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A Time-based Pellet Melting Approach to Model Feed Pile Formation in Electric Smelting Furnace

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Tata Steel Netherlands (TSN) produces approximately 7 million tonnes of steel annually, which is equivalent to the national consumption, resulting in about 12 million tonnes of CO_2 emissions per year, which accounts for around 7% of the Dutch total. Nearly 90% of these emissions originate from producing hot metal in blast furnaces.

To reduce emissions by 70% by 2035, TSN, under the Groeien met Groen Staal (GGS) program funded by the Dutch government through the National Growth Fund, plans to replace its two blast furnaces with more sustainable production routes. One potential route involves reducing iron ore pellets in a Direct Reduction Plant (DRP) to produce Direct Reduced Iron (DRI) pellets, which is then melted in an Electric Smelting Furnace (ESF). In the ESF, DRI pellets and additives are charged from the top, forming a solid feed pile that penetrates the slag and hot metal layers, where heat is transferred from electrodes to the pellets via the slag and hot metal layers, causing them to melt.

One key uncertainty in this process is the formation and behaviour of the feed pile under varying operational conditions, which involves a balance between feeding, pellet melting, and interactions of pellets with the slag and hot metal layers. This study investigates feed pile formation using a coupled Discrete Element Method (DEM) and Computational Fluid Dynamics (CFD) method with a time-based melting approach.

Two scenarios are modeled: one allowing slag penetration into the feed pile, and another excluding it, resulting in a dry pile consisting only of pellets and gas in the pore space, with a transition zone of a few pellet diameters to the slag and hot metal layers (Figure 1).

https://imgur.com/a/JjUkJG4
Figure 1 –Illustration of feed pile interaction with the slag layer under two conditions: (a) slag penetration into the pile, where buoyancy forces (Fb,a) act upward within the pile; (b) dry pile condition, buoyancy forces (Fh,a) act primarily at the pellet-pile interface.

A time-based melting model describes the DRI melting process in three stages: (1) shell formation, (2) shell remelting, and (3) pellet core melting. To extend the model and incorporate more physics, a cohesion model based on the Johnson-Kendall-Robertson (JKR) theory is implemented to account for inter-pellet cohesive forces during melting. A preliminary parameter study is also conducted to evaluate the influence of key variables on feed pile shape.

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