UDC 669.162.1.001.57

Research of obtained green pellets with the use of mathematical models

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Abstract
The main mathematical models of green pellets obtaining processes are considered. The reasonability of pelletizing ability indicator use of fine iron ore materials for modeling of pelletizing processes is shown. The most adequate model of pelletizing ability of fine material, and also determination technique of the values, which this model includes, are proved on the basis of the analysis of pelletizing ability models using the characteristic moisture capacity.
Key words: PELLETIZING, MATHEMATICAL MODEL, GREEN PELLETS, PELLETIZING ABILITY, CHARACTERISTIC MOISTURE CAPACITY

Determination of optimum parameters of pelletizing process implementation is one of the most important subjects of researches in metallurgy. These researches will allow carrying out of further optimum automation of production process, and also taking of measures optimizing technology of production process of qualitative iron ore pellets. Obtaining of standard green pellet is one of the major tasks of pellets production. The granulation is the technological operation, which is responsible for the formation process of a solid crude lump of optimum shape and size. All the investigated granulation process parameters, namely selection of the equipment and its working modes, quantity and ways of water supply and various additives in the pelletizing charge, are determined by physical and chemical properties of pelletized iron ore materials. Today, the development of universal mathematical model of granulation process of iron ore pellets is a relevant scientific and technical task. However, there is no universal mathematical description of granulation process up to the present day, in view of the complexity of the consideration of all the factors defining efficiency of granulation process, and also absence of the mathematical description of some physical phenomena.

Various fine materials possess different pelletizing ability and strength characteristics of finished products, as they are characterized by various pelletizing ability. The pelletizing ability indicator is the important characteristic of fine materials properties, allowing estimating of their role during pelletizing. The ability of materials to form strong units, lumps, granules under influence of dynamic loadings and water is called as pelletizing ability. The pelletizing ability of fine materials (K) is defined by adhesive strength of raw material particles. It is possible to define the pelletizing mode and optimum parameters of the pelletizing unit operation by the use of pelletizing ability indicator. It is necessary to spend different amount of the mechanical energy energized to pelletizer in order to obtain the green pellets of the corresponding quality from materials of various pelletizing ability. The indicator K helps to learn necessary amount of the energy spent for a solid granule formation, and also optimum moisture content of pelletized material. The characteristic of material moisture capacities is accepted to use for detecting of the pelletizing indicator. However, for the moment, the single distinctively reasoned dependence of pelletizing indicator on various characteristic moisture capacities is not established, and also there are a number of different techniques of characteristic moisture capacities definition. Possibility of a moisture capacity definition of material is limited significantly by the experimental techniques and equipment available for today. Moisture capacities are determined by practical consideration by using of measurement of saturation rate of materials stationary layer with water [1]. One of the first formulas for pelletizing calculated definition according to the size of characteristic moisture capacities was offered by V. M. Vityugin and A.S. Bogma [2]:

$$K = \frac{MMMC}{MCMC - MMMC}, \qquad (1)$$

where MMMC - maximum molecular moisture capacity, %; MCMC – maximum capillary moisture capacity, %. MMMC corresponds to the charge condition, where all the surface of charge particles is covered with molecules of the adsorbed water of the maximum thickness, which material is capable to reach. MCMC considers the water, which is under negative pressure, in material layer capillaries. These moisture capacities can be established by practical consideration only. Techniques of MMMC and MCMC definition are described in paper [3]. MMMC of fine material is defined by the pressure vessel maintaining a certain air humidity - drying bottle. MCMC is defined by measuring of saturation time of materials layer and amount of the moisture absorbed by it, applying the Darcy rule [4]. However, the reasonability of use of MCMC definition technique by means of the Darcy linear filtration law was disposed in paper [5]. Saturation rate of the charge materials moisture is a necessary indicator when determining of characteristic moisture capacities. The specific surface determined by the condition of the pelletized materials layer affects this indicator in large measure. However, the structure of material layer changes during pelletizing. Its specific surface is not uniform; the size and shape of pore and capillaries, and also water pressure value under the centrifugal forces influence are changed. Using formula (1) the indicator of the charge optimum humidity was found in paper [6]:

$$W_{opt} = \frac{MMMC}{K} \qquad (2)$$

The optimum humidity calculated by formula (2) for the Sokolov-Sarbai concentrate is equal to 12%, though in practice, it is 8.5-8.6%. The experiments results show that the formula (1) is not adequate model of fine materials pelletizing. This technique of definition of K does not consider the dynamics of granulation process depending on the centrifugal forces magnitude operating on the material and water. For the same reason, the maximum hygroscopic moisture capacity of a material (MH) is not considered during pelletizing. Therefore, all known mathematical descriptions of the charge pelletizing ability with the use of MH indicator can be considered as not adequate mathematical models. The condition of charge is changed during pelletizing from friable wet mass with the developed pore system to consistent solid pellets with much smaller pores and capillaries. This process can be described physically considering the capillary and motionless moisture kept by a pellet after full grains compression. The smallest capillary moisture capacity (SCMC) is capillary and still water in disperse material layer. The adsorbed, strongly connected and motionless capillary pendular moisture is included in SCMC. This characteristic moisture capacity is recommended to be used instead of MMMC [7]:

$$K = \frac{SCMC}{MCMC - SCMC}, \qquad (3)$$

The increase in operating humidity of pelletized material over SCMC value will cause the increase of moisture mobility and will affect positively the pelletizing rate; however, thus, a pellet solidity and durability will be reduced. At the maximum compression, SCMC reflects the ability of material to hold the moisture in comparison with unconsolidated wet material. The technique of SCMC determination according to experimental graphic dependences of material humidity on the capillary impregnation rate is described in work [8]. The tests are moistened to MCMC, dehydrated in a gravitational centrifugal field to the residual moisture at various dehydration rates. This technique is not suitable for practical application when green pellets producing; as it does not describe the moisture behavior in capillaries under the impact of forces and loads on all the material when pelletizing.

Considering the water and physical characteristics, the assessment of K must allow determining of optimum parameters of pelletizing process and force intensity of impact on material necessary for achievement of the best efficiency of pelletizing on the basis of material properties only.

The analysis of well-known mathematical descriptions of pelletizing ability of fine materials shows that the most adequate formula is (3), which describes the process and behavior of materials when pelletizing. The determination of the characteristic moisture capacities, which are part of a formula (3), is possible by empirical techniques only; however, the properties of materials, which are reflected in these moisture capacities, are constant. The iron ore concentrate, on the basis of which the charge for pellets production is formed, is hydrophobic material. The role of molecular adhesive forces when forming of a pellet from such charge consists only in holding of hygroscopic moisture, which does not reach 0.5% of the charge general moisture capacity in practice. Therefore, the value of a capillary moisture capacity of charge dominates when pelletizing. If the pellet is not formed, the pelletizing ability is influenced by MCMC, and in the compacted layer of materials (lump), SCMC affects it. The empirical techniques of characteristic moisture capacities determination must model the behavior of moisture and materials as accurately as possible when green pellets granulating. The technique [9], which reflects real process at the most, was offered for increase of determination accuracy of fine materials pelletizing. Its nature consists in pelletizing of single charge portions in a drum at initial moisture above the optimum. At that, the lumps durability and the corresponding moisture are periodically determined by dropping. The pelletizing ability is determined by calculation according to well-known techniques using the moisture value and capillary moisture capacity. Moreover, the data on a characteristic moisture capacity are obtained directly from the experiment on pelletizing of this material in the periodic mode. The dependence of droppings number before pellet destruction on the moisture content is determined graphically or using other way; SCMC is defined as a maximum of this dependence.

Conclusion

The research of production processes of green pellets using the mathematical models will give the chance to study the parameters and indicators of pelletizing process completely. The most adequate model of fine iron ore materials pelletizing is based on the use of the smallest and maximum capillary characteristic moisture capacities − SCMC and MCMC. Thus, the determination technique of SCMC must consider the features of properties of the granules, which are formed during material pelletizing.

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