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A technique to measure fuel oil viscosity in a fuel power plant

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A B S T R A C T

The viscosity measurement and control of fuel oil in power plants is very important for a proper combustion. However, the conventional viscometers are only reliable for a short period of time. This paper proposes an on-line analytic viscosity evaluation based on energy balance applied to a piece of tube entering the fuel oil main heater and a new control strategy for temperature control. This analytic evaluation utilizes a set of temperature versus viscosity graphs were defined during years of analysis of fuel oil in Mexican power plants. Also the temperature set-point for the fuel oil main heater output is obtained by interpolating in the corresponding graph. Validation tests of the proposed analytic equations were carried out in the Tuxpan power plant in Veracruz, Mexico.

1. Introduction

There are several ways to produce electric power. However, the use of fossil fuel is still the most popular in the world. For example, in Mexico 51% of the generation of electric power is based on fossil fuel (including gas and combustoleum) [3]. Specifically, 30.2% of the generation is steam based using fuel oil. Other installations also generate power using fuel oil, like Pemex (Mexican Petroleum Company) refineries, platforms, and other petrochemical industries.

In a traditional thermoelectric power plant, fuel oil is burned at the steam generators or boilers to produce steam that transfers its calorific energy to the rotation of the steam turbine and therefore, to the electric power generator. Fig. 1 shows the basic process that follows the fuel oil from the daily storage tank to the boiler. The fuel oil is heated by the suction and the main heaters in order to reach the required temperature at approximately 120–140 °C, to be properly burned. Once heated, the fuel oil is atomized by mixing the fuel oil with steam and it is burned combined with air in the combustion chamber. The circles in Fig. 1 correspond to special instrumentation or local control loops. For example, there are two pairs of temperature transmitter (TT) and temperature controller (TC). The red TT and TC circles of Fig. 1 represent the conventional temperature controller of the main heater that provides the fuel oil with the appropriate temperature for a correct atomization. This produces the proper combustion.

The correct atomization depends on the size of the droplet produced. One of the main characteristics of the fuel oil for good droplet spreading inside the furnace is the fuel oil viscosity. Viscosity is inversely related to the fuel oil temperature, so that in general, cold liquids flow slower than hot liquids. Then, when the burners in a boiler receive a fuel oil with high viscosity, atomization results in larger drops. In contrast, if the fuel arrives at the burners with low viscosity, the atomization results in smaller droplets. With larger oil droplets, an incomplete combustion reaction takes place, and so part of the fuel is expelled to the atmosphere as contamination. Besides, the combustion efficiency is reduced. If the droplet is smaller than the optimal size, then side reactions may take place and the combustion heat of the fuel may be degraded. This also produces a reduction of the combustion efficiency.

Traditionally the fuel oil viscosity control is done indirectly through the outlet fuel oil temperature of the main heater, as the controlled variable in a temperature control loop. This paper proposes an alternative control strategy in which the temperature control of the main heater is done by changing the steam transfer area, moving the level of condensate water inside of the tubes by means of the control drain valve. Fig. 2 shows a schematic diagram of the main heater construction.

This paper is organized as follows. The next section describes an alternative control strategy using the analytic viscosity evaluation. Section 3 reviews the related work that has been done to estimate the viscosity in power plants. Section 4 describes the

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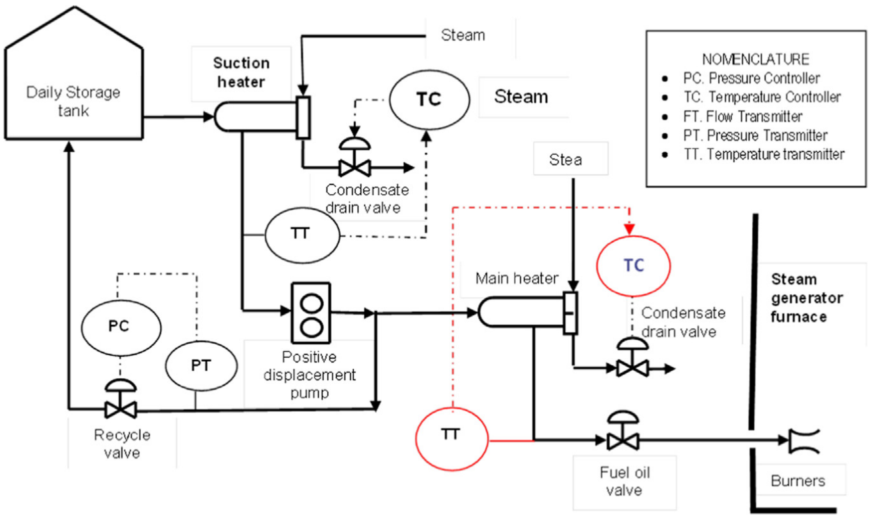

Fig. 1. Fuel heating in a conventional power plant. (For interpretation of the references to color in this figure, the reader is referred to the web version of this paper.)

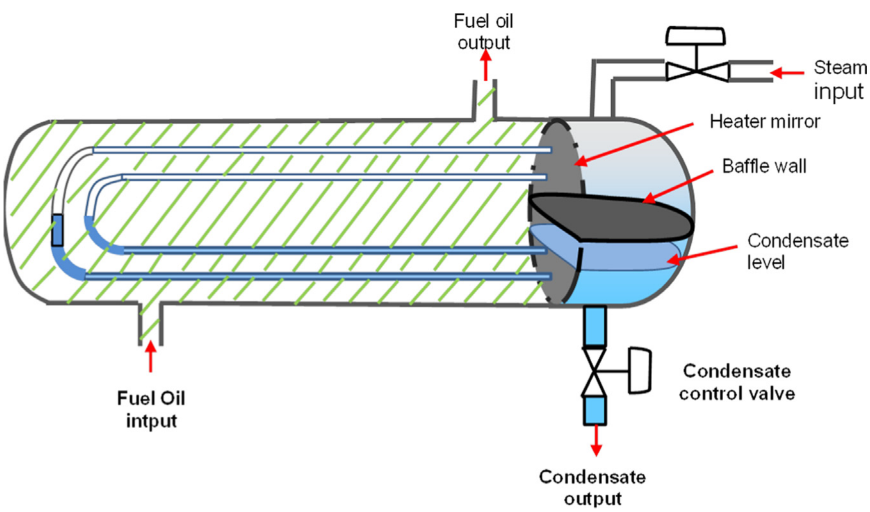

Fig. 2. Schematic diagram of the main heater.

analytical development proposed in this paper for the estimation of viscosity. Next, Section 5 describes the representation of the characteristics of viscosity versus temperature of the analysis made of hundreds of fuel oil types. These curves allow a mapping between the evaluated viscosity and the optimal fuel oil temperature that will produce the optimal combustion. Section 6 describes the experiments conducted in the laboratory and in the plant, with a discussion of the results obtained. Lastly, Section 7 concludes the paper and discusses future research.

2. Alternative control strategy

The proposed alternative includes the construction of an analytic viscosity evaluation and a temperature set-point evaluation for the control temperature of the main heater. This is shown in Fig. 3. The red squares represent the modules proposed in this paper: first, the viscosity estimation and the temperature evaluation that will be used in the temperature control of the main heater. Fig. 4 is a photograph of the studied heater in Tuxpan, Mexico.

The fuel temperature for a good droplet spreading is approximately 120–140 °C. Usually, viscometers must carry out the measurement around this temperature range. The viscosity setpoint value normally is fixed by the burner's manufacturer. However, the fuel oil viscosity is usually controlled at a temperature setpoint which depends on the fuel oil composition. Frequently, the fuel oil viscosity is found by a laboratory analysis that is made when a new oil shipment arrives. Laboratory analyses of viscosity are performed at standard temperatures (50 °C and 82.2 °C).

Baert [1] demonstrated a relation between droplet size, asphaltene fraction, and coke residue formation. Kobayasi [9] studied the burning of heavy fuel oil with frothing and splashing of a burned viscous residue that produces secondary splashes that solidify into carbon particles, producing a change in the droplets' diameters associated with the combustion's being so complex. García-Rodríguez [7] pointed out that a fuel droplet in a fossil fuel boiler can be pyrolysed (molecular dissociation due to heat) because some regions of the boiler may lack oxygen. Also, partial burning or partial decomposition produces a variety of hydrocarbon compounds as well as oxides of sulfur, oxides of nitrogen, and carbon monoxide that are harmful for the environmental atmosphere and health.

The project described in this paper is based on previous project carried out at the same institution. The fuel viscosities of more than 400 fuel oil samples from historical data of different oil compositions were obtained from plant and laboratory records, and arranged so that all available oil compositions were