Investigations into Optimal Pulse Cleaning of Dust Filter Media

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ABSTRACT Reverse jet pulse cleaning is a widely adopted method for cleaning filters in industrial applications. Such filters can typically take the form of bag filters or pleated cartridges – the actual mechanisms for particle removal from the media being different in both cases and are strongly influenced by the pulse pressure that presents against the internal surface of the filter media. Current practice in industry can see the use of compressed air reservoirs operating up to 5 bar to deliver a compressed air pulse into the throat of filters (via one or more distribution pipes) – however, in many cases the pressure used in the system can be arbitrarily arrived at and may not be optimal (resulting in poor cleaning and/or wasted energy in the form of compressed air). This paper considers the output from a novel small scale air filter media test rig which indicates the potential for defining an optimal cleaning pressure using an accelerated test procedure.

1. INTRODUCTION

The configuration of air supply to reverse jet pulse cleaning filtration systems has scope for adjusting supply reservoir pressures and solenoid operational durations. From the perspective of hardware, little can be modified once a bag house / silo filter house has been installed to directly influence the cleaning function of a given filter array (bags or cartridges). In the context of an installed system, venturi may have been incorporated in the design, which will serve to optimise the functional aspects of the pressure pulse that will propagate from the blast tube into the filters (1, 2, 3). Retrofitting of venturi is usually not a viable proposition due to the lack of height between the throat of the venturi and the outlet port of theblast tube to adequately allow the pulse 'cone' to expand to the venturi throat diameter (and hence optimal gas induction effects are compromised).

Common to virtually all industrial systems is the use of a common air pressure reservoir external to the head space that connects via individual solenoids to multiple blast tubes that run along the axis of bags or cartridge arrays across the breadth of the filter housing. In most cases, these blast tubes feature simple drilled apertures (approx. 6mm diameter) that are intended to align with the centreline of cartridges (such precision being unnecessary for apertures arrayed along the axis of a bag tube filter media), however the presence of a vertical stub may also be found, which is intended to impart a vertical presentation of the gas pulse into system (as opposed to the air trajectory delivery associated with a plain perforated blast tube). Some reverse jet systems employ a blast tube (4) arranged vertically down the axis of the filter with the intention that a preservation of gas pressure from air reservoir to the filter face can occur (in this instance, the distance from the blast tube aperture to the media permits minimal expansion of the pulse 'cone') and thus the interaction area tends to be small. The use of an inverted cone insert down the interior of a cartridge filter has also been investigated as a means for preserving outward pulse pressure (Li, 2015).

Generally, it should be clear to the reader that the practical scope for improvement in cleaning performance is limited to pulse pressure and pulse duration. With this in mind, it should come as no surprise that many installed filter system settings are 'optimised' at a local level – the mindset being that if some nominal air settings are good, then increases (usually in air reservoir pressures) in those settings will bring still greater efficiencies. The use of excessive air settings to 'improve' cleaning often does not bring the anticipated benefits and in many cases can incur reductions in cleaning performance and high energy costs (in terms of compressed air consumption). In this respect the question that arises is what is the optimal cleaning pressure and pulse duration? This question has been the basis for investigations undertaken at The Wolfson Centre for Bulk Solids Handling Technology, University of Greenwich, UK.

2. TEST EQUIPMENT

The apparatus used to evaluate the effect of pulse pressure on cleaning efficiency has been designed and constructed in-house. The key features are shown below (Fig 1).

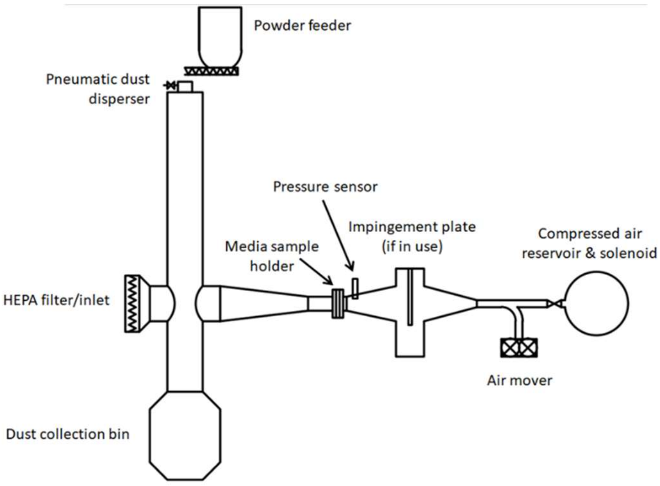
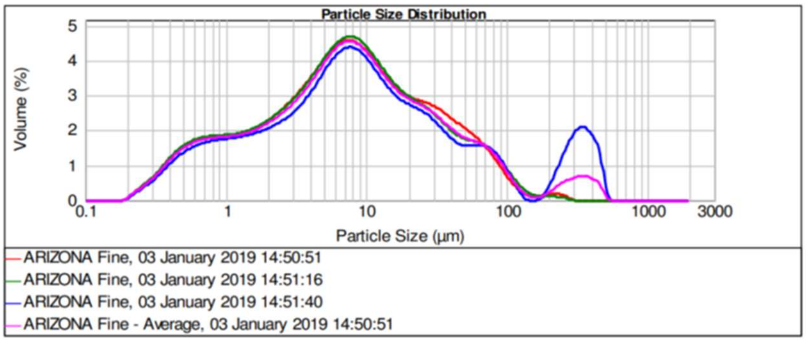


Figure 1 Schematic drawing of the filter test rig

The test rig consists of a K-tron K20 powder feeder that doses the test powder into a 150mm diameter vertical pipe that features an air jet after the end of the screw to induce a dispersion of the powder that descends towards the collection chamber at the base of the 2m tall tube. At a point 1.5m from the start of the vertical tube, a junction is present that has a short horizontal stub and HEPA filter on one side and a transition pipe that reduces from 150mm diameter to 60mm diameter over a distance of 1m. At this point, a clamped flange arrangement is used to hold a 90mm diameter of filter media (which, when installed, presents a face diameter of 60mm). Pressure transducers are installed to record the pressure drop across the membrane as trials progress. Beyond the media holder, the duct progresses past an impingement chamber (not employed in this investigation) and is directly connected to a solenoid valved ahead of an air reservoir (noting that the pulse path is directly inline with the filter media test sample). A branch curves downwards and connects to a sliding vane vacuum pump.

The 'dust' employed in this apparatus was a standard "Arizona fine dust" (Fig 2)



Sample reference	Particle Size Distribution		
	d_{10}	d_{50}	d_{90}
Arizona Fine	0.8µm	7.4µm	55.1µm

Figure 2 Particle size distribution for the Arizona fine dust used in the investigation (noting that the reported 'coarse' content was most likely agglomerations and not grit).

The filter media was supplied by Filtration Group GmbH and was a non-directional (i.e. filtering from either side of the media) standard polyester wet-lay fibre form (Fig 3).

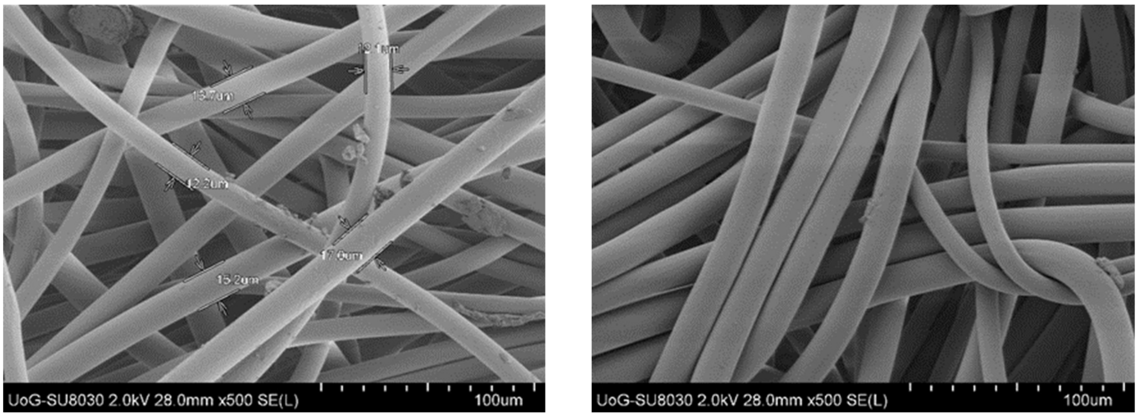


Figure 3 SEM images of the polyester fibres at high magnification (scale bar = 100µm)

2.1 Test methodology

The requirement for the test rig was to provide an indication of the impact of pulse pressures on filter service life. In the context of this study, the definition of 'service life' for the test filter media was based on the progressive accumulation of irrevocably embedded particles relative to the total mass responsible for achieving a 15mbar pressure drop across the membrane. Within industry, it is well understood that almost all regenerative filters undergo a period of 'conditioning' during which particle capture into the media forms an element of the ongoing filtering function. Such conditioning periods can take up to two weeks – being influenced by many installation specific variables. From the perspective of a laboratory-scale approach, many compromises are necessary, and in this respect, the cycling of the test filter in an industrial time frame was not viable for the large number of data points required. In this respect, the approach adopted was for an accelerated test procedure to artificially drive the media to an 'end of service life' condition. This was achieved through the use of a face velocity of 100mm/s (normal operating conditions for a new reverse jet filter in industry being typically ~35mm/s).

Although the use of 100mm/s may seem an extreme face velocity to impose, it should be born in mind that once a filter is installed and brought into service in industry that the functional filter area can reduce substantially as a result of several (often interacting) factors. A common reduction in functional filter area (in the context of reverse jet pulsing) relates most significantly to systems that employ venturi into the throat of the filters. The absence of these venturi usually results in the interception of the pulse 'cone' of pressure intercepting with the interior filter wall at a distance of ~0.2m from the top of the filter. This upper 0.2m distance will see a gas induction effect, and a cleaning function cannot occur over this region. Thus, within a filter, conditions can develop that support both full and incomplete cleaning (5, 6) – often termed as 'patchy' cleaning. Data obtained in previous test programmes by author supports this gas distribution effect (Fig 4).

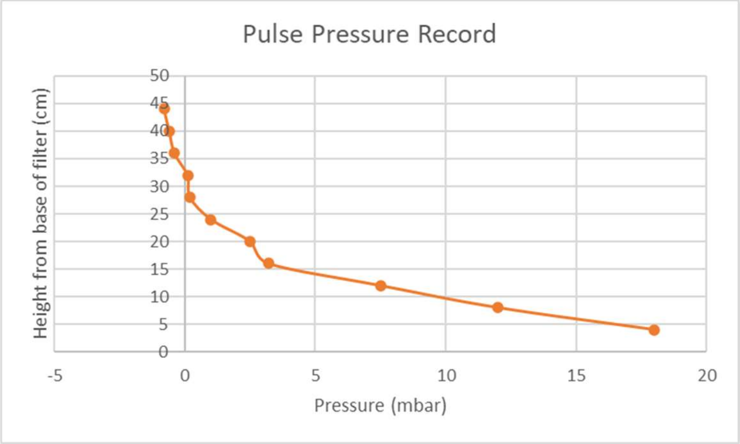


Figure 4 Lateral pulse pressure distribution for a single 500mm long cartridge filter element

Thus, although a given filter array may be critically sized to deliver ~35mm/s face velocity, it is very likely that many filter arrays operate with much higher face velocities. With this in mind, the adoption of 100mm/s face velocity in the test apparatus is not as extreme as it may appear on the first inspection. It was considered that the selected velocity presented the best compromise for obtaining an accelerated set of test data that could be considered as a 'benchmark' rather than a direct reflection of an industrial system.

The approach employed in the test programme was to draw dust onto the filter media and record the increase in pressure drop to a peak value of 15 mbar, at which point the equipment would be shut down and the test sample removed and weighed (having previously recorded the weight of the clean sample). From this, the total mass of dust responsible for the peak ΔP was ascertained. The sample would then be reinstalled and subjected to a reverse pulse of air, following which the sample would be removed and reweighed – from which the particle mass removed and the particle mass retained into the media could be calculated. Repeating this over a number of loading and cleaning cycles would generate data that could be plotted out, with the intercept between the mass removed and the mass retained being used as the endpoint for the test programme. Fig 5 presents a plot for one such series of tests.

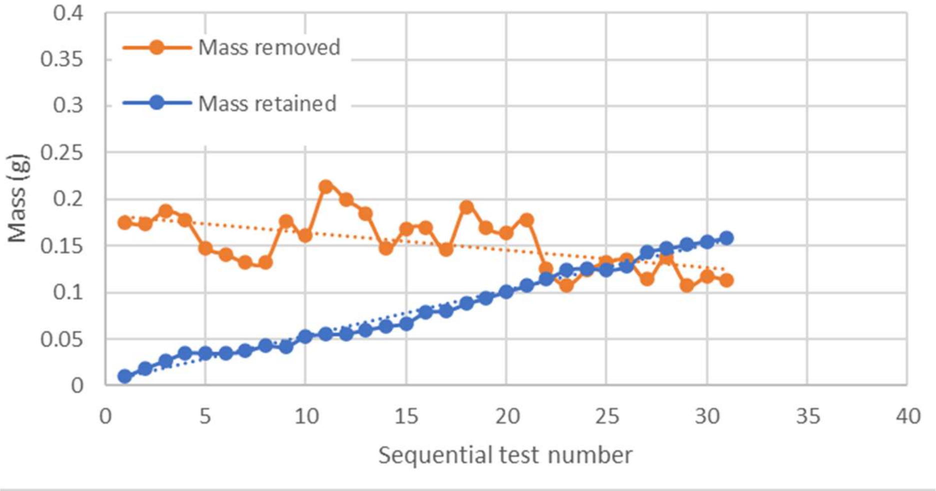


Figure 5 Example plot illustrating the intercept point of particle mass removed and particle mass retained

3. TEST OUTPUT

A series of tests were undertaken using pulse pressures of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 & 3.5 bar in combination with a solenoid trigger duration of 100ms. The results obtained as an average of two test series for each condition appear in Fig 6.

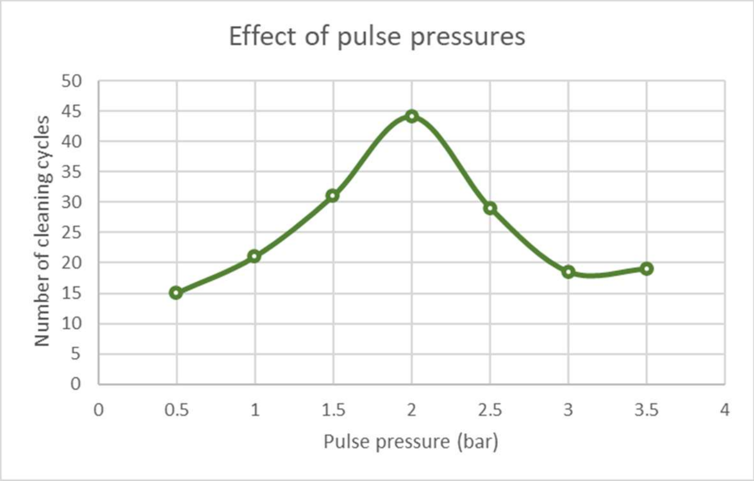


Figure 6 Graph showing the impact of pulse pressure relative to the number of cleaning cycles before ΔP becomes dominated by irretrievably embedded particles.

4. DISCUSSION

Inspection of the data indicates that for a given filter media subjected to the imposed test conditions, an optimum pulse pressure has been found to exist. In this graph (Fig 6) it can be seen that below 2.0 bar pulse pressure, the filter media is attaining the intercept condition for removed and retained (which is the cut off point for efficient filter operation in the context of the test programme). Conversely, pressures beyond 2.0 bar can be seen to also reduce the number of test cycles before the intercept condition develops – allowing a substantial increase in test cycles compared to the next pressure preceding and following 2.0 bars.

Considering this cleaning behaviour, the relatively poor particle removal characteristics can be attributed to a basic lack of gas velocity to drag particles back out of the chaotic labyrinth structure of passageways into which the particles have lodged. The progression of passageway blocking (and hence pressure drop development) proposed in this investigation considers that the most convoluted passage choke first, whilst the larger of more direct passageways will naturally pass more air and self-clear or start to generate a lateral migration as the pressure drop within them starts to evolve. Ultimately restricted pathways connecting to the surface and lateral pathways choke, and the pressure drop in the more dimensionally ‘open’ channels starts to build and ultimately would lead to stalling of particle migration. During the test programme, evidence of lateral migration of particles within the media was found to occur to a radius of ~5mm from a given entry point. Thus, a reverse pulse must be able to deliver gas (expanding to atmospheric pressure through the media) with sufficient energy to dislodge embedded particles in a reverse direction to their original migration route. The distribution of pathway characteristics in the opposite direction to the embedment route dictates that the ability to get enough into the media and for it to distribute is key to particle removal.

However, if the pressure of the gas delivered to reverse face of the media is too high, it is speculated that the local pathway pressure drop serves to choke the volume of gas that can enter into the media and hence internal velocities fall to a level that dislodgment become adversely affected.

Evidence of the flow choking effect when local velocities into open pathways surrounded by choked pathways can be seen in Fig 7. This effect can be found referred to as ‘pin holing’, and due to the choking off of the relatively minor pathways through the media, local gas velocities increase proportionally through the available channels leading to a choked gas flow and increased pressure drop.

Figure 7 Evidence of scope for ‘pin-holing’ and the presence of pathways clear of build-up (image from a previous study with a different filter media, but identical test conditions).

5. CONCLUSIONS

Despite the presented data set having been obtained from tests undertaken with a single filter media and particulate type, the results tend to support the contention that for a given industrial application, an optimium pulse pressure exists – beyond which the cleaning function may deteriorate. The general peak cleaning characteristic that has been reported is considered likely to shift to higher or lower pulse pressures in response to differences in filter media form and dust particle characteristics. The implied oprtimal cleaning pressure will also be influenced by how well the triggering of the gas pulse is linked to the peak pressure drop that a given filter is driven to. Delayed triggering, as would be associated with a poorly configured time based cleaning system, could result in stronger lodgement of particles into the filter media and hence present a requirement for either longer pulse duration or adjustment of pulse pressure (the test data presented here was generated by a employing strictly observed peak pressure drop of 15mbar).

The test method employs operational variables that are the result of the need to obtain repeatable test data within a reasonable period of time (each series of media 'life span' tests requiring up to 14 hours of activity) and the procedure is considered to offer a useful, accelerated method for benchmark evaluation of filter media performance.

Further parameters that will be examined in future work will include pulse duration, alternative filter media and filter forms (i.e. pleated media).

6. ACKNOWLEDGEMENTS

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7. REFERENCES

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