Dissertation abstract

This doctoral dissertation presents both model-scale and full-scale industrial studies aimed at determining the effect of changing the circulation loop of solids feeding the Intrex heat-exchanger chamber and at predicting the feasibility of implementing these changes on the industrial unit.

The research was initiated by the need to improve Intrex operating conditions by altering the solids circulation path and reducing the Intrex chamber fluidization velocity, which in a subsequent step would enable closing the connection between the Intrex chamber and the furnace and introducing biomass and alternative fuels into the fuel mix.

Model tests were conducted on a 1:10 scale model of the Łagisza CFB-1300 boiler. The hydrodynamics of the fluidized bed were reproduced in accordance with scaling rules, allowing the transfer of findings to the industrial scale. Tests covered the 40 %–100 % MCR load range (MCR, Maximum Continuous Rating) and considered two modes of feeding the Intrex chamber with circulating solids. The first reflected the current operating state, where the Intrex chamber is supplied by two solids streams: internal circulation (bed material coming directly from the combustion chamber) and external circulation (material separated in cyclone separators and recirculated to the boiler loop). The second mode supplied the Intrex chamber exclusively with solids from the external circulation. Recorded measurements made it possible, for each boiler load band and configuration, to determine changes in exchanger heat duty and heat-transfer coefficient. The analysis confirmed the influence of internal circulation on heat transfer, as follows:

1. At 40 % MCR, exchanger heat duty decreased by ~6 %, and the heat-transfer coefficient by ~5 %.
2. At 60 % MCR, heat duty decreased by ~4.5 %, and the heat-transfer coefficient by ~3.5 %.
3. At 80% MCR, heat duty decreased by <1%, and the heat-transfer coefficient by ~3.6 %.
4. At 100 % MCR, an increase in both heat duty and heat-transfer coefficient was observed: heat duty rose by <1% and the heat-transfer coefficient by <0.5 % with internal circulation closed. This change is attributed to a slightly higher solids density in the upper part of the model furnace during the test, and thus a higher circulating solids flux.

Industrial tests on the CFB-1300 boiler at the Łagisza power plant (Tauron S.A.) involved reducing the Intrex chamber fluidization velocity from 0.56 m/s to 0.30 m/s. Four Intrex exchangers on the live-steam path were tested. The data revealed the effect of lowering the fluidization velocity: the average heat duty of all exchangers increased by 8 %, and the average heat-transfer coefficient increased by 13%. Literature data confirm this trend—decreasing fluidization velocity increases the contribution of particle-to-surface convection relative to gas-phase convection, thereby increasing the overall heat-transfer coefficient.

Changing the fluidization velocity reduces the consumption of high-pressure air, which can then be allocated to pneumatic conveying of limestone and fly ash. This enables shutting

down blowers previously used to supply conveying air, generating savings in electricity use as well as service, parts, and consumables. Additionally, reducing the fluidization velocity lowers the risk of failures by reducing the erosion coefficient.

Combining the laboratory and industrial results enabled a prediction of how changing the solids circulation loop would affect Intrex operation and the resulting benefits are:

1. Closing the connection between the furnace and the Intrex chamber is feasible. The reduction in heat transfer caused by eliminating internal circulation is offset by the increase in heat duty and heat-transfer coefficient resulting from optimizing Intrex chamber fluidization velocity. In addition, on the live-steam path there is a temperature buffer in the form of desuperheating water injections used for steam-temperature control, which in the current configuration lowers the steam temperature upstream of the last superheating stage - Intrex (SH IV) - by a total of 60 °C at 40 % load and by 25 °C at 100 % load.
2. Adjusting the fluidization velocity of the Intrex chambers yields savings in high-pressure air that can be used for pneumatic conveying, and it generates savings by allowing shutdown of the equipment previously used for this purpose.
3. Lower fluidization velocity reduces the risk of failures due to a lower erosion coefficient.
4. Closing the connection between the furnace and the Intrex chamber opens the possibility of introducing biomass and alternative fuels (including those classified as renewable) into the fuel mix. The shares of individual fuels in the blend should be determined on a case-by-case basis depending on the selected fuel and remain at the discretion of the owner of the Łagisza CFB-1300 boiler.

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