ISIJ International 掲載記事概要

ISIJ International, Vol. 32 (1992), No. 4 掲載記事概要

Production and technology of iron and steel in Japan during 1991 (Review) By *S.* Hosoki

Preparation and Beneficiation

Simulation of the blast furnace by a mathematical model By *Xuegong* Bi *et al.*

An one-dimensional static model for simulation of the blast furnace process has been developed. This simulation model is a part of the KTH Blast Furnace Process Model. The internal state of the furnace is described by the calculated distribution of fourteen process variables along the furnace axis which include temperature of the gas and condensed phases, composition, volumetric flow-rate, density and pressure of the gas phase, degree of iron ore reduction, limestone decomposition and coke solution loss.

The behaviour of these process variables in the blast furnace is described by a set of ordinary differential equations together with three algebraic equations. In order to solve these fundamental equations and facilitate the treatment of operational data from blast furnace plants, the following submodels have been built up : (1)submodel for data base creation, (2)mass balance submodel for the whole furnace, (3)heat balance submodel for the whole furnace and (4)submodel for determination of the reaction rates.

This simulation model has been used for the simulation of two Nordic blast furnaces. The calculated profiles of gas temperature and iron ore reduction degree show similar aspects to those measured by shaft sensors in working blast furnaces. The model is useful for obtaining a deeper understanding of the blast furnace process.

Prediction of the blast furnace process by a mathematical model By *Xuegong* Bi *et al.*

A prediction model has been developed based on the simulation model presented previously. These models are the two components of the KTH Blast Furnace Process Model. The concept of this prediction model is to use the same fundamental equations as in the simulation model and to use some output of a simulation of a blast furnace. Certain assumptions should be made for an individual in operational conditions in order to build up the mass balance and heat balance submodels for the determination of the boundary conditions in a prediction. The ore to fuel ratio and the CO utilization are adjustable parameters in the model. The furnace internal state as well as furnace productivity and fuel consumption in the last iteration are considered to be the predicted results.

The prediction model has been designed for the following five cases : (1) increased blast temperature, (2)oxygen enrichment of the blast, (3)coal injection, (4)coal injection combined with oxygen enrichment and (5)changed coke quality. Morever, This model can also been used for analysis of the thermal conditions in a blast furnace when an operational parameter, such as blast temperature, coke moisture and iron content in the ore, fluctuates.

The predicted operational indices were compared to the ones from industrial tests. The validity of the KTH model is indicated by this comparison.

Oxidation kinetics of cement-bonded natural ilmenite pellets By *Kang* Sun *et al.*

三種類の天然イルメナイトをつかって作成した非焼成ペレットの酸化反応の速度を熱重量法により検討した．純酸素でこれらのペレットを酸化すると，ペレット内部に顕著な温度上昇がみられた．この温度上昇を抑制するため N_2 で希釈した酸素 (9.8 mol% O_2-N_2) を使用し，1073 から 1273 K の温度範囲において酸化実験を行った．実験データを未反応核モデルで解析した結果，この酸化反応は主として酸素の粒子内拡散と化学反応によって律速されていることがわかった．また，速度パラメーターの温度依存性も得られた．

Reduction kinetics of cement-bonded natural ilmenite pellets with hydrogen By *Kang* Sun *et al.*

三種類の天然イルメナイトから作成した非焼成ペレットについて，1073 から 1273 K の温度範囲で熱重量法により，水素還元反応の速度を検討した．予備酸化されたイルメナイトの還元挙動については 973 から 1273 K の温度範囲で同様の手法により検討した．還元反応はトポケミカル様式で進行したが，ペレットを構成するグレイン粒子の挙動はもっと複雑である．予備還元されたペレットの還元速度は 2 界面未反応核モデルで解析し，予備酸化されたイルメナイトペレットの還元反応を構成する二つの主反応：$Fe^{3+} \rightarrow Fe^{2+}$ と $Fe^{2+} \rightarrow Fe^{0}$ の速度パラメーターの値を求めた．予備酸化しないペレットの還元実験のデータは 2 界面未反応核モデルに基づき導出された修正 1 界面未反応核モデルによって説明することができた．これらの還元反応における主要な律速過程はガスの粒子内拡散と化学反応であることがわかった．

Behavior of fines in the blast furnace By *M.* Ichida *et al.*

高炉三次元半裁模型を用いて，羽口からの粉コークス吹込み実験を行い，装入物の降下と通気に及ぼす粉吹込み量と粒径の影響を解析すると同時に高炉内の粉の堆積挙動を考察した．羽口からの粉の吹込み量の増加にともない，スリップ・ガス圧力が増大し，レースウェイ形状の変動が増加する．ただし，粉の粒径が装入物の粒径に対して十分小さい場合には，粉吹込みの影響は小さい．羽口から吹き込まれた粉は，炉芯表層部と炉壁近傍の降下速度の小さい領域に堆積しやすい．そして，炉芯表層部と炉壁近傍に粉の高濃度領域が形成されると，炉下部での装入物の降下領域が縮小し滞留時間が短くなる．中心流が抑制された V 型分布の場合には層頂部の中心部に粉が堆積しやすく，その堆積物は装入物とともに降下する．

Smelting and Refining

Modeling of laminar phenomena of chemical heat treating processes By *K. T.* Raic *et al.*

A general equation of the concentration distribution under laminar conditions was proposed. On the basis of this equation an integral method was derived. This method is based on setting a balance of flux gradients of the transfer phenomena that occur. It was shown that the flux gradient is identical to the characteristic quantity N which defines the state at the cross-section perpendicular to the surface, the definition of which enables the formulation of the proposed general equation.

The general appoximative integral method was applied to the phenomena on the metal surface, mass transfer during a heterogeneous chemical reaction in the laminar boundary layer over a flat plate-measuring foil. A model of the mass transfer coefficient was presented as a

function of the limiting heterogeneous chemical reaction rate constant, characteristic time relation and surface function of the appropriate gas atmosphere.

The proposed model is a theoretical basis for the development of a measuring device of non-equilibrium gas carburizing processes.

Meniscus shape of molten steel under alternative magnetic field By *H.* NAKADA *et al.*

交流磁場下における溶鋼のメニスカス形状を 2 次元スラブの場合について MHD 近似を用い，有限差分法により計算した．計算の際には磁力線の溶鋼内部の浸透も考慮されている．本報告では計算についての詳細な方法を示すとともに，計算値と理論値との比較により，計算方法が妥当であることが確認された．溶鋼保持高さは磁束密度の 2 乗に比例して増加する．また周波数が高くなることによっても増大するが 120 mm 厚のスラブの場合 2.3 kHz 程度で飽和することがわかった．ショートコイルを用いた場合には均一磁場下，あるいはロングコイルを用いた場合よりメニスカス形状をより矩形に近い形で保持可能なことが明らかとなり，電磁鋳造を行うという面から有利なことが判明した．さらにコイル中心位置もメニスカス形状に大きな影響をおよぼすことも明らかとなった．

Deoxidation of ESR slags By *F.* REYES-CARMONA *et al.*

The deoxidation system in the ESR process is a complex balance between atmosphere/slag/metal reactions involving the alloy composition, the electrode inclusion content and additions of metallic deoxidants during melting. We describe the relative contributions of slag/metal reactions and added deoxidants to the inclusion-forming system. It is concluded that the oxide compositions found in ESR ingots of low alloy steel can be explained using the slag FeO content as a monitor of the reaction scheme. Following this finding we also conclude that it is not possible in presently-developed ESR systems to produce oxide (or sulphide) inclusions with a Ca-content sufficiently high for shape control.

Dissolution of Fe_2O_3 and FeO pellets in bath smelting slags By *B.* OZTURK *et al.*

The rate of the dissolution of hematite and wustite pellets in bath smelting type slags was investigated at 1 723 K. The rates were measured by the change in their diameter and the rate of gas evolution from the pellet. The diameter of the pellets, as a function of time, was obtained from recorded X-ray radiograph pictures. For unstirred slags it was found that the dissolution of hematite pellets was faster than that of wustite pellets due to gas evolution from the hematite pellets which increases heat and mass transfer. The rate of the dissolution of wustite and hematite pellets were much faster in slags stirred with argon and, in this case, wustite dissolved faster. The rate of gas evolution during the dissolution of hematite with an inert gas over the slag was also measured by using a mass flowmeter. The rate of gas evolution was also determined under different CO-CO_2 gas mixtures by analyzing the off gas with a mass spectrometer. It was found that the amount of oxygen evolved increases with decreasing the CO_2/CO ratio. From the experimental results the heat transfer coefficient for the present conditions was estimated. These values were extrapolated to the actual operating conditions of a bath smelter and the melting time and the amount of undissolved pellets at the steady state in the slag were calculated. It was estimated that the pellets melt in less than 10 sec and the fraction of unmelted pellets, in the slag in a typical practice, is less than 1% of the volume of the slag. The rate of production in a bath smelter depends on the amounts of Fe^{2+} and Fe^{3+} resulting from the dissolution of the pellets. The present results indicate that for Fe_2O_3 pellets the rate of iron production will be about 25% less than for FeO.

Mechanical Behavior

The effect of hold time on low cycle fatigue of 2 ¼ Cr-1 Mo steel By *Sehwan* CHI *et al.*

2 ¼Cr-1Mo 鋼の焼ならし焼もどし材（NT 材）の低サイクル疲労挙動に及ぼす保持時間効果を明らかにする目的で，900，1 800，3 600 s の 3 段階の引張保持を含む低サイクル疲労試験を，真空中，723 K で実施した．保持時間が増すにつれて，繰返し破断寿命（N_f）が低下し，同時に，応力幅（$\Delta\sigma$）の低下と塑性歪み範囲（$\Delta\varepsilon_p$）の増加（軟化）が観察された．OM，SEM，TEM による破面，組織の観察結果と併せて解析した結果，引張保持による寿命低下は，クリープ効果ではなく，軟化にともなう繰返し疲労損傷の増加に起因するものと解釈された．

Surface and Environment

Analysis of Al in Zn hot dip galvanizing bath sample by X-ray fluorescence spectrometry By *Y.* MATSUMOTO

溶融亜鉛めっき鋼板の製造においては，製品の品質を維持するために，めっき浴中の Al 濃度を一定範囲に保持する必要がある．この目的のため，蛍光 X 線分析法による Al の正確な定量について研究した．結果は次のとおりであった．

（1）試料表面での Al の濃化のため，AlKα 線強度が試料調製後の時間経過とともに増加した．

（2）40 番 SiC の粗い研磨紙により試料調製を行い，試料調製後 3 min の短時間に X 線強度測定を開始することにより正確な分析が可能であった．