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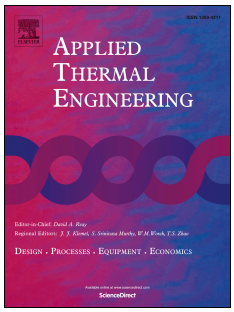

Thermodynamic properties calculation of the flue gas based on its composition estimation for coal-fired power plants

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Thermodynamic properties calculation of the flue gas based on its composition estimation for coal-fired power plants

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Abstract: Thermodynamic properties of the working fluid and the flue gas play an important role in the thermodynamic calculation for the boiler design and the operational optimization in power plants. In this study, a generic approach to online calculate the thermodynamic properties of the flue gas is proposed based on its composition estimation. It covers the full operation scope of the flue gas, including the two-phase state when the temperature becomes lower than the dew point. The composition of the flue gas is online estimated based on the routinely offline assays of the coal samples and the online measured oxygen mole fraction in the flue gas. The relative error of the proposed approach is found less than 1% when the standard data set of the dry and humid air and the typical flue gas is used for validation. Also, the sensitivity analysis of the individual component and the influence of the measurement error of the oxygen mole fraction on the thermodynamic properties of the flue gas are presented.

Keywords: online calculation, thermodynamic property, flue gas, composition estimation, component sensitivity.

1. Introduction

In the coal-fired power industry, boiler design, unit optimization and efficiency assessment rely greatly on the accurate thermodynamic calculation [1-4], where the thermodynamic properties, including the specific enthalpy, the specific heat, and the density, are fundamental [5]. Water and steam is generally used as the working fluid in the heat cycle of power plants. In 1997, a new formulation IAPWS-IF97 for calculating the thermodynamic properties of water and steam was published by IAPWS (International Association for the Properties of Water and Steam) [6, 7]. Nowadays, it has been widely applied to calculate the thermodynamic properties of the working fluid in energy engineering. However, the online calculation of the thermodynamic properties of the flue gas, which is the combustion product of the coal in the power plant, faces some problems [3].

Flue gas is composed of many components, including N_2, CO_2, O_2, H_2O, NO_x, SO_2, etc. The mass flow rate and the thermodynamic properties of the flue gas are dependent on its temperature, pressure, and composition [8, 9]. According to the combustion theory, the composition of the flue gas is calculable with the data of offline ultimate analysis of the coal under certain excess air ratio [10, 11]. However, such calculation is relatively complex and a high accuracy of the coal sample assay is a prerequisite which can rarely be met in real power plants. Some continuous emission monitoring systems (CEMS) based on wet chemical reaction, spectroscopy or chromatography [10, 12, 13], are applied to monitor the concentrations of CO_2, SO_2, and NO_x in the flue gas. However,