Раздел 1. «Металлургия»

МРНТИ 53.31.23
УДК 159.964.33

V.D. Sorotsky[1], S.A. Smailov[1]

[1]*Karaganda Industrial University, Temirtau, Republic of Kazakhstan*
E-mail.ru: vladimirsorockij@gmail.com, s.smailov@tttu.edu.kz

Modernization of continuous steel casting machines to increase the quality of finished products using the method of electromagnetic stiring (EMS)

To prevent the formation or suppress the development of crystallization, shrinkage and liquation defects, various methods of physical influence on the solidifying melt are used. When choosing a technology in each specific case, one should proceed primarily from its cost-effectiveness, efficiency and environmental standards.

A method of physical influence on a crystallizing ingot is considered: electromagnetic stirring (EMS).

According to the authors of the article, EMF of the liquid hole of a continuous ingot is the most effective way to actively intervene in the crystallization process of a continuous ingot directly during casting with a guaranteed ability to control the structure formation process. Currently, in world practice, EMF of liquid metal on continuous casting machines has become an integral part of the progressive technology for producing high-quality workpieces. As a result, the growth of requirements for product quality and the development of effective methods and means of electromagnetic processing of melts have led to the fact that contractual requirements for the quality of continuously cast billets include provisions for the mandatory use of EMF in the production of products from high-quality steels.

It is shown that in order to eliminate a number of defects in the macrostructure of a continuously cast billet associated with the crystallization process, shrinkage and segregation phenomena, which cannot be completely eliminated even with optimal design features of the continuous caster equipment and rational technological parameters of the continuous casting process, it is necessary to additionally use methods of physical influence on the process solidification of liquid steel. The method used depends on the continuous casting technology and the existing caster equipment.

This method is considered using the example of Russian metallurgical plants, since this method was not used in Kazakhstan.

Key words: continuous casting of steel; crystallizing ingot; methods of physical influence; elimination of macrostructure defects.

Continuous casting machines (CCMs) are one of the main links in the technological cycle of steelmaking. Today, about 96.1%, or 1564.2 million tons, are bottled on continuous casters in the world [1].

Solving the problems of reducing production costs, expanding the product range and improving the quality of finished products is impossible without optimizing the technological parameters of casting while simultaneously improving the surface and macrostructure of continuously cast billets (CC) and rolled products.

The quality of the caster produced is determined by a number of technological measures, including the choice of casting modes and parameters, the refractories used in the steel-pouring ladle - caster mold section, the protection of steel from secondary oxidation, the optimal temperature conditions and casting speed, as well as the design features and condition of the caster equipment. High requirements for the quality of workpieces lead to the need for careful preparation of liquid steel for casting and the application of a number of restrictions, for example, on casting speed and temperature, which not only reduces the productivity of the continuous caster, but in some cases causes a deterioration in the quality of the finished product.

Analysis and taking into account the features of the hydrodynamics of the movement of the melt, heat and mass transfer and physical and chemical processes occurring at the solidification stage makes it possible to develop appropriate measures to improve the casting technology, the design of the machine and the mold [2]. However, there are a number of defects in the macrostructure of continuous casting machines associated with the crystallization process, shrinkage and segregation phenomena, which cannot be completely eliminated even with optimal design features of continuous casting equipment and rational technological parameters of the continuous casting process.

In this regard, it is obvious that in order to obtain a high-quality macrostructure of continuous steel castings and rolled products, especially from critical steels, it is necessary to actively intervene in the crystallization process of a continuous ingot directly during casting with a guaranteed ability to control the structure formation process.

To prevent the formation or suppress the development of crystallization, shrinkage and liquation defects, many researchers use various methods of physical influence on the solidifying melt.

Modern developments indicate that even materials with the same grain sizes can differ in properties if they are obtained by different methods. Therefore, it is not indifferent by what means the production of high-quality metal products will be achieved. When choosing a technology in each specific case, one should proceed primarily from its cost-effectiveness, efficiency and environmental standards [2].

According to the authors, the most effective way to actively intervene in the crystallization process of a continuous ingot directly during casting with a guaranteed ability to control the process of structure formation is the method of electromagnetic magnetic field of the liquid well of a continuous ingot.

Currently, in world practice, EMF of liquid metal on a continuous caster has become an integral part of the progressive technology for producing high-quality workpieces [3-6]. As a result, the growth of requirements for product quality and the development of effective methods and means of electromagnetic processing of melts have led to the fact that contractual requirements for the quality of NLZ include provisions for the mandatory use of EMF in the production of products from high-quality steels.

During EMF, the liquid phase of a crystallizing ingot is mixed through electromagnetic forces that arise when a magnetic field interacts with an electric current.

Depending on the cross-section of the NLZ and the requirements for the macrostructure of the EMF system, it can be located in the crystallizer (MEMS), in the ZZO (SEMS) or in the final solidification zone (FEMS). When casting high-carbon, pipe and other steels for critical purposes, especially into large-section workpieces, it is possible to simultaneously use EMF at three and sometimes at four levels. The number of EMF devices and their installation location are determined for each specific continuous caster based on its design features, the grade range of steel being cast, the cross-section of the billet being cast and the technological parameters of casting.

Currently, EMF systems for the liquid phase of a crystallizing ingot have found wide application. EMF systems in the crystallizer in Russia are equipped with long-form and bloom casters of metallurgical plants - Magnitogorsk, Severstal, EVRAZ ZSMK, Chelyabinsk, Ural Steel and Oskol Electrometallurgical Plants, as well as Volzhsky and Seversky Pipe, Pervouralsk Novotrubny, Taganrog, UMMC-Steel ", Nizhneserginsky hardware and Omutninsky metallurgical plants. The continuous casting machines of the Izhstal metallurgical plant and the continuous casting machines of the Elektrostal plant are equipped with EMF systems at two levels - in the mold and in the cooling zone.

The use of EMF has shown that the EMF in the crystallizer has the maximum effect on the quality of the surface and macrostructure of the NLZ. Most foreign manufacturers of such devices mainly offer EMF systems with an external stator location. In this case, the external EMF stator covers the mold body from the outside, while the stator and mold bodies are made of non-magnetic steel of the austenitic class.

One of the main advantages of using external EMP stators is the minimum required number of such stators, which corresponds to the number of continuous caster strands. However, this arrangement has a number of disadvantages. For example, the external location of the EMF inductor leads to a significant increase in the interpolar distance of the magnetic system and, consequently, to an increase in the dimensions of the stator, its mass and, as a consequence, to an increase in the load on the swing mechanism if the stator is installed on its swing frame. An increase in the distance between the poles, in turn, leads to a decrease in the induction value and, accordingly, to a decrease in the speed of movement of the melt. When the stator is located externally, a separate cooling circuit with specially prepared water is required, which significantly

increases capital and operating costs. Deterioration in the quality of cooling water is often the cause of failure of EMF systems of this type.

It should also be noted that the use of standardized EMF systems located outside the mold body, in some cases when the smaller format of the cast blanks differs significantly from the larger one, neutralizes the effect of EMF when casting blanks of a minimum cross-section due to the distance of the inductor from the blank. VNIIMETMASH has been developing EMF systems for continuous casting machines since the 70s of the last century and has accumulated significant experience in this area.

VNIIMETMASH is ready to develop and supply complete EMF systems with external stators. However, according to the authors, the built-in EMF system is more effective for EMF in continuous caster molds casting long, bloom and round billets. The concept is based on the principle of bringing the stator poles as close as possible to the liquid phase of the ingot in order to achieve high mixing speeds with low power consumption. This is achieved mainly due to the fact that the EMF device, which creates a rotating magnetic field, is built into the crystallizer body. A distinctive feature of the design of the EMP crystallizers developed by VNIIMETMASH is that the cooling of the stator pole coils, both external and built-in, is carried out with water intended for cooling the copper working walls of the crystallizer. In this case, a separate additional cooling circuit and special expensive preparation of water cooling the stator are not required. In this case, the stator and mold body are designed for the maximum size of the workpiece. When switching to a smaller workpiece size, it is necessary to remove the sleeve and shell of the same size and then install and secure the sleeve and shell of a smaller size with flanges from below and above. This arrangement of the EMF system in the crystallizer makes it possible to reduce the consumption of electricity consumed by 2-4 times with the same impact compared to the external location of the inductor.

A metallographic study showed [7] that the use of EMF in the continuous caster mold affects the quality of the surface and macrostructure of high-carbon steel billets, while (Fig. 1):

- the quality of the surface and subsurface layer improves;
- zonal and axial liquation is reduced;
- carbon segregation coefficient decreases;
- the length of martensitic sections in rolled products is no more than 20 microns;
- the maximum score for central porosity is reduced from 4.0 to 2.5.

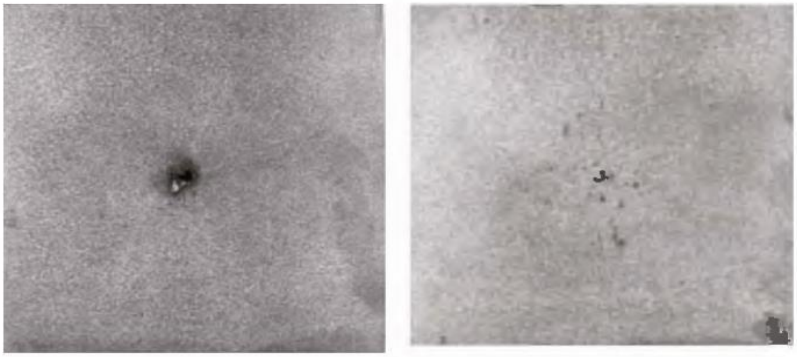

Рис. 1. *Макроструктура поперечных темплетов сортовых непрерывнолитых заготовок из высокоуглеродистых сталей, отлитых с ЭМП конструкции ВНИИМЕТМАШ, и контрольных*

1. To eliminate a number of defects in the macrostructure of continuous casting machines associated with the crystallization process, shrinkage and segregation phenomena, which cannot be completely eliminated even with optimal design features of continuous casting equipment and rational technological parameters of the continuous casting process, it is necessary to additionally use methods of physical influence on the solidification process of the liquid become. The method used depends on the continuous casting technology and the existing caster equipment.

2. According to the authors, EMF is the most effective way to actively intervene in the crystallization process of a continuous ingot directly during casting with a guaranteed ability to control the structure formation process.

3. To achieve optimal results in terms of the quality of the macrostructure and surface of the continuous casting steel, especially large cross-section steels with a wide crystallization range, the use of complex effects is often required, for example, EMF in the crystallizer and MO or EMF at two levels - in the mold and the zone of completion of solidification.

List of references used

1. World steel in figures. World Steel Association 2017. - 17 p.

2. Vdovin K.N., Tochilkin V.V., Yachikov I.M. Continuous casting of steel. Hydromechanics of continuous casting machines. - Magnitogorsk: MSTU publishing house, 2014. - 348 p.

3. Grundy A.N., Yeke M., Feldhaus S. Design and first operational results from 5 strand billet, bloom and beam blank combicaster at Kardemir, Turkey // Proceedings of 8th European Continuous Casting Conference, 23-26 June 2014, Graz, Austria . R. 406-415.

4. Dwivedi S.P., Sharma S. Electromagnetic Stir Casting and its Process Parameters for the Fabrication and Refined the Grain Structure of Metal Matrix Composites - A Review // International Journal of Advance Research and Innovation. 2014. Vol. 2. No. 3. R. 639-649.

5. Toh T., Hasegawa H., Harada H. Evaluation of Multiphase Phenomena in Mold Pool under In-mold Electromagnetic Stirring in Steel Continuous Casting // ISIJ International. 2001. Vol. 41. No. 10. R. 1245-1251.

6. Stransky R., Kavicka F., Sekanina B., Stetina J. The effect of electromagnetic stirring on the crystallization of CONCAST bills // Materiali in tehnologije / Materials and technology. 2011. No. 45 (2). R. 163-166.

7. Smolyakov A.S., Shakhov S.I., Rogachikov Yu.M. Electromagnetic stirring systems for continuous casting machines // Heavy mechanical engineering. 2017. No. 5. P. 7-11.

В.Д. Сороцкий, С.А. Смаилов

Электромагнеттік қарастыру (эмс) әдісімен дайын өнімдердің сапасын арттыру үшін үздіксіз болат құю станоктарын жаңғырту

Кристалдану, шөгу және ликвация ақауларының пайда болуын болдырмау немесе дамуын басу үшін қататын балқымаға физикалық әсер етудің әртүрлі әдістері қолданылады. Әрбір нақты жағдайда технологияны таңдағанда, ең алдымен оның экономикалық тиімділігіне, тиімділігіне және экологиялық стандарттарына сүйену керек. Кристалданатын құймаға физикалық әсер ету әдісі қарастырылады: электромагниттік араластыру (ЭМС).

Мақала авторларының пікірінше, үздіксіз құйманың сұйық тесігінің ЭҚК құрылым түзілу процесін басқарудың кепілді мүмкіндігімен құю кезінде тікелей үздіксіз құйманың кристалдану процесіне белсенді араласудың ең тиімді әдісі болып табылады. Қазіргі уақытта әлемдік тәжірибеде үздіксіз құю машиналарындағы сұйық металдың ЭҚК жоғары сапалы дайындамаларды алудың прогрессивті технологиясының құрамдас бөлігіне айналды. Нәтижесінде өнім сапасына қойылатын талаптардың өсуі және балқымаларды электромагниттік өңдеудің тиімді әдістері мен құралдарының дамуы үздіксіз құйылатын дайындаманың сапасына қойылатын шарттық талаптар өндірісте ЭҚК міндетті түрде қолдану туралы ережелерді қамтуына әкелді. жоғары сапалы болаттан жасалған бұйымдар.

Үздіксіз құйылатын дайындаманың макроқұрылымындағы кристалдану процесіне, шөгу және сегрегация құбылыстарына байланысты бірқатар ақауларды жою үшін үздіксіз құйма жабдығының оңтайлы конструктивтік ерекшеліктерімен және ұтымды

технологиялық параметрлермен толық жоюға болмайтыны көрсетілген. үздіксіз құю процесінде сұйық болатты қатаю процесіне физикалық әсер ету әдістерін қосымша қолдану қажет. Қолданылатын әдіс үздіксіз құю технологиясына және қолданыстағы құю жабдығына байланысты.
Бұл әдіс Қазақстанда қолданылмағандықтан ресейлік металлургиялық зауыттардың мысалында қарастырылады.

Кілт сөздер: болатты үздіксіз құю; кристалданатын құйма; физикалық әсер ету әдістері; макроқұрылым ақауларын жою.

В.Д. Сороцкий, С.А. Смаилов

Модернизация машин непрерывного литья стали с целью повышения качества готовой продукции методом электромагнитного перемешивания (ЭМП)

Для предотвращения образования или подавления развития кристаллизационных, усадочных и ликвационных дефектов применяются различные методы физического воздействия на затвердевающий расплав. При выборе технологии в каждом конкретном случае следует исходить прежде всего из ее экономичности, эффективности и экологических норм.
Рассмотрен метод физического воздействия на кристаллизующийся слиток: электромагнитное перемешивание (ЭМП).
По мнению авторов статьи, ЭМП жидкой лунки непрерывного слитка является наиболее эффективным способом активного вмешательства в процесс кристаллизации непрерывного слитка непосредственно по ходу разливки с гарантированной возможностью управления процессом структурообразования. В настоящее время в мировой практике ЭМП жидкого металла на МНЛЗ стало неотъемлемой частью прогрессивной технологии получения высококачественных заготовок. В результате рост требований к качеству продукции и развитие эффективных методов и средств электромагнитной обработки расплавов привели к тому, что в контрактные требования к качеству непрерывнолитых заготовок вносятся положения об обязательном использовании ЭМП при производстве продукции из высококачественных сталей.
Показано, что для устранения ряда дефектов макроструктуры непрерывнолитой заготовки, связанных с процессом кристаллизации, усадочными и ликвационными явлениями, которые не могут быть полностью устранены даже при оптимальных конструктивных особенностях оборудования МНЛЗ и рациональных технологических параметрах процесса непрерывного литья, необходимо дополнительное применение методов физического воздействия на процесс затвердевания жидкой стали. Применяемый способ зависит от технологии непрерывной разливки и существующего оборудования МНЛЗ.
Данный метод рассмотрен на примере российских металлургических комбинатов, так как в Казахстане данный метод не применялся.

Ключевые слова: непрерывная разливка стали; кристаллизующийся слиток; методы физического воздействия; устранение дефектов макроструктуры.

Список использованной литературы

1. мировая сталь в цифрах. World Steel Association 2017. - 17 С.
2.Вдовин К. Н., Точилкин В. В., Ячиков И. М. непрерывная разливка стали. Гидромеханика машин непрерывного литья заготовок. - Магнитогорск: Изд - во МГТУ, 2014. - 348 С.

3. Гранди А. Н., Йеке М., Фельдхаус С. проектирование и первые эксплуатационные результаты комбикастера 5-прядных заготовок, Блюма и балочных заготовок в Кардемире, Турция // материалы 8-й Европейской конференции непрерывного литья заготовок, 23-26 июня 2014 г., Грац, Австрия.Р. 406-415.

4. Двиведи С. П., Шарма С. Литье с электромагнитным перемешиванием и его технологические параметры для изготовления и уточнения зернистой структуры Металломатричных композитов-обзор / / International Journal of Advance Research and Innovation. 2014. Vol. 2. № 3. P. 639-649.

5. Тох т., Хасегава Х., Харада Х. оценка многофазных явлений в ванне кристаллизатора при электромагнитном перемешивании в кристаллизаторе при непрерывной разливке стали / / ISIJ International. 2001. Т. 41. № 10. P. 1245-1251.

6. Странский Р., Кавицка Ф., Секанина Б., Стетина Дж. Влияние электромагнитного перемешивания на кристаллизацию вогнутых заготовок / / материалы в технологии / материалы и технологии. 2011. № 45 (2). P. 163-166.

7. Смоляков А. С., Шахов С. И., Рогачиков Ю. М. электромагнитные перемешивающие системы машин непрерывного литья заготовок / / тяжелое машиностроение. 2017. № 5.С. 7-11.