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Towards Modelling Feed Pile Shape in Reducing Electric Furnace (REF)

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Tata Steel Netherlands (TSN) produces approximately 7 million tonnes of steel annually, resulting in about 12 million tonnes of CO₂ emissions, which corresponds to nearly 7% of the total emissions in the Netherlands. These emissions originate mainly from blast furnace operations. With support from the Groeien met Groen Staal program, TSN aims to reduce its emissions by 70% by 2035 by replacing its two blast furnaces with more sustainable steelmaking routes.

One potential pathway involves the reduction of iron ore pellets in a Direct Reduction Plant (DRP) to produce Direct Reduced Iron (DRI), which is subsequently melted in a Reducing Electric Furnace (REF). In the REF, DRI pellets and additives are charged from the top, forming a feed pile that penetrates the slag and hot metal layers. Heat transfer from the electrodes to the pellets initiates melting, as schematically shown in Figure 1.

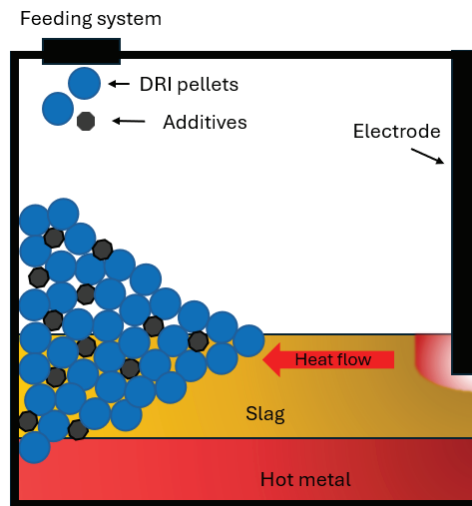


Figure 1. Schematic of the Reducing Electric Furnace (REF)

A key uncertainty in the REF is the formation and behaviour of the feed pile. This behaviour is governed by (a) the interaction of solid pellets with the surrounding hot liquid layers and (b) heat transfer and pellet melting at the interface between the pile and the hot layers. This study focuses on the interaction between solid pellets and hot liquid layers using the Discrete Element Method (DEM), integrated with a newly developed algorithm to model interactions with liquid layers.

Two extreme scenarios are considered: (i) slag penetration into the feed pile and (ii) a dry pile consisting only of pellets and interstitial gas, separated from the slag and hot metal layers by a transition zone. These scenarios result in different buoyancy force distributions acting on the pellets (Figure 2).

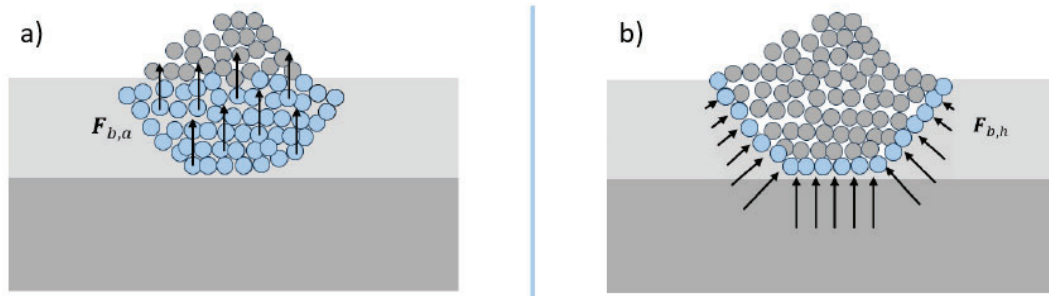


Figure 2 – Illustration of feed pile interaction with liquid layer under two conditions: (a) slag penetration into the pile, where buoyancy forces ($F_{b,a}$) act upward within the pile; (b) dry pile condition, buoyancy forces ($F_{b,h}$) act primarily at the pellet-pile interface.

These two extreme scenarios provide the upper and lower bounds for the shape of the solid feed pile interacting with hot liquid layers. Preliminary experimental observations suggest limited liquid penetration into the bulk of the pile. Therefore, the actual system is expected to lie between the two limiting cases, with behaviour closer to the dry pile scenario.