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

By

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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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DEO GLORIA

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NOMENCLATURE

Symbol

ΔG^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_{SiO2}	Molar fraction of silicon dioxide
I	Maximum jet impact pressure (N/mm^2)
SP	System pressure (Pascal - Pa)
T	Temperature (Kelvin - K)
K_p	Parabolic rate constant (kg^2/m^4s)
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^2)
e	Slab steel thickness (m)
Δm	Mass variation of the slab after reheating (Kg)
Gm	Gain of sample weight after reheating (Kg/m^2)
C_f	Surface concentration of mould flux on the sample surface (g/cm^2)
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)
ΔPs	Difference in pressure between two digital transmitters (%)
ΔP	Difference in pressure between two digital transmitters (Pa)
Qt	Water flow rate measured at the first transmitter (l/min)
Qb	Water flow rate measured at the second transmitter (l/min)
Qav	Average water flow rate (l/min)
P_s	Powder consumption per unit area of mould (kg/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^2)
l	Scale thickness(mm)
Δp	Descaling header pressure (Pa)

Greek symbols

ρ_{flux}	Density of the melted liquid flux (Kg/m^3)
β	Angle of inclination of the descaling Nozzle (º)
α	Nozzle spray angle (º)
γ	Offset angle of nozzle against pipe roll axis (º)
δ	Thermal diffusivity of the scale (m^2/s)

Abbreviations

AES	**A**uger **E**lectron **S**pectroscopy
EDS, EDX	**E**nergy-**D**ispersive **X**-ray **S**pectroscopy
ICP-AES	**I**nductively **C**oupled **P**lasma-**A**tomic **E**mission **S**pectroscope
SEM	**S**canning **E**lectron **M**icroscope
SEM -BSE	**S**canning **E**lectron **M**icroscope **B**ack-**S**cattered **E**lectron
SEM-SEI	**S**canning **E**lectron **M**icroscope **S**econdary **E**lectron **I**mage
SMF	**S**ynthetic **M**ould **F**lux
XRD	**X**-Ray **P**owder **D**iffraction
XRF	**X**-Ray **F**luorescence **S**pectroscopy
XPS	**X**-Ray **P**hotoelectron **S**pectroscopy
FWHM	**F**ull **W**idth **H**alf **M**aximum