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Disturbance Attenuation Using Fluidized Bed of Nanoparticles

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Abstract **–** The present work investigates the attenuation of disturbance through a fluidized bed containing highly porous ultrafine nano-powder. In order to characterize the disturbance attenuation through the bed, fast pressure transducers with a response time of 1 ms were used while the bed was subjected to flow pulsation of different frequencies. Using pressure transducers, pressure transients across the whole bed as well the middle section of the bed were rigorously monitored and recorded with the help of data acquisition system sampling at rate of 1000 Hz. Velocity perturbations were introduced in the bed by controlling the inlet flow of the air to the fluidized bed with the help of solenoid valve that was operated using digital input-output signal from the data acquisition system. It is shown here that disturbances introduced in the bed due to velocity fluctuations are mitigated the fluidized bed. This aspect of the fluidized bed of nano-powders can be effectively utilized for the attenuation of disturbances.

Keywords**:** Fluidized beds, Ultrafine nanopowders, Disturbance attenuation, Pulsation, Pressure transients

1. Introduction

Ultra-fine powders of hydrophilic nanoparticles often exhibit tremendously high porosities. In some cases, their void fractions could reach as high as 0.98 as compared to 0.40–0.50 normally encountered with beds of micro- or macro-sized solids. Whilst most current large-scale applications of nanoparticles are mainly geared towards utilizing their tremendously high surface area for enhancing surface based rate processes which are often compromised due the agglomeration phenomena, the high porosity aspect of the ultrafine nano-powders however remains unaffected by the agglomeration phenomenon. Since pressure drop is strong function of bed porosity, both in laminar as well as turbulent flow regimes, the existence of high bed porosity ensures extremely low pressure drop. It is shown here that this aspect of the nano-powders coupled with their low minimum fluidization velocity can be effectively utilized for the attenuation of strong disturbances. Since the porosities of the bed of nano-powders is substantially higher than those of granular media composed of bigger-sized solids, the propagation of pressure waves could similarly be significantly different (Hostler and Brenen 2005).

2. Experimental

Details of the experimental set up are described elsewhere (Ali and Asif, 2012). Due care were taken to ensure elimination of entry effects using high density of 0.20-mm perforation drilled on a 12-mm thick plate distributor, which was preceded by 0.50-m long calming section. As shown in Fig.1, the test section was 1.5-m long and 70-mm internal diameter Plexiglas followed by 0.50-m long and 0.10-m internal diameter disengagement section. Fluctuation free compressed air was available at 85-psig pressure. Its flow was monitored using electronic flow-meter that provided an analog output in the range of 0–5V. As shown in Fig. 2, a two-way normally-open solenoid valve was located between the flow meter and the column. The opening and closing of the valve was controlled using a data acquisition system (DAQ) connected to a laptop running Labview software. The valve opening allowed the abrupt start of the flow of the air through the column while the valve closing ensured an abrupt supply cut-off. The air flow rate was carefully recorded by connecting the output signal of the flow meter DAQ.

Flow pulsation in the inlet air was introduced to the test section of the column (packed bed) at a preset air flow. Three different pulse frequencies, namely 0.25 Hz, 0.10 Hz and 0.05 Hz, were used for introducing disturbances in the bed. A pulse of 0.25 Hz means that the air supply was allowed for the duration of 2 seconds and closed for another 2 seconds.

The pressure transients of the bed were carefully monitored using fast response piezo-resistive differential pressure transducers with a response time of 1 ms. Local pressure drop was recorded with pressure ports located 110 mm and 230 mm above the distributor using a sensitive bidirectional pressure transducer, Omega PX163-005BD5V. Its measurement range was ±5 inches of water. The global pressure drop was also recorded using a differential pressure transducer (Omega PX163-010D5V) with a range of 0–10 inches of water. The lower port of the global pressure drop measurement was located immediately above the distributor while the upper port was exposed to the atmosphere. The settled bed height of the bed material was approximately 340 mm. Thus, the upper port of the local pressure drop measurement was always below the settled bed height.

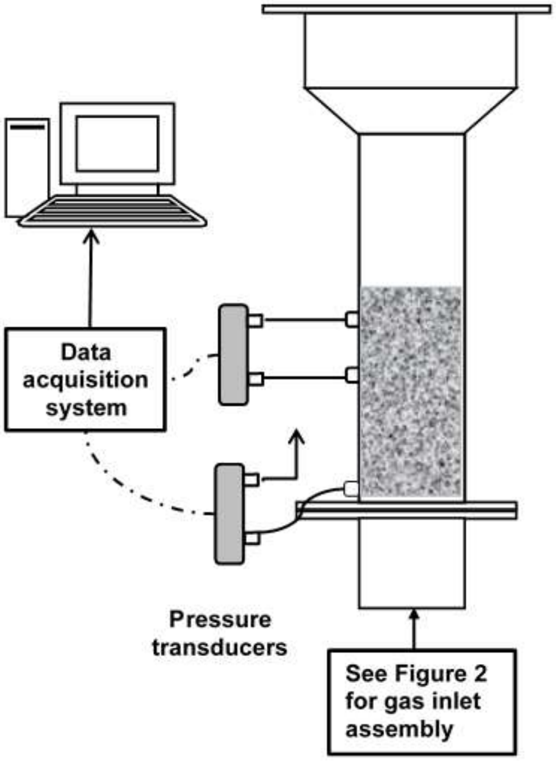

Fig. 1: Schematic of fluidized bed containing highly porous ultrafine nano-powder.

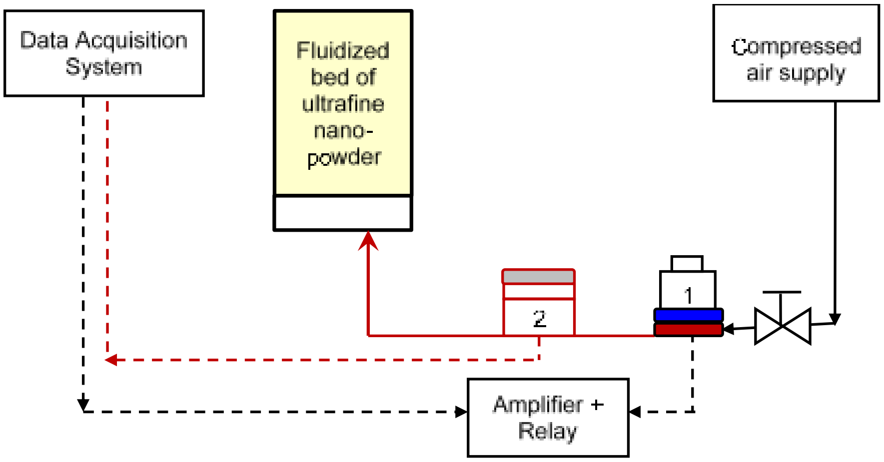

Fig. 2: Schematic of inlet flow scheme using pulsed flow ; 1-Normally open 2-way solenoid valve as shown in Fig. 1; 2- Electronic flow controller for primary flow

3. Results and Discussion

A typical bed response is shown in Figs. 3a-b for the velocity of 33.2 mm/s which is just above the minimum fluidization velocity. The case of 'no pulse', which means that a steady and non-fluctuating flow of the air is maintained through the bed, is also shown in the figure. This reflected in the steady pressure drop in the bed. It is seen in Fig. 3a that the local steady state pressure drop is almost 25 Pa which sharply rises to as much as 100 to 120 Pa due to the pulse. Thus, the increase in the pressure drop is almost five times due to the disturbance introduced by the step change in the velocity. In fact, it is the pressure buildup in the air inlet line when the valve is closed that yield a several fold increase in the velocity over that of its preset value. This phenomenon is reflected in the sharp peaks in the pressure transients. It is moreover seen that peak values are higher in the case of higher frequency pulse owing to the larger valve closing time. Once the flow pulse starts, it quickly attains a steady value. The time of attaining the steady value is nevertheless not affected by the pulse frequency. There is another notable feature of the figure. When the valve is closed, both 2-s as well as 5-s pulses show negative pressure drop, which slowly move towards attaining the steady state value. Note that while 2-s time duration is just enough to attain the steady value after the valve opening, the same time duration is not enough for the bed to attain the zero value after the valve closing. The negative value in the pressure drop is caused due the backflow of the trapped air in the bed when the air supply is abruptly switched off by the valve closing.

The case of global pressure drop is depicted in Fig. 3b for the velocity of 33.2 mm/s. The steady state pressure drop when there is no pulse higher than what is seen for the case of flow pulsation. This is due to the fact that the bed was a little non-homogeneous before the start of the flow pulsation. Therefore, 115 Pa can be taken to be a more accurate value of the steady state pressure drop. There are no peaks seen in the global pressure drop as against several peaks noticed for the local pressure transients. This is a clear indication that the bed attenuates the disturbance in the velocity signal which is reflected in the attenuation of the pressure signal.

Another case of higher velocity is shown in Fig. 4a and Fig. 4b for the local and global pressure transients, respectively. Since the bed is fully fluidized at this velocity, the difference between the pressure-drop for the case of no pulsation is approximately the same as the one obtained when the pulsed bed, irrespective of pulsation frequency, attains at the steady state. As compared to the previous case of low velocity, the pressure peaks are not as severe. But, the disturbances in the present case appear to be much vigorous. On the other hand, it is once again evident from the global pressure transients that perturbations introduced by the velocity fluctuations are mitigated by the fluidized bed as the profiles are seen to be smooth.

The pressure signal in the case of the global pressure drop is much more broadened as compared to sharp peaks seen for local pressure signals. Since the energy of any perturbation is conserved, the broadening of the peaks reflects the slower rate of energy dissipation.

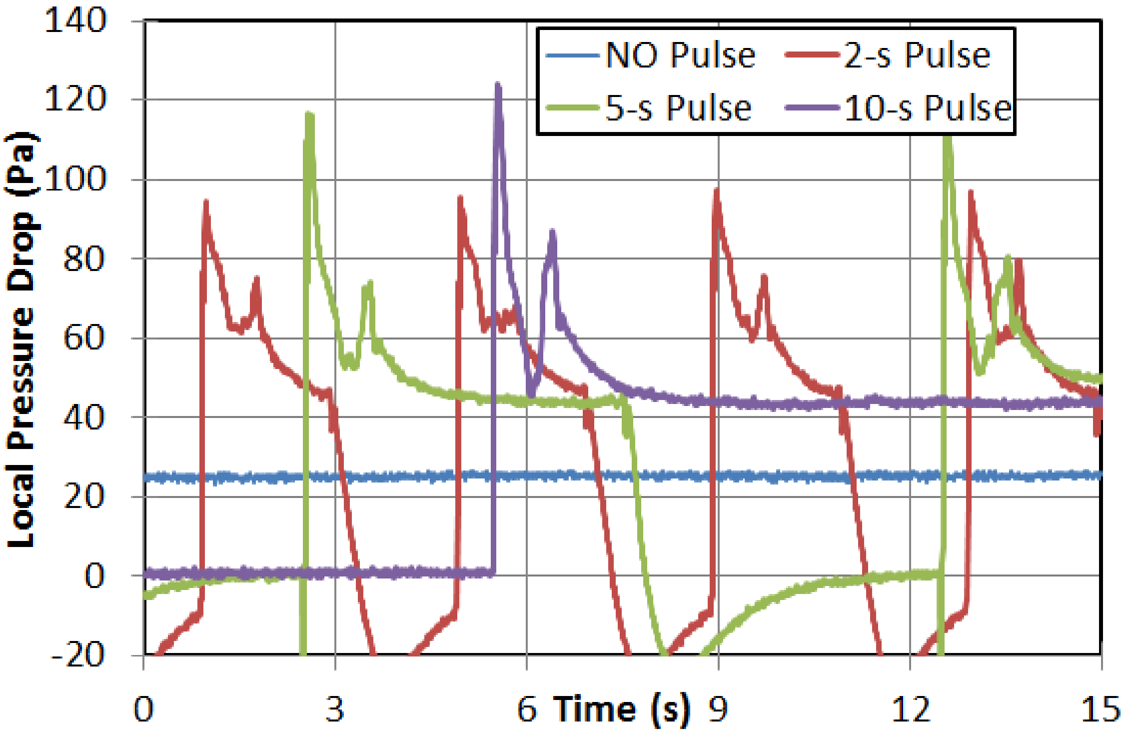

Fig. 3a: Local pressure transients for different frequencies at 33.2 mm/s

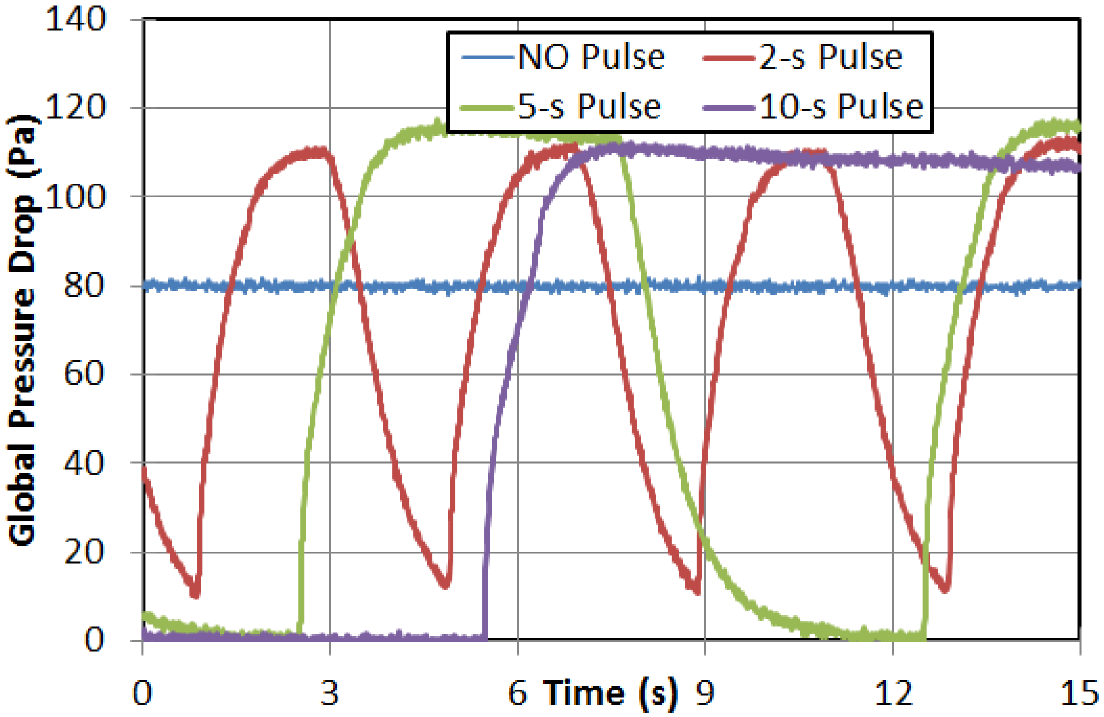

Fig. 3b: Global pressure transients for different frequencies at 33.2 mm/s

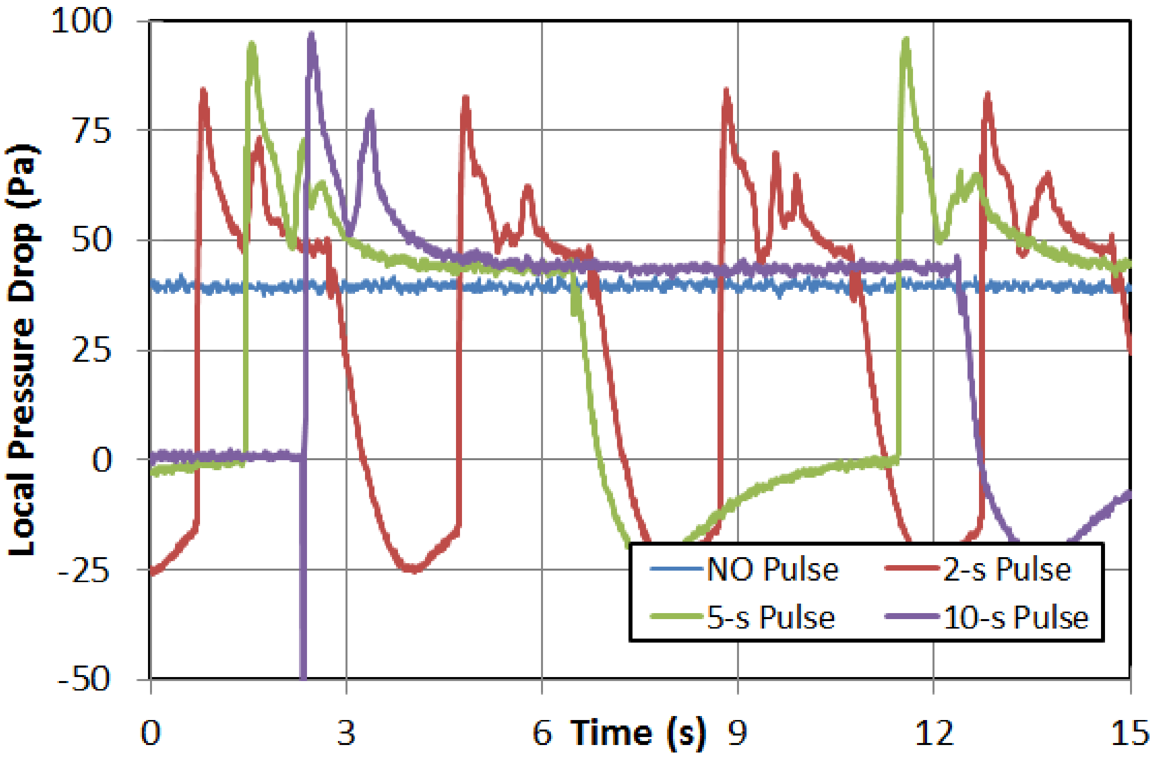

Fig. 4a: Local pressure transients for different frequencies at 65.9 mm/s

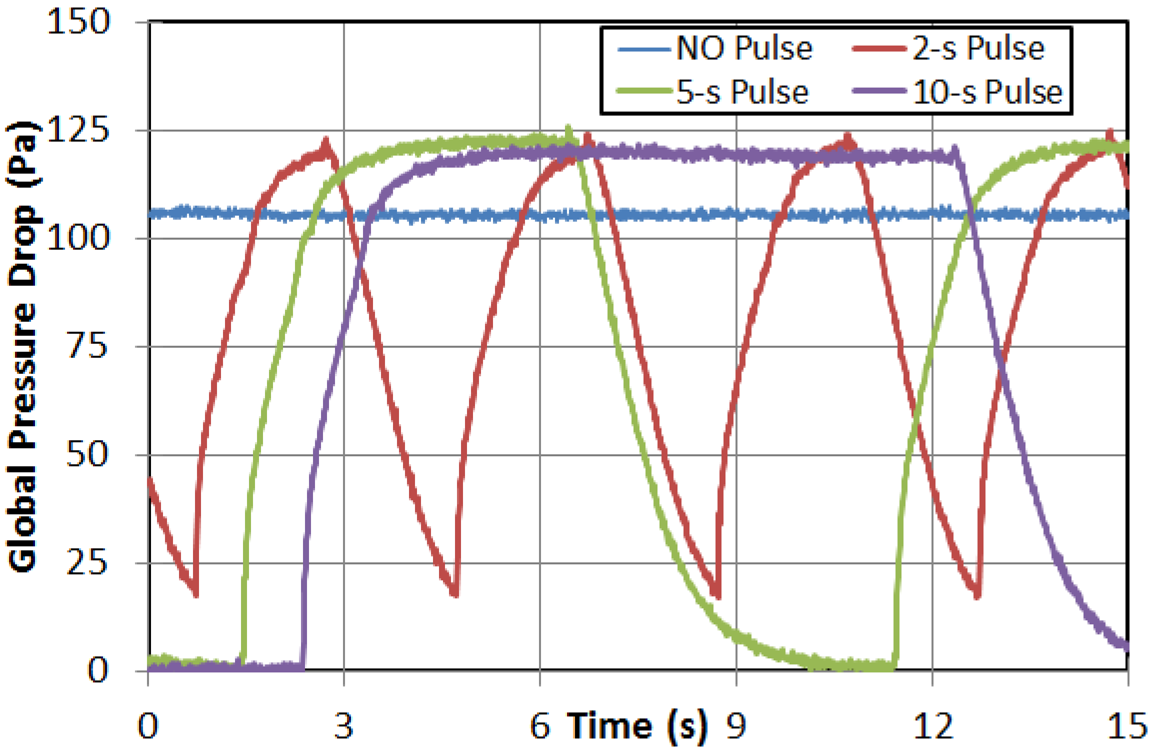

Fig. 4b: Global pressure transients for different frequencies at 65.9 mm/s

4. Conclusion

While the flow pulsation has proved to be effective in promoting the de-agglomeration nano-powders as the velocity fluctuation when introduced impart their momentum to break the large agglomerates (Ali and Asif, 2013; Ali et al. 2014), there is clearly an entirely new dimension to this research that can be used to attenuate strong disturbances or perturbations with the help of bed of nanoparticles..

Acknowledgements

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References

Ali S. S., Asif M., Ajbar A. (2014). Bed collapse behaviour of pulsed fluidized beds of nano-powder. Adv. Powder Technology, 25, pp. 331–337.

Ali S. S., Asif M. (2012). Fluidization of nano-powders: Effect of flow pulsation. Powder Technology, 225, 86–92.

Asif M., Ali S. S. (2013). Bed collapse dynamics of fluidized beds of nano-powder. Adv. Powder Technology, 24, 939–946.

Hostler S. R., Brenen C. E. (2005). Pressure wave propagation in a granular bed. Physical Review E, 72, 031303.