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Hot gas filters for coal-based power generation systems: Operating experiences

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ABSTRACT

A semi-industrial filtration facility is currently in operation at the ETSI-University of Seville, with financial support from the European Commission and the Spanish Ministry of the Environment. This pilot plant allows testing different elements and reverse-flow pulse cleaning strategies using real coal ash and under diverse operating conditions such as temperature and pressure. The aim of the on-going research is the evaluation of the alternatives for hot gas filtration technologies and the optimisation of the operation and performance of the filtering elements.

The first experimental campaign carried out in the filtration facility commenced in 2005. Four types of elements were tested at maximum temperature and pressure of 235 °C and 7.5 barg respectively. This paper describes the main results obtained during the second phase of the experimental campaign, in which the temperature was increased up to 370–550 °C. Three types of elements (one type of bag filter and two types of candles) were tested. Main parameters investigated for the characterisation of the filtering elements performance were the pressure drop across the element, the cleaning pulse interval, the baseline pressure drop, the filtration efficiency and the durability of the elements. Dependences on the particle loading and temperature among others were also established. Results obtained and conclusions extracted provide a useful tool for the implementation of the filtration technologies at industrial scale.

1. Introduction

Global primary energy demand is growing and is like to continue growing during the next decades. Sustainable development demands a balance between social, economic and environmental considerations. Energy projections made by the World Energy Council, the International Energy Agency (IEA) and the US Energy Information Administration give similar pictures of the dominant role of fossil fuel in the future primary energy global demand. Global demands grow by 40% between 2007 and 2030, with coal use rising the most in absolute terms. Energy efficiency and renewables are in the long term the most sustainable solutions both for security of supply and climate [1–4].

In this scenario, the development of clean technologies capable of increasing the efficiency in power generation systems, and combining the use of renewable such as biomass is of relevance. Hot cleaning gas technologies are framed in this concept since important thermodynamic efficiency improvement could be achieved. However, high filtration temperatures, while beneficial for cycle efficiencies, impose severe limitations on the mechanical durability and corrosion resistance of components in the cleaning gas unit among other aspects. Appropriate hot cleaning gas technologies are therefore being developed and there are numerous R&D programmes worldwide in this sense.

The work presented in this paper summarises the main results obtained from the second experimental campaign carried out in a semi-industrial installation on gas filtration at high temperature 370–550 °C and high pressure (7.5 barg) aiming to investigate the performance and parameters of influence of new-generation filtering elements under a wide range of operating conditions. Three types of elements (one type of bag filter and two types of candles) were tested.

2. Material and methods

2.1. Experimental facility

A simplified diagram of the hot gas filtration test facility is illustrated in Fig. 1. Main characteristics of the facility and the fly ash used for the experimentation are listed in Tables 1 and 2 respectively. A complete description of the hot cleaning gas installation could be found elsewhere [5–8].

2.2. Filtering elements

Three types of filtering elements were tested, one type of bag filter and two types of candles. Relevant characteristics of the filters are presented in Table 3.

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Nomenclature

T	temperature (°C)
μ	gas viscosity (kg m/s)
u	filtration velocity (cm/s)
z_m	thickness of the porous media (mm)
k_m	Darcy's law resistance referred to the porous media (m^{-2})
k'_m	modified Darcy's law resistance referred to the porous media (m^{-1})
Δp_{max}	maximum pressure drop (mmwc)

2.3. Methodology

Three levels of operating temperature were defined. The first level of temperature was fixed at 235 °C, which is the nominal temperature at the dedusting system of ELCOGAS IGCC Power Station. The second level was established at 370 °C as it is the maximum operating temperature of the 3MFB700 bag filters. The third level was set at 550–600 °C; higher temperatures would imply the selection of more heat-resistant materials in some of the elements of the installation (rotating valve, control valve, etc.) which were not available in the market at suitable pilot-size. Additionally, the operation at higher temperatures would not comparatively provide much more information about the effect of the temperature on the performance of the filters. Table 4 shows the levels of temperature corresponding to the filter tested.

Following the methodology proposed in previous testing campaigns [8], characterisation tests were done in first place with the aim of defining the test matrix and the base case, that is, the determination of the parameters of influence on the performance of the filters according to the particular operating conditions.

This phase firstly covered experiments with the *virgin* or *fresh* filter (new filters and tests without injection of particles). Since no particles were injected during these experiments, the influence of the temperature and filtration velocity on the pressure drop across the porous media can be investigated, particularly the value of the permeability of the filter media.

General approaches pursued by most researchers on gas filtration for industrial applications started with Eq. (1) which describes flow through porous media:

$$-\frac{dp}{dz} = k_1\mu U + k_2\rho U^2 \quad (1)$$

where $(-dp/dz)$ is the pressure gradient in the direction of flow, U is the filtration velocity (defined as the volumetric gas flow divided by the external superficial area of the media), so that the first term describes the effect arising from gas viscosity μ, and the second term from gas density ρ.

This way, the flow through an incompressible granular media can be written in this form, known as the Ergun equation, with [9,10]:

$$k_1 = \frac{150(1-\varepsilon)^2}{\varepsilon^3(\phi d)^2} \quad (2)$$

$$k_2 = \frac{1.75(1-\varepsilon)}{\varepsilon^3(\phi d)} \quad (3)$$

where ε is the granular medium porosity, d is the mean diameter and ϕ is the sphericity of the individual granules.

This is normally the case in hot gas filtration applications, with Reynolds number for flow through the medium very small ($U\rho d/\mu \ll 1$). The inertial term-density dependent-term can be then omitted from Eq. (1), leaving the well known Darcy's Law:

$$-\frac{dp}{dz} = k\mu U \quad (4)$$

where k is the medium resistance. Permeability, $1/k$, is defined as the property of the media that permits a fluid to pass through under a giving pressure.

For laminar flow, Eq. (4) still applies for porous media in general. Fibrous porous media suitable for hot gas filtration can reach porosities around 0.8–0.9, with Reynolds number ≪1 for hot gas flow through the media. This way, most authors directly used this

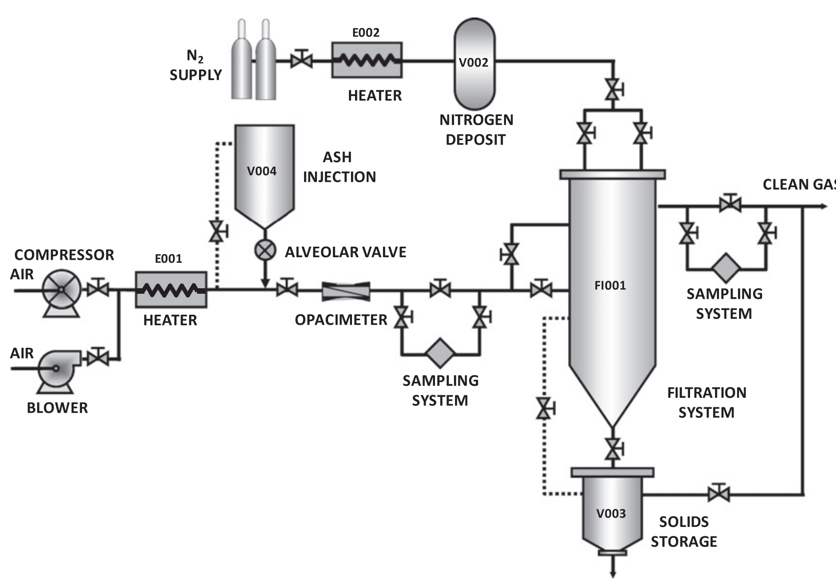

Fig. 1. Basic diagram of the test facility.