The Effects of Reverse Jet Pulse Over-Pressurisation on Dust Filter Performance

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Abstract

Industrial use of air filtration systems is widespread and the range of approaches to achieve particle capture reflects the fact that such systems need to be tailored to specific applications if good performance is to be achieved. Commonly the budget for air filtration systems is one the early victims to 'value engineering' in plant projects – with obvious implications for the specification of particle capture equipment. The method of cleaning filter systems can range from agitated frame supported bags to reverse jet cleaning systems (the latter becoming increasingly the norm in industry). The quality of engineering in reverse jet cleaning systems can vary considerably – with the end user usually being oblivious of the implications for life cycle for different styles of system.

This paper considers the operational aspects of parallel and tapered form pleated cartridges based on pulse pressure propagation and particle dislodgement (and more critically particle retention at different pulse conditions).

Introduction

Reverse jet cleaning systems are widely applied into many vendors filtration equipment and can provide a very effective means by which to dislodge particles from filter media. A useful amount of work has been undertaken by researchers [1] in this field whereby pressure drop development and cleaning functions have been evaluated at single sock and multiple sock scales of scrutiny. Within these works useful comparisons have been made regarding on line versus off line cleaning functions and the effects of these on interpreting performance data.

The pressure drop that develops over the service life of a filter that is cleaned using either back flush or reverse jet cleaning does so as a result of particle penetration into the filter media which progressively saturates the interval voids to the extent that particle holding capacity reduces and particles begin to accumulate on the face of the filter. The initial stage (capture within the media) is associated with a fairly slow pressure drop progression, whilst the latter stage results in a markedly higher rate of pressure drop progression. Over time the performance of a given filter will reduce (in the context of reducing time to reach a given peak pressure drop – triggering cleaning) which is a function of a progressive accumulation of permanently lodged particles within the media. This trend is shown in Fig 1, whereby the total mass of material accumulated for a given pressure drop has been weighed before and after pulse cleaning of a 60mm diameter filter sample. For the purposes of this experiment a reservoir gas pulse pressure of 0.5 bar was applied to clean the target – which is a value well below levels commonly employed in industry but which serves to give an exaggerated indication of the problem that can develop if particles become permanently lodged within the filter media.

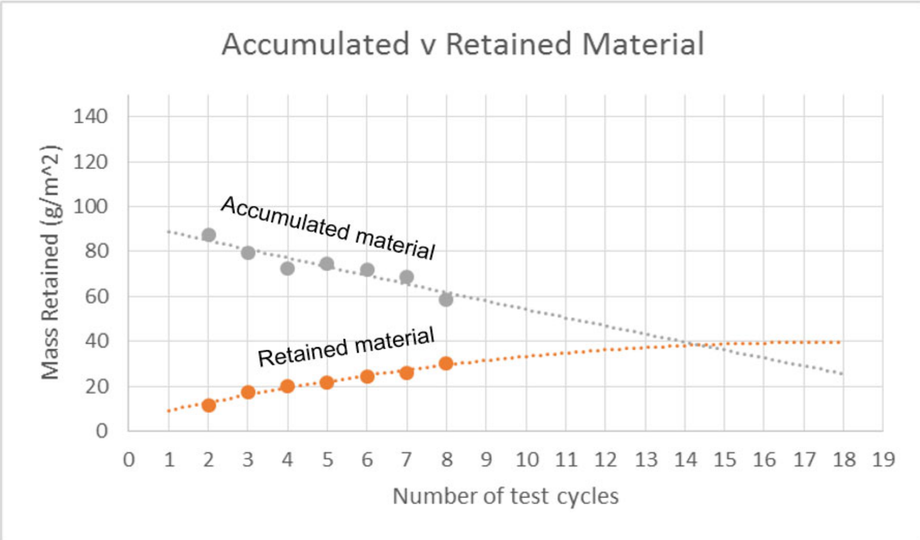

Fig 1 Trends for particle mass responsible for pressure drop contributions (0.5bar pulse cleaning)

Clearly for filtration systems used in industry the ability to slow the rate of permanent embedment is critical to the overall life cycle for a given set of filters and in this respect a perceived tendency towards an increased rate of pressure drop development is sometime countered (at maintenance level) by increasing pulse pressure in reverse jet systems. This can have detrimental effects and actual worsen the operating conditions of the filter. In order to make sense of this statement, it is important to consider the cleaning mechanism for a given filter media subjected to a pulse of gas. It is generally considered that particle dislodgement and transport away from the face of a filter is a multi-stage process [1], whereby the initial phase is a reversal of pressure gradient through the media followed by an acceleration of the media. Particle dislodgment occurs at the point in time that the media has reached the limit of its expansion and rapidly decelerates – at which point the particles (that can be dislodged) continue to move outwards and away from the surface of the media. The gas volume behind the pressure front then supports transport of particles away from the filter. This general descriptive for particle removal will obviously vary down the length of a given filter as the pressure decays and the gas volume increases (hence the use of tapered filter cartridges is sometimes favoured for its potential benefits relating to maintaining pressure pulse strength as the circumference reduces). It has also been noted that, typically, only 1 – 10% of the particles dislodged in a cleaning cycle actually leave the local environment of the filter media and deposit into the base of the filter housing [2]. This is because of the brevity of the pulse duration (~10 msec), which when dissipated is quickly reversed by the operating pressure within the filter house, local fugitive particles may be re-entrained into the filter. By contrast the off-line cleaning function associated with mechanical agitation of filter frames or back flush (which are, in effect, off-line functions) have a substantially greater duration (several minutes) over which to achieve dislodgement and particle settlement into the filter house - accepting that in the former case the deposit for removal would only present on the filter face under normal conditions.

Within the dynamic conditions leading to particle removal, there are clearly very strong influences exerted by the filter media that dictate the efficiency of particle removal. Aside from the physical structure of the filter lay and it specification for a given application (which clearly influences capture and pressure drop characteristics), the resulting rigidity of the media and its form dictates the operating condition for cleaning. In particular an important aspect is the resulting rigidity of the filter. If it is accepted that deceleration of the media is key to initiating particle disengagement, then the pulse pressure required to provide the excitation of the media must be appropriate. Previous work on this subject [2, 3, 4] has shown that for flexible bag fabrics 30g deceleration is adequate for cleaning, whilst more rigid media could require up to 200g (typically 125g) for complete cleaning. It is clear that a trend exists that relates the ability to clean to a relationship between media rigidity and available pressure – for a given media type.

Adding complexity into the inter relationship between media form and pulse pressure is the effect of pulse pressure at elevated values. Recognising that pulse pressure is key to the ability of reverse jet systems to clean effectively, it follows that pulse pressure decay can become an issue when operating in conjunction with long filters (~2m). It has been found that in such situations pulse pressures at or above 3 bar are typically required to provide a useful cleaning function [1, 5] - noting that as pulse pressures increase so does the risk of pulse reflection from the end cap of the filter candle which can serve to induct local fugitive material onto the filter.

Preliminary studies undertaken at The Wolfson Centre for Bulk Solids Handling Technology using a laboratory scale filter media test rig (which has the capability to test either 90mm diameter flat discs or 200x200mm pleated media forms) to measure pressure drop progression and particle dislodgement have shown an effect of pulse pressure on cyclic filter loading behaviour. Fig 2 shows a typical regressive trend associated with the initial and progressive cyclic loading of a new filter

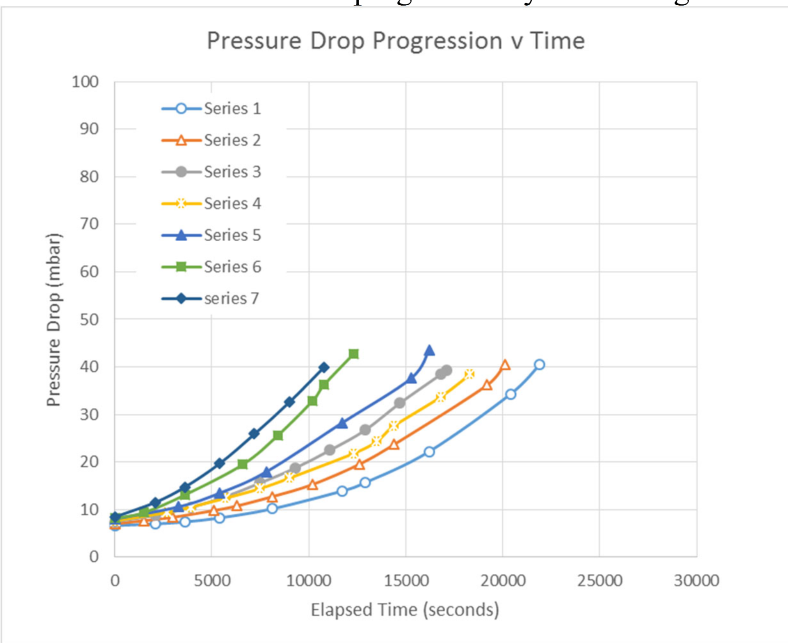

Fig 2 Regressive pressure development profiles for wet laid synthetic filter media pulsed off line at 0.5 bar reservoir pressure

Within these trends it can be seen that the time taken to reach a user defined peak pressure drop decreases as the irretrievably lodged particle population increases (noting from previous Fig 1 that the actual retrievable particle mass will be reducing over time). The trends shown here are accelerated over the likely deterioration behaviour for a full size cartridge out of necessity to obtain indicative information within a reasonable time span. For a full size system these trends could be anticipated to collapse down to a much reduced rate of pressure deterioration – but still progress over time to an unserviceable condition. The data gathered was obtained by measurements of pressure drop across the test filter sample followed by removal and weight comparison between the original clean weight, the accumulated mass held in/on the filter and the gain in mass following a reverse pulse cleaning cycle at a user defined pressure (hence the data in Fig 1 can be derived).

Using the same test methodology and new samples, the media was cleaned using a 2 bar pulse – which resulted in the trends shown in Fig 3.

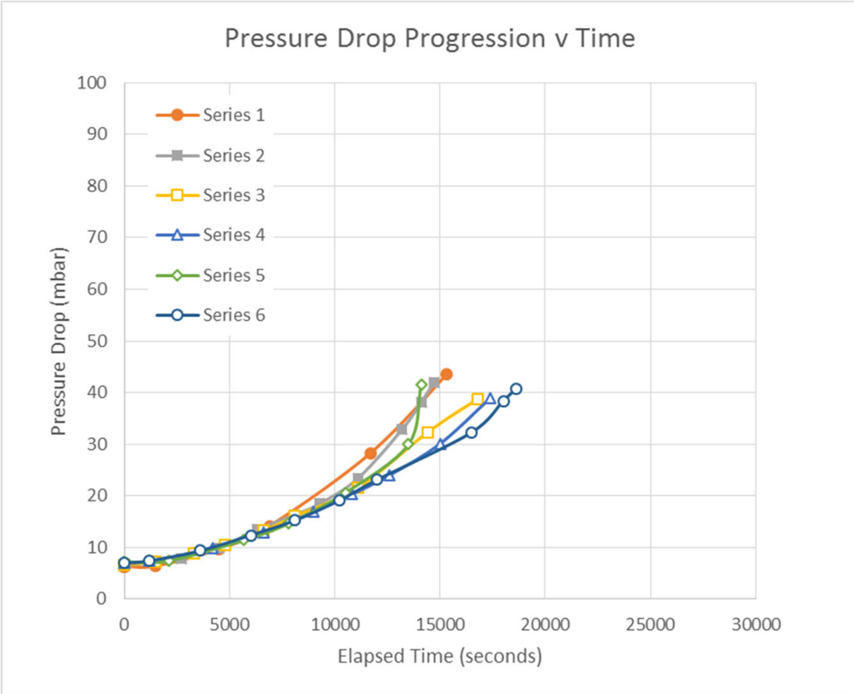

Fig 3 Regressive pressure development profiles for wet laid synthetic filter media pulsed at off line 2 bar

Comparing the data presented in Figs 2 & 3, it is very clear that the characteristics for the media have changed for the same test conditions. The trends can now be seen to have collapsed onto each other in the early stage of particle capture, but the test results now suggest an extension of the collapsed trend towards a finite point where all data will lie closely together on a common trend. This final behaviour is likely to represent a stable filter condition.

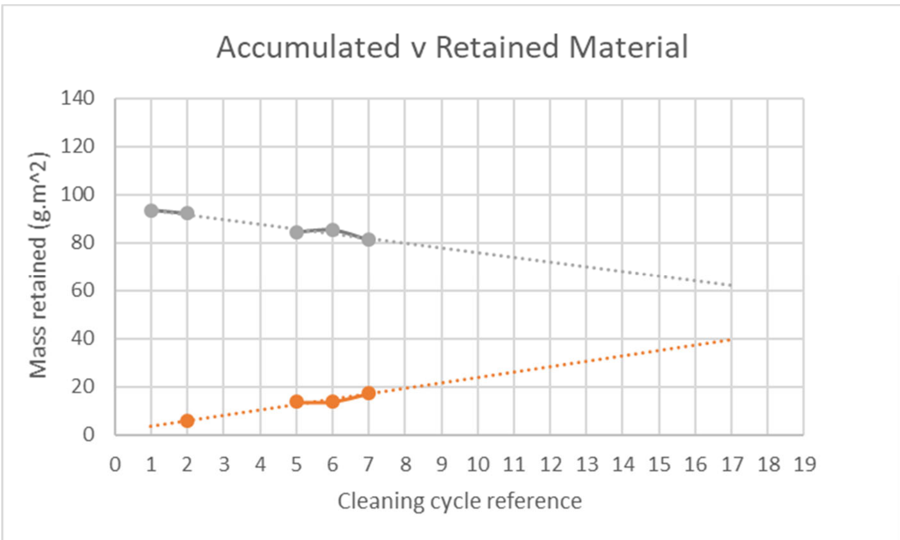

Fig 4 Trends for particle mass responsible for pressure drop contributions (2 bar reservoir pulse cleaning)

Examining Figs 1 & 4, it can be seen that (based on a projection from a limited number of data points) the rate of irretrievable embedment is significantly lower. Had the test programme progressed for longer it is considered likely that the irretrievable embedment rate would decrease further (i.e. the filter media would attain its 'conditioned' stable operating loading).

Accepting that the preceding examples of laboratory data have been obtained at a small scale, it does nonetheless present an interesting comparison of the effect of pulse pressure on filter cleaning for common loading conditions. It can be argued that since pressure decay for reverse pulse travelling down a permeable tube is inevitable, then the phenomenon captured in the test work may be analogous to the upper and lower operating / cleaning conditions down through a filter [6]. Noting that for a typical reverse jet system, maximum pressure / cleaning efficiency occurs approximately 0.2m from the throat of a cartridge filter (where the pressure front first intercepts with the wall of the filter) and progressively deteriorates from that point downwards [6]. Thus, the cleaning mechanism is not constant down the length of a filter candle –meaning that particle capture will also be influenced, by virtue of different regions of the filter being at different stages of the progression from in-depth particle saturation to surface capture.

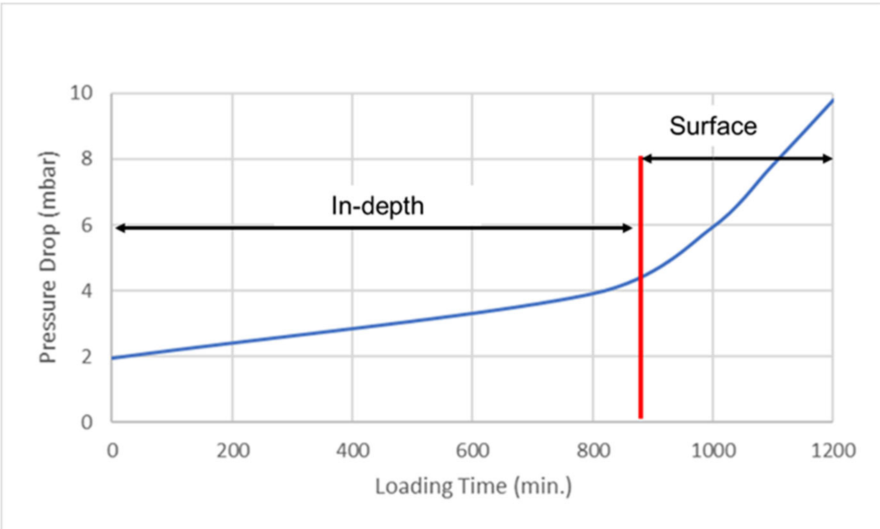

Fig 5 Graph showing typical change in pressure gradient at the transition from in-depth to surface capture [7]

In such a scenario of variable cleaning down a filter, it can be appreciated that it may not be correct to assume a homogenous loading and release occurring. Constraining bands and end plate attachment bonds will also lead to local increases in filter rigidity, which can influence the efficiency of the pressure pulse [3].

Conclusion

In summary, it has been shown that pulse pressure has a strong influence over the ability of a filter media to dislodge particles and extend the life cycle for filter units. During the operation of reverse jet cleaned filters, energy consumption related to compressed air usage can be significant – thus a balance needs to be achieved between pulse strength and frequency. Moderate reductions in both parameters can bring useful energy savings, however such fine tuning can only be undertaken with confidence if the operating characteristics of the filter media are known (or benchmarked against alternatives).

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