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Project Summary

Performance of a High-Velocity Pulse-Jet Filter, III

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Dust can pass straight through a pulse-jet-cleaned fabric filter and can also pass through by seepage. A model is presented which describes penetration by each of these processes. Comparison of the model with data shows that outlet mass flux from operating filters can be accounted for by seepage alone. Although insufficient information is available to use the model for penetration prediction on an absolute scale, these conclusions suggest that additional research on developing a penetration model should emphasize seepage of collected particles through the filter rather than the process of particle collection itself. Furthermore, these results suggest the trends in outlet flux that should occur with changes in operating variables such as filtration velocity, pulse pressure, and fabric type.

The utility of the present model lies in its ability to interpret penetration characteristics of pulse-jet-cleaned filters that previously could not be explained effectively. The agreement found between data and model predictions for outlet flux over a range of filtration velocities, aeral dust densities, and for two different fabrics lends strong support to the validity of the assumptions used in the model's derivation. These results strongly suggest that penetration models which do not consider seepage as an important penetration mechanism are seriously flawed. Furthermore, these results indicate that penetration models intended to describe the fractional efficiency characteristics of a pulse-jet-cleaned filter must consider the agglomeration characteristics and particle-size-dependent release characteristics of the fabric and dust deposit, rather than relationships between particle size and straight-through penetration alone. These results suggest which future research is likely to be productive, and which is not.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

This report is the third in a series dealing with performance of pulse-jet-cleaned fabric filters. Although each report can be read and understood independently, they are all aimed at the same goal—a better understanding of the factors controlling pulse-jet-filter performance. Maximum understanding may be gained by reading all three reports.

Although pulse-jet-cleaned filters comprise a substantial portion of the fabric filter market in the United States, the factors that affect filter efficiency and pressure drop are not yet well understood. It is likely that filter performance can be improved additionally when a better understanding of the factors that affect performance can be applied to filter design and operation.

This report describes studies of pulse-jet-cleaned fabric filters operated at filtration velocities ranging from conventional to high. It consists of two parts: first, a model for dust penetration through pulse-jet-cleaned filters; and second, an investigation of the forces necessary to remove deposited dust from the surface of a fabric.

Penetration Through a Pulse-Jet-Cleaned Fabric Filter

In spite of many attempts to model penetration through fabric filters (1-4), there is no satisfactory way to predict dust penetration through a pulse-jet-cleaned fabric filter. This is not because of insufficient interest in the problem. Pulse-jet filters have captured a substantial portion of the fabric filter market (5), and the efficiency with which they operate is of strong interest to regulatory officials, to industrial users who must meet emission regulations, and to equipment manufacturers who supply these filters with a performance guarantee.

Performance characteristics which must be considered when modeling penetration include: (1) particle collection by clean fibers in a new fabric, (2) particle collection by the dust deposit accumulated on and in these fabrics, and (3) retention of this dust so it does not seep through the fabric during the rather violent cleaning cycle.

An adaptation of clean fiber bed theory to a study of particle penetration through clean felt of the kind used in pulse-jet-cleaned filters was undertaken by Hampl and Rimberg (1). They found that penetration of 0.35 to 1.1 μm particles through clean, new industrial felts ranged from 20 to 70% at typical pulse-jet filtration velocities, penetrations that are much higher than the 1% or less generally found for intermittently cleaned industrial filters using fabrics well conditioned with dust (6-8). Although agreement is excellent between penetration theory and data for clean, new felt fabrics (1), the performance of new felt in the laboratory is clearly different from that of a well conditioned felt when used in an industrial pulse-jet filter.

Dust Removal from Non-Woven Fabrics

The pulsed jets of compressed air commonly used to clean non-woven fabrics in fabric filters are inefficient at removing the deposited dust (6,9). Measurements on a pilot-scale pulse-jet fabric filter using fly ash test dust indicate that less than 1% of the dust on a bag is typically removed to the hopper by a cleaning pulse (9,10).

Improving the effectiveness of pulse-jet cleaning offers the potential for dramatically improving pulse-jet filter performance. Both pressure drop and, to a lesser extent, collection efficiency are adversely affected by the failure to clean the fabric efficiently. The basic processes controlling the removal of dust from non-woven fabrics must be understood if improvements in cleaning efficiency are to be identified. This section of the full report describes the results of an experimental program to investigate factors affecting dust removal from non-woven fabrics.

Dust is removed from a non-woven fabric in two stages. First, the cleaning pulse separates some fractions of the dust from the fabric. Second, the separated dust falls toward the hopper. Some fraction of the removed dust actually reaches the hopper, but some redeposits on the cleaned bag or on adjacent bags. The fraction of dust reaching the hopper, ε, is thus the product of two separate processes:

$$\varepsilon = \alpha\beta$$

where
α = fraction of dust removed from the fabric by a cleaning pulse
β = fraction of removed dust which falls to the hopper.

As discussed above, the fraction of dust reaching the hopper in actual practice is very low; this can be caused by a failure to remove dust from the fabric, the redeposition of the removed dust, or a combination of both factors. Some investigators (5) have assumed that redeposition predominates, (i.e., the cleaning pulse removes most of the dust deposit) so that dust retention is caused primarily by redeposition. No experimental evidence has yet been presented, however, to confirm or deny this assumption.

It is important to determine the relative importance of inefficient dust removal and redeposition to inefficient cleaning, as system modifications to improve performance (i.e., reduce dust retention) could differ greatly depending on which factor is more important. System modifications which would eliminate redeposition altogether (e.g., compartmentalization and air flow shut-down) might have no effect on improving dust removal from the fabric.

Factors affecting the removal of dust from a non-woven fabric by a compressed air pulse are discussed elsewhere (11). The air pulse causes static pressure to increase inside the bag; the difference between this static pressure and the operating pressure drop across the bag during cleaning causes a force which accelerates the fabric and dust outward. The fabric is not stretched tightly around the cage, and so can accelerate radially outward to reach a maximum velocity during cleaning, v_c.

At some point after attaining velocity v_c the fabric approaches its full outward expansion and decelerates; the dust deposit, however, tends to continue traveling radially outward. If the adhesion force binding the dust to the fabric is less than the peak deceleration force caused when the fabric substrate slows as the bag reaches full expansion, the dust will separate from the fabric.

At least one other mechanism could operate to remove deposited dust during a cleaning pulse. Besides flexing the fabric, the pulse causes air to pass in the reverse direction through the fabric and dust; this reverse air flow could reentrain and remove deposited dust particles. Löffler (12) has summarized the available experimental data concerning "blowoff" of particles from fibers. The velocities needed to remove a deposited particle are always much higher than the velocity at which the particles were deposited. Smaller particles are more difficult to remove than larger particles because of their larger adhesive/drag force ratio. Even relatively large particles need rather high velocities to blow them off fibers. For example, Larsen (13) found that a velocity of 20 m/s was required to remove the first 16 μm diameter glass sphere from an 830 μm glass fiber.

Conclusions

Dust can pass straight through a pulse-jet-cleaned fabric filter and can also pass through by collection and subsequent seepage. A model is presented that describes penetration by each of these processes. The model reflects empirical data that show that most dust loss from operating filters takes place by seepage alone. Although insufficient information is available to use the model for penetration predictions on an absolute basis, the results may be used to indicate the penetration trends that will occur with changes in such operating variables as filtration velocity, cleaning pulse pressure, and fabric type. These results indicate that research should emphasize seepage of collected particles through the filter rather than the process of particle collection itself.

Although pulse-jet cleaning has advantages over other fabric filter cleaning systems, an inability to discharge a large fraction of the deposited dust to the dust hopper can have a seriously adverse effect on system pressure drop. Bench-scale tests indicate that pulse-jet cleaning may become very inefficient for removing deposited fly ash from the surface of polyester felt. Experiments over a wide range of fabric cleaning conditions measured dust removal efficiencies from 2 to 36%. Tests under conditions thought to be typical of a full-scale system resulted in a dust removal efficiency of about 12%.

The fraction of dust removed from a felt fabric during cleaning was found to be closely correlated with the kinetic energy imparted to the dust deposit. If cleaning energy could be transferred to the dust deposit more efficiently, either by improving the pulse-jet or applying different cleaning methods, non-woven fabric filters could be operated at higher filtration velocities or at lower pressure drops.

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The complete report, entitled "Performance of a High-Velocity Pulse-Jet Filter, III," (Order No. PB 82-196 361; Cost: $7.50, subject to change) will be available only from:
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