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MECHANISM AND PROCESS OF SELF-PROPAGATING HIGH-TEMPERATURE SYNTHESIS OF SOLID CHEMICAL COMPOUNDS

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Abstract. The article presents the advantages and disadvantages of the technology of self-propagating high-temperature synthesis (SHS) of solid chemical compounds. Reactions and products of SHS of solid chemical compounds (carbides, nitrides, borides, oxides, etc.) are given. This method is relevant for processing dispersed waste of ferroalloy production. When grinding large-tonnage ferroalloys, cyclone dust is formed and accumulates.

The SHS process is based on the use of various chemical compounds as the main raw material, including pulverized waste from the production of ferroalloys. With minimal energy consumption, the SHS process allows obtaining high-quality composite materials based on iron. The main application of the products obtained is in the machine–building industry (abrasives, hard alloys, tool materials), use as an alloying material in the production of steel, as well as in the production of refractory materials for metallurgical furnaces.

Key words: high-temperature synthesis, cyclone dust, alloying material, dispersed waste, pulverized waste.

Self–propagating high-temperature synthesis (SHS) of solid chemical compounds is a new technological process for the production of materials based on the exothermic chemical reaction of the interaction of the initial reagents in the form of gorenje. Simply put, SHS is the synthesis of materials by gorenje. For the organization of such gorenje process, solid reagents almost always have to be used in the form of powders. However, here gorenje is not a conventional reaction of oxidation of powdered substances with oxygen to form the corresponding gaseous oxides, but a highly exothermic reaction of interaction of powdered reagents with each other or powdered reagents with liquid or gaseous reagents, for example, liquefied or gaseous nitrogen, with the formation of solid chemical compounds. Most often, these are refractory inorganic compounds (carbides, nitrides, borides, etc.) that do not decompose during gorenje, and materials based on them.[1]. The process of obtaining solid chemical compounds by the SHS method has the following advantages:

1. Low power consumption. A little energy is needed in the SHS method to heat the ignition coil and ignite the starting powder. Further, the synthesis process proceeds due to its own internal heat release as a result of a highly exothermic synthesis reaction, i.e. due to self-heating. The energy here is not consumed from the outside, but on the contrary is released inside. So then, after synthesis, it has to be taken outside, cooling the incandescent synthesis products.
2. The SHS method is characterized by simple and small-sized equipment. To implement the SHS process, there is no need for long-term high-temperature external heating, in bulky furnaces with heating systems, heat protection and thermoregulation.
3. The SHS method has a high performance, where due to self-heating during combustion, very high temperatures are reached, significantly exceeding the heating temperatures in powder metallurgy processes, therefore the synthesis reaction rate is much higher.Gorenje.
4. The product obtained by the SHS method is characterized by high purity and environmental safety. This is also due to very high synthesis temperatures compared to furnace synthesis. At such high temperatures, harmful impurities decompose and evaporate from the product, ensuring its increased purity and environmental safety of the SHS process.
5. The SHS method provides a wide range of materials: powders, porous materials, non-porous compact, cast, composite, surfacing and coatings. This is achieved by changing the composition of the initial powders and the conditions of their combustion. By changing them, first of all, the gorenje temperature and pressure, we can obtain a variety of synthesis products in a very different form. As a result, the SHS method has great flexibility, allowing you to obtain a wide variety of products on almost the same equipment.
6. SHS products find practical application in many industries:

- mechanical engineering: abrasives, hard alloys, tool materials;

- metallurgy: refractories, ferroalloys;

- electrical engineering and electronics: heating elements, ferrites, superconductors, highly conductive ceramics and adhesives, electro-conductive solid lubricants;

- chemical industry: catalysts;

- medicine: materials with shape memory, etc. [2].

The main drawback of SHS is the requirement of high exothermicity of the reaction of interaction of the initial powder reagents, so that the reaction of the synthesis of products takes place in the form of gorenje phenomenon, so that the initial powder can be ignited.

Reactions and products of SHS. Mixtures of elements or their compounds are used as reacting systems for SHS of inorganic compounds, materials and products, mainly in the form of powders capable of releasing a large amount of heat during interaction. There are several ways: SHS from elements, SHS with the participation of chemical compounds.

SHS of the elements is the most extensive and studied class of SHS reactions. It can be divided into three subclasses according to the types of mixtures of elements: 1. Metals with nonmetals; 2. Metals with metals; 3. Nonmetals with nonmetals. Reactions of synthesis from elements belong to the category of oxygen-free gorenje. In most of them, metal is combustible, and nonmetal is an oxidizer. Nonmetals in SHS reactions can be solid, gaseous and liquid. Reaction mixtures of metals with solid nonmetals are prepared in the form of powder mixtures, which are then burned, realizing the reaction of SHS of inorganic compounds of different classes:

carbides:

$Ti + C \rightarrow TiC$, $T_{ад}$ = 3290K;

$Ta + C \rightarrow TaC$, $T_{ад}$ = 2570K;

borides:

$Ti + 2B \rightarrow TiB_2$, $T_{ад}$ =3193K;

$Ti + B \rightarrow TiB$, $Ta + B \rightarrow TaB$, $T_{ад}$= 2500K;$T_{ад}$ = 2190K;

$Mo+ 2B \rightarrow MoB_2$, $T_{ад}$ = 2320K;

silicides:

$5Ti + 3Si \rightarrow Ti_5Si_3$, $T_{ад}$ = 2400K;

$Ti + Si \rightarrow TiSi$, $T_{ад}$ = 1920K;

$Mo + 2Si \rightarrow MoSi_2$, $T_{ад}$ = 1920K;

In the case of gaseous nonmetals (N2, H2), metal powders are burned in the atmosphere of these gases created in the SHS reactor, usually with increased pressure. The gas is absorbed during synthesis by the metal powder, and the following compounds are formed:

nitrides:

$2Ti + N_2 \rightarrow 2TiN$, $T_{ад}$ = 4897K;

$2Nb + N_2 \rightarrow 2NbN$, $T_{ад}$ = 2800K;

$2Al + N_2 \rightarrow 2AlN$, $T_{ад}$ = 3638K;

hydrides:

$$Ti + H_2 \rightarrow TiH_2, \qquad T_{ад} = 1123К;$$

$$Zr + H_2 \rightarrow ZrH_2, \qquad T_{ад} = 1323К.$$

An example of a liquid nonmetal can be liquefied nitrogen. In this case, a cryogenic vertical reactor in the form of a Dewar vessel with thick walls is used for conducting SHS. Liquid nitrogen is poured into the reactor, and then a porous tablet of compressed metal powder is lowered, which must be tested. The reactor is screwed with a lid through which a tungsten spiral passes, brought into contact with a metal tablet. When an electric current is applied, the spiral heats up and ignites the tablet. [3].

SHS involving chemical compounds as reagents is another extensive class of SHS reactions. It can be divided into four subclasses: 1. chemical compounds as oxidizing agents; 2. chemical compounds as combustible; 3. SHS with a reducing stage:

1. SHS oxides from chemical compounds. In many processes, not the elements themselves can be used as oxidants, but their compounds: ammonia NH3, hydrazine N2H4, azides (NH4N3, NaN3, etc.), silanes SinH2n+2, hydrocarbons and polymers of SpNm. In SHS reactions, they, interacting with the fuel elements, give, respectively, its nitrides, silicides, borides and carbides.
2. Chemical compounds as combustible. Not the elements themselves, but their chemical compounds, alloys and solid solutions can be used as fuels.
3. SHS with a recovery stage. A significant subclass of SHS reactions is in which not the elements themselves, but their oxides or other halides together with a reducing metal can be used as both combustible and oxidizing agents. These are the so-called SHS reactions with a reduction stage. In them, aluminum and magnesium are mainly used as a reducing metal. The prototype of such reactions is the long-known metallothermic reactions of gorenje termites, carried out in order to obtain melts of metals by reduction from their oxides.

Thus, the review is devoted to a new technological process for obtaining materials based on the SHS of solid chemical compounds (carbides, nitrides, borides, oxides, etc.) during the exothermic chemical reaction of the interaction of the initial reagents in the form of gorenje. [4].

The main purpose of SHS is the synthesis of substances and materials, the creation of new technological processes and the organization of new technological processes and the organization of new productions. Currently, SHS is a whole scientific and technical field that is intensively developing.

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ҚАТТЫ ХИМИЯЛЫҚ ҚОСЫЛЫСТАРДЫҢ ӨЗДІГІНЕН ТАРАЛАТЫН ЖОҒАРЫ ТЕМПЕРАТУРАЛЫ СИНТЕЗІНІҢ МЕХАНИЗМІ ЖӘНЕ ПРОЦЕСІ

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Аңдатпа.. Мақалада қатты химиялық қосылыстарды өздігінен таралатын жоғары температуралы синтез (СВС) технологиясының артықшылықтары мен кемшіліктері келтірілген. Қатты химиялық қосылыстардың реакциялары мен өнімдері (карбидтер, нитридтер, боридтер, оксидтер және т.б.) келтірілген, бұл әдіс Ферроқорытпа өндірісінің дисперсті қалдықтарын өңдеуге қатысты. Ірі тонналы ферроқорытпаларды ұсақтау кезінде циклон шаңы пайда болады және жиналады.

СВС процесі негізгі шикізат ретінде түрлі химиялық қосылыстарды, оның ішінде Ферроқорытпа өндірісінің шаң тәрізді қалдықтарын пайдалануға негізделген. Электр энергиясының минималды шығынымен процесс темір негізіндегі жоғары сапалы Композициялық материалдарды алуға мүмкіндік береді. Алынған өнімдердің негізгі қолданылуы машина жасау саласында (абразивтер, қатты қорытпалар, аспаптық материалдар), болат өндірісінде легірлеуші материал ретінде, сондай-ақ металлургиялық пештер үшін отқа төзімді материалдар өндірісінде қолданылады.

Кілт сөздер: жоғары температуралы синтез, циклон шаңы, легірлеуші материал, дисперсті қалдықтар, шаң тәрізді

МЕХАНИЗМ И ПРОЦЕСС САМОРАСПРОСТРАНЯЮЩЕГОСЯ ВЫСОКОТЕМПЕРАТУРНОГО СИНТЕЗА ТВЕРДЫХ ХИМИЧЕСКИХ СОЕДИНЕНИЙ

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Аннотация. В статье приведены преимущества и недостатки технологии самораспространяющейся высокотемапературного синтеза (СВС) твердых химических соединений. Приведены реакции и продукты СВС твердых химических соединений (карбидов, нитридов, боридов, оксидов и др.) Указанный метод актуален для переработки дисперсных отходов ферросплавного производства. При измельчении крупнотоннажных ферросплавов образуется и накапливается циклонные пыли.

СВС процесс основан на использовании в качестве основного сырья различных химических соединений, включая пылевидные отходы производства ферросплавов. При минимальном расходе электроэнергии СВС процесс позволяет получать высококачественные композиционные материалы на основе железа. Основное применение получаемых продуктов – это в машиностроительной отрасли (абразивы, твердые сплавы, инструментальные материалы), использование в качестве легирующего материала при производстве стали, а также при производстве огнеупорных материалов для металлургических печей.

Ключевые слова: высокотемпературный синтез, циклонная пыль, легирующий материал, дисперсные отходы, пылевидные отходы.