ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ
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ХАБАРЛАРЫ

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Казахский национальный исследовательский
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NEWS

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN
Kazakh national research technical university
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SERIES
OF GEOLOGY AND TECHNICAL SCIENCES

1 (439)

JANUARY – FEBRUARY 2020

THE JOURNAL WAS FO67UNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

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«ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Меншіктенуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).
Қазақстан республикасының Мәдениет пен ақпарат министрлігінің Ақпарат және мұрағат комитетінде 30.04.2010 ж. берілген **№10892-Ж** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Мерзімділігі: жылына 6 рет.
Тиражы: 300 дана.

Редакцияның мекенжайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., 220, тел.: 272-13-19, 272-13-18,
http://www.geolog-technical.kz/index.php/en/

Редакцияның мекенжайы: Қазақстан, 050010, Алматы қ., Қабанбай батыр көш., 69а.
Қ. И. Сәтбаев атындағы геология ғылымдар институты, 334 бөлме. Тел.: 291-59-38.

Типографияның мекенжайы: «NurNaz GRACE», Алматы қ., Рысқұлов көш., 103.

«Известия НАН РК. Серия геологии и технических наук».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан (г. Алматы)
Свидетельство о постановке на учет периодического печатного издания в Комитете информации и архивов Министерства культуры и информации Республики Казахстан **№10892-Ж,** выданное 30.04.2010 г.

Периодичность: 6 раз в год
Тираж: 300 экземпляров

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, ком. 219, 220, тел.: 272-13-19, 272-13-18,
http://nauka-nanrk.kz /geology-technical.kz

Адрес редакции: Казахстан, 050010, г. Алматы, ул. Кабанбай батыра, 69а.
Институт геологических наук им. К. И. Сатпаева, комната 334. Тел.: 291-59-38.

Адрес типографии: «NurNaz GRACE», г. Алматы, ул. Рыскулова, 103.

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News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Owner: RPA "National Academy of Sciences of the Republic of Kazakhstan" (Almaty)
The certificate of registration of a periodic printed publication in the Committee of information and archives of the Ministry of culture and information of the Republic of Kazakhstan N 10892-Ж, issued 30.04.2010

Periodicity: 6 times a year
Circulation: 300 copies

Editorial address: 28, Shevchenko str., of. 219, 220, Almaty, 050010, tel. 272-13-19, 272-13-18,
http://nauka-nanrk.kz/geology-technical.kz

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Editorial address: Institute of Geological Sciences named after K.I. Satpayev
69a, Kabanbai batyr str., of. 334, Almaty, 050010, Kazakhstan, tel.: 291-59-38.

Address of printing house: «NurNaz GRACE», 103, Ryskulov str, Almaty.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 439 (2020), 114 – 121 **https://doi.org/10.32014/2020.2518-170X.14**

UDC 621.9.044

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INFLUENCE OF THE GEOMETRIC SHAPE OF THE MOLD ON THE CAST BILLET STRUCTURE FOR FORMING PROCESSES

Abstract. The article shows the effectiveness of system analysis based on Shubnikov-Curie symmetry principle, in solving problems of thermal effect on the molten liquid metal when it is solidified in a mold. It has been suggested that a binary axis, relative to the lateral surface, appears in the ingot structure. In accordance with the generalized structure of the billet, geometric structure of crystallites and crystallographic texture are determined by the influence of the thermal field during the crystallization of the melt. The thermal field is determined by the geometry of the mold and the structural features of its sprue and bottom parts.

Analysis of the generalized structure of the field of physical activity allows us to optimize the properties of the cast billet for subsequent forming processes of semi-finished products for mechanical engineering. This is important for the performance characteristics of the finished products.

It has been experimentally proved that the structure of the cast billet (distribution of grains in the material) undergoes changes in accordance with Shubnikov-Curie principles of symmetry, during the crystallization process in the molds of various sections. It affects the physico-mechanical properties of the cast billet, including the plastic deformation during further forming processes.

Key words: forming processes, crystallization, symmetry, heat flux, texture, Shubnikov-Curie principle, mold.

Introduction. The production of metallurgical billets consists of two main technological processes: 1) obtaining a cast ingot by pouring the molten metal into the casting mold; 2) pressure treatment of the ingot, mainly rolling. As a result, the billet acquires certain mechanical and crystallographic texture – the predominant orientation of its internal components. The crystallographic texture determines the anisotropy of the polycrystalline materials properties.

Formation of properties in the cast billet (i.e. casting) depends on heat removal from the melt into the mold during its solidification. The crystallographic texture is responsible for the formation of the physico-mechanical properties.

In the known technological metal forming processes, the results of transcrystallization have a significant impact on the macro- and microstructure of semi-finished products, as well as their quality. This is primarily due to the presence of both globular and axial textures in the ingot [1-3]. Consequently, one of the promising ways to improve the physico-mechanical properties of polycrystalline materials is a comprehensive consideration of the natural anisotropy of the polycrystalline grains properties (crystallographic texture) and their geometric shape texture at all stages of technological processing.

Researches considering texture in wrought alloys are non-systematic and are aimed at solving particular problems. For example, in 1994, an application was filed and a patent for an invention to improve the ingot technology for the production of multilayer rolling was obtained [4]. The results did not attract wide scientific attention, apparently due to the lack of a systematic approach.

Possible ways to control the crystallization process in order to obtain a given crystal structure of ingots and castings are usually limited to the analysis of the methods of grinding crystalline grains in conventional casting molds [5,6,7].

Methods for obtaining shaped castings with a directional crystal structure (texture) are based on controlling the relation of macrostructural zones in the system: peripheral fine-grained zone – columnar crystals – equiaxed crystals.

The question concerning the microstructure of ingots of wrought alloys (texture) is not considered properly. Here, the ingot texture will be understood as features of the structure due to crystallographic directions and planes, related by symmetry characteristics to the structure of the thermal field (created by the mold during the process of crystallization), as well as the structure of the melt before it is cast into the mold.

The formulation of the research objective and the physical essence of the process. This research is carried out with the help of the system analysis, which is based on the generalized Shubnikov-Curie symmetry principle [8,9]. The work investigates how the thermal field structure of a casting mold influences on the macrostructure of the cast billet.

The formation of the crystallographic texture of the castings can be studied at thermal and heat-kinetic levels simultaneously. The study at thermal level is based on the heat-transfer process between the boundary surface of the melt and the relatively cold wall of the mold. The basis of heat-kinetic research is analysis of crystallization processes.

Heat-transfer processes will be determined by the generalized structure of the thermal field, which can be identified on the basis of the Curie symmetry principle for heterogeneous systems. In this case, the heterogeneous system is represented, on the one hand, by the symmetry characteristic of the crystallographic texture of the anisotropic metal sheet from which the wall of the mold is made. On the other hand, it is represented by the symmetry characteristic of the thermal field structure of the melt (due to the cross-sectional shape and geometric relations of the limiting surfaces of the mold), as well as the influence of the pouring conditions and the difference in the heat removal conditions between the bottom and the sprue parts of the mold.

Symmetry of the crystallographic texture of the metal sheet (which is obtained by the method of lengthwise rolling and is used for manufacturing of the walls and bottom of the mold) can be represented by the following formula. It includes the generating elements of symmetry of the generalized structure of the physical field of rolling, characterized by the relation of kinematic and geometric parameters of the dynamic system. This system determines the set of generating elements of symmetry and their relative position:

$$G_{\text{пр}} = m\ m\ 2, \tag{1}$$

where G is a symmetry group; *m* – plane of symmetry; 2 – binary axis.

The structure of the thermal field of the melt relative to the normal of the side surface can be represented by an expression that includes the plane of symmetry m relative to the side surface of the melt, passing through the axis of the mold, aligned with the Z axis in an orthogonal coordinate system. It coincides with one of the symmetry planes (which belong to the symmetry group, describing the structure of the thermal field relative to the axis of the mold). In this case, the generalized structure of thermal field for the side surface of the ‘melt-mold’ system can be represented in the following way:

$$G_{\text{сис}} = G_{\text{пр}} \subseteq G_{\text{расп.}} = m. \tag{2}$$

According to the Curie principle, the symmetry group of a system is the highest subgroup of intersection groups of a system. Thus, the generalized structure of the side surface of the thermal field can be described by a single symmetry plane, which is common to the structure of the thermal field and the structure describing crystallographic texture of the anisotropic sheet.

The generalized structure of the thermal field relative to the normal, combined with the axis of the mold, is determined by the cross-sectional shape and geometric relationships of the bounding surfaces of the mold, as well as the influence of the pouring conditions and the difference in the heat removal conditions between the bottom and the sprue parts of the mold. However, in this case, the structure of the thermal field must be considered for three-dimensional space. It is necessary to take into account the structure of the heat removal of the total lateral surface in the volume of the entire melt. The geometrically connected lateral surfaces are the system-forming elements of the generalized structure of the thermal field.

Thermal field isotherms will be determined by the anisotropy of the mold wall. They can be described based on the symmetry characteristics of the geometric and crystalline textures, as a response of previous methods of processing the materials from which the wall of the mold is made.

For thin-walled molds, the temperature field can be considered like for two-dimensional space, neglecting the direction perpendicular to the plane, which coincides with the plane of the mold wall. In this case, the distribution pattern of the thermal field isotherms in the system "side wall of the mold – external environment" will be determined by the temperature field of the side surface of the melt in the system "side wall of the mold – melt".

The physical nature of the isotherms distribution on the wall of the mold is determined by the thermal conductivity k [$V \cdot m^{-1} \cdot K^{-1}$], linking the heat flux h [V/m^2] with the temperature gradient dT/dZ via a well-known formula:

$$h = -k\frac{dT}{dZ}. \tag{3}$$

In case of real anisotropic materials, the heat flux is not parallel to the temperature gradient; therefore, the thermal conductivity is described by the polar tensor of the second rank (which is considered to be symmetric for this process). In this case, the symmetry of the polar tensor of the second rank is expressed by Neumann's principle (the main postulate in crystallography) and thermodynamic relations, which describe the irreversibility of these processes for heat transfer. So, for the symmetric polar tensor of the second rank, the following equality can be created:

$$k_{ij} = k_{ji}. \tag{4}$$

The polar tensor of the second rank, which describes the thermal conductivity, is symmetric relative to the main diagonal. Only six independent coefficients have to be determined for the further calculations.

The value k_{ij} is considered in two directions: the direction in which we measure the temperature gradient, and the direction in which we measure the heat flux. In general, these directions do not coincide, and the analytical form of the relation is:

$$h_i = -k_{ij}\frac{dT}{dZ_j}. \tag{5}$$

The minus sign shows that the heat is always directed opposite to the direction of the temperature gradient.

Based on (1), the components of the thermal conductivity of the symmetric tensor of the second rank are calculated as follows:

$$k_{ij} = \frac{h_i}{\frac{dT}{dZ_j}}. \tag{6}$$

They can be presented in the following matrix form:

$$k_{ij} = \begin{bmatrix} k_{11} & k_{12} & k_{13} \\ k_{21} & k_{22} & k_{23} \\ k_{31} & k_{32} & k_{33} \end{bmatrix}. \tag{7}$$

Considering the influence of anisotropy on the distribution of properties, it is important to accurately determine the measured values at the stage of designing the shape and volume of the mold.

Since metallic materials are mainly used in polycrystalline state, the mechanism of their texture formation depends on the structure of the original billet. The distribution of the texture intensity is determined by the initial crystallographic texture, as a response of the last technological process. In the known technological metal forming processes, during the first hot rolling of ingots, the results of crystallization have a significant impact on the macro- and microstructure of the billet, as well as its quality. This is primarily due to the presence of both the globular an axial texture in the ingot [1].

In determining the effect of symmetry on the physico-mechanical properties of semi-finished and finished products, four types of symmetry are studied: the symmetry of the original billet, the symmetry of the external field effects, the symmetry of the resulting change and the symmetry of the physical properties of the product [4].

The definition of the symmetry of physical properties is based on the Neumann's principle: the symmetry group of any physical property $G_{св}$ should include all the elements of a point group (crystallographic class) of a crystal $G_к$. In other words, the group $G_к$ either coincides with the group $G_{св}$, or is its subgroup. This statement can be presented, using the elements of the theory of groups:

$$G_к \subseteq G_{св.} \tag{8}$$

Mathematically, this condition is expressed by the equality of the tensors *T*:

$$T'_{ijk....} = T_{ijk.....} \tag{9}$$

Nowadays the idea that the final physico-mechanical properties of semi-finished products and operating characteristics of finished products are formed at the process stage has become widely accepted [15]. Thus, it is important not only to consider the initial structure of the cast billet, but also to set it when designing the specified operational properties of the finished product.

Based on Shubnikov-Curie principle of symmetry, a technology of directional crystallization in ingots was developed, in order to consider their physico-mechanical properties. This is possible due to the specified temperature gradient in the considered directions of the heat flux during the ingot crystallization [16-23].

Experimental research and discussion of the results. The current paper presents the results of an experiment to obtain a casting in a mold of a pentagonal cross section, a physical system for creating a controlled heat flux (figure 1 *a*, *b*).

a) b)

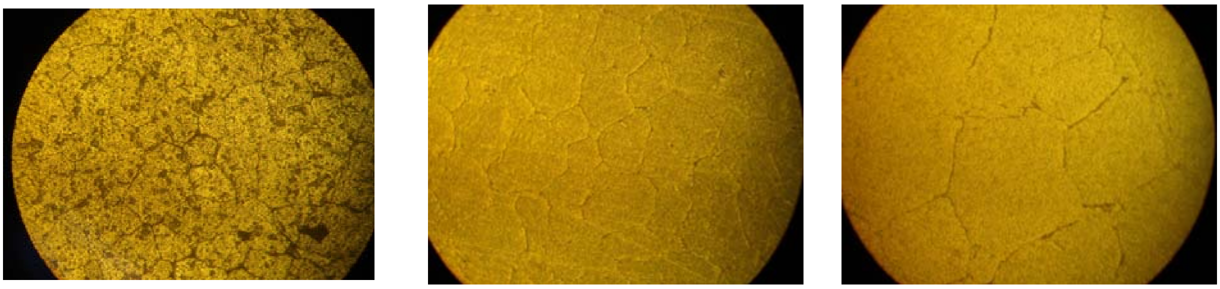
Figure 1 – Pentagonal casting (*a*) and mold (*b*)

The source material is an aluminum bar AD 1 (1.5 kg) and an aluminum ingot (1.5 kg). The metal was heated in the furnace up to 820°C.

A steel plate (5 mm thick) was used as the substrate for the metal mold, in order to create directional solidification. The lower part of the mold was filled with sandy-clay mixture and placed on a plate (figure 1, *b*).

Before being poured, the melt was cooled to the temperature T_{fill}. = 700° C (controlled by the thermocouple). After that, the metal was poured into the prepared mold (unheated, at room temperature). The cooling of the casting (60 min) was carried out in the open air.

The results of the metallographic study of the obtained samples are shown in figure 2.



a) *b*) *c*)

Magnification: *a*) 100x; *b*) 200x; *c*) 500x

Figure 2 – Microstructure of aluminum-copper alloy, pentagon casting, pouring at 700 °C, unheated mold, cooling outdoors, etching with hydrofluoric acid solution

Figure 2 shows that the grain boundaries are viewed weakly, due to the short duration of etching. The shape of grains is also very remarkable. They are identical with the geometry of the casting mold. However, as it has been mentioned, the heat transfer in different directions is not the same for each point, and therefore the grains grow in the shape of irregular pentagons. Nevertheless, extraordinary polycrystallites can also be observed. Their shape coincides almost perfectly with the geometric shape of the mold. This fact can be explained by the Curie dyssymmetrization principle.

Figure 3 – Macrostructure of an aluminum alloy ingot with the response of the generalized structure of the thermal field

Figure 3 shows the macrostructure of the aluminum alloy ingot, with the response of the generalized structure of the thermal field. Geometric texture is clearly expressed there, due to the geometric parameters of the heat removal.

Conclusion.

1. In order to study the crystallographic texture of the ingot, it is necessary to consider the generalized structure of the thermal field as a heterogeneous system. This system is formed by different relations of geometrically connected lateral surfaces of the mold and the symmetry characteristics of the melt at heat kinetic level.
2. The effectiveness of system analysis (based on the Shubnikov-Curie principle of symmetrization-dissymmetrization) in solving problems of thermal effect on the molten liquid metal, is experimentally proved.
3. Based on the system analysis, it can be argued that the billet, obtained by casting into a mold with a pentagonal cross-sectional shape according to the presented technology, has reduced ductility and elasticity properties and cannot be recommended for further forming processes.
4. Based on theoretical studies and experimental data, it can be argued that the management of crystallographic texture in casting processes and its consideration in the design of metal forming technologies will optimize the properties of semi-finished and finished products for mechanical engineering.

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ИЗЛОЖНИЦАНЫҢ ГЕОМЕТРИЯЛЫҚ ПІШІНІНІҢ ҚЫСЫММЕН ӨҢДЕУГЕ АРНАЛҒАН ҚҰЙЫЛҒАН ДАЙЫНДАМА ҚҰРЫЛЫМЫНА ӘСЕРІ

Аннотация. Металлургиялық дайындама құйып алып кейін қысыммен өңдеу процесінде белгілі механикалық және кристаллографикалық текстураға, яғни оның ішкі элементерінің (кристалиттерінің) айрықша бағытына ие болады. Біртекті металдың кристаллиттері бір кристалдық құрылысына ие болып кристаллографиялық текстурасымен басқаша айтқанда, кристаллографиялық остерінің өзара бағыттарымен айырылады. Дәл осы кристаллографиялық текстурасы физика-механикалық қасиеттерінің пайда болуына жауапты және көпкристалдық материалдың қасиеттері анизотропиясын анықтайды.

Текстура және, демек, қасиеттердің пайда болу процесі балқыма қатаю кезінде жылуды балқымадан қалыпқа (изложницаға) беру құбылысына байланысты. Жылу беру процестері жылу өрісінің Кюридің гетерогенді жүйелер үшін симметрия принципі негізінде айқындалатын жалпыланған құрылымымен анықталады. Бұл сәтте гетерогенді жүйе бір жағынан қалып қабырғасы жасалған анизотропты металл парағының кристаллографиялық текстурасының симметриялық сипаттамасымен білінеді. Екінші жақтан балқыманың жылу өрісі құрылымының симметриялық сипаттамасымен көрсетіледі. Ал сол құрылым қалыптың көлденең қимасы пішінімен және беттерін шектейтін геометриялық қатынастармен, сонымен бірге балқыма құю жағдайларының әсерімен және қалыптың (изложницаның) түбі мен құю жақтарындағы жылуды әкету жағдайларының айырмашылығымен анықталады.

Мақалада изложницада қатайғанда сұйық металл балқымасына жылу әсері есептерін шешу үшін Шубников-Кюри симметризация-диссимметризация принципі негізінде жүйелің талдау қолданудың тиімділігі көрсетіледі. Сығымдама құрылымында бүйірлік жағы бойынша екінші реттік симметрия осі пайда болу туралы болжам ұсынады. Дайындаманың жалпыланған құрылымына тиісті, кристаллиттердің геометриялық құрылымы және кристаллографиялық текстурасы балқыма кристалданған кезіндегі жылу өрісінің әсерімен анықталады. Жылу өрісі изложницаның геометриясымен және оның құю мен түп бөліктері құрылысының ерекшеліктерімең анықталады.

Сығымдаманың кристаллографиялық құрылымын зерттеу үшін жылу өрісінің жалпыланған құрылымын қалыптың (изложницаның) геометриялық байланған бүйір беттерінің және балқыманың жылу-кинетикалық деңгейіндегі симметриялы сипаттамаларының әртүрлі қатынастарымен түзілген гетерогенді жүйе ретінде қарастыру қажет.

Физикалық әсер ететін өрісінің жалпыланған құрылымын талдау машина жасауда пайдаланатын жартылай өнімдерді қысыммен өңдеу процестерімен алу үшін құйылған дайындаманың қасиеттерін тиімді етуге мүмкіндік туғызады. Осыны дайын бұйымның пайдаланушылық қасиеттерін есепке алу үшін білу қажет.

Қимасы әртүрлі изложницаларда кристалдану процесінде құйылған дайындаманың құрылымы (материал көлемінде дәндер таралуы) Шубников-Кюри симметризация-диссимметризация принципіне сәйкес өзгеретіндігі эксперименталды көрсетілген. Құрылым өзгеруі өз ретінде құйылған дайындаманың физика-механикалық қасиеттеріне әсер етеді.

Түйін сөздер: қысыммен өңдеу, кристалдану, симметрия, жылу ағыны, текстура, Шубников-Кюри принципі, изложница.

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ВЛИЯНИЕ ГЕОМЕТРИЧЕСКОЙ ФОРМЫ ИЗЛОЖНИЦЫ НА СТРУКТУРУ ЛИТОЙ ЗАГОТОВКИ ДЛЯ ОБРАБОТКИ ДАВЛЕНИЕМ

Аннотация. Металлургическая заготовка в процессе литья и последующей обработки ее давлением приобретает определенную механическую и кристаллографическую текстуру – преимущественную ориентацию составляющих ее внутренних элементов (кристаллитов). В однородных металлах кристаллиты обладают одинаковым кристаллическим строением, но отличаются взаимной ориентацией кристаллографических осей – кристаллографической текстурой. Именно кристаллографическая текстура ответственна за формирование физико-механических свойств и определяет анизотропию свойств поликристаллических материалов.

Процесс формирования текстуры и, соответственно, свойств зависит от отвода теплоты от расплава в форму (изложницу) при затвердевании расплава. Процессы теплопередачи будут определяться обобщенной структурой теплового поля, которая может быть выявлена на основе принципа симметрии Кюри для гетерогенных систем. В данном случае гетерогенная система представлена, с одной стороны, симметрийной характеристикой кристаллографической текстуры анизотропного металлического листа, из которого изготовлена стенка изложницы. С другой стороны – симметрийной характеристикой структуры теплового поля расплава, обусловленной формой поперечного сечения и геометрическими соотношениями ограничивающих поверхностей изложницы, а также влиянием условий заливки и различием условий теплоотвода между донной и литниковой частью изложницы.

Показана эффективность применения системного анализа на основе принципа симметризации-диссимметризации Шубникова-Кюри при решении задач теплового воздействия на расплав жидкого металла при его затвердевании в изложнице. Выдвинуто предположение о появлении в структуре слитка оси симметрии второго порядка относительно боковой поверхности. В соответствии с обобщенной структурой заготовки, геометрическая структура кристаллитов и кристаллографическая текстура определяются воздействием теплого поля при кристаллизации расплава. Тепловое поле определяется геометрией изложницы и особенностями строения ее литниковой и донной частей.

Для исследования кристаллографической текстуры слитка необходимо рассматривать обобщенную структура теплового поля как гетерогенную систему, образованную различными соотношениями геометрически связанных боковых поверхностей изложницы и симметрийными характеристиками расплава на теплокинетическом уровне.

Анализ обобщенной структуры поля физического воздействия позволяет оптимизировать свойства литой заготовки для последующих процессов обработки давлением полуфабрикатов для машиностроения. Это необходимо для учета эксплуатационных свойств готового изделия.

Экспериментально показано, что структура литой заготовки (распределение зерен в объеме материала) в процессе кристаллизации в изложницах различного сечения претерпевает изменения в соответствии с принципами симметрии Шубникова-Кюри, что, в свою очередь, оказывает влияние на физико-механические свойства литой заготовки, в том числе и на характер пластической деформации в процессе дальнейшей ее обработки давлением.

Ключевые слова: обработка давлением, кристаллизация, симметрия, тепловой поток, текстура, принцип Шубникова-Кюри, изложница.

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REFERENCES

[1] Silnikova E.F., Silnikov M.V. Crystallographic texture and texture formation. SPb.: Science, 2011. 552 p. (in Russ.).

[2] Zolotorevsky N.Yu. Rybin V.V. Materials Science. Fragmentation and texturearray during the deformation of metallic materials. Publ. Yurayt, 2016. 207 p. (in Russ.).

[3] Aptekar N.M. Belokurov E.S., Polyakov V.F., et al. a Method of casting ingots – RF Patent 2083316, Appl. 01.08.1994, application No. 94028805/02, publ. 10.07.1997. (in Russ.).

[4] Nikitin V.I., Nikitin K.V. Heredity in cast alloys. Ed. 2nd, revised and supplemented. - M.: Engineering-1, 2005. 476 p. (in Russ.).

[5] Pikunov M.V., Konovalov A. N. Fundamentals of the theory of casting processes. Crystallization of alloys. M.: Ed. House MISIS, 2015. 91 p. (in Russ.).

[6] Neganzi J.A. Steel castings. M.: Ed. lit. on ferrous and nonferrous metallurgy. 1948. 766 p. (in Russ.).

[7] Chernyshov E.A., Evstigneev A.I. Theoretical bases of foundry production. The theory of the formation of the casting. M.: Engineering, 2015. 480 p. (in Russ.)

[8] Koptsik V.A. principles of symmetrization-dissymmetrization of Shubnikov-Curie for composite physical systems // Problems of modern crystallography: Sat. in memory of A.V. Shubnikov. M.: Science, 1975. 407 p. P. 42-60. (in Russ.).

[9] Mishnev, S.V. determination of the forms of the tensors of stresses based on the principle of Curie. – Bulletin of Kazan state technical University: mechanical engineering, Issue 15. Krasnoyarsk, 1999. P. 184-189. (in Russ.).

[10] Baraz V.R., Levchenko V.P., Povzner A.A. Structure and physical properties of crystals. Ekaterinburg: UGTUUPI, 2009. 164 p. (in Russ.).

[11] Belov N.P., Prokoptseva O.K., Yaskov A.D. The basics of crystallography and crystal physics. Part I. Introduction to the theory of crystal symmetry. SPb: SPbSU ITMO, 2009. 43 p. (in Russ.).

[12] Grachev S.V., Baraz V.R., Bogatov A.A., Shveikin V.P. Physical metallurgy. − Ekaterinburg: publishing house of Ural state technical University, 2001. 534 p. (in Russ.).

[13] Wooster W. application of tensors and group theory to describe the physical properties of crystals. M.: World, 1977. 383 p. (in Russ.).

[14] Dimitrienko Yu.I. Tensor calculus. – M.: Higher school, 2001. - 577 p. (In Russian)

[15] Durnev V.D., Malashkevich I.P. Symmetry in technology. St.Ptg: Polytechnic, 1993. 247 p. (in Russ.).

[16] Mishnev S.V., Volodin P.A., Inanimate A.V. Influence of the thermal field structure on the structure of annealed material. Materials science. 2011. N 6. P. 13-16. (in Russ.).

[17] Malashkevich I.P., Martyanov M.A., Mishnev S.V., Khapilin S.N. The technology of obtaining longitudinal rolling of anisotropic metal sheets // Bulletin of KSTU. Krasnoyarsk: KSTU, 2000 (in Russ.).

[18] Khapilin S.N., Mishnev S.V., Malashkevich I.P. Festoon formation deep drawing of metal sheets with different symmetry physical and mechanical properties // Materials of VI international scientific-practical conference of students, postgraduates and young scientists "Modern technique and technologies", February 28 - March 3 2000, Tomsk: TPU, 2000 (in Russ.).

[19] Mishnev S.V., Malashkevich P.I., Durnev V.D. Technology of production of textured sheet metal differential rolling // Bulletin of KSTU, Issue 15: Engineering, Krasnoyarsk, 1999. P. 66-73. (in Russ.).

[20] Mishnev S.V. Technology of obtaining a differential rolling of metal sheets with different symmetry textures // abstract of candidate of technical sciences. Krasnoyarsk, 2000. 29 p. (in Russ.).

[21] Berezyuk V., Kuzembayev S., Sherov K., Sikhimbayev M., Mishnev S. and other. Increase of precision of casting blocks by applying acoustical oscillations in gas-impulsive moulding. Journal of Vibroengineering. The Lithuanian Academy of Sciences. Kaunas, August 2015, Vol. 17, Issue 5 (1667), pages 2178-2185 (in Eng.).

[22] Sherov K.T., Sikhimbayev M.R., Absadykov B.N. and other. Control's accuracy improvement and reduction of labor content in adapting of ways of metalcutting tools. News of the Academy of Sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. 2018, N 6. P. 170-179. https://doi.org/10.32014/2018.2518-170X.47 (Online), ISSN ISSN 2224-5278 (Print) (In Eng.).

[23] Kurmangaliyev T.B., Sherov K.T., Sikhimbayev M.R., Absadykov B.N. and other. Experimental study of optimal parameters of pneumatic motor of vibration table for inertial vibroabrasive machining the parts on the basis of beryllium oxide. News of the Academy of Sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. 2018, N 5, P. 184-191. https://doi.org/10.32014/2018.2518-170X.24 ISSN 2518-170X (Online), ISSN 2224-5278 (Print) (In Eng.).

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ISSN 2518-170X (Online), ISSN 2224-5278 (Print)

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Редакторы *Д. С. Аленов, М. С. Ахметова, Т. А. Апендиев*
Верстка *Д. А. Абдрахимовой*

Подписано в печать 05.02.2020.
Формат 70x881/8. Бумага офсетная. Печать – ризограф.
11,0 п.л. Тираж 300. Заказ 1.

Национальная академия наук РК
050010, Алматы, ул. Шевченко 28, т. 272-13-19, 272-13-18