostructure testament accommodate a high-pitched heterogeneous of mechanical and technological properties and a mark down imagination to the materialisation of transmissible microheterogeneity during consequent plastic and heat treatment of behaviour towards of pipes made of steel 25CrV.

Funding information

This work was supported by the Ministry of Education and Science of the Republic of Kazakhstan within the framework of grant funding of young scientists for scientific and (or) scientific and technical projects for 2022-2024 under the IRN AP14972971 project «Research the structure formation and mechanical properties of oil assortments pipes produced from cast hollow billets».

Conclusions

To provide improved mechanical characteristics of pipe billets made of steel 25CrV, it is necessary to obtain a finely branched transcrystalline macrostructure, which can be done at a melt casting temperature of 1525 °C. Such casting parameters provide a higher complex of mechanical and operational characteristics.

REFERENCES

1 **Zhakupova, A.** «The Influence of the Initial Billet on the Mechanical Properties of Pipes» / A. Zhakupova, A. Bogomolov, A. Zhakupov // IOP Conference Series: Materials Science and Engineering, vol. 969(1), article 012033, 2020, [Electronic resource]. – doi: 10.1088/1757-899X/969/1/012033.

2 **Choudhary, S.** «Influence of Modified Casting Practice on Steel Cleanliness» / S. Choudhary // ISIJ Int., vol. 51(4), P. 557–565, 2011, [Electronic resource]. – doi: 10.2355/isijinternational.51.557.

3 **Kobayashi, M.** «Technical progress in steelmaking and casting for special bar and wire steel at Muroran work» / M. Kobayashi, K. Isobe, M. Arai // Nippon Steel Technical Report, vol. 394, P. 119–124, 2012.

4 **Rogberg, B.** «Influence of Soft Reduction on the Liquid Flow Velocity and Pore Formation in the Mushy Zone» / B. Rogberg // In The 2nd ISIJ-VDEh-Jernkontoret Joint Symposium, pp. 12–13, 2017.

5 **Smirnov, Y.** «Development of the method prevention of internal cracks in process of soft reduction contiuously cast blooms» / Y. Smirnov, V. Sklyar // METAL 2010 – 19th International Conference on Metallurgy and Materials, Conference Proceedings, 2010.

6 **Dauby, P.** «Application of micro-refrigerators as the active element on the crystallization of metal» / P. Dauby, S. Kunstreich // ISS Tech, pp. 491-504, 2003.

7 **Nakashima, J.** «Micro–refrigerators» / J. Nakashima, A. Kiyose, Y. Ohtani, J. Fukuda, T. Kawase, M. Doki // Nippon Steel Technical Report, vol. 86, P. 68–73, 2002.

8 **Thome, R.** «Principles of billet soft-reduction and consequences for continuous casting» / R. Thome, K. Harste // Isij International, vol. 46(12), P. 1839–1844, 2006, doi: 10.2355/isijinternational.46.1839.

9 **Zhakupov, A.** «Determination of technological parameters for continiuous casting of a hollow pipe billet» / A. Zhakupov, A. Bogomolov, A. Zhakupova, S. Abdulina, V. Salina // Metalurgija, vol. 60(3-4), P. 329–331, 2021, [Electronic resource]. – https:// hrcak.srce.hr/clanak/372265.

10 **Yong, T.** «Optimization of submerged entry nozzles to improve steel cleanliness and productivity» / T. Yong, G. Hackl, G. Nitzl // Proceedings of 8th European Continuous Casting Conf., Graz, Austria, P. 487–497, 2014.

Material received on 06.09.23.

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Материал 06.09.23 баспаға түсті.

ҚҰЮДЫҢ ӘРТҮРЛІ ТЕМПЕРАТУРАЛЫҚ ЖАҒДАЙЛАРЫНДА 25ХМФА БОЛАТТАН ЖАСАЛҒАН ҚУЫС ДАЙЫНДАМАНЫҢ МАКРОҚҰРЫЛЫМЫ

Бұл жұмыста әртүрлі температурадағы механикалық қасиеттерге қуыс құйылған 25ХМФА болат дайындамаларының технологиялық факторлары мен макроқұрылымының әсері зерттелді. Құбыр дайындамаларының тармақталған транскристаллитті макроқұрылымы ең қолайлы болып табылады. Құбырлы қуыс дайындамалардың тармақталған транскристаллитті макроқұрылымын алуды қамтамасыз ететін үздіксіз құюдың температуралық параметрлері анықталды. Транскристаллитті (бағаналы) макроқұрылымы бар балқыманы құюдың әртүрлі температурасында алынған құбыр дайындамаларының механикалық қасиеттеріне салыстырмалы талдау жүргізілді және оның дисперсия дәрежесінің жоғарылауымен беріктік пен пластикалық қасиеттер артады. Температураның үлкен градиентінің болуы бағаналы кристалдардың пайда болуына ықпал етеді, олардың бағыты жылу ағынының бағытымен анықталады. Механикалық қасиеттердің жоғары

көрсеткіштерін қамтамасыз ету үшін дайындамалардың жұқа тармақталған транскристаллитті макроқұрылымын алу қажет.

Кілтті сөздер: 25ХМФА, қуыс дайындама, макроқұрылым, механикалық қасиеттері, құю температурасы.

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Материал поступил в редакцию 06.09.23.

МАКРОСТРУКТУРА ПОЛОЙ ЗАГОТОВКИ ИЗ СТАЛИ 25ХМФА ПРИ РАЗЛИЧНЫХ ТЕМПЕРАТУРНЫХ УСЛОВИЯХ РАЗЛИВКИ

В данной работе исследовано влияние технологических факторов и макроструктуры полых литых заготовок из стали 25ХМФА на механические свойства при различных температурах. Установлено, что наиболее благоприятной является разветвленная транскристаллитная макроструктура трубных заготовок. Определены температурные параметры непрерывного литья, обеспечивающие получение разветвленной транскристаллитной макроструктуры трубных полых заготовок. Проведен сравнительный анализ механических свойств трубных заготовок, полученных при различной температуре заливки расплава, которые имеют транскристаллитную (столбчатую) макроструктуру, и с увеличением степени ее дисперсности прочностные и пластические свойства возрастают. Показано, что наличие большого градиента температур способствует образованию столбчатых кристаллов, ориентация которых определяется направлением теплового потока. Для обеспечения высоких показателей механических свойств необходимо получение тонко разветвленной транскристаллитной макроструктуры заготовок.

Ключевые слова: 25ХМФА, полая заготовка, макроструктура, механические свойства, температура разливки.

Теруге 08.09.23 ж. жіберілді. Басуға 29.09.23 ж. қол қойылды.
Электрондық баспа
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