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Experimental Study on the Heat-Transfer Characteristics of a 600 MW Supercritical Circulating Fluidized Bed Boiler

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ABSTRACT: Heat-transfer characteristics such as the distribution of the local heat-flux and the water-side and fire-side heat-transfer coefficients of the water-wall at the dilute phase region of a 600 MW supercritical circulating fluidized bed (CFB) boiler operating at boiler loads of 60%, 80%, and 100%, were experimentally investigated. The temperature of the water-wall at furnace heights of 9 to 55 m was *in situ* measured using K-type thermocouples, and the water-side heat-transfer coefficient, the distribution of local heat-flux, and the fire-side heat-transfer coefficient between the furnace and water-wall were calculated based on the measured temperature result. The results showed the water-side heat-transfer coefficient was raised from 8600 $W{\cdot}m^{-2}{\cdot}K^{-1}$ to 31000 $W{\cdot}m^{-2}{\cdot}K^{-1}$ as the furnace height increased. Moreover, the water-side heat-transfer coefficient was large enough to ensure the heat-transfer deterioration would not take place in the water-wall tubes. Meanwhile, it was revealed that the heat-flux was higher at the corner of the furnace in the lower furnace, and the heat-flux was lower at places where the heating-surfaces arranged in the upper furnace, indicating that the distribution of local heat-flux was mainly influenced by the corner effect at the lower part of the furnace as well as the arrangement of heating-surfaces in the upper furnace. Moreover, the fire-side heat-transfer coefficient decreased from 239.1 $W{\cdot}m^{-2}{\cdot}K^{-1}$ to 197.7 $W{\cdot}m^{-2}{\cdot}K^{-1}$, 185.2 $W{\cdot}m^{-2}{\cdot}K^{-1}$ to 153.5 $W{\cdot}m^{-2}{\cdot}K^{-1}$, and 179.7 $W{\cdot}m^{-2}{\cdot}K^{-1}$ to 138.3 $W{\cdot}m^{-2}{\cdot}K^{-1}$ at 100% MCR, 80% MCR, and 60% MCR, respectively. Furthermore, the bed-to-wall heat-transfer coefficient was consistent with the furnace height above 30 m, owing to limited capacity of the entrainment effect of the fluidizing air, which led to the consistent voidage in the furnace. In addition, comparison between the fire-side radiation heat-transfer and convection heat-transfer showed the radiation heat-transfer was higher in the dilute phase of the furnace, which illustrated furnace temperature was one dominant factor that influences the heat transfer in the dilute phase region of the furnace.

1. INTRODUCTION

Supercritical circulating fluidized bed (CFB) boilers have received more and more attention due to increasing requirements for higher thermal efficiency for power generation and lower dust, SO_2 and NO_x emissions in China.[1−3] To guarantee safety operation and maintain the thermal efficiency, a uniform combustion and an even heat-transfer distribution in the furnace are required. However, this is often hard to achieve due to the limited awareness of the working conditions in the supercritical CFB boilers. Therefore, investigation into the heat-transfer characteristics in the furnace of the supercritical CFB boiler is essential to optimize the boiler's design and operation.

A significant number of experimental studies on the heat-transfer in the furnace of CFB boilers have been studied by many scholars.[4−14,25,29,31−36,38,41,42] These experimental results were mainly carried out in the lab-scale CFB system.[4−12] The results obtained from lab-scale experiments revealed that particle concentration was the most influential factor for the variation in heat transfer in the furnace, followed by the furnace temperature.[4−10] In addition, the particle diameter of the bed material also influenced the heat-transfer in the CFB boiler furnace, showing an increase in heat-transfer coefficient with increasing particle size.[5−7,14]

Although the current literature reports have achieved huge progress regarding the heat-transfer characteristics in CFB furnaces, experimental studies on heat-transfer in practical large-scale CFB boilers are spare.[11−14] In particular, the tests results from lab-scale CFB combustors were not always applicable in practical CFB boilers; this is because the operating conditions are much more changeable in the practical CFB boiler than in lab-scale CFB combustors. Moreover, the furnace structures of supercritical CFB boilers are far different from that of the subcritical CFB boiler, which might lead to the difference in the thermal properties and the gas−solid flow in the furnace. Particularly, the heat-transfer in the dilute phase region of the supercritical CFB boiler's furnace is significantly different from those in subcritical CFB boilers. As the heat from the furnace is mainly absorbed by the water-wall in the dilute phase region, investigation into the heat-transfer between the furnace and the water-wall tubes in the dilute phase zone of the furnace is of significant importance. In the opening literature, there are few reports on the heat-transfer characteristics of the supercritical CFB boilers,[13,14] and there are no reports on the heat-transfer characteristics of the 600 MW supercritical CFB boilers.

Therefore, this work was aimed to investigate the heat-transfer characteristics of a practical 600 MW supercritical CFB boiler. The local temperature on the backside of water-wall tubes at the boiler dilute phase region was *in situ* measured at 60%, 80%, and 100% MCR (maximum continuous rating) loads. Combined

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