ISIJ International, Vol.33 (1993), No.5 掲載記事概要

High Temperature Processes

Kinetics of the Oxidation and Reduction of Synthetic Ilmenite

By K.SUNG et al.

タブレット状の合成イルメナイトの酸化および還元の反応速度を熱重量分析法によって測定し、その結果は不均一、非触媒反応の速度論に基づいて検討した。酸化発熱の影響を小さくするため、酸化反応の実験は90.2mol %のN_2ガスで希釈したO_2ガス、還元反応はH_2ガスを使用して行なった。その温度範囲は973～1,273 Kである。酸化と還元の反応はトポケミカル様式であることが明らかとなり、その速度パラメータは未反応核モデルに基づいて決定した。部分的に酸化または還元したイルメナイトの鉱物組成はX線回折により決定した。酸化したイルメナイトは二つの異なった相を持っていた。その一つは高濃度のチタニウムを、他の相は高濃度の鉄を含有していた。還元したイルメナイトはほぼ完全に分解した二つ相であった。その一つはほとんど金属から成っており、他の相は主に二酸化チタンであった。酸化したイルメナイトの高濃度チタニウム相には$Fe_2O_3 \cdot TiO_2$から$Fe_2O_3 \cdot 3TiO_2$までが存在していた。

Multiparticle Dissolution Kinetics of Carbon in Iron Carbon Sulphur Melts

By J.K.WRIGHT et al.

The derivation of a model of the dissolution of carbon particles following their injection into an iron bath is presented. The model is based on the dissolution of single particles in complete contact with the liquid iron and predicts the change in bath carbon concentration under continuous injection conditions. The model takes into account rate limitation by mass transport, chemical or mixed control.

The model predictions are shown to be consistent with the results of laboratory studies of the injection of high purity graphite into iron when mass transport limitations dominate. This is so for both pure iron/carbon alloys and those containing up to 1.0 % dissolved sulfur. If a carbon source such as petroleum coke is substituted for graphite the experimental results deviate from the model predictions. This experimental result suggests that factors other than mass transport can be significant in limiting the rate of dissolution of non-graphitic carbon into liquid iron.

The experimental and industrial implications of the model are discussed and future plans for extension of the model are presented.

Ironmaking・Reduction

Thermodynamic Simulation on the Behavior of Recycling Elements in the Iron Bath Smelting Reduction Process

By H.-J.LI et al.

A computer program system was developed to simulate the smelting reduction ironmaking process. This system, combining the database MALT with the phase equilibrium calculation software Chem Sage-derived from the widely well-known SOLGASMIX, can be expected to deal with problems encountered in metallurgical processes. As an example, the behaviors of some recycling elements, such as Na, K, Zn and S, in the smelting reduction process have been investigated from the thermodynamic point of view in case of the dust being recycled. The simulation results indicate that Zn is most influential on sulphur behavior among Zn, Na and K, and ZnS is the prevailing form of the deposited sulphur when there is zinc existing in the system. Zn can effectively prevent sulphur from entering the outlet gas. Alkaline components, especially potassium K, accumulate as carbonates in the system. At a high post combustion ratio of the gas generating from the smelting reduction furnace, or at a lower temperature of Cooler1, FeS deposition takes place and results in an appreciable amount of sulphur leaving the system in the outlet gas.

Sulphur Partition between $CaO-SiO_2-Ce_2O_3$ Slags and Carbon-saturated Iron

By H.-G.LEE et al.

A slag-metal equilibrium study was carried out to investigate the effect of rare earth oxides on the sulphur partition between $CaO-SiO_2$ slage and carbon-saturated iron at 1,500°C. The sulphur partition was increased with increase in Ce_2O_3 concentration in the slag. The oxygen potential of the system was found to be controlled by the Fe-FeO equilibrium. Sulphide capacities of $CaO-SiO_2-Ce_2O_3$ slags measured in the present study agreed well with the values predicted by the optical basicity method. It was tentatively concluded that Ce_2O_3 decreases the activity coefficient of SiO_2 in the $CaO-SiO_2-Ce_2O_3$ slag.

Steelmaking・Refining

Mathematical Modeling of Inclusion Transport and Removal in Continuous Casting Tundishes

By A.K.SINHA et al.

Three-dimensional mathematical models are currently being used successfully to model liquid steel flow and turbulence behavior in continuous casting tundishes. Traditionally, this information is used to calculate the residence time distribution (RTD) of liquid metal in the given tundish configuration. The RTD curve provides the effectiveness of a tundish to produce cleaner steel in an indirect and qualitative manner. Recently, some computational models have been developed to predict the inclusion trajectories and their rate of flotation in a semi-quantitative manner. In the present work, a model that addresses the inclusion transport and removal phenomena from the molten matal has been developed. The model examines three modes (flotation to the surface, coalescence of particles to form larger inclusions, and sticking to the solid surfaces) of inclusion density reduction from molten steel in the tundish were considered. The effect of various flow control devices, such as dams, weirs, and baffles with holes on each of these inclusion reduction modes were investigated and their inclusion removal efficiencies were compared. The role of different flow control devices in producing cleaner steel has been discussed.

Fe-Cr Melt Nitrogenation when Exposed to Nitrogen Plasma

By O.P.SINHA et al.

The nitrogen absorption/desorption for pure iron and Fe-C alloys have been investigated in detail in levitated melts. However, limited study seems to be made while molten Fe-Cr alloy is exposed to nitrogen plasma. Nitrogen plasma offers an attractive means to nitrogenise Fe-Cr alloys in view of rapid absorption to higher nitrogen content. Several workers have reported that sulphur in the melt renders higher nitrogen. Industrially melt with higher nitrogen with sulphur may not be attractive. The experimental condition

of present study solves this problem. Melts were made to observe the effect of arc current, plasma gas composition, surface active elements (SAE) in melt on melt nitrogen content. It was noted that the nitrogen was first absorbed upto certain maximum limit [N max] followed by its desorption on continued plasma exposure may be due to nitrogen bubble formation. The maximum nitrogen level in melts could be enhanced when rate of absorption in plasma arc zone was much higher with low desorption occurring in non-plasma arc zone of the melt. The use of higher melt temperature and low SAE in melt rendered higher absorption rate. The slower desorption rate could be obtained by maintaining lower SAE and temperature in melts. The nigrogen absorption in plasma arc zone followed first order reaction rate, however, desorption was probably depended on bubble formation frequency.

Iron Droplet Formation Due to Bubbles Passing through Molten Iron/Slag Interface

By S.KOBAYASHI

気泡が溶融鉄/スラグ界面を通過するとき粒鉄が生成する。本論文は粒鉄生成を説明しスラグ中での粒鉄の挙動を評価するモデルを述べる。

気泡が溶融鉄/スラグ界面を通過するとき気泡表面に鉄膜が形成すると考えられる。この膜は長くとも0.5秒内に一定厚さに達すると予測される。膜の厚さと面積を用いて可能な粒鉄質量の範囲を計算した。粒鉄質量の実験値は予測範囲内に入った。気泡と鉄膜の表面エネルギをエネルギ源としてスラグ中での粒鉄の運動を評価した。粒鉄のスラグ慣入距離とスラグ中滞留時間はそれぞれ、1～6 cmおよび1～0.1秒であった。この小さい値は粒鉄が鉄とスラグ相の間を界面を通して高速で循環する可能性が高いことを示唆する。

Casting and Solidification

A Solid-Liquid Diffusion Couple Study of a Peritectic Reaction in Iron-Carbon System

By K.MATSUURA et al.

δ鉄と液相で構成される拡散対を作成し、Fe-C系の等温包晶反応速度を測定した。また、液相とγ相およびδ相にわたる炭素濃度分布を測定した。

一方で、拡散律速機構に基づく包晶反応過程の数値計算を行った。

包晶反応速度と炭素濃度分布に関する測定と計算の結果を検討した結果、以下の結論を得た。

1) Fe-C系の包晶反応は、γ相中を通って液相からδ相へ流れる炭素の拡散に律速される。
2) 包晶反応速度は、温度の低下につれて増大する。
3) δ相の初期炭素濃度が低いとき、包晶反応の初期速度は遅い。しかし、時間経過とともに、反応速度は放物線則に近づく。

The Development of a Mathematical Model to Predict Composition Distribution in Casting Slab and Intermix Slab Length during Ladle Changeover Period and its Verification by Physical Model

By J.-L.YEH et al.

It is desirable to be capable of determining the composition distribution in casting slab and the intermix slab length during the ladle changeover period of the continuous casting operation. A3-D mathematical model has been developed based on the SOLA-SURF technique and the K-ε two equations turbulence model to simulate the fluid flow and mass transport phenomena in tundishes during this period, which in turn determines the composition distribution in the casting slab. The free surface which varies during the ladle change over period was treated by a kinematic equation of height function rather than assuming it to be constant and flat. The model was designed to be executable on an IBM compatible 386 or 486 personal computer. An irregular mesh system was also employed to handle the actual dimensions of the ladle nozzle, tundish, and submerged nozzle to the casting mold. The mathematical model was then verified with the measurement data obtained from a full scale water model . The comparison results are rather satisfactory. It is shown from this study that the quantity of the residual fluid in the tundish when ladle changeover occurs affects the composition distribution in the transitional slab and thus the intermix slab length.

Mathematical Modeling of Single Roll Continuous Steel Strip Caster Based on Fluid Flow and Heat Transfer Considerations

By R.K.MALLIK et al.

The single Roll Continuous Strip Casting Process has been quantitatively analysed using a mathematical model based on fluid flow and heat transfer considerations. The process is divided into four distinct zones : (1) liquid metal reservoir. (2) liquid metal pool, (3) solid strip zone, and (4) caster drum. Model equations are formulated using a control volume approach and setting up equations representing balances of mass, momentum and energy for these various zones. These equations, which are coupled by the thermophysical properties and various interfaces, are solved using an itertive finite difference technique. It has been possible to simulate the process and predict the effect of various process parameters on the process performance using the model. The parameters examined include : (1) liquid steel head in the tundish, (2) speed of rotation of the caster drum, (3) superheat of melt in the tundish, (4) gap between the caster drum and the tundish, (5) cooling conditions prevailing at the inner surface of the drum, (6) drum geometry, and (7) drum material. While the speed of rotation of the caster drum and the physical dimensions of the liquid metal pool affect the process strongly, the cooling conditions prevailing at the inner surface of the drum only marginally affect the process as far as the final strip thickness is concerned. These, however, along with the drum material affect the temperature distribution in the drum which may have a direct bearing on the microstructure of the product.

Microstructure

Static Recrystallization in Austenite and its Influence on Microstructural Changes in C-Mn Steel and Vanadium Microalloyed Steel at the Hot Strip Mill

By S.F.MEDINA et al.

By using torsional test, microstructural changes in commercially available C-Mn and vanadium microalloyed steel were studied and changes in austenite on rolling through roughing and finishing mills were estimated on the basis of preliminary static recrystallization determinations. A method for determining the temperature at which recrystallization starts to be inhibited in microalloyed steel involving experimetal measurements of the activation energy was developed. The influence of the activation energy on changes in austenite brought about by rolling at an ordinary hot strip mill was established by torsional simulation of various thermal cycles, both at a roughing and at a finishing mill. Austenite in C-Mn steel was found to be impossible to harden under these conditions not even on rolling at a finishing mill at temperatures close to Ar_3-as a result of its activation energy being constant at all temperatures. On the other hand, hardening of austenite in microalloyed steel was readily accomplished at a finishing mill at temperatures below the critical recrystallization temperature (915°C) as the activation energy increases sharply below such a temperature.