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Digital Twin of a Torpedo Ladle: The Simulated Future

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ABSTRACT

This study investigated the construction of a reduced-order model based digital twin of a torpedo ladle using Ansys Twin Builder. Finite element models were used to generate the training and validation data sets, based on 3D thermal analyses. Distinct scenarios were evaluated with full time, empty time, refractory age, hot metal volume, hot metal inlet temperature and refractory initial temperature as examples of input variables. A critical analysis of the technology readiness and future steps is also included in the investigation.

INTRODUCTION

In the current steelmaking market, where environmental demands and product quality become each day stricter, digital transformation is an essential path towards greener production. Clients want more data traceability, process control and precise evaluation of the products' carbon footprint. Political and regulatory entities are interested in the reduction of production's environmental impact whilst keeping technological advantages in the local industry. Such challenging conditions require quick and assertive decisions to steer the production of traditional companies.

One of the major challenges in thermal logistics in the steel industry is maintaining the correct temperature of the hot metal as it is transported from the blast furnace to the oxygen steel plant. If the hot metal temperature is too low, it can negatively impact the process by introducing the necessity of a reheating step or reducing the amount of mixed scrap in the converter. If the temperature is too high, it can accelerate the wear of the refractory materials and introduce safety and operation concerns.

In the past, torpedo ladle cars at Tata Steel Nederland (TSN) were filled based on the first-in-first-out principle, which was non-optimal with respect to energy efficiency, refractory lifetime and hot metal quality. A first upgrade of the thermal logistics model (empirical) was introduced based on finite element method (FEM) simulation and thermocouple measurements. Although this model provides satisfactory thermal-logistics management support, it has limited applicability and accuracy regarding future torpedo ladle and processes modifications. Hence, more sophisticated and flexible models are required in order to deal with the ever-increasing demands for more efficient process control.

One important asset in the digital transformation is the construction and usage of digital twins. A digital twin (DT) is a realistic digital representation of assets, processes or systems in the built or natural environment, synchronized at certain frequency and fidelity in order to track the past, provide deeper insights about the present, predict and influence future behaviour based on simulation [1].

A digital twin of the thermal logistics system can help address this challenge by simulating the behavior of the system under different conditions. Sensor data from the physical systems can be integrated into the digital twin, allowing engineers to monitor the performance of the thermal logistics system in real-time and make adjustments when needed. Another benefit of using digital twin technology in thermal logistics is improved safety. By simulating the behavior of the system under different conditions, engineers can identify potential hazards and take steps to mitigate them before they occur in reality.

