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On the motion prediction of DRI particles from chute into Slag in Electric Arc Furnace: Theory and Experiment

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Introduction

Predicting the motion of DRI particles in slag is a key problem to design effectively the MHS system and chute with respect to optimizing the DRI smelting in Electric Arc furnace. This paper deals with both theory as well as real upgrade in DRI based Electric Arc furnace. The motion of DRI in slag is the result of gravity, drag forces, added mass and eventually history forces. In current work, the differential equation of DRI motion has been solved based on Lagrangian approach. It has been shown that the slag density and initial velocity are critical items in emergence of DRI into Slag to reach into the slag-molten metal boundary. The initial velocity to be more than a specific value will guarantee the best cause and this will provide the design basics of MHS and DRI chute to guarantee penetration in different slag density. Finally, the mentioned study has been applied to a real DRI-based Electric Arc furnace chute system to increase the speed of DRI particles. This furnace has been suffered of so many problems in melting such as electrodes upright movements. After this upgrade, the performance of this furnace has been improved significantly.

KEYWORDS: DRI charging – Electric Arc Furnace (EAF) – Slag Density – Falling Speed – Melting Time

FORMULATION AND NUMERICAL METHOD

The motion equation of small particles in a viscous quiescent fluid is a work of BBO (Basset, Bossiness and Oseen) as per below solving of the "Navier Stokes" equation and the Newton's second law :

$$m_p \frac{dU}{dt} = -6a\pi\mu_f U\varphi - \frac{1}{2} m_f \frac{dU}{dt} + (m_p - m_f)g - 6a^2\sqrt{\pi\mu_f\rho_f}\int_0^t \frac{dU/_{dt}}{\sqrt{t-\tau}}d\tau \quad \text{(Eq. 1)}$$

Where,

ρ_f : is the density of the fluid,

μ_f : is the viscosity of the fluid,

U : is the particle velocity,

α : is the particle radius,

m_P : is the particle mass and

m_f : is the mass of the fluid displaced by the particle.

The left hand side of the above equation is the acceleration term of the particle and the right hand side included all the forces exerted on the particle as, steady drag (F_D), virtual mass Force (F_A), Gravity Force (F_G) and Basset or History Force (F_H).

Simulation Results

The main concept is that we want to know if we throw DRI into bath, where it is melting. It is optimum for us that melting being done in the border of steel and slag and definitely to being melted inside slag. In the case of melting inside slag, below phenomenon are happening:

Slag conductivity increases: It leads to pass some portion of current of phases goes through slag which is heating up slag and leads to increase energy consumption and refractory corrosion.

As in the major portion of DRI melting, especially with low quality DRI, Slag coming out of furnace, lots of Iron will lose in slag and yield drops down.

The density of slag increases. It will be shown how much density is effecting into the amount of DRI melting inside slag or melting inside steel. Therefore increasing density will drastically increases melting portion of DRI inside slag and consequently items a and b phenomenon increases progressively.

The melting time of one pellet with the size of 15mm which is being studied in this research is 25 seconds for DRI with metallization of 92%[4]., while in the case of touching steel by DRI it will melt in less than second. Therefore what is important for us is to calculate how long does it take for one pellet to cross slag depending on changes in slag density and falling speed.

We have used MATLAB software to write the RK4 (Runge-Kutta of the forth order) of the Eq. (1) assuming real plant data of the following:

Tab. 1- Assumption

Item	Value
DRI Diameter	15mm
Slag height	600 mm
DRI Density	2.6 T/m3

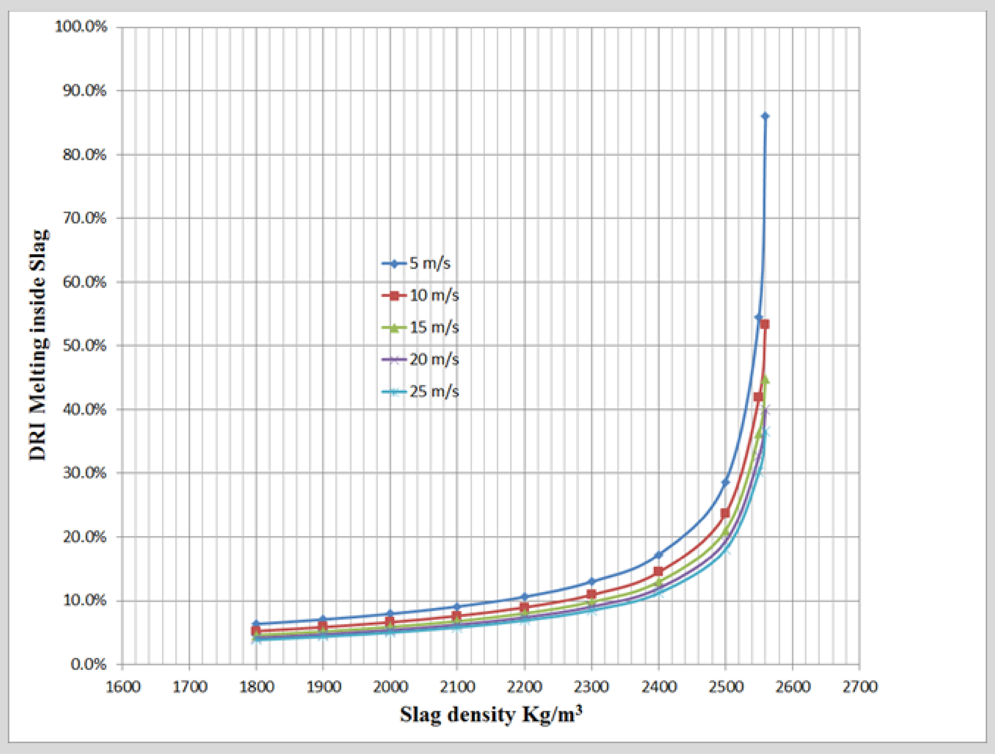

Fig. 1 - Melting time and DRI melting percentage based on density in different falling speeds of DRI

As you can see in Fig. 1, changes in density have a clear major effect on melting time of DRI. As it is shown in Fig.2 for speed of 15m/s for different slag densities, The reason is that when the DRI density comes near to slag density, buoyancy force will weaken while drag and friction forces, which are against it, are strengthening. In the model the changes of DRI size during melting is considered base on linear approximation based on time changes. This fact shows how much important is to control slag density by make it foamy and decreasing Fe content of slag.

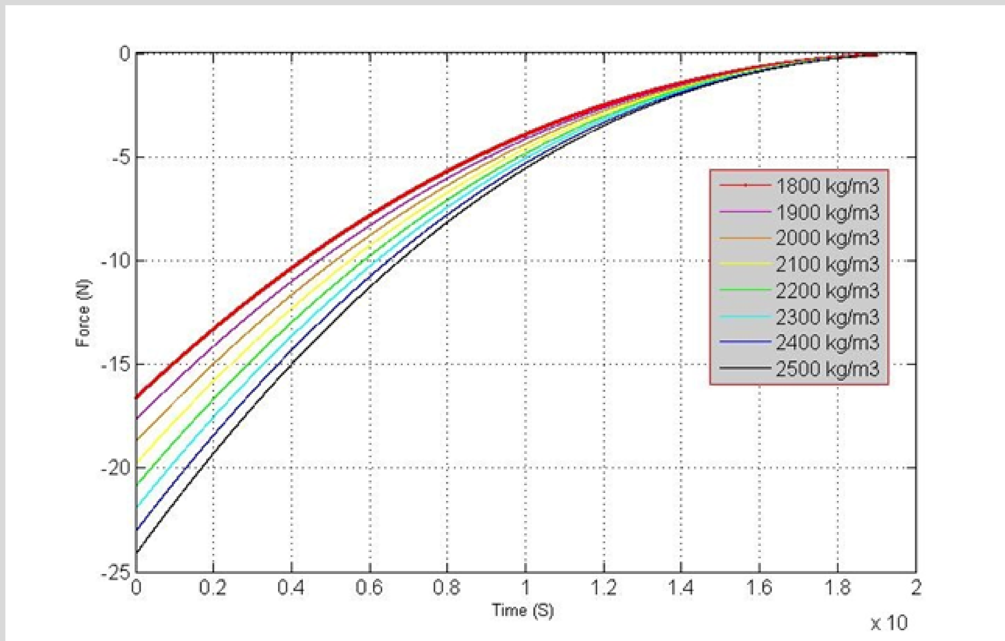

Fig. 2: BOUYANCY AND FRICTION FORCES IN DIFFERENT SLAG DENSITIES

The other investigated issue in Fig. 1 is the effect of falling speed on DRI melting percentage inside slag. It is shown that in low slag density, speed is not so much effective in different densities, but in higher densities speed has the main role. It means we have two options for operation, one is to work always with low density DRI or to fall DRI with high speed. This is a fact that it is hard to control slag density for all period of operation especially when we are charging a massive Iron in one point, therefore a minimum speed shall consider in the design not to let DRI being melted inside slag.

EXPERIMENTAL RESULT

The above discussed phenomena are being investigated in one DRI furnace with tapping weight of 150T and charging of DRI up to 180 tons per hour. The initial speed of DRI charging was 10m/s and there was so many electrodes rises up during melting. In order to solve this issue, operators were trying to decrease DRI charging rate which was showing that a great portion of DRI is melting inside slag makes it conductive. Therefore a revamp was done on DRI charging system to increase falling speed from 10m/s to 15 m/s which is shown in Fig.3.

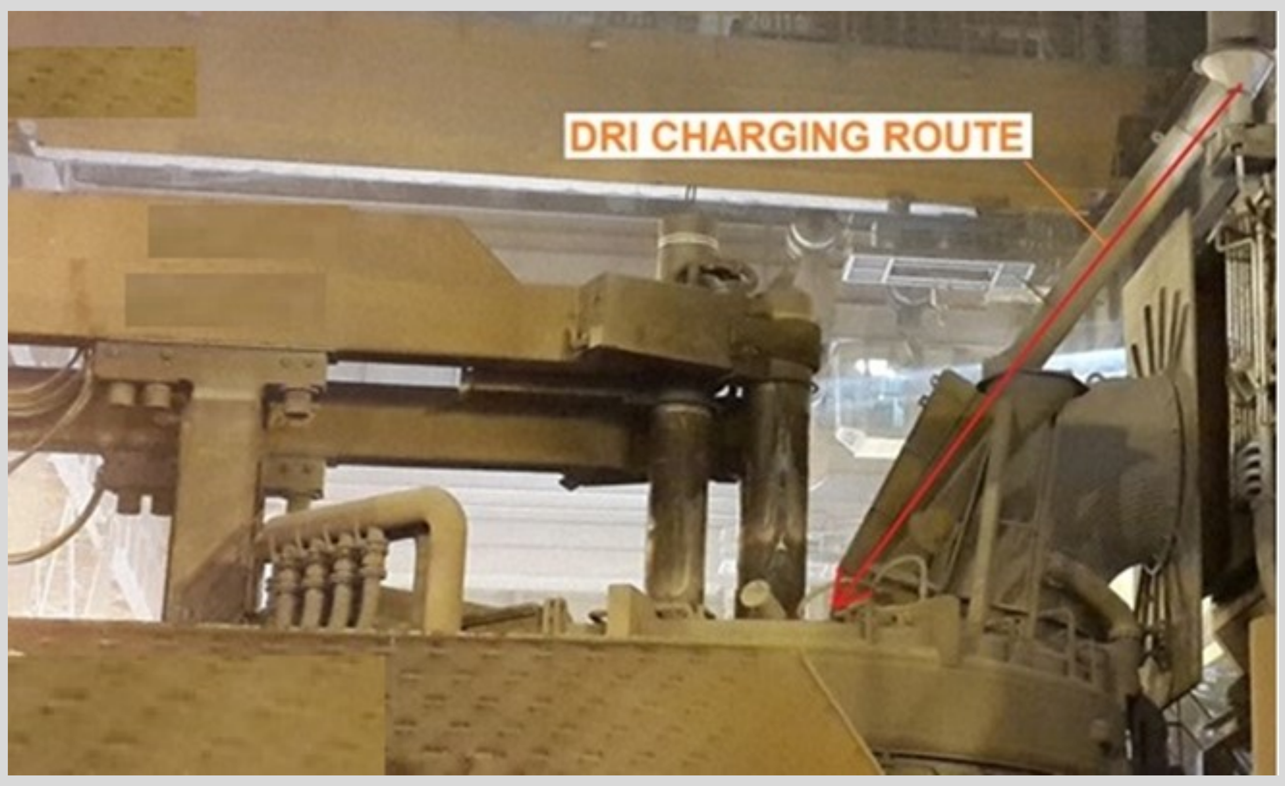

Fig.3 - The modified DRI charging point

This modification leads to removing of Electrode lifting completely as it could be seen in Fig.4 where the locations of electrodes are shown during melting time.

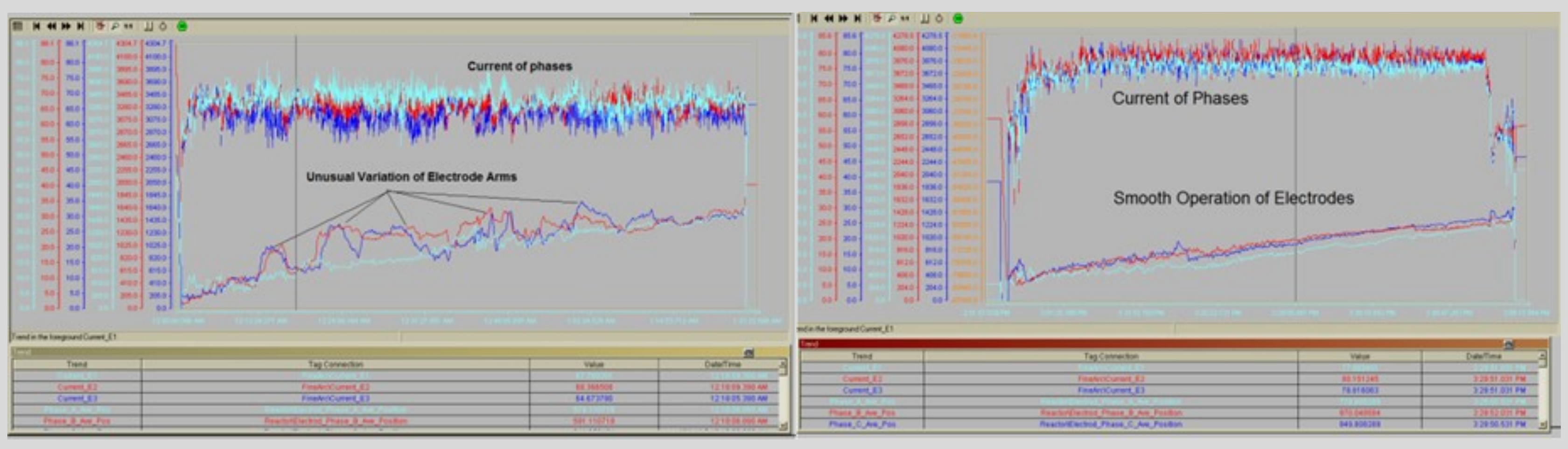

Fig.4 – Improvement of Arc by increasing DRI charging speed from 10m/s to 15m/s

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