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Study of slagging and fouling mechanisms in a lignite-fired power plant

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ABSTRACT

A significant proportion of the electrical power requirements of Greece are covered by lignite-fired power plants. Greek lignite is characterized by a high water and ash content and a low heating value. Slagging and fouling are common inside the power units and severely affect the performance of the power plants (reduced efficiency, steam leakage in the superheaters and water walls whereas the high temperature of the exhaust gases leads to the mal-functioning of the electrostatic filters). In addition excessive interior pollution cause the units to stop for cleaning resulting in a reduced production and increased maintenance costs.

In this paper the results from a measurement campaign in a steam boiler affected by excessive deposits are presented and compared against the manufacturer's operating data. A number of differences were found between the two sets of data and were attributed to the particulars of excessive amount of deposits in the boiler. In addition, the present study investigates the chemical composition and behavior of the slagging and fouling deposits that occur in units of the Kardia power plant as well as of a bottom ash and a fly ash sampled from the same unit. The steam path of the unit was simulated using the DNA software in order to model the effect of the contamination on the global performance parameters of the power plant and the results were compared against the experienced operational performance parameters. In addition, a number of practices are proposed and assessed for reducing the levels of boiler contamination and extending the time between successive maintenance stoppages.

1. Introduction

Lignite is the most abundant fuel in Greece and the lignite mines in Ptolemais and Megalopolis provide Greece with great amounts of the fuel which is essential for the production of relatively cheap electricity. Greece has the second place in coal production in the European Union and the sixth worldwide. Based on the total reserves and the scheduled rate of consumption, it is estimated that in Greece the existing lignite is enough for the next 45 years. So far a total of 1.3 billion tons of lignite have been mined and the exploitable reserves amount to 3.1 billion tones. In 2006 a total of 62.5 million tones were mined. Today, Public Power Corporation (PPC) owns eight lignite-fired power plants. These power plants account for 42% of PPC's installed capacity and produce about 56% of PPC's net electricity production.

The Thermoelectric Power Station (TPS) of Kardia is one of the six lignite-fired power stations located in Western Macedonia (Fig 1a) with a total capacity of 1,250 MW. TPS Kardia (Fig. 1b) consists of four subcritical pressure power units of 300 MW, put into operation successively in 1974–1975 (units No I and No II) and in 1980–1981 (units No III and No IV).

Each unit of the TPS Kardia has a tower type pulverized lignite-fired boiler, consisting of water walls, three superheater (SH) rows, two reheater (RH) rows and an economizer (ECO). Fig. 2 presents a side section of a TPS Kardia boiler.

The furnace area of each boiler contains four lignite burners connected with eight fan type mills and eight oil burners. Each unit contains 24 retractable soot blowers arranged in three clusters. Between S/H Ib and S/H II, S/H II and S/H III and between R/H Ib and R/H II a water injection system is installed to preserve the steam temperature at acceptable values.

Greek lignite is brownish-black in color and has a high inherent moisture content and a high ash content. The heating value ranges from 4082 to 5778 kJ/kg in Megalopolis, Amynteon and Drama

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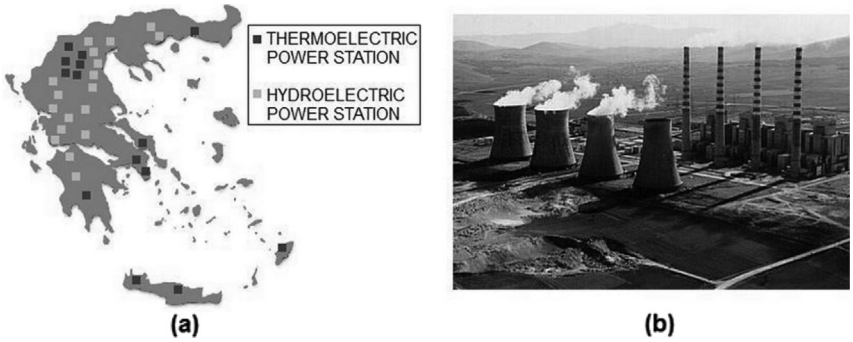

Fig. 1. (a) Location of thermoelectric and hydroelectric power stations in Greece and (b) the power plant of Kardia.

mines, from 5280 to 6762 kJ/kg in Ptolemais mine and from 8068 to 9450 kJ/kg in Florina and Elassona mines. The results of proximate analysis of lignite mined in Ptolemais area (both as received and dry), are presented in Table 1. In Table 2 the results of ultimate analysis of the same lignite is presented. As can be seen total moisture is as high as almost 60%. Dry lignite contains about 28% ash and almost 36% volatiles when the fixed carbon content is about 29%. The lower heating value of lignite "as received" is almost 5,234 kJ/kg.

From Tables 1–3, it can be seen that a significant feature of Greek lignite is its low sulfur content. In contrast, it can be found that ash contained in lignite mined in Ptolemais has significant calcium content.

It should be mentioned that, due to the time at which the sample was taken, the moisture of the samples presented above was below the average price of Ptolemais lignite. This means that the heating value of the two samples is above the design value.

Reviewing the recent history of the chemical analysis data of the lignite burned in TPS Kardia's units, it can be found that all the slagging and fouling indices (including the CaO content) have an increasing trend (Fig. 3).

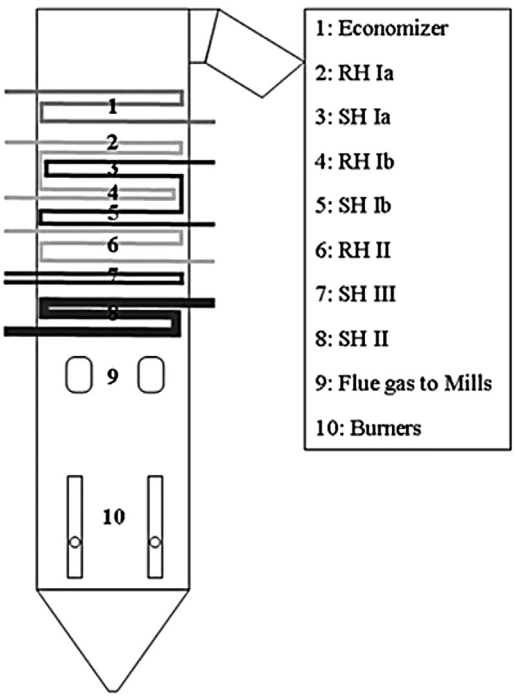

Fig. 2. Typical pulverized-lignite fired boiler of the Kardia power plant.

Due to lignite's high water and ash content important technical and environmental problems arise during combustion. Deposits are common inside the power units and severely affect the performance of the power plants.

Deposits in boilers like the ones of TPS Kardia are usually classified into two generic types: slagging and fouling [1]. Slagging refers to the deposition taking place in sections of the boiler where heat transfer due to radiation is dominant (water walls making up the furnace and the first rows of superheaters). Fouling, defined as deposits on the surface of convective tube bundles. Slagging and fouling have been studied through the years as they appear in almost any coal fired power plant in different extent, depending on the quality of the fuel used and the operation conditions [1–10]. Fig. 4 presents photos taken during the optical inspection described in a following section. Fig. 4a presents the formations of fouling on the surfaces of SH Ia (58.17 m) and in Fig. 4b slagging is presented (left: SH Ib – 55.82 m, right: blocked recirculation exit of flue gas from boiler interior to mill). Recent mineralogical studies [11,12] of deposits found in TPS Kardia's boilers showed that the dominant constituents in all samples taken from various heights of the boiler were CaO and SO_3. Fe_2O_3 contents were also high in samples taken from the lower and the middle heights of the boiler but very low in samples taken from higher heights. The SiO_2, Al_2O_3 and MgO contents were not so high and increased in the higher boiler zones forming fouling deposits. A graphical representation of the major deposit constituents is presented in Fig. 5.

The present study investigated the results from a measurement campaign in the steam boiler No IV of Kardia power plant which is affected by excessive deposits. The deposits have a dramatic effect on boiler heat transfer which results in a reduced boiler thermal efficiency and a reduced overall efficiency. On the other hand, the flue gas temperature is increased and the usage of water flow injection in SH/RH is increased. The extensive slagging on SH Ib causes the increased usage of soot blowing. Furthermore, apart from the difficulties and problems caused to the boiler operation by deposits, another phenomenon worsens the boiler operation in unit No IV. Massive accumulation of deposits leads in damaging the boiler walls and SH/RH tubes. In addition, shedding of deposits causes severe damage of the boiler bottom. The fall of solid material not only results in damage of the boiler, but it is often a life threat for the personnel entering to maintain the boiler. As a result, the reliability and availability of the unit is reduced.

Table 1
Typical proximate Ptolemais' lignite chemical analysis.

Lignite sample	Total moisture (%)	Ash (%)	CO_2 (%)	Volatiles (%)	Fixed carbon (%)
As received	50.9	13.5	3.8	17.7	14.1
Dry	–	27.5	7.7	36.1	28.7

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