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Agglomeration in Metallurgy

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The book is dedicated to our colleagues,
agglomeration specialists,
who give new power to ... powder

Preface

Prometheus stole fire from Hephaestus, the patron saint of metallurgy, and presented it to people, for which, as we know, was severely punished by the gods. Finding fire, of course, changed a person's life in the literal and figurative sense, but also, in particular, turned into many problems. The punishment, according to Greek mythology, came to people in the form of Pandora with her ill-fated box. Fire (high-temperature treatment, roasting) of course, plays a very important role in metallurgical processes, being practically the only possible method of smelting metal. Unfortunately, it is Pyrometallurgy that is one of the main sources of harmful emissions into the atmosphere, creating serious threats to the very life of mankind. In the structure of these emissions, a significant proportion (up to 50%) is composed of emissions from sinter plants. Therefore, the efforts of scientists and metallurgists to find ways of the so-called cold agglomeration of raw materials for smelting iron do not stop.

This book was originally conceived by the authors as a continuation of the book by Kurunov and Bizhanov (*Stiff Extrusion Briquetting in Metallurgy*, Springer, 2018) devoted to the description of the new technology of briquetting, based on stiff vacuum extrusion, already widely used in practice. In particular, the authors assumed to compare it comprehensively with the classical agglomeration methods used in modern metallurgy.

But as the content of the book was formed and the manuscript was being prepared, novelties of technical solutions in classical technologies of agglomeration came to light, which were not adequately covered in available literary sources. Not to dwell on such materials would simply be wrong, for this would largely narrow the understanding of the current level of classical technologies and the prospects for their development. These considerations led to the structure of the book, in which, besides briquetting, due process is also given to the processes of roasting agglomeration—sinter and pellets production.

The generalization of information sources is not limited to time periods, but reflects the most significant milestones for the technologies of agglomeration, partly forgotten or unclaimed ideas, hypotheses, technical solutions that have remained relevant to the present time, with an emphasis on the experience of improving the quality of sinter and pellets, increasing the productivity of sintering and firing machines, resource efficiency, ensuring environmental safety of the production of raw materials.

The chapters “Sinter Production” and “Production of Pellets” were prepared by Dr. Sci., Prof. Valentina Chizhikova, chapter “Briquetting”—by Ph.D. Aitber Bizhanov. Chapter 4 was written by the authors jointly.

The authors in no way claim to the indisputability of the assessments and conclusions, which are built on the arguments currently available at their disposal, and fully allow for the further development of views and ideas in the theory and technology of the agglomeration of dispersed materials.

The authors are grateful to the research teams and researchers who shared in their publications their own ideas, their theoretical rationale and engineering embodiment, as well as colleagues all over the World who helped the authors in their scientific work.

The authors are especially grateful to the publisher for the goodwill and the possibility of publishing this book and efforts to publish it.

The publication is addressed to metallurgical engineers, personnel of metallurgical enterprises, researchers and can be useful to teachers of higher educational institutions of metallurgical or polytechnic profile, graduate students, undergraduates, students studying the specialty “Metallurgy”.

With all the best wishes.

Moscow, Russia

Aitber Bizhanov
Valentina Chizhikova

Introduction

Time to cast away stones and a time to gather stones together…
(Ecclesiastes 3:5, English Standard version)

The scheme of steel production developed by the beginning of the twenty-first century, based on a three-stage processing (preparation of raw materials for the production of primary metal, production of primary metal, processing of primary metal into steel) provides high technical and economic indicators of the industry and, obviously, will remain the preferred scheme of metal production. The dominant position in the production of primary metal is occupied by the blast furnace process [1], the main charge component of which is the agglomerated iron ore raw material (sinter, pellets and briquettes). In 2016 the global production of the hot metal achieved 1164 million tons, which required 398 million tons of pellets and more than 750 million tons of sinter [2].

Sinter is a solid lumpy product with an irregular shape of the pieces, formed as a result of high-temperature treatment of the charge, and isolated from the cake by crushing and screening [3].

Pellet is a solid spherical body obtained by pelletizing fine ore materials with the addition of binders, followed by hardening by firing, cementation or autoclaving [3].

Briquette (briquette)—a prismatic or cylindrical solid formed by mechanical forces, depending on the molding method, containing a binder, with further strengthening by aging under natural conditions or by autoclaving.

The first patent for the method of agglomeration by sintering was obtained in 1887 by the English F. Geberlein and T. Huntington. It was related to the oxidizing firing of sulfide ores and did not provide for the introduction of a special fuel into the charge, since the heat demand of the process was provided by the oxidation of sulfide sulfur. With regard to the agglomeration of iron ores, the engineering solution with the introduction of coke or coal fines was proposed by the German specialist D. Zavelsberg in 1905 [4], who introduced the term “sintering”. Process received commercial distribution after the invention of Dwight A. and R. Lloyd of the belt (conveyor) sinter machine in 1906, and the commissioning of the first installation of its kind in the city of Birdsboro (USA) opened the era of commercial application of the sintering of charge materials on the conveyor machines. Modern sintering machines have a sintering area of up to 700 m^2.

The technology of pellet production was born a little later than sintering: the first patent was taken in 1912 by Swedish Anderson [5]. This technical idea was further supported and developed in Germany, starting with the Brakkelsberg patent in 1913 for the method of pelletizing of finely divided iron ore [6] and up to the construction of an industrial pelletizing plant in 1926 in Dillingen. A new stage of interest in this method arose in the 40s in the United States with the advent of industrial volumes of fine concentrates obtained during the enrichment of taconites. It was at this time that the term "pellet" was born (in the Russian version of "okatysh"). The date of the beginning of industrial production of pellets as raw materials for blast furnaces can be considered as 1955, when the first pellet factory was introduced in the United States (Silver Bay). Modern installations for oxidizing firing of pellets can have an area of up to 780 m^2.

Industrial briquetting began with the first commercially successful project for the production of briquettes from fine magnetite iron ore, implemented in 1899 in Finland. By 1913, there were 38 such briquetting lines in the world (including 16 in Sweden, 12 in England, and 6 in the USA). For the production of briquettes various presses were used (Sutcliffe, lever, revolver, ring, conveyor, roller). The low productivity of briquetting equipment and, often, the insufficient strength of briquettes did not allow this technology to play a significant role in the agglomeration of raw materials for blast-furnace production. The development of briquetting technology with the advent of technologies such as stiff vacuum extrusion allows you to neutralize the shortcomings noted and thus rehabilitate the technology of briquetting as a method of agglomeration of raw materials for blast furnace smelting.

The production of agglomerated raw materials as an industrial technology in modern conditions faces a number of challenges that form additional requirements both for production and for the product or impose certain restrictions:

Increased requirements for the quality of raw materials for blast furnace smelting.

The modern blast smelting technology, aimed at the utmost coke saving, provides for a number of technological innovations that lead to increased demands on the quality of agglomerated raw materials:

- due to the desire to increase the iron content, the proportion of pellets in the charge of blast furnaces increases, since every 1% increase in iron content reduces coke consumption to 1.3% [7]; in recent years in Russia, it has risen to 40%, in the USA, the consumption of pellets in the charge reached 1000 kg/t of pig iron, and some furnaces operate on 100% pellets;
- separation of fine fractions of sinter (with special conditions of its loading into the blast furnace); the increased content of fines in the iron ore part of the blast furnace charge causes coke overruns of up to 2% for each percent increase in the fraction—5 mm in the sinter or pellets [7].
- injection of pulverized coal.

Unlike sinter plants (and briquetting workshops), integrated in the structure of metallurgical production, pelletizing factories are focused on the ore base, and the raw materials produced must be delivered to the consumer with numerous overloads. Transportation of pellets of unsatisfactory quality leads to the actual loss of raw materials up to 50 kg/t of pellets.

Public concern about resource availability and resource saving.

Sustainable development of society according to American scientists [8] is predetermined by the conservation of raw materials, energy, environmental and other resources. At the same time, global public production is characterized by extremely low efficiency with respect to resources: only 2% is used positively, the remaining 98% is transferred to secondary materials or waste. In this regard, the problems of resource saving are global in nature.

The paradigm of sustainable development of civilization, which determined the resource and ecological strategy of industrial development in the 90s of the twentieth century, establishes certain improvement criteria, including the production processes of the primary metal:

1. resource saving (mainly due to the high material consumption of the primary metal production processes, focused on the maximum involvement of anthropogenic materials into the economic turnover);
2. energy saving due to the need to solve global environmental problems (greenhouse effect);
3. environmental requirements (minimizing the negative impact on the environment).

The level of negative impact is an important resource aspect of the operation of metallurgy. According to [9] in Russia, for example, emissions from metallurgical production (ferrous and non-ferrous metallurgy, production of finished metal products) account for more than 20% of gross national emissions from stationary sources. In the structure of the metallurgical enterprise of a full cycle sinter production represents up to 50% of gross emissions, the volume of which is primarily due to the technological features of the process.

It is easy to see that the terms, such as quality, pollution level, energy saving, are in a close relationship and interdependent. Improving the quality of the agglomerated product (first of all, its durability) ensures a reduction in recycling costs and is accompanied by a decrease in energy consumption for production and a decrease in dust emission.

The way to improve the quality of the product with uncontrolled energy consumption (for example, the mechanical activation of charge components in the production of pellets or sinter) in terms of resource conservation is unacceptable. It should be taken into account that the thermal regulation of the product quality, which is traditional for high-temperature sintering processes, is largely associated with energy waste (approximately 0.5 m^3 for every 10 °C of heating).

Actually, these ideas created the basic concept of the book, which consists in highlighting theoretical ideas about the processes of agglomeration of iron containing raw materials and the ideas, proposals and solutions aimed at managing the quality of raw materials for blast-furnace smelting while minimizing energy consumption and limiting environmental impact (environmental aspects).

The concept is based on the principle of sustainable environmental management, the observance of which is guaranteed by:

– preservation of material resources (in the form of metallurgical coke) while increasing the strength of the agglomerated material and the quality of pellets by reducing the content of fines and other measures;
– saving energy resources (process fuel) in the implementation of effective technical and technological solutions in the agglomeration;
– reduction of emissions in the technological process (effective technologies, including environmental), due to the production of high-quality raw materials, the use of stiff extrusion briquettes, waste disposal, the use of new binders in the production of pellets and briquettes.

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About the Authors

Aitber Bizhanov was born on October 6 1956 in Buinaksk, Russia. Graduated from the Moscow Physical-Technical Institute in 1979. Aitber spent eleven years as a senior researcher with the Institute for High Temperatures, USSR Academy of Sciences, focusing on solar heat storage technologies. In 1992, he left academia, joining EVRAZ, a large, vertically integrated steel and vanadium enterprise with global assets. Following two years as Commercial Director and Executive Plant Director with ChTPZ-Complex Piping Systems, Aitber joined Kosaya Gora Iron Works in 2005 as Commercial Director, introducing a briquetting technology that used metallurgical wastes. Since then, he's worked on agglomeration and briquetting of the metallurgical wastes as Wastes Management Expert for HARSCO Metals. Today, Aitber is an Independent Representative of the J.C. Steele & Sons, Inc. Company in Russia & CIS, Eastern Europe and Turkey. Has Ph.D. degree in the agglomeration of natural and anthropogenic materials in metallurgy. Author of more than 60 publications and is owner and co-author of 14 Russian Patents in the field. Author and owner of the "BREX" trademark. With his personal participation, projects of briquetting of natural and anthropogenic raw materials of ferrous metallurgy were successfully implemented in a number of countries. Aitber is a member of Institute for Briquetting and Agglomeration (IBA) since 2011.

Valentina Chizhikova was born and lives in Moscow. Graduated with honors from the Moscow State Institute of Steel and Alloys (MISiS) with an engineer-metallurgist qualification. Her Ph.D. thesis marked the beginning of the study of solid-phase sintering processes in relation to pellet firing, her doctoral (Dr. Sci.) thesis was devoted to a wide range of tasks related to sinter and pellet production, namely, improving the quality of agglomerated raw materials, resource saving and environmental safety. She has more than 30 years of teaching experience at MISiS (now the National University of Science and Technology), as a professor. In scientific terms, the activities of Valentina Chizhikova have always been devoted to solving industry-specific tasks. Under her leadership and direct participation, more than 30 major research projects were successfully implemented. She is the author of about 200 publications, including 80 copyright certificates and patents, the author and co-author of 8 books on the theory of metallurgical processes, techniques and technologies for the production of agglomerated raw materials and pig iron smelting, environmental problems of metallurgy. In practical terms, she served for 13 years (until April 2018) at a large metallurgical enterprise (PJSC Novolipetsk Metallurgical Plant) as a chief ecologist.