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Short term online corrosion measurements in biomass fired boilers. Part 1: Application of a newly developed mass loss probe

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ABSTRACT

Online corrosion probes enable the online determination of high-temperature corrosion rates in biomass combustion plants. These probes are exposed to the flue gas and require a layer of corrosion products and deposits on their surface to be able to perform the corrosion measurements. The formation of this layer takes time and depends on the build-up rate of the deposits as well as on the ability of the deposits to form a conductive layer. During this initial phase, which lasts about 300 h based on experiences with forest wood chip combustion, the measurements are inaccurate. This inaccuracy can be neglected during long-term measurements performed at real-scale plants which last more than several 1000 h. Since high-temperature corrosion in biomass combustion plants is known to generally follow a paralinear trend, high corrosion rates prevail in the beginning. Following, if short-term measurements shall reflect or come close to real-life conditions, this "start-up" effect cannot be neglected.

Consequently, to be able to correct this "start-up" effect, a methodology has been developed which combines results from parallel measurements of an online corrosion probe and a mass loss probe. The mass loss probe consists of multiple test rings and is exposed to the flue gas next to the corrosion probe with similar surface temperatures. With the mass loss probe the trend of the corrosion rate within the first 300 h is determined by gravimetric mass loss measurements of each ring. For evaluation this trend of the corrosion rate from the mass loss probe is coupled with the signal from the corrosion probe. Hereby, the inaccuracy at the beginning of the online corrosion probe measurements can be eliminated and reliable short-term measurements can be performed. A 50 kW biomass grate combustion system coupled with a drop tube was used for the development of the mass loss probe and the evaluation methodology. Such a test rig provides multiple advantages for high-temperature corrosion measurements compared to a real-scale plant. Specific and homogenous fuels can be tested, specific influencing parameters can be adjusted and varying operating conditions occurring in a real-scale plant are excluded.

1. Introduction and objectives

The combustion of biomass is often linked to ash related problems such as deposition formation and corrosion. High-temperature corrosion of heat exchanger tube bundles reduces their lifetime and causes unexpected plant shutdowns. Influencing parameters are the surface temperature of the heat exchanger, the flue gas temperature, the flue gas velocity as well as the composition of the depositions and the flue gas. To minimize failures caused by high-temperature corrosion, steam parameters (temperature and pressure) in combined heat and power (CHP) plants are nowadays often kept on rather moderate levels, which reduces the overall efficiency of the plants. The determination of corrosion rates for superheater materials exposed to flue gases from different biomass fuels is therefore an important step towards increased steam parameters in future biomass CHP plants.

Investigations of high-temperature corrosion are usually performed either in real-scale plants (e.g. [1–4]) or under laboratory conditions using synthetic flue gases and deposits (e.g. [5–9]). Tests in real-scale plants provide the possibility to investigate corrosion processes at plant operation conditions. However, access to the boiler is often only possible at certain positions, which results in flue gas conditions (temperature and composition) which can deviate from conditions at the actual superheaters. Furthermore, operating conditions and fuel compositions can vary significantly. Also the control of an influencing parameter is often limited (e.g. flue gas temperature). Therefore, the determination of the influence of single parameters on the corrosion rate is often not possible.

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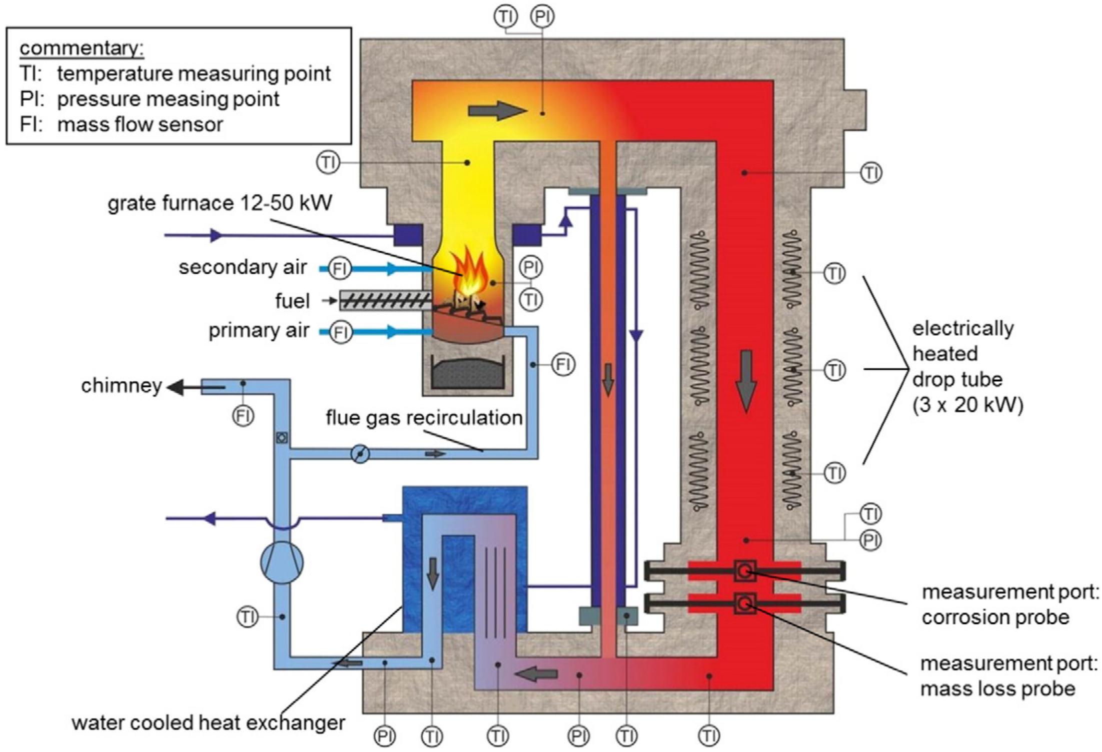

Fig. 1. Scheme of the combined packed bed/drop tube reactor.

Laboratory investigations using synthetic flue gases and deposits on the other hand provide the possibility to investigate high-temperature corrosion under well controlled temperatures and compositions of deposits and flue gases. However, due to the simplifications made, these investigations are suitable for fundamental studies but the application of the results for real-scale plants is difficult.

Test rigs based on biomass combustion systems provide a realistic combustion environment [e.g. [10–13]]. The resulting flue gas compositions and the deposit formation processes are comparable to real-scale plants. Therefore, corrosion processes are close to reality compared to laboratory investigations. In contrast to real-scale plants, such test rigs can be operated at well-defined conditions and the use of more homogeneous fuels is possible. Additionally, parameters of interest such as the flue gas temperature or the flue gas velocity can be arbitrarily defined. Consequently, a test rig allows the determination of the influence of single parameters on high temperature corrosion in more detail.

Online corrosion probes simulate a heat exchanger tube and allow the monitoring of the actual corrosion attack continuously. The system measures an electrical resistance between test rings via a conductive layer consisting of corrosion products and deposits on the probe surface. The probes have been successfully applied in real-scale plants using municipal solid waste [14,15] and biomass fuels [16]. In combination with a test rig, a detailed investigation of high-temperature corrosion is possible [10,11].

Since the conductive layer on the probe surface is formed during the measurement, the signal at the beginning of a test campaign is inaccurate until a fully developed conductive layer is formed. This inaccuracy can be neglected at long-term measurements that last more than several 1000 h which are usually performed in real-scale plants. High temperature corrosion of low-alloyed boiler steels in biomass combustion plants has been found to often follow a paralinear trend [17,18]. Therefore, high corrosion rates prevail at the beginning. Following, if short-term measurements using such steels and lasting about 500 h shall reflect or come close to real-life conditions, this “start-up” effect cannot be neglected. Therefore, a mass loss probe has been developed, which allows the determination of the corrosion kinetic in the initial phase. The mass loss probe is used in parallel with the online corrosion probe and allows for a correction of the measurement data obtained from the corrosion probe.

The aim of the presented work was the combination of data resulting from an online corrosion probe and a newly developed mass loss probe.

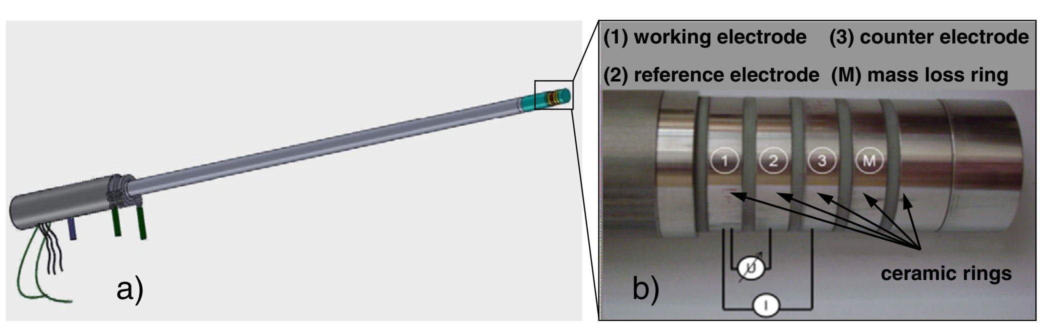

Fig. 2. Scheme of the online corrosion probe. Explanations: a) corrosions probe; b) sensor with three electrodes (1–3) and the mass loss ring (M); source [19].