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Indirect sensing of dynamical and distributed variables in combustion processes, based on spectral analysis

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Abstract

Combustion diagnostics and control has been an active research area for the last several decades. In this Thesis, it is discussed the state-of-the-art for combustion diagnostics based on optical devices, and their subsequent control and optimization methods. From the above, it is established the problem to propose suitable combustion diagnostics methods for a closed loop operation. For combustion diagnostics, passive optical sensors show great potential, between the field information and the combustion quality. This research presents the fundamentals of novel propositions, using the optical information measured from the chemiluminescence of the flame with a spectrometer or a CCD camera, to obtain optical variables suitable for feedback operation, which provides an improved performance on the process. Two combustion diagnostics methodologies have been proposed. The first, is strictly based on spectrometer measurements and a spectral baseline estimation methodology, to compute the total radiation emitted by the flame. Secondly, it is proposed a high resolution spatial and spectral combustion variable of Global Radiation Index, based on the use of flame images processing and the spectral estimation model with off-line referential flame's spectra. This optical combustion diagnostics variable has been used in order to determine the smoke point of combustion, relevant value that marks the operational threshold for a low environmental impact of combustion process operation. Both methods provides high accuracy in the estimated continuous component of the flame spectra, with values of $GFC > 0.99$. Finally, to illustrate the achieved benefits of the optical combustion diagnostics variables, a model based optimization study is realized. This model based study verify the benefits, in terms of operational enhancement and pollutants emissions reduction. In addition, encouraging experimental results in a steel manufacturing are reported, to propose a closed loop control scheme in a industrial combustion process with optical variables. Finally, conclusions about the Thesis contributions and future work is presented.