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Research Paper

Investigation of the pyrolysis behaviour of hybrid filter media for needle-punched nonwoven bag filters

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HIGHLIGHTS

- Py-GC–MS was proposed analyzing the contents of PTFE for hybrid filter media.
- The pyrolysis temperature was 750 °C with the most abundant species identified.
- The contents of order for PTFE were found with hybrid filter media B, A and C.

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ABSTRACT

Hybrid polymer fibre filter media are critical to the effectiveness of needle-punched nonwoven bag filters. We investigated the pyrolytic behaviour of hybrid filter media to analyze the contents of the components. The pyrolytic behaviour was investigated using pyrolysis-gas chromatography–mass spectrometry (Py-GC–MS). Pyrolysates were directly injected for GC–MS analysis. In total, 19, 22 and 23 compounds were identified with contents varying from 0.29% to 78.30%, 0.14% to 78.75% and 0.34% to 70.96% for hybrid filter media A, B and C, respectively. A large number of monocyclic and polycyclic aromatic compounds were formed when the pyrolysis temperature was greater than 650 °C. The contents of aromatic hydrocarbons increased with increasing temperature. In addition to the aromatic compounds, monomeric and diploid tetrafluoroethylene were produced. The contents of the fluorochemical for the hybrid filter media A, B and C were 46.04%, 52.60% and 1.85%, respectively, when the pyrolysis temperature was 750 °C. A pyrolysis mechanism for the hybrid filter media was proposed based on the determined pyrolysates. The investigation results provide useful information for understanding the thermal properties of hybrid filter media. The contents of PTFE were quantitatively analysed to assess the influence of the hybrid filter media on the abrasion resistances.

1. Introduction

Bag filters are pollution-reduction tools that have been extensively employed in boilers and incinerators and used in the pitch, cement, metallurgy, chemical, mineral, iron and steel industries.

Filter bags comprising fibre-based filter media are typically used to collect particulate matter. The type of filter media used is critical to the effectiveness of a filter bag and determines its filtering efficiency and cleaning frequency. Dust initially collects in the body of a filter bag, and once the bag is filled, dust subsequently collects on the filter bag surface. This filtering process results in the formation of filter cakes [1]. Filter cakes properties, such as specific resistance, height and area distributions, and mean density, depend on many factors, including filtration velocity and dust concentration [2–4]. Filter bags prevent filtered dust from blowing away by utilizing the formed filter cakes. In the dust-collection process, the lifespan of a filter bag is dependent on the duration of exposure to the environment, exposure to acids or bases, steam, high-temperature air, SO_2, NO_x, O_2, and mechanical stresses. Needle-punched, nonwoven fabrics are one of the most common filter media used in filter bags and are regenerated by pulse-jet cleaning [5,6]. The abrasion and fatigue resistances of these fabrics, such as polyphenylene sulphide (PPS), were improved by blend-spinning with polytetrafluoroethylene (PTFE) [7]. The pore size distribution and filtration performance of these composite filter media have been investigated [8]. The mechanical behaviour of PPS needle-punched felt was superior to those of polyimide (P84) and PTFE [9]. Hybrid spun-laced filter media properties, such as

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filtration performance and oxidation, acid and alkali, and high-temperature resistances, were affected by the blend ratios of PPS and PTFE [10]. However, the contents of PTFE in the hybrid filter media comprising PPS and PTFE have not been previously investigated.

Hybrid polymer fibres were used in this experiment to produce a layered filter media comprising PPS and PTFE fibre nonwoven fabric layer, a PTFE filament grid layer, and a PPS and PTFE fibre nonwoven fabric layer. The blended polymer fibres of PPS and PTFE were opened, carded, lapped, and pre-punched to form a pre-punched web for the surface layer of the hybrid filter media. The pre-punched web surface layer and a PTFE filament grid were laminated together in a sandwich structure, which was then needle punched, calendared, thermally pressed and impregnated with a PTFE emulsion to form a hybrid filter media for filter bags. Needle-punched nonwoven filter bags were intentionally prepared with different hybrid filter media compositions A, B and C having the same layered structures but different blended proportions of PPS and PTFE in the surface layers for comparison purposes. The decomposition products were different for the PPS and PTFE polymers; thus, the contents of PTFE were quantitatively analysed according to the pyrolysis products.

Next, the pyrolysis behaviour of the hybrid filter media was chemically analysed to understand the thermal properties of hybrid filter media and evaluate their influence on the rupture strength characteristics of the blended polymer chain. The contents of PTFE were quantitatively analysed to assess the influence of the hybrid filter media on the abrasion and fatigue resistances according to the pyrolysis products. The pyrolysis of a polymer fibre results in a complex mixture and may include different homologous molecules [11,12]. To isolate and characterize these complex pyrolysates, gas chromatography (GC) is typically combined with other detection methods, such as mass spectrometry (MS), Fourier transform infrared spectrometry (FTIR), and nuclear magnetic resonance (NMR) spectroscopy. The most often used technique is pyrolysis-gas chromatography–mass spectrometry (Py-GC–MS). In Py-GC–MS, pyrolysis components are separated and identified by matching measured mass spectra against library standards via probability-based match (PBM) algorithms [13,14]. For complex mixtures, PBM results could be determined with the aid of retention behaviour [15,16].

In this study, hybrid filter media used in a needle-punched nonwoven bag filter was pyrolysed under a helium atmosphere at 550, 650 and 750 °C. The objective of this study was to simulate the pyrolytic behaviour of the media in an oxidant-deficient environment to determine the resultant pyrolysis products. In total, 19, 22 and 23 components were detected with varying contents from 0.29% to 78.30%, 0.14% to 78.75% and 0.34% to 70.96% for hybrid filter media A, B and C, respectively. The detected compounds included decomposition products and other compounds produced by primary and secondary pyrolysis reactions, such as monocyclic and polycyclic aromatics, and other hydrogen sulphide and hydrocarbon-based compounds. A hybrid filter media pyrolysis mechanism was proposed based on the chemical analyses of these pyrolysates. These results are useful for understanding the thermochemical properties of hybrid filter media used in needle-punched nonwoven bag filters and for evaluating the potential influence of the rupture strength characteristics of the hybrid polymer molecular chains. The contents of PTFE were quantitatively analysed to assess the influence of the hybrid filter media on the abrasion and fatigue resistances.

Table 1
Characteristics of the hybrid filter media.

Performance items	Hybrid filter media A	Hybrid filter media B	Hybrid filter media C
Basic weight (g/m^2)	620	668	588
Thickness (mm)	1.95	1.84	2.14
Air permeability at 200 Pa ΔP ($m^3/(m^2 \cdot min)$)	16.89	12.73	19.24

2. Experiment and data process

2.1. Characteristics of the hybrid filtration material

Hybrid filter media was provided by Longyuan Environmental Co., Ltd. (Nanjing, China) for use in the removal of fine solid particulates from discharged flue gases of a coal-fired power plant.

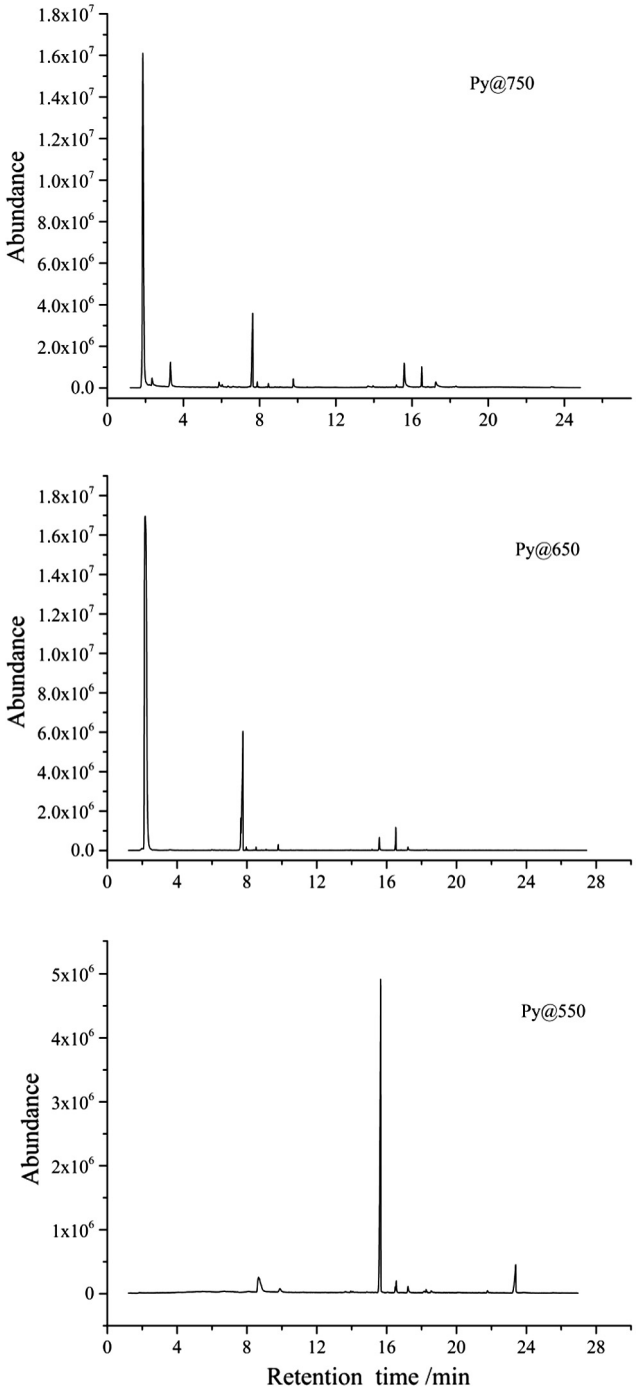

Fig. 1. Total Ion Current Chromatograms (TICs) of the pyrolysis products of hybrid filter media A at different temperatures.