

High Temperature Processes

Electrical Conductivity of Molten Slags of $\text{CaF}_2/\text{Al}_2\text{O}_3$ and $\text{CaF}_2/\text{Al}_2\text{O}_3/\text{CaO}$ Systems for ESR

By W. CHIHO, et al.

The electrical conductivity of the molten slags of the $\text{CaF}_2 + \text{Al}_2\text{O}_3$ and $\text{CaF}_2 + \text{Al}_2\text{O}_3 + \text{CaO}$ systems for the practical ESR was determined, using the constant-current single pulse technique with three lead-electrodes. All the measurements were carried out under high-purity argon atmosphere, employing a high-purity molybdenum metal crucible with pure iron wire electrodes. The effects of FeO , MnO , MgO , Cr_2O_3 , TiO_2 , SiO_2 and other oxide components and temperature on the conductivity of the slags were examined. The results indicated that in the common concentration ranges for the ESR practice, the specific conductivity values of the slags in these two systems are monotonously increasing with the FeO and MnO contents in the slags following an essentially similar pattern; the additions of MgO , Cr_2O_3 and TiO_2 change also evidently the conductivity but in another roughly similar mode and make it have a maximum value, whilst the influence due to a small amount of SiO_2 (≤ 1.5 mass %) is relatively not large; the conduction of CaF_2 -based multicomponent and complicate liquid slags may be treated as a rate process.

Deoxidation Equilibrium of Silicon in Liquid Nickel-Copper and Nickel-Cobalt Alloys

By F. ISHII, et al.

脱酸平衡定数におよぼす種々の合金元素の影響を把握するために、 SiO_2 飽和においてNi-CuとNi-Co合金の珪素による脱酸平衡を $1450^\circ\text{C} \sim 1750^\circ\text{C}$ で研究した。

Ni-Cu合金系のNi側基準では、脱酸の濃度積 $\log K'_{\text{Si}}(\text{Ni}-\text{Cu})$ は銅を添加すると増大する実験式を得た。また、60% Cu以上の測定値から $1450^\circ\text{C} \sim 1550^\circ\text{C}$ の範囲で純銅の脱酸平衡値を予測し、Cu基準における脱酸の濃度積 $\log K'_{\text{Si}}(\text{Ni}-\text{Cu})$ がNiの存在で大きくなる結果を得た。

Ni-Co合金系では、Ni基準における脱酸の濃度積 $\log K'_{\text{Si}}(\text{Ni}-\text{Co})$ はCo濃度が高くなると僅かに大きくなる結果を得た。純Coの脱酸平衡定数を $1550^\circ\text{C} \sim 1650^\circ\text{C}$ の範囲で求め、Co側基準の $\log K'_{\text{Si}}(\text{Ni}-\text{Co})$ はNiの影響が小さいことを明らかにした。

さらに、これらの結果より導出される相互作用係数および γ_{Si} についても検討した。

Estimation of Viscosities of Liquid Alloys

By M. HIRAI

溶融合金の粘度におよぼす合金組成および温度の影響について、文献に見られる各種組成の金属の粘度値のデータを系統的に解析し、次のような結果が得られた。

溶融合金の粘度と温度の関係は、通常の液体と同様に $\eta = A \exp(B/RT)$ の関係がある。そのBの値は合金の液相線温度によって決まり、Aの値は合金の種類によって異なり、その金属の基礎的性質によって決まる。

溶融合金の粘度計算式として次式が得られた。

$$\eta = A \exp(B/RT) \quad [\text{mPa}\cdot\text{s}]$$

$$A = \frac{1.7 \times 10^{-4} \rho^{2/3} T_m^{1/2} M^{-1/6}}{\exp\left\{\frac{B}{RT_m}\right\}} \quad [\text{mPa}\cdot\text{s}]$$

$$B = 2.65 T_m^{1.27} \quad [\text{J}\cdot\text{mol}^{-1}]$$

R; 気体定数 $8.3144 [\text{J}\cdot\text{mol}^{-1}\text{K}^{-1}]$ 、 ρ ; 合金の密度 $[\text{Kg}\cdot\text{m}^{-3}]$ 、 T_m ; 液相線温度 $[\text{K}]$ 、 T ; 溶融金属の温度 $[\text{K}]$ 、 M ; 金属の質量 $[\text{Kg}\cdot\text{mol}^{-1}]$ 。

Ironmaking-Reduction

Production of High-carbon Ferromanganese Using a Shaft Type Furnace with Coke Packed Bed Injected with Oxygen and a Large Quantity of Pulverized Coal

By H. YAMAOKA, et al.

Experiments of high-carbon ferromanganese production were performed using an experimental melting furnace with coke packed bed injected with oxygen and pulverized coal and following results were obtained.

(1) In the experimental plant, high-carbon ferromanganese of $[\text{Mn}] = 75\%$ was produced stably with coal rate of $1500\text{--}1600 \text{ kg/t}$, coke rate (containing 56 % of non-coking coal) of 1100 kg/t and productivity of $3.11 \text{ t/(dm}^3)$.

(2) On the basis of the results obtained by this tests and Thyssen's blast furnace operation, the indices of a commercial plant of 170 t/d in production capacity was estimated. Although the fuel rate is higher than that of the blast furnace method but the total coal consumption is less than that of the blast furnace because a large quantity of pulverized coal is used in this process. Through these investigations, this process has been confirmed to be useful one as a ferromanganese production process instead of electric furnace method and blast furnace method.

Scrapmelting Using a Shaft Type Furnace with Coke Packed Bed Injected with Oxygend and a Large Quantity of Pulverized Coal

By H. YAMAOKA, *et al.*

スクラップの大量溶解技術としては電気炉法と転炉法等があるが、これらはそれぞれ、電力料金の高い我国では電力コストが高い、熱効率と耐火物寿命の面で改善すべき点が多い、等の問題がある。これらの問題に対処可能な方法を検討するため、微粉炭多量吹込みを併用する高濃度酸素吹き堅型試験炉を使用してスクラップ溶解試験を実施し、下記の結果を得た。

1) 高炉用コークス及びスクラップ100%を使用して、高炉並に加炭、脱硫された溶鉄の製造が可能である。

2) 燃料比=240~290kg/t、出鉄比=14.7t/d/m³の成績が得られた。

3) シャフト部から炉内へ空気を吹き込んで二次燃焼させることにより、燃料比を低下させ、生産性を向上させ得る。

次に、実験結果をもとにして電気炉、及び転炉によるスクラップ溶解法とのエネルギー消費量の比較を行い、いずれの方法よりもエネルギー消費を節減しうる可能性を確認した。

Size Degradation of Dead-man Coke by Reaction with Molten FeO in Blast Furnace

By K. SUNAHARA, *et al.*

高炉炉下部には炉芯と呼ばれる比較的長期停滞するコークス充填層が形成される。この炉芯コークスは、炉下部の通気性、通液性などの面から高炉操業にとって非常に重要であるにも関わらずその挙動については未解明である。本報では、溶融FeOとの反応による炉芯コークスの細粒化に着目した基礎検討を行った。コークスと溶融FeOとの反応実験から求めた2つの速度パラメータを用いて作成した一次元反応モデルによって実高炉を想定したシミュレーションを行った。その結果、炉芯コークスは反応により上部から細粒化していき、約1mほどの深さで消滅し、この領域で更新が繰り返される。この現象は約2週間ではほぼ一定に落ちつくが、炉芯温度、鉬石溶け落ち時の還元率、出鉄量に依存することが明らかとなった。

Steelmaking・Refining

Mechanism of Spinel Ferrite Powder Generation in Electric Arc Furnace Steelmaking

By C.-L. LI, *et al.*

By examining the oxidation reactions in the steel making process and investigating the behavior of spinel ferrite powder in EAF dust, an insight into the mechanism of

spinel ferrite powder generation was gained. The results are summarized as follows: (1) the chemical formula of spinel ferrite particles in EAF dust is $(\text{Mn}_x\text{ZnX}_y\text{Fe}_{1-x-y})\text{Fe}_2\text{O}_4$; (2) when oxygen is transferred at the slag-metal interface, a series of oxide layers form on the molten steel (going from the surface to the interior of the liquid, one progresses through $(\text{Mn}, \text{Zn})\text{Fe}_2\text{O}_4$, $(\text{Mn}, \text{Zn})\text{Fe}_2\text{O}_4\text{-Fe}_3\text{O}_4$, $\text{Fe}_3\text{O}_4\text{-(Mn, Fe)O}$ and $(\text{Mn, Fe)O}$, respectively); (3) some of the coarse spinel ferrite powders are often hollow contain surface blowholes suggesting that CO gas atomizes liquid iron oxides; and (4) CO gas evolution atomizes various liquid oxides. These droplets may oxidize to varying degrees as they solidify and cool producing various compositions of $(\text{Mn}, \text{Zn})\text{Fe}_2\text{O}_4$ and/or $(\text{Mn}, \text{Zn})\text{Fe}_2\text{O}_4\text{-Fe}_3\text{O}_4$ powders.

Formation of Clogging Materials in an Immersed Nozzle during Continuous Casting of Titanium Stabilized Stainless Steel

By Y. GAO, *et al.*

Ti含有ステンレス鋼の連続 casting 用浸漬ノズルの閉塞物の生成機構について現場実験とるつば実験を行い、以下の知見を得た。

1) 铸造後の浸漬ノズルの内表面に付着した閉塞物は、EPMAおよび臭素メタノール抽出法で同定した結果、 TiO_2 と Al_2O_3 が主成分であり、一方、タンディッシュ内溶鋼中の非金属介在物は、 TiN と Al_2O_3 であることを明らかにした。

2) 雰囲気制御可能なケラマックス炉でるつば実験より、 Ar-N_2 雰囲気下では溶鋼中に TiN が析出し、その後、酸化雰囲気中に切り換えた場合、ノズル閉塞物と同一形態、組成の TiO_2 が生成することを確認した。

3) 上記より、ノズル閉塞物の TiO_2 は、溶鋼の温度降下により、最初に TiN が析出し、その後 TiN が酸化して TiO_2 に変化したものであることを明らかにした。

Casting & Solidification

Observations of Vortexing in the Mould of a Continuous Slab Caster (Communication)

By Q. HE

Mechanism of vortex formation in the continuous casting mould was investigated using a full scale water model. Vortices normally occur close to the SEN, while for wide mould casting with as shallow SEN immersion depth, they take place near the narrow faces. It was found that vortexing around the SEN was due to interaction between the two surface streams flowing inwards, and those near the narrow faces result from interaction between the surface stream and the narrow faces, which generates rotational

flows. Biased flow as such does not generate vortexing in the mould, but increases its intensity and frequency. Vortex intensity increases with increasing casting speed for a given mould width. Vortexing in the mould can be reduced by diminishing biased flow and optimising the SEN design.

Surface Science & Technology

Y_2O_3 Dispersion Effect on Al_2O_3 Protective Coating Examined on the Basis of Five Models

By Y. IKEDA

酸化物分散型合金が優れた耐酸化性を有することは良く知られているが、その理由は十分解明されていない。そこで Al_2O_3 スケールのシミュレーションとして、かつコーティング技術の基礎として Al_2O_3 コーティング膜の保護性に対する Y_2O_3 分散の効果を調べた。実験は次の五つのモデルに基づいて行った。モデルI：Sは合金表面に偏析して Al_2O_3 膜の剥離を助長するが、分散 Y_2O_3 はSを合金内部にトラップすることにより剥離を抑える。モデルII： Al_2O_3 /合金界面にYを含むバリエー層を生じ合金元素が Al_2O_3 中へ拡散するのを抑える。モデルIII：このYを含む層は Al_2O_3 と合金との接着剤としても働く。モデルIV： Al_2O_3 中へ取り込まれた Y_2O_3 は合金元素の拡散を抑制する。モデルV： Al_2O_3 中へ取り込まれた Y_2O_3 は Al_2O_3 の塑性変形能を増大し剥離を抑制する。実験の結果、Sのトラップ(モデルI)が最も重要で、拡散抑制効果も顕著であるが(モデルII、IV)、接着剤効果(モデルIII)と塑性変形能効果(モデルV)はわずかであった。

Dross Phases Formed in Galvanizing Baths Containing (0-0.1) wt% Nickel at 450°C

Z. W. CHEN, *et al.*

The structure and composition of the intermetallic dross phases formed in zinc baths containing (0-0.1) wt% nickel at 450°C have been investigated by X-ray diffraction and energy dispersive spectroscopy. Two intermetallic phases were identified and the presence of each of these phases depends on the nickel content of the bath. ξ (isomorphous with $FeZn_{13}$) phase, which probably contains less than 0.5 wt% nickel, was the intermetallic phase present in baths with bath nickel contents of less than 0.06 wt%. In baths containing (0.06-0.09) wt% nickel both ξ and Γ_2 (isomorphous with $FeZn_4$) phases were present. When the bath nickel content was above 0.06 wt%, the nickel content of the ξ phase was found to increase significantly whilst the nickel content of the Γ_2 phase only increased slightly with increasing bath nickel content. When the bath nickel content was above 0.09 wt%, the intermetallic phase was found to be mainly Γ_2 . Based on the experimental data, a

more precise version has been proposed for the zinc-rich corner of the Zn-Fe-Ni phase diagram at 450°C.

Microstructure

Texture and Microstructure of Ti-49at%Al after Dynamic Recrystallization and Annealing

By C. HARTIG, *et al.*

A Ti-49at%Al gamma-base titanium alloy was deformed at high temperature ($T=1\ 150-1\ 200^\circ\text{C}$) and low strain rates as well as at lower temperature ($T=1000^\circ\text{C}$) and higher strain rates. Textures with distinctly different strength occurred depending on the deformation conditions. Subsequent heat treatments were applied in order to investigate the development of textures and microstructures. Textures and microstructures after deformation at $1150^\circ\text{C} < T < 1200^\circ\text{C}$ are stabilized by α_2 -Ti₃Al-precipitates at the γ -TiAl grain boundaries which occur after the first annealing at $1\ 050^\circ\text{C}$.

Physical & Mechanical Properties

Change of Residual Stresses in Austempered Spheroidal Graphite Cast Irons due to Repeated Stress

By H. SUNADA

オーステンパー処理された球状黒鉛鋳鉄の疲労挙動におよぼす残留応力と残留オーステナイトの影響について調べた。オーステンパー処理を施すと残留応力を生ずる。繰返し応力による残留応力の緩和の程度は負荷応力比(Γ_a/Γ_B)によって変化する。高負荷比側では、その程度は最初の負荷応力の大きさに依存する。低負荷比では繰返し応力と繰返し数の重畳効果によって変化する。一方、残留オーステナイト量は負荷比に関係なく繰返し数の増加とともに減少していく。これらの結果から使用中の残留応力の大きさや残留オーステナイト量の変化測定から疲労損傷の予知が可能である。

New Materials & New Processes

A General Statement of the Problem and Description of a Proposed Method of Calculation for Some Meniscus Problems in Materials Processing

By L. M. RACZ, *et al.*

The equilibrium shape of a liquid meniscus at a liquid-gas phase boundary of a system in which solid, liquid, and gaseous phases coexist is given by a balance of forces acting on the system. It is often greatly desirable in many materials processing applications to know and be able to predict this meniscus shape, because controlling it often affects the structure or properties of the resulting material. A method of calculation is introduced along with the Surface Evolver computer program, and solutions for

simple geometries obtained using this program are compared with existing analytical and simple numerical solutions.

Determination of Equilibrium Shapes and Optimal Volume of Solder Droplets in the Assembly of Surface Mounted Integrated Circuits

By *L.M.RACZ, et al.*

The equilibrium shape of a liquid meniscus at a liquid-gas phase boundary of a system in which solid, liquid and gaseous phases coexist is given by a balance of forces acting on the system. A method of calculation was

introduced in Part I of this series for determining this equilibrium shape. Here, this method is used to calculate the equilibrium shapes of solder joints surrounding gullwing and j-bend type lead wires present in surface mounted integrated circuits. A study is also done to determine the optimal volume needed to produce a good solder joint. Criteria are established, dimensionless calculations are done for gullwing and j-bend leads, and a method is outlined for applying these results to lead wires with different geometries.

Call for Papers of ISIJ International Special Issues

① Surface Modification of Materials

A special issue on surface modification of materials is planned for publication in September or October 1993. Recent progress in CVD, PVD, thermal spraying and related techniques used to deposit monolayer, multilayer and multi functional thin/thick films and coatings on metal or ceramic substrate has been reported for a number of applications including wear, erosion, corrosion and thermal protections.

The Editorial Board is calling for original and review papers relating to all aspects of surface modification of metals and ceramics. The issue covers the following subjects:

- 1) CVD or PVD
- 2) Surface treatment by laser or plasma
- 3) Surface treatment by molten salt
- 4) Spraying
- 5) Ion implantation or ion beam enhanced dynamic mixing
- 6) Hotdipped coating, electroplating or electroless plating

Authors wishing to submit a paper for publication in the special issue are asked to send the manuscript before **March 31, 1993**

② Physical Metallurgy of Ultralow Carbon Interstitial Free Steels

A special issue on physical metallurgy of ultralow carbon interstitial free steels is planned for publication in January 1994. The production and the range of use of the so-called interstitial free (IF) steels are remarkably increasing with the advancement of steel making and subsequent continuous manufacturing processes. This special issue is planned for the purpose of understanding the present state of research and technology of IF steels with emphasis on the microstructure and its relationship to mechanical properties.

The Editorial Board is calling for original and review (invited) papers dealing with the following subjects related to the heat treatment, mechanical working, thermomechanical processing *etc.* of IF steels:

- 1) Recrystallization, precipitation, phase transformation and microstructure formation.
- 2) Deformation, grain boundary characterization and mechanical properties.
- 3) Thermodynamics and thermodynamic properties.

Authors wishing to submit a paper for publication in the special issue are asked to send the manuscript before **April 20, 1993**.

この件に関する問合せ先：社団法人 日本鉄鋼協会 編集・業務室 欧文会誌係