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**EFFECT OF MOULD FLUX ON SCALE ADHESION  
TO  
REHEATED STAINLESS STEEL SLABS**

By

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REHEATED STAINLESS STEEL SLABS

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## ABSTRACT

Effects of mould flux contaminant on scale-steel adhesion and hydraulic descaling of scale formed on slabs were investigated. In this investigation, stainless steel type 304 (austenitic with 18% Cr and 8% Ni) and specific mould fluxes were used when growing the scale on contaminated samples under simulated industrial reheating conditions, with subsequent high pressure water hydraulic descaling.

The basic hypothesis was that the steel-scale adhesion depends on the microstructure of different phases present in the scale, the segregation of specific elements at the interface and the interfacial morphology of the scale after reheating.

It was found that mould flux contaminant decreases scale-steel adhesion and therefore improved the descaling effectiveness significantly compared to non contaminated stainless steel.

The descaling effectiveness of contaminated and uncontaminated slab was dependent to the presence of metal free paths (chromite layers along the austenite grains boundaries) and the presence of unoxidized metal in the scale due to nickel enrichment at the interface.

Compared to the uncontaminated samples, the descaling of contaminated samples was efficient which could be due to the fact that some mechanisms which increase scale-steel adhesion (notably nickel enrichment at the interface) were considerably reduced.

For all contaminated samples, the descaling effectiveness after visual observation were close to 100% and it was found that mould flux type 832 ( low basicity) gave a high descaling efficiency with better steel surface quality after descaling compared to mould fluxes type 810 and RF1.

**Key words:** Stainless steel, mould flux, reheating, hydraulic descaling, internal oxidation, chromite, scale, tendrils of nickel-rich filigree, austenite grain boundaries, interfacial morphology, free oxygen

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## NOMENCLATURE

### Symbol

|              |  |
|--------------|--|
| $\Delta G^o$ | Gibbs free energy change under standard conditions (J/mol)                     |
| M            | Metal  |
| MO           | The lowest oxide of the metal M  |
| $P_{O_2}$    | Oxygen partial pressure (Atmosphere – atm)                                     |
| SEN          | Submerged Entry Nozzle   |
| $X_{Fe}$     | Molar fraction of Iron   |
| $X_{Cr}$     | Molar fraction of Chromium   |
| $X_{Ni}$     | Molar fraction of Nickel   |
| $X_{CaO}$    | Molar fraction of calcium oxide  |
| $X_{SiO_2}$  | Molar fraction of silicon dioxide  |
| I            | Maximum jet impact pressure (N/mm <sup>2</sup> )                               |
| SP           | System pressure (Pascal - Pa)  |
| T            | Temperature (Kelvin - K)   |
| $K_p$        | Parabolic rate constant (kg <sup>2</sup> /m <sup>4</sup> s)                    |
| R            | Gas constant   |
| Q            | Water flow rate (litres/min)   |
| t            | Time (hour - h)  |
| v            | Speed of steel under jet (m/s)   |
| $m_i$        | Slab steel mass before reheating(Kg)   |
| $m_a$        | Slab steel mass after reheating(Kg)  |
| $m_F$        | Mass of mould flux powder (Kg)   |
| $f_l$        | Average thickness of the liquid flux film in the mould (m)                     |
| $S_s$        | Slab steel surface (m <sup>2</sup> )   |
| e            | Slab steel thickness (m)   |
| $\Delta m$   | Mass variation of the slab after reheating (Kg)                                |
| Gm           | Gain of sample weight after reheating (Kg/m <sup>2</sup> )                     |
| $C_f$        | Surface concentration of mould flux on the sample surface (g/cm <sup>2</sup> ) |
| $B_s$        | Slag basicity in steelmaking   |



|              |  |
|--------------|--|
| $B_F$        | Basicity of mould powder   |
| $P_r$        | Dry air regulator pressure (Pa)                                      |
| $P1s$        | Pressure at the first digital transmitter (%)                        |
| $P1$         | Pressure at the first digital transmitter (Pa)                       |
| $P2s$        | Pressure at the second digital transmitter (%)                       |
| $P2$         | Pressure at the second digital transmitter (Pa)                      |
| $\Delta P_s$ | Difference in pressure between two digital transmitters (%)          |
| $\Delta P$   | Difference in pressure between two digital transmitters (Pa)         |
| $Q_t$        | Water flow rate measured at the first transmitter (l/min)            |
| $Q_b$        | Water flow rate measured at the second transmitter (l/min)           |
| $Q_{av}$     | Average water flow rate (l/min)                                      |
| $P_s$        | Powder consumption per unit area of mould ( $\text{kg}/\text{m}^2$ ) |
| $P_t$        | Powder consumption per steel mass (kg/Tonne of steel)                |
| $f$          | Fraction of the powder producing slag.                               |
| $R_m$        | Ratio of surface area to volume of the cast profile                  |
| $e_m$        | Width of the mould (m)   |
| $l_m$        | Thickness of the mould (m)   |
| $A$          | Jet length (m)   |
| $B$          | Jet width (m)  |
| $D$          | Overlap (m)  |
| $E$          | Nozzle distance (m)  |
| $H$          | Distance from mid-spray beam to lower edge of strip (m)              |
| $S$          | Strip thickness (m)  |
| $d$          | Outer diameter of pipe (m)   |
| $C$          | Jet width in jet direction (m)                                       |
| $h_1$        | Vertical height of nozzle (m)  |
| $h_2$        | Vertical spray height (m)  |

|            |  |
|------------|--|
| U          | Specific water impingement (litre/m <sup>2</sup> ) |
| l          | Scale thickness(mm)                                |
| $\Delta p$ | Descaling header pressure (Pa)                     |

### Greek symbols

|               |  |
|---------------|--|
| $\rho_{flux}$ | Density of the melted liquid flux (Kg/m <sup>3</sup> ) |
| $\beta$       | Angle of inclination of the descaling Nozzle (° )      |
| $\alpha$      | Nozzle spray angle (° )                                |
| $\gamma$      | Offset angle of nozzle against pipe roll axis (° )     |
| $\delta$      | Thermal diffusivity of the scale (m <sup>2</sup> /s)   |

### Abbreviations

|          |   |
|----------|---|
| AES      | Auger Electron Spectroscopy                             |
| EDS, EDX | Energy-Dispersive X-ray Spectroscopy                    |
| ICP-AES  | Inductively Coupled Plasma-Atomic Emission Spectroscopy |
| SEM      | Scanning Electron Microscope                            |
| SEM -BSE | Scanning Electron Microscope Back-Scattered Electron    |
| SEM-SEI  | Scanning Electron Microscope Secondary Electron Image   |
| SMF      | Synthetic Mould Flux                                    |
| XRD      | X-Ray Powder Diffraction                                |
| XRF      | X-Ray Fluorescence Spectroscopy                         |
| XPS      | X-Ray Photoelectron Spectroscopy                        |
| FWHM     | Full Width Half Maximum                                 |