Characteristics of Pulse Cleaning in the Ceramic Filter Unit at High Temperature

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ABSTRACT

In order to optimize the pulse cleaning system, the experimental study in a hot bench unit and the flow simulation around the pulse nozzle at steady state were carried out. The bench scale unit that contains the six ceramic filter candles of 1.5m length was operated from 400 to 600 °C using an oil combustion gas and fly ash. The simulation study was carried out with FLUENT code using K-ε turbulent model of Re-normalization Group. The performance of pulse cleaning was estimated by the measurement of the overpressure in the filter cavity during the pulse cleaning. The guideline to determine the optimum size of the pulse nozzle and the diffuser was suggested by both the results of the simulation and experiment.

INTRODUCTION

Particles of a high concentration in a process gas are accumulated on the surface of the ceramic filter, which forms a dust cake. The dust cake is periodically released in order to clean the cake- forming filter element. During the build-up of the dust cake the pressure drop of the filter system increases and is recovered by the pulse cleaning. So the pulse cleaning is one of the key technologies in the operation of the ceramic filter unit.

The cleaning effect of the filter element depends on the pulse system as well as the operation conditions. The purpose of this investigation is to determine the design conditions of the pulse nozzle and the diffuser under which the performance of the filter candle can be maximized. The steady state flow distribution was calculated by a FLUENT code using K- ε turbulent model of Re- normalization Group. And the bench scale unit of the ceramic filter candle was operated at high temperature to observe the real operation performance.

EXPERIMENTAL AND SIMULATION

The experimental set- up of the hot bench test unit was previously reported [1]. However, the scale of the filter unit was enlarged by mounting the six elements of the commercial SiC filter candle of 1.5m length on the half part of the tube sheet as shown at Fig.1. And the inlet gas was introduced downward from the top of the tube sheet to achieve the co- current flow with the direction of the falling dust during the pulse cleaning. The measuring points of the transition pressure were indicated in Fig.1. The filter elements were arrayed in three groups with two elements in a group. The typical dimensions and the features of the concentration pulse nozzle and the venturi diffuser were shown at Fig.2. The size of the pulse system elements was shown in Table 1.

Table 1 Specification of the pulse cleaning systems.

Unit	Specification	Unit	Specification
Pulse tank size	68.5	Pulse valve	
Manifolder size	40 mm	• Type	Solenoid (normally closed)
Pulse pipe size	20 mm	• Orifice size	15 mm
Pulse nozzle size	variable	• Flow coefficient	20 /s bar

The hot dusty stream was prepared with the exhaust gas from an oil burner in which the fly ash was fed with a screw feeder. Fly ash of a conventional coal power plant has its mass median particle size of 11.2μm after being cut with a cyclone.

In order to simulate the flow dynamic of the pulse cleaning, the axial symmetric equations of Navier- Stokes at steady state was calculated using a FLUENT code[2]. RNG(Re- normalization Group) k-ε turbulent model was adopted. The pressure drop through the filter element was calculated using Darcy' law. Fig.3 shows the axial symmetric geometry and the computational grid for the simulation.

RESULTS AND DISCUSSIONS

1. The entrainment effect

It has been observed that the surrounding gas of the nozzle and the diffuser is entrained with the pulse gas during the pulse cleaning[3]. This effect is very important to enhance the magnitude of the pulse intensity as well as to reduce the tendency of thermal shock owing to the heating effect of the cold pulse cleaning gas. Fig. 4 and Fig.5 show the patterns of the pressure and the pressure distributions, respectively, around the diffuser when the pressure in the pulse tank is 5bar. The pressure at the end of the pulse nozzle was about 3bar. However, it reduced suddenly below the value of the background while the velocity increased abruptly. This results means that the force of the pulse gas transferred partially into the kinetic energy. And the reduced pressure has a room to accept the environmental gas, which is so called a entrainment effect. The pressure of the entering gas was recovered during its pass through the diffuser and showed the positive one in the filter cavity. However, the negative pressure was developed in the top area of the filter cavity when the insufficient mixing occurred. In this case a patch of the cake remained undetached within several centimeter from the open end of the filter element[3]. The experimental observation of this phenomena were shown at Fig.6. The pressure in the clean chamber of the filter unit as well as the pressure near the top of the open end were slightly reduced during the initial stage of the pulse cleaning was also slightly reduced. This result means that the background gas was entrained when the operation temperature was 10°C. However, the entrainment effect was very small at high temperature of 500°C as shown at Fig.6 (A). So it seems that it has a strong relation with the gas density.

2. The development of overpressure in the filter cavity

The measurement of the overpressure(the differential pressure between in the filter cavity and in the filter chamber) is one of the useful scale to estimate the intensity of the pulse cleaning. Fig.7 shows the effects of the tip size of the concentrating pulse nozzle on the development of the overpressure in the middle position of the filter cavity when the pulse pressure is 6bar. The overpressure increased with the nozzle size with the increasing rate was slightly decreased at the high valve. And the overpressure per pulse mass decreased gradually as the nozzle size increased. In general, the pulse mass of the pulse gas leaving the pulse gas increased linearly with the nozzle size. So it is evident that the entrainment effect reduces as the nozzle size increases[4]. It was not easy to set up the criterion to determine the optimum nozzle size because the overpressure increased with the size of the pulse nozzle. However, the proper nozzle size was about 9mm after which the intensity of pulse effect was sharply dcaeased.

Fig.8 shows the effect of the throat size of the diffuser of which dimension was fixed at the value shown at Fig.2 except its throat size. The overpressure was increased but keep constant at the size more than 23mm. Of course, the optimum size of the diffuser should be adjusted if the feature and the size of the diffuser are changed. So it mostly depends on the art of skill to design the high performance diffuser. Fig.9 indicates that the optimum size of the diffuser throat is 23mm in the case of this study and that it is beneficial to reduce the pulse duration as possible as.

CONCLUSIONS

Some aspects of the pulse cleaning for the ceramic filter candle system was studied by the steady state simulation and by the operation of bench scale unit at high temperature.

The entrainment effect was explained with the fact that the pressure near the diffuser was drop under the background one by the transfer of the pressure force into the kinetic energy. One method to determine the optimum sizes of the pulse nozzle and the diffuser was suggested by measuring the overpressure in the filter cavity. There was no clear criterion to determine the optimum nozzle size because the overpressure increases with the nozzle size. The diffuser had its maximum value of the overpressure when its throat size was 23mm.

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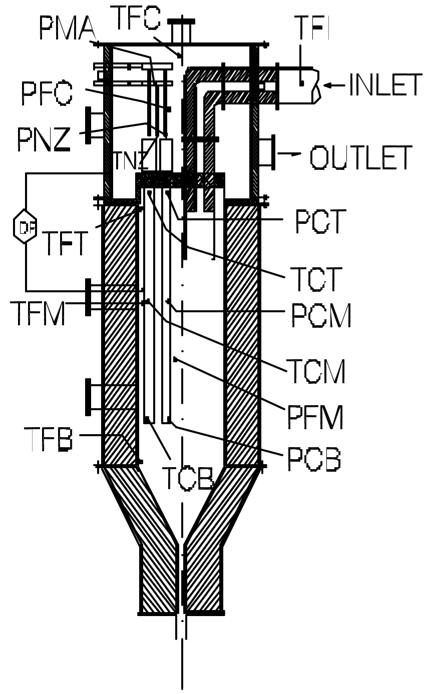
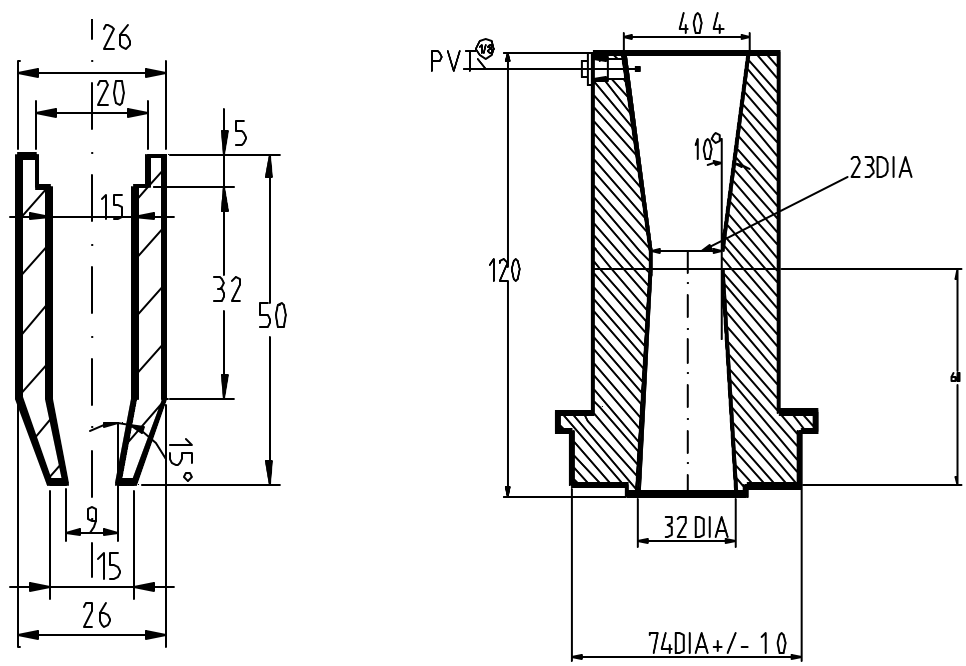
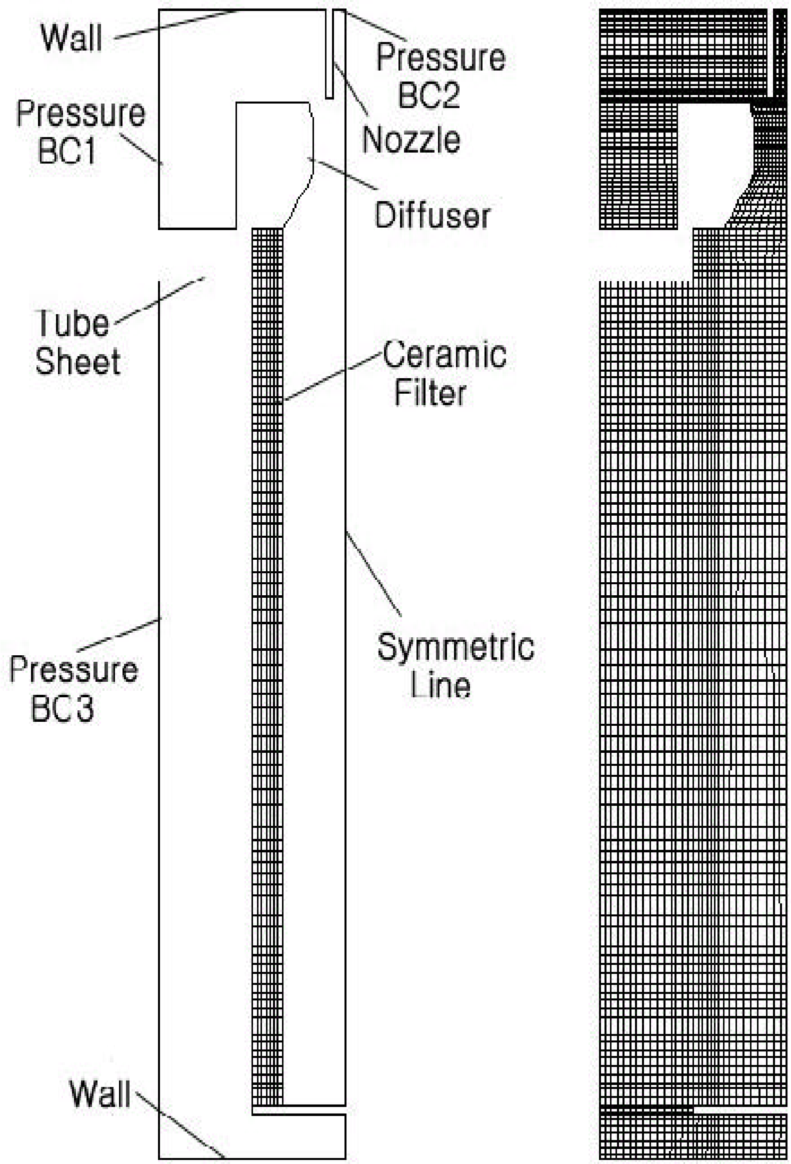


Fig.1. Drawing shows the measurement points of T & P.



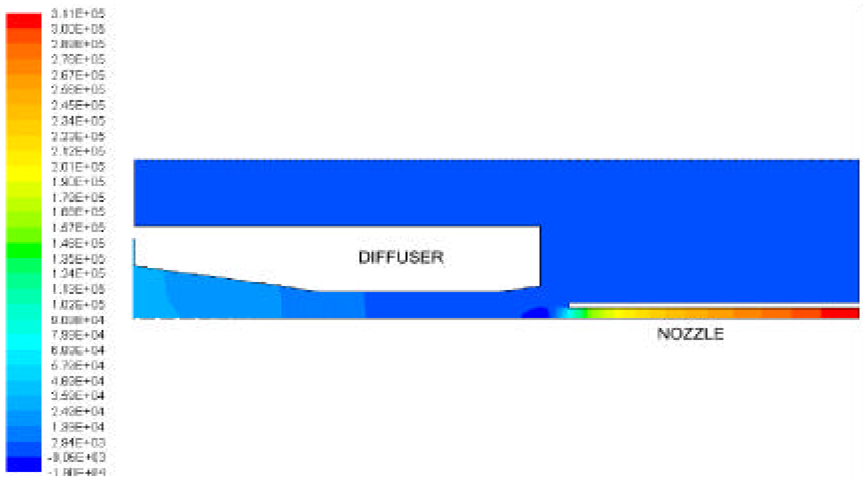
(a) (b)

Fig.2. Drawings show the dimensions of the nozzle (a) and Diffuser (b).

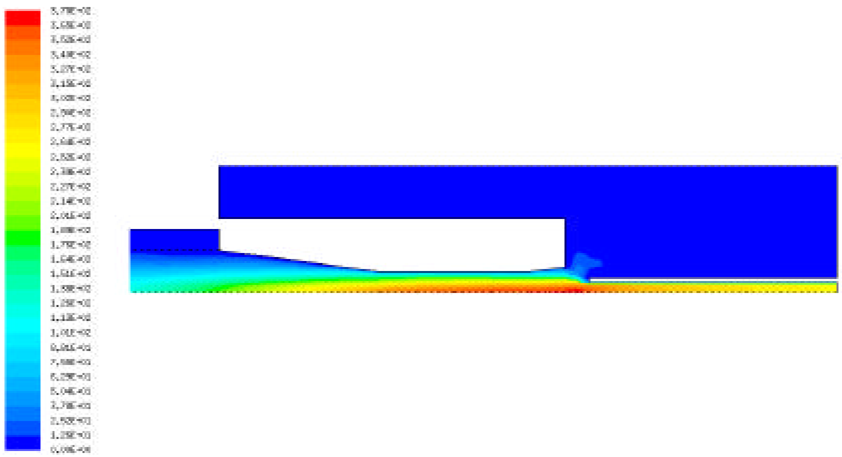


(a) Geometry (b) Grid system

Fig. 3. Geometry and computational grid for the ceramic filter system.



(a)



(b)

Fig.4. Contour lines of the static pressure and the velocity magnitude near the nozzle tip.

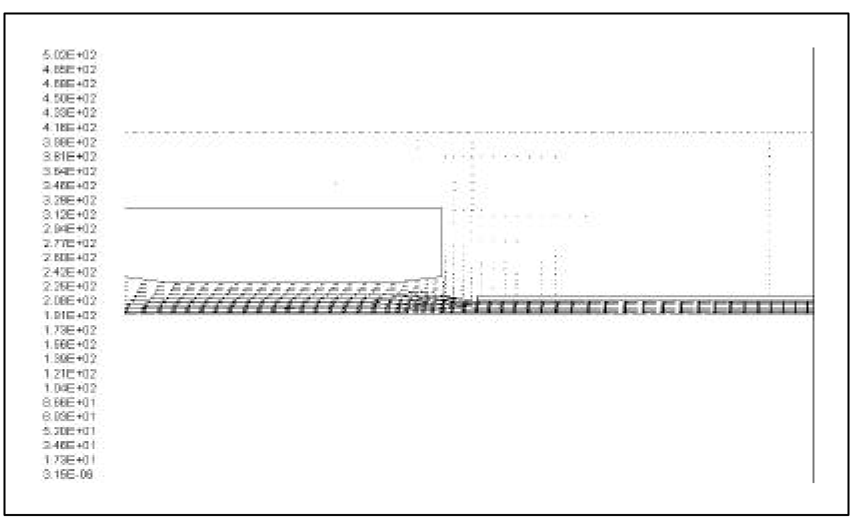
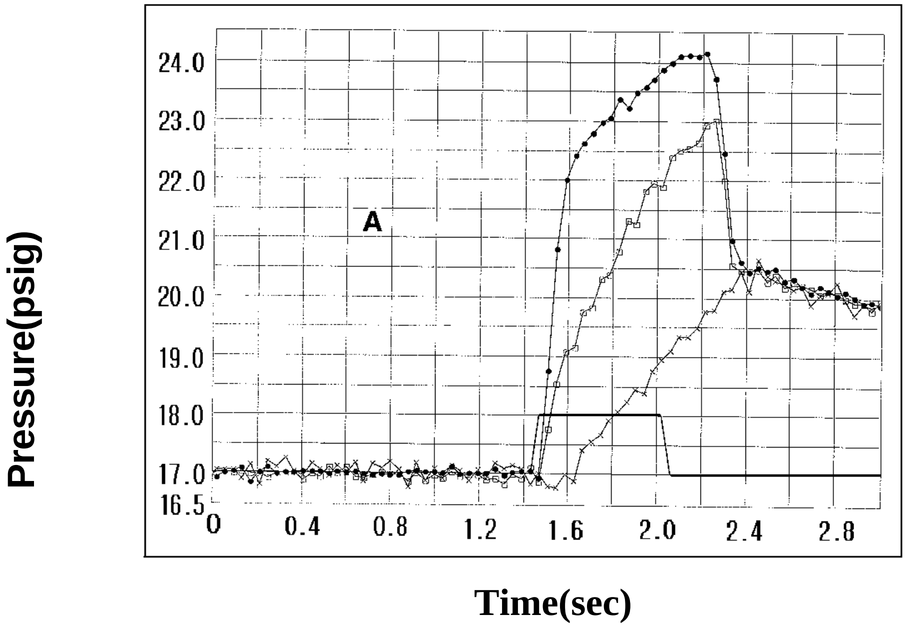


Fig. 5. Velocity vectors around the diffuser.



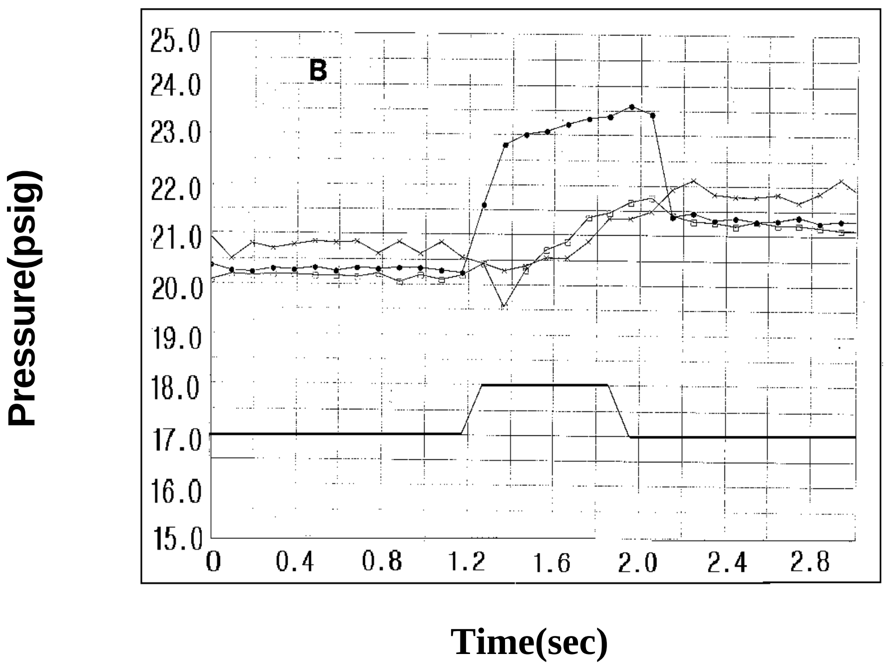
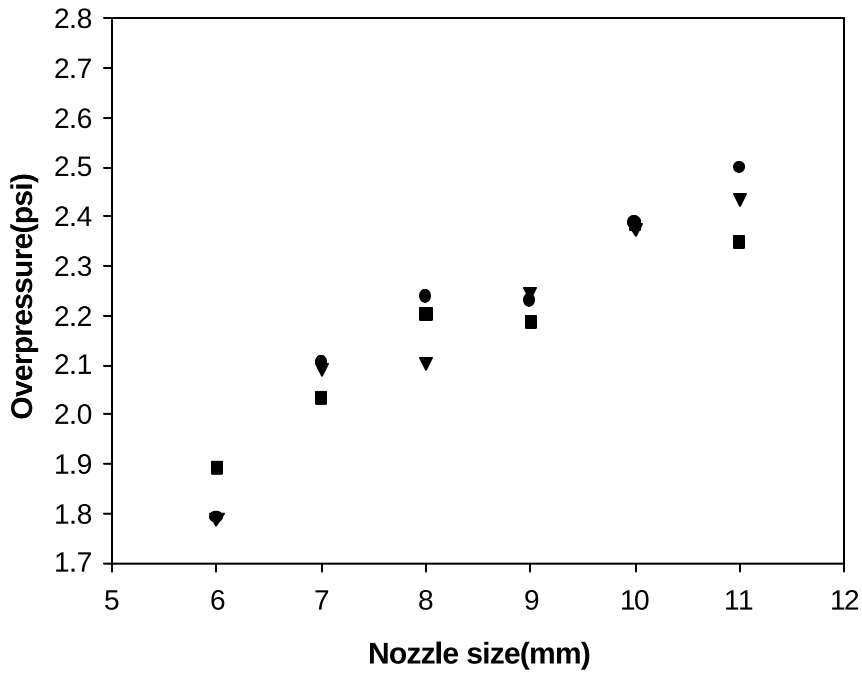


Fig.6. Traces of pressure at bottom(1) and top(„) of the filter cavity and at the clean chamber(×) when the operation temperature are 500 (A) and 10 (B).

. Pulse duration : 0.2sec



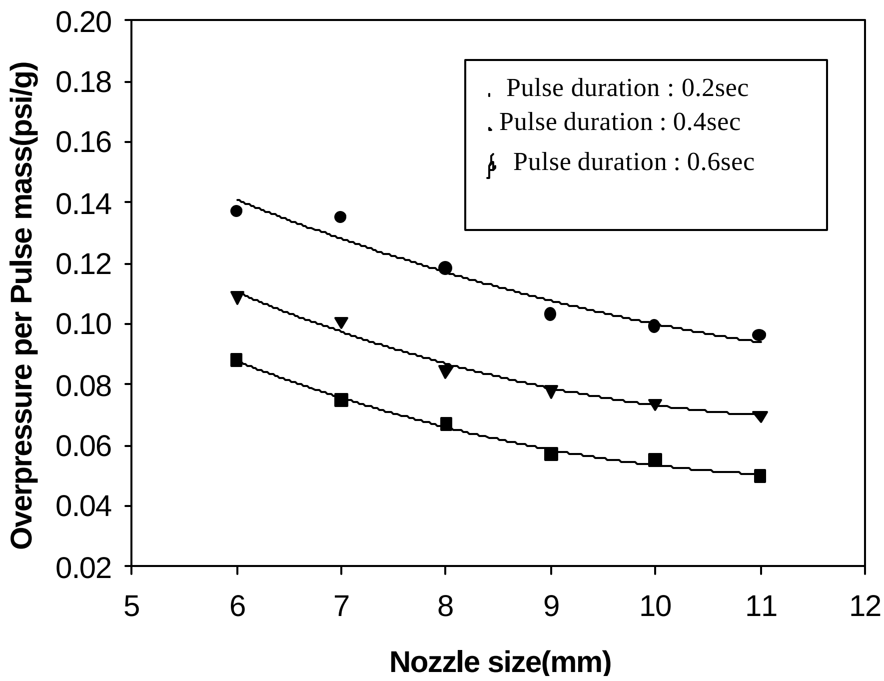


Fig.7. The effect of the nozzle size on the development of overpressure in the filter cavity.

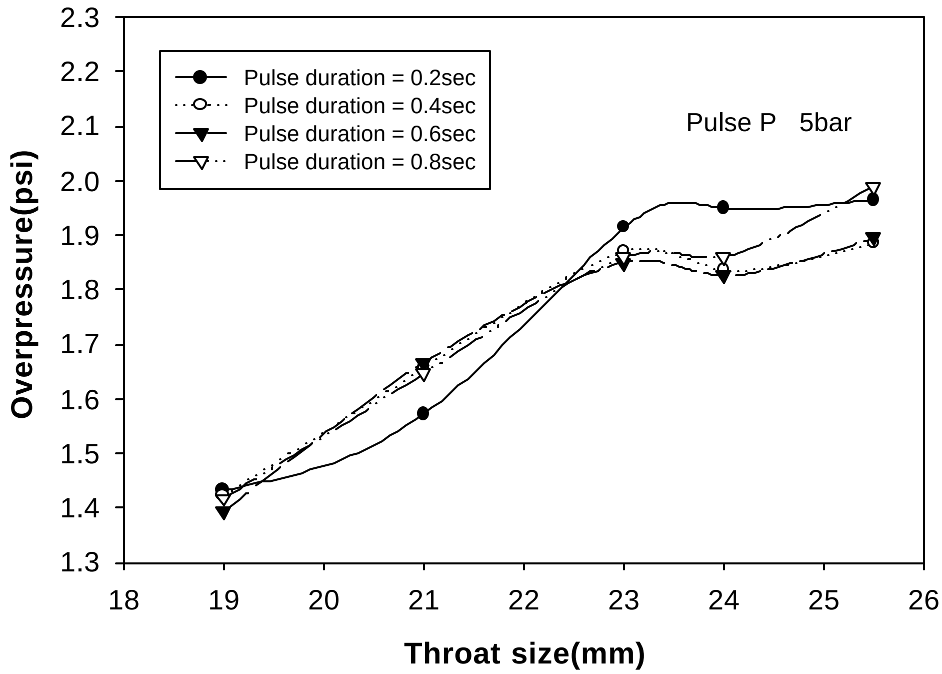


Fig.8. The effect of the throat size of the diffuser on the development of overpressure in the filter cavity middle.

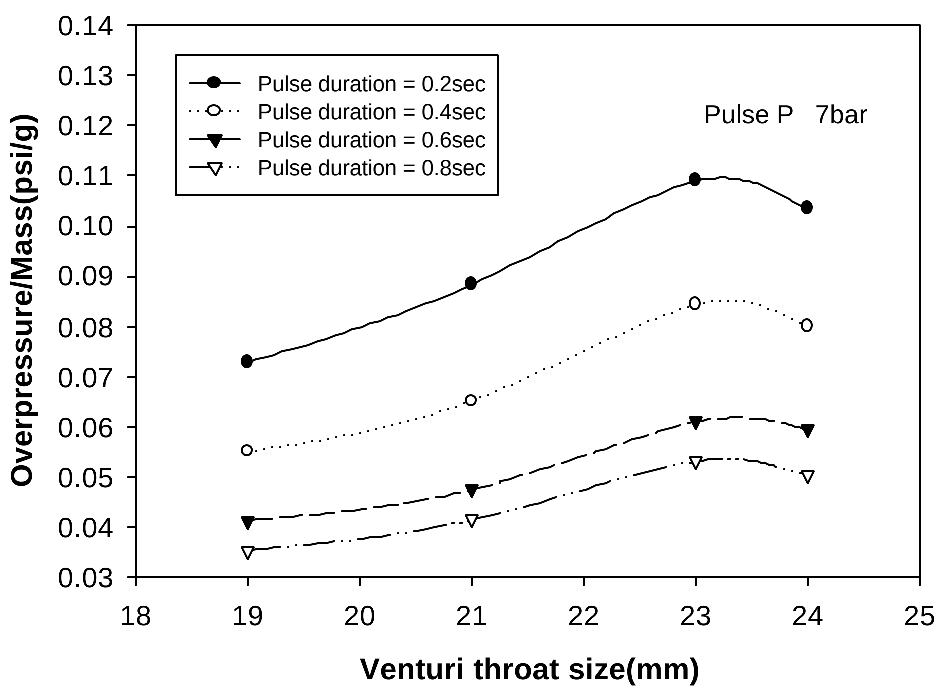


Fig.9. The effect of the venturi throat size on the overpressure in the filter cavity middle.