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Magnetic crystalline alignment (Review)

S.Asai

A new technology relating to crystalline alignment and texture control has emerged by the development of superconducting technologies. Its principle based on magnetization force can be applied to non-magnetic materials with asymmetric unit cells. In this paper, the principle is described and the recent development of the magnetic crystalline alignment of inorganic materials is summarized.

(cf. *ISIJ Int.*, **47** (2007), 519)

Brief review on microwave (MW) heating, its application to iron & steel industry and to the relevant environmental techniques (Review)

N.Yoshikawa et al.

In this article, history of MW heating and its general application are reviewed first. The MW heating started from 60 years ago, and their high temperature application was from about 80s. MW heating application can be classified with respect to the heating temperature. The applications were discussed in relation with their heating mechanisms, taking special account for the magnetic field contribution to the heating.

Researches on MW application to the iron and steel industry field have been conducted, recently. There are active research group members in ISIJ who have been performing both the fundamental and the application researches on the MW heating. Their works are briefly reviewed.

The authors' recent studies on the MW heating of Ti-containing Chinese blast furnace slags, and on the fundamental studies of MW carbo-thermal reduction of NiO for recycling metals from the pickling sludge are briefly presented.

(cf. *ISIJ Int.*, **47** (2007), 523)

The review of microwave applications in metallurgical process in China (Review)

C.Bai et al.

As a heating method, microwave heating plays an important role in foods, materials and minerals processing because it has properties like selective heating, volumetric heating and rapid heating, which also attracts more attention for researchers to apply microwave to metallurgical processes. For example, some researchers have investigated microwave sintering of magnetite concentrates, green balls roasting, slag treatment and metal minerals treatment. This paper briefly summarizes the development of microwave applications in metallurgical process in China, mostly involving in drying of agglomerations, sintering of magnetite concentrates and reduction of iron ore concentrates. Although a great improvement of microwave application has been attained in China, it is still in lab-scale, while how to apply these processes or technologies to industry scale still needs a further research.

(cf. *ISIJ Int.*, **47** (2007), 528)

Microwave technology in steel and metal industry, an overview (Review)

D.Malmberg et al.

In many metallurgical operations, effective analysis of the processes can be very difficult with available technology. This is especially true if the analysis is to be performed on-line and in a harsh environment characterized by high temperatures, dust and liquid metal. Protection of the equipment requires both rugged encapsulation as well as elaborate sampling systems and exposure of the equipment to the hazardous environment must be minimised. Often this result in an increased level of service and maintenance requirements and, in the worst case, the maintenance cost might be so high that the equipment is not installed. Microwave technology is a versatile and powerful tool with many different applications in the scientific community. It is insensitive to dust and fume and, for several years, the technology has been tested at MEFOS and evaluated for different metallurgical processes. It has been applied to slag thickness measurement and slag composition in an induction furnace, 3D imaging of the burden surface in a charging model on pilot scale as well as raceway depth measurements in a Blast Furnace. The idea of using microwave technology for gas analysis in metallurgical processes has also been explored. However, despite its many advantages, microwave technology is still not employed extensively in the steel and metal industries.

(cf. *ISIJ Int.*, **47** (2007), 533)

Characteristics of millimeter-wave heating and smart materials synthesis (Review)

Y.Makino

Characteristics and advantages of heating processing based on millimeter-wave are described from the standpoint of the interaction between electromagnetic energy and solid materials. High capabilities of the electromagnetic processing are indicated by exemplifying several successful results such as sintering of alumina and AlN and post-annealing of aerosol-deposited PZT films. In these examples, it is shown that well-characterized properties such as high thermal conductivity and high bending strength are obtained by the inherent effect in the millimeter-wave processing. In the millimeter-wave processing, high thermal conductive AlN with over 210 W/(m·K) can be synthesized by rapid sintering at lower temperature, compared with the conventional method. Suppression of the interfacial reaction between PZT film and substrate steel can also be attained using the millimeter-wave processing. It is explained that the high capabilities of applying millimeter-wave processing to smart materials synthesis originates from the non-thermal effects due to high frequency field of millimeter-wave.

(cf. *ISIJ Int.*, **47** (2007), 539)

Mathematical modeling of incompressible MHD flows with free surface

K.Takatani

Mathematical model for incompressible magnetohydrodynamics (MHD) flows with complex free surfaces has been developed, the transient 3D Navier–Stokes equations with Lorentz force induced by static magnetic field are solved. In this model, the simplified marker and cell (SMAC) method is used for solving the Navier–Stokes equations, the dynamic conditions at free surface are implemented through the continuum surface force (CSF) model with the volume of fluid (VOF) method, the compressive interface capturing scheme for arbitrary meshes (CICSAM) scheme is used for the VOF convection, and anti-diffusion procedure is conducted to suppress the numerical diffusion caused by the VOF convection. Effect of the anti-diffusion operation is investigated, and coalescence of two gas bubbles and impact of a drop on shallow liquid film are examined in order to verify the validity of the present mathematical model. As MHD flow examples, pouring of liquid metal into a rectangle insulated container and coalescence of two gas bubbles in the static magnetic field are simulated.

(cf. *ISIJ Int.*, **47** (2007), 545)

Confining of molten metal by imposition of D.C. magnetic field and D.C. electric current

Y.Hirono et al.

A new method of confining a molten metal by imposing D.C. magnetic field and D.C. electric current has been proposed. The confinement of a molten metal was demonstrated by a model experiment using a molten gallium with low melting temperature. By using of newly proposed plural pairs of electrodes, the molten metal could be confined under rather weak magnetic field of 0.5 T. The electric current required for confining a molten metal has been theoretically predicted. It has been found that the theoretical prediction agrees well with experimental data. The model experiment demonstrated that the method proposed in this study is promising for industrial applications.

(cf. *ISIJ Int.*, **47** (2007), 552)

Creation of nanomagnetite aggregated iron oxide hydroxide for magnetically removal of fluoride and phosphate from wastewater

A.Eskandarpour et al.

A new chemical adsorbent for fluoride and phosphate removals was produced by applying a novel nanomagnetite aggregation process through the formation procedure of an iron oxide hydroxide, *i.e.*, schwertmannite. Although there was no evidence of magnetite related peaks in the XRD pattern of the new adsorbent, because of the very small amount of the used magnetite particles, the SEM picture reveals a surface alteration on the crystal structure of the new adsorbent comparing to the schwertmannite. The results of magnetic removal of fluoride and phosphate using the new adsorbent indicate that nanomagnetite aggregation process not only improves the magnetic property, but also provides a highly-promoted fluoride and phosphate adsorption capacities comparing to the schwertmannite.

(cf. *ISIJ Int.*, **47** (2007), 558)

Semi-continuous magnetic removal of phosphate using an iron oxide hydroxide adsorbent and regeneration of its adsorbent

A.Eskandarpour et al.

Phosphate removal from wastewater using fine-

particles of schwertmannite was performed by use of a semi-continuous magnetic filtration. The effects of two main parameters of magnetization and drag forces on the performance of the magnetic filtration were investigated. By increasing the magnetic intensity from 0.4 to 4 T, the magnetic filter performance was increased from less than 0.7 up to 0.99 depending on the fluid velocity through the magnetic filter. The measured results in magnetic filtration tests were in consistence with the theoretical results applied in this study. It was revealed that the schwertmannite possessed a high regeneration ability with trivial loss of adsorption capacity. Moreover, the phosphate adsorption capacity in schwertmannite was remarkably increased by using an acid-modification method.

(cf. *ISIJ Int.*, **47** (2007), 563)

Large eddy simulation on flow structure in centrifugal flow tundish

F.WANG et al.

Centrifugal flow tundish which the molten steel is horizontally rotated by electromagnetic force has been developed to produce high quality steel with high productivity. Because the swirling flow in the rotation chamber is crucial for the effectiveness of centrifugal flow tundish, it is beneficial to search the way to enhance the swirling flow and understand the flow structure in centrifugal flow tundish. Large Eddy Simulation (LES) technique is developed to simulate the complicated flows. LES is computationally much more intensive than k–ε and cost less than direct numerical simulation (DNS), but offers a new level of insight into transient phenomena. In the present works, flow structures in three cases are simulated and analyzed, *i.e.* the swirling flow is produced by (a) electromagnetic force with the direct nozzle, (b) bending nozzle using height potential energy of molten steel, (c) combination of electromagnetic force and bending nozzle. The swirling flow and vortices are clearly displayed. The effectiveness of bending nozzle is validated by 17% increment of maximum swirling velocity in rotation chamber.

(cf. *ISIJ Int.*, **47** (2007), 568)

Numerical simulation of liquid metal free-surface flows in the presence of a uniform static magnetic field

T.TAGAWA

Three-dimensional numerical simulations with a new-developed modeling of two-phase flow have been carried out for free-surface flows of an electric conducting fluid in the presence of a uniform static magnetic field. In this study, several examples such as collapsing liquid column, oscillating droplet in a non-gravitational field and falling droplet in a gravitational field are presented. The driving mechanisms of the flow in these problems are the gravity and the surface tension. The numerical results reveal that the induced electromagnetic force acts to dampen the electric conducting fluid flow efficiently when a uniform vertical magnetic field is applied while it acts to enforce a tendency of two-dimensional flow when a uniform horizontal magnetic field is applied.

(cf. *ISIJ Int.*, **47** (2007), 574)

Microwave absorption behavior of iron–alumina mixed powder at elevated temperature

S.SANO et al.

Recently, it has been reported that metal powders can be heated by microwave irradiation and many attentions have been attracted on the research field. More effectively heating of iron powder in H field than E field has also been reported. From this result, it is supposed that microwave absorbability of iron powder may change at Curie temperature since iron losses magnetism at the temperature. The objective of this work is to reveal the microwave absorption behavior of iron powder around Curie temperature. For this purpose, microwave absorption behavior of iron–alumina mixed powder at elevated temperature was measured by using a circular wave-guide fixture and a microwave vector network analyzer. When iron powder was subjected to a measurement, compact body of iron powder became a reflector for microwave above 700°C, hence any change of absorbability around Curie temperature (780°C) could not be obtained. When iron(50mass%)–alumina(50mass%) powder was subjected to measurement, drastic change of microwave absorbability was observed at Curie temperature. From the absorbability change around Curie temperature, it was estimated that contribution ratios of magnetic loss is 72% and of dielectric loss is 28% on microwave absorbability for iron(50mass%)–alumina(50mass%) mixed powder.

(cf. *ISIJ Int.*, **47** (2007), 588)

Effects of 28 GHz/2.45 GHz microwave irradiation on the crystallization of blast furnace slag

T.KUROKI et al.

The effects of microwave irradiation on the crystallization of 40%CaO–40%SiO_2–20%Al_2O_3 synthesized slag and actual blast furnace slag were investigated using a 28 GHz multimode microwave irradiation system, a commercial microwave oven (2.45 GHz), and an electric resistance furnace. While it was observed that the 2.45 GHz centimeter-wave had little effect on the samples, the 28 GHz millimeter-wave was found to accelerate crystallization significantly, especially at lower temperatures at which the crystalline phases are never generated by external heating.

Further, the effects of the precipitated phases and impurities on the crystallization with the 28 GHz microwave irradiation were investigated. The temperature of the glassy slag increased more rapidly as compared to that of the crystalline phases that exist in the practical blast furnace slag. In addition, a small amount of impurity was found to improve the heating property of the slags.

(cf. *ISIJ Int.*, **47** (2007), 592)

Fabrication of deep, narrow holes in steel using high-speed electrical discharge machine with conductive aqueous working fluid

S.KUMAGAI et al.

Conductive aqueous working fluid is increasingly being used instead of dielectric oils or deionized water for hole-fabrication in steel by means of electrical discharge machining (EDM). In the present study, the drilling speed, rate of wear on a tool electrode, and the precision of a hole-fabrication EDM system using aqueous working fluid (conductivity$<$ 1000 μS/cm) were examined. The working fluid was deionized water containing an additive which was composed of a surfactant (dispersant for other contents), a cleaner, an extreme pressure agent, an antirust agent, an antiseptic, and an antifoaming agent. For holes of diameter 0.40–1.20 mm and depth of 20 mm fabricated in S50C steel, the drilling speed and the wear on the tool electrode were improved by increasing the amount of additive. However, the precision of the fabricated hole decreased when the additive was used.

(cf. *ISIJ Int.*, **47** (2007), 596)

Gasification and reduction behavior of plastics and iron ore mixtures by microwave heating

K.NISHIOKA et al.

Effective utilization of waste materials is a key issue for environmental protection. In this work, fundamental research on co-generation of H_2 and metallic iron from plastics and iron ore powder mixtures by microwave heating was carried out. Thermal decomposition behaviors of plastics powders, the effects of plastics type and their blending composition on the H_2, CH_4, CO, CO_2 generation from the samples were studied.

As the results, about 57–88% of hydrogen contained in the samples were recovered in forms of H_2 and CH_4. Concentration of generated gas was able to control by changing the blending composition of plastics and iron ore powders mixtures. Under the condition of C/O=2, about 88% of hydrogen in the sample was recovered in forms of H_2 and CH_4, and hydrogen did not contribute to the reduction of iron ore, apparently.

(cf. *ISIJ Int.*, **47** (2007), 602)

Quantification of isothermal phase transformation in solid metals based on measurement of magnetic susceptibility

T.ONO et al.

A new method that provides quantitative information of phase transformation in solid metals by measuring a magnetic susceptibility has been proposed. The principle of the method is based on that the magnetic susceptibility is different from one phase to another and additive identity holds in the magnetic susceptibilities. This method directly reflects the phase transformation and provides more accurate information in comparison with conventional methods, which are based on indirect measurements of various physical properties or micro-structure observation. This method not only enables continuous measurement of phase transformation, but also can clearly indicate the start and end points of it.

In this study, this new method was applied to measure the α/γ isothermal transformation rate in an Fe–C alloy above the Curie temperature.

(cf. *ISIJ Int.*, **47** (2007), 608)

Effect of the melt flow on the solidified structure of middle carbon steel by means of the levitation method using alternating and static magnetic fields

H. YASUDA et al.

Effect of melt flow on the solidified structure of middle carbon steel was examined by a levitation method using alternating and static magnetic fields. In this study, solidification in the lower undercooling region (less than 70 K) was studied. As the static magnetic field increased, the melt flow in the levitated melt was continuously reduced. Portion of the equiaxed structure in the solidified structure also decreased with decreasing the melt flow velocity. The equiaxed structure was not observed when a static magnetic field exceeding 0.8 T was imposed during solidification. Average of the relative velocity, which was defined from motion between the inclusions for representing the melt flow velocity, was reduced to be approximately 0.01 m/s at a magnetic field of 0.8 T. The present results showed that fragmentation of the dendrite arms could be suppressed when the flow velocity in the melt was reduced to be in the order of 10^{-3} m/s.

(cf. *ISIJ Int.*, **47** (2007), 612)

Recent progress of EPM in steelmaking, casting, and solidification processing (Review)

H. YASUDA et al.

This paper reviews recent trends of electromagnetic processing in steelmaking, casting and solidification processing. Electromagnetic vibration for controlling the solidified structure and application of microwave in materials processing are also presented. Aim of this paper is to prospect the recent trends in electromagnetic processing of materials.

(cf. *ISIJ Int.*, **47** (2007), 619)