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THE ELECTROCHEMICAL NATURE OF REACTIONS TAKING PLACE AT SOLIDIFYING CR-NI STEEL AND GREEN SAND MOULD INTERFACE

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The reactions taking place in mould cavity is one of the most elaborated topics of foundry. In the present paper physicochemical reactions occurring between solidifying stainless steel and green sand mould have been experimentally studied. The experimental work essentially consists of collecting burnt sand from the surface of the casting and analysing it. From the products and composition of the burnt sand, the electrochemical nature of the chemical reactions taking place at the steel mould interface during solidification is being theoretically elaborated.

The stainless steel having the composition: carbon, 0.28–0.4%; silicon, 0.15 max; manganese, 1% (max), chronium 12–14%; nickel, 8% (max), was taken in a ladle of 40 kg capacity lined with dolomite, pre-heated with the ordinary natural gas flame for about 75 min and was cast in the moulds of following composition:

Table 1.

Ingredient		Composition %	Characteristics
SiO_2	) 75	20	Moisture 2.9
Sand	) 48	25	
	) 70	20	Permeability 408*
		20	
Fireclay		20	Green compressive strength 0.35 Kg/cm^2
Bentonite		8	Mould hardness 80-90 Dietert No.
Water		3	(Grade of ramming)
Dextrine		2	

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DISCUSSION

The results of the experiments conducted to study the phenomenon of interaction between green sand mould and carbon steel, cast at 1530°, have indicated that, the burnt moulding sand adjabcent to the casting contains about 2% oxides of iron which are the product of oxidation of liquid iron by oxygen dissociating from water vapour. Resently the electrochemical nature of some of the oxidation and silicate reactions taking place at steel mould interface during the casting of plain-carbon steel cast in green sand mould, has been explained by some of the investigators. The author, on the basis of this knowledge have and endevoured to explain the phenomenon of oxidation reduction and electrochemical nature of silicate reactions.

$$H_2O \rightarrow H_2 + \tfrac{1}{2}O_2 \quad 2H^+ + O^{2-} \tag{1}$$

$$\tfrac{1}{2}O(g) + Fe(1) = Fe^{2+} + O^{2-} \tag{2}$$

$$\tfrac{1}{2}O_2(g) = 2Fe^{2+} + 3O^{2-} = 2(FeO_2)^- \tag{3}$$

$$2(FeO_2)^{\mp} \; Fe(1) = 3Fe^{2+} + 4O^{2-} \tag{4}$$

$$SiO_2 + O^{2-} = (SiO_3)^{2-} \tag{5}$$

$$\tfrac{1}{2}O_2 + (SiO_3)^{2-} = (SiO_4)^{4-} \tag{6}$$

$$(SiO_4)^{4-} + 2Fe^{2+} = SiO_2 + 2\,(Fe) + 2(O) \tag{7}$$

$$SiO_2 + 2(Fe) + 2(O) = 2FeO.\ SiO_2 \tag{8}$$

The dissociation of water vapour as indicated by reaction (1) releases oxygen which enters into the oxidation reactions (2 and 3). The transient radical $(FeO_2)^-$ formed is reduced by the liquid iron (reaction 4).

The ionized oxygen reacts with the stable silica thus changing it from the stable to transient state ($SiO_2 \rightarrow (SiO_3)^{-2} \rightarrow (SiO_4)^{4-}$ (reactions 5 – 6). The transient radical $(SiO_4)^{4-}$ is reacted by ionized iron thus forming fayalite ($2FeO.\ SiO_2$) (reaction 7 and 8).

Nickel melts at 1435° and above this temperature it is oxidized by oxygen and the electro-chemically these reactions can be explained as follows:

$$Ni \rightarrow Ni^{2+} + 2/e^{-};$$

$$\tfrac{1}{2}O_2 + 2/e^{-} \rightarrow O^{2}$$

$$Ni + \tfrac{1}{2}O_2 \rightarrow Ni^{2+} + O^{2-} \quad (9)$$

$$Ni^{2+} + O^{2-} \rightarrow NiO \quad (10)$$

NiO formed does not react with FeO or SiO_2 and is found in fayalite in the free state.

Chromium reacts with water vapour at 1835°c and this reaction is not expected to exist because maximum casting temperature of Cr-Ni-steel is 1530°c.

CONCLUSIONS

1. A detailed study of the physico-chemical aspects and thermodynamical analysis of the reactions occupying in the mould has suggested certain measures which may be taken to reduce the effect of chemical reactions on the quality of casting. The interaction between metal and mould may produce certain defects (e.g. sand burn-on, blow holes etc.), but by varying the mould atmosphere the speed and nature of the reactions can be changed and so these defects can be prevented. The fayalite reaction which creates sand burn-on, can occur only in the presence of oxidizing atmosphere, so that in order to prevent this defect, it is necessary to create reducing or neutural atmosphere in the mould, which can be created by the carbon containing additives in the mould.
2. The dissociation of hydrocarbon gases at 650-1200°c, produced by the carboneceous materials in the mould results in the formation of "lustrous carbon" which deposits on the surface of the mould and thus helps in obtaining the castings with a clean surfaces.
3. For a better surface quality of casting, the composition of the mould washes should be such that the adhesion between metal and mould is as little as possible.
4. Some sources have recommended the utilization organic binding materials with long molecular chain which form products of high stability and greater covering capacity for mould [1].
5. In the Czechoslovakian fourndries, the mould washes based on cyclohexane (Marshalite, 30-40%, propane asphalt, 2%, boric acid 0-2%, Al cyclohexane, 53-65%) have used sucessfully to prevent sand burn-on [3].
6. In the foundries of West Germany, the mould washes based on benzene (Zircon =22%, corrundum = 22% stearate of aluminium, 14%, and benzene 41.8%) are commonly used. [2].
7. In series of researches, it has been concluded that if some fusible material is added to the mould wash, it melts and increases the binding capacity of refractory particles. In this formulation the following crystalline powders are recommended:
$Al\,NH_4\,(SO_4)_2 \cdot 12H_2O$; NH_2PO_4; $12H_2O$; $Al(NO_3)_3 \cdot 9H_2O$, a mixture of 55% KNO_3 & 45% $NaN_{O}2$. As the binding capacity of refractory particles of mould wash increases, its capacity of covering the mould surface also increases, resulting in minimising the the chances of contact of liquid steel with mould, and thus reducing the possibility of appearance of surface defects [1].

Table 2.

Sample No.	Analyst	SiO_2 %	Al_2O_3 %	MgO %	FeO %	Fe_2O_3	Cr_2O_3 %	NiO %	CaO %	Balance %	Total
	Sand burn-on of Cr-Ni steel:										
1.	S.S.P. Karachi	83.5	4.95	1.05	1.92	0.13	0.19	0.080	4.95	2.5	100
2.	S.S.P. Karachi	84.5	4.49	1.10	Nil	Nil	0.015	0.030	4.49	5	100
	Sand burno-on of carbon steel					Total				MnO	
3.	I. I. Medvedeev [4]	82-83.5		2.07 to 2.64	0.54 to 0.73	(FeO+Fe_2O_3) 0.97–1.92 –	1.26 to 1.50	7.70 to 9.47			

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