Investigation of Performance Parameters of Self Priming Venturi Scrubber

Siddhi Jadhav[1],Kuldip Wakade[1], Neha Mahamuni[1], Yashwant Mente[1], Ashish Umbarkar[2]
[1]*UG Student, Mechanical Engineering, Smt. Kashibai Navale College of Engineering, Pune*
[2]*Assistant Professor, Mechanical Engineering, Smt. Kashibai Navale College of Engineering, Pune*

ABSTRACT: The venturi scrubber is one of the efficient devices to remove the particulate matter from a gas stream. In this paper collection efficiency, pressure drop across venturi scrubber and collection efficiency of the self-priming venturi scrubber are analysed by using experimental method. In self priming venturi scrubber Injection of scrubbing liquid takes place due to difference in hydrostatic pressure of liquid and static pressure of gas at the throat section. The venturi scrubber encases dust particle and small water droplets flowing into it.Ash is used as dust particle and dust(ash) particle size varies from 0.1μm to 100μm. Filtration technique is utilised to determine the concentration of ash particles at inlet and outlet. The results show that pressure drop decreases with increase in water head and collection efficiency increases from 95.6% to 99.6% with increase hydrostatic pressure head of water from 30cm of water to 80cm of water.

KEYWORDS: Self priming, venturi scrubber, collection efficiency, pressure drop.

I. Introduction

Industrial pollution is one of the primary sources of environmental contamination.A wide range of contaminants are produced by the human action on industries, like carbon monoxide, particulate matter, nitrogen oxides, hydrocarbons and different synthetic compounds. It is necessary to remove pollutants from the exhaust gas stream of industries. Various systems such as settling chambers, electrostatic precipitators, cyclones, wet scrubbers are available to clean the exhaust gas stream. Wet scrubber is one of the most efficient devices which utilises liquid scrubbing technique to remove particulate matter and pollutants from gas stream. Wet scrubber is classified into various scrubbers having different arrangement like splash tower scrubbers, pressed bed scrubbers, ionizing wet scrubbers, catenary network scrubbers, impact scrubbers, ejector scrubbers, and venturi scrubbers.

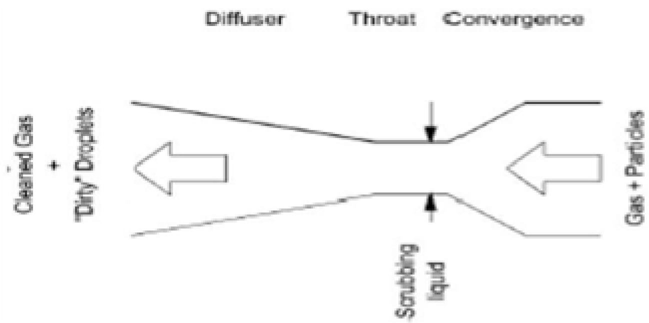

Fig.1 Venturi scrubber

Venturi scrubber is one of the most satisfactory and proficient devices which uses scrubbing liquid in the form of droplets to collect the particulate matter and Gaseous pollutants (ranging from size 1 μm to 300μm) from a gas stream. They are usually compact equipment of simple construction, and can handle well hot gases and sticky or inflammable particles. Venturi scrubbers find its application in many industries such as iron and steel foundries, metallurgic industries, cement production, ceramic industries and others. The venturi scrubber is shaped like a venturi tube which is utilized, for instance, as a flowmeter.

A classic Venturi scrubber consists of three main parts: a convergent, a throat and a diffuser. Convergent part is used for acceleration of gas to atomize the scrubbing liquid. Throat part is between convergent and diffuser, which is used for interaction of liquid and gas, whereas diffuser is used for deceleration of gas to allow some pressure recovery. Self-priming method is utilised for injection of scrubbing liquid into the venturi scrubber in which liquid injection takes place due to pressure difference composed of hydrostatic pressure of the liquid and static pressure of the gas (Mayinger and lenher,1995). Fig.2. demonstrates the scrubber which was utilized for the exploratory examinations. Literature study reveals that liquid is introduced in a venturi scrubber in three different forms; film, jet or spray. In wetted-wall venturi scrubber, the liquid is introduced as a film just upstream of convergence section (Majid Ali ,2012). Collectionefficiency depends on various factors such as pressure drop, droplet size, particle size, gas velocity, scrubbing liquid flow rate.

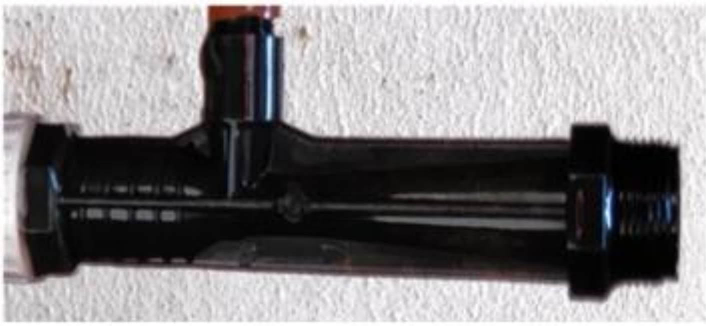

Fig.2. Venturi scrubber used for experiment

The collection efficiency is also affected by different mechanisms such as inertial impaction, interception, diffusion, electrostatics, nucleation and, growth and condensation. Size of particle and droplet and their relative velocity resolves the mechanism. The position of an injecting liquid and length of throat as for geometry and operating factor affects the performance of venturi scrubber. High pressure drop results in high operating cost. Optimization of pressure drop improves the efficiency of self-priming venturi scrubber. The droplet's formation due to atomization of a liquid will act as cleaning elements in the venturi scrubbers. The collection efficiency of particle and gas absorption is dependent upon the size of droplet. Therefore, droplet size is one of the fundamental parameters for the scrubber performance. J.A.S. Gonc¸alves et al. [3] droplet distribution depends on design parameters such as the injection system and the fluid velocities. The utilization of an adequate droplet dispersion model helps to optimize droplet throat coverage without increasing liquid usage unnecessarily, thus reducing operational costs.

This study deals with the pressure drop at the throat section, liquid loading and collection efficiency of dust(ash) in self-priming venturi scrubber. The liquid to gas ratio and collection efficiency was analysed at different liquid flow rate, and dust concentrations. Pressure drop was calculated at different water head above the divergent section of venturi scrubber. The principle mechanism of dust removal in this venturi scrubber is the inertial impaction.

II. Experimental Setup

The schematic diagram of experimental setup to study the performance parameter of a self-priming venturi scrubber is shown in Fig.3. Pressurised air from compressor is used for experiment instead of polluted flue gases exposed to the atmosphere by the industries. Pressure regulator is used to control the input pressure of a fluid to achieve desired value at its output. The air flow rate is adjusted by using air rotameter. Charging the gas with dust particle achieved by injecting ash into the loop. The mean size of ash particle used as a dust particle is 1 um. To ensure that there are no leaks or pressure changes pressure gauges are used and non-return valve is used to allow fluid flow only in one direction.

The water is used as scrubbing liquid which is supplied to venturi scrubber from secondary tank. The water tank is filled at certain height to create requires hydrostatic head effect. A constant water level is maintained for each run. The dust encapsulated droplets are collected in venturi tank. The venturi scrubber is operated at throat gas velocity 45m/s to 120m/s and dust concentration varies from 120lpm to 180lpm. Dust concentrations at inlet and outlet are measured by filtration technique. Water is drained off with semi permeable membrane to restrict the fly ash particles from draining off and the total mass of the dust particles collected is found by taking the difference between the weight of filter paper and filter paper containing the collected dust particles.

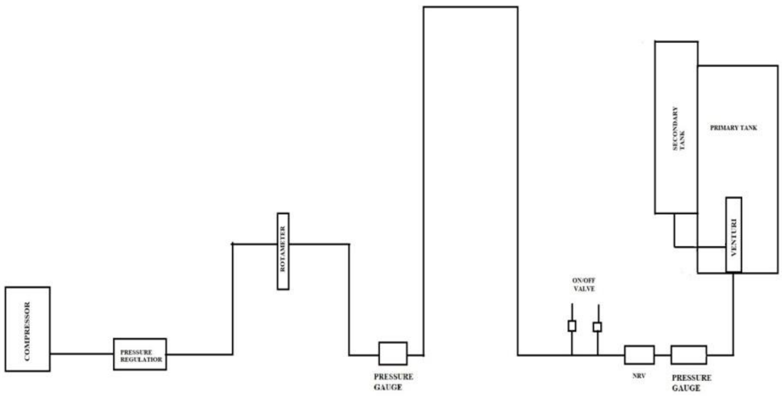

Fig.3. Schematic diagram ofexperimental setup of self-priming venturi scrubber

III. Results and Discussions

A. Behaviour in self-priming operation and pressure drop:

For self-priming operation of venturi scrubber pressure drop is very important performance parameter to be analysed. In the converging section of the venturi scrubber, the pressure energy is converted into kinetic energy which causes drop in static pressure of gas stream. Due to difference in hydrostatic pressure of scrubbing liquid(water)and static pressure of gas scrubbing liquid is most often introduced as jets through orifices at the beginning of the throat and atomizes into droplets. Dust particles are captured by the mechanism of impaction. The high energy of the gas promotes the atomization of the jets into a large number of small droplets.

In this study, pressure drop across venturi scrubber is calculated by calculating difference between pressure inlet at converging section of venturi and pressure outlet at diverging section of venturi. Pressure head above the venturi was taken as 30 cm, 50cm, 80cm.Fig.4, fig.5, fig.6 shows that by increasing the water head over the venturi scrubber, pressure drop decreases from 4.55 to 4.2 for the same values of pressure (2 bar to 5 bar) at the inlet of venturi scrubber. As high pressure drop results in high operating cost decrease in pressure drop causes to increase in the efficiency of self-priming venturi scrubber.

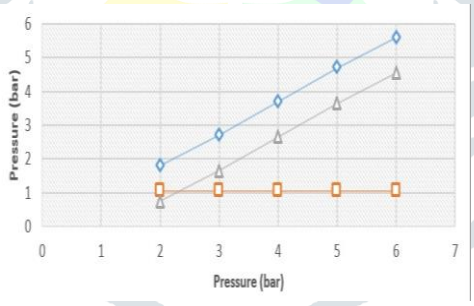

Fig.4Pressure drop at water head of 30 cm

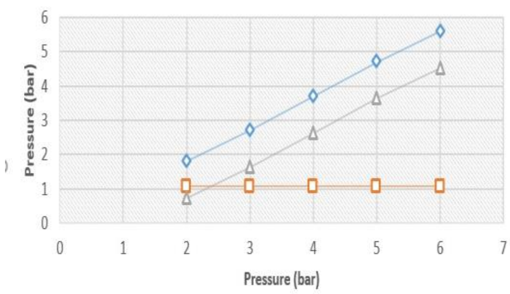

Fig.5 Pressure drop at water head of 55 cm

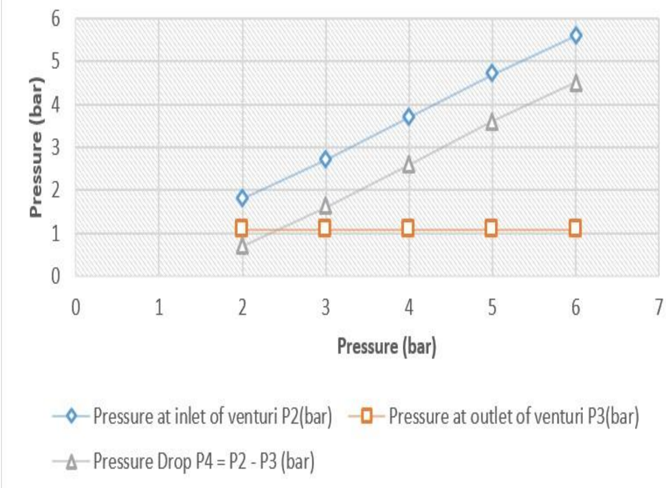

Fig.6 Pressure drop at water head of 80 cm

B. Collection efficiency:

For calculating Collection efficiency quantity of fly ash particles to be inserted in the pressure line was measured using (weighing scale). Dust particles were inserted in the pressure line. By using filtration technique with the help of semi-permeable membrane water is drained off to restrict the fly ash particles from draining off. The quantity of ash particles collected and measured and collection efficiency was calculated for different values of water head of 30 cm, 55cm, 80cm by using following formula.

$$\eta = \frac{\textbf{(Quantity of ash particles collected) * 100}}{\textbf{(Quantity of ash particles inserted)}}$$

And the results show that with increasing water head from 30cm to 80cm, pressure drop decreases which increases the collection efficiency from 95% to 97%.

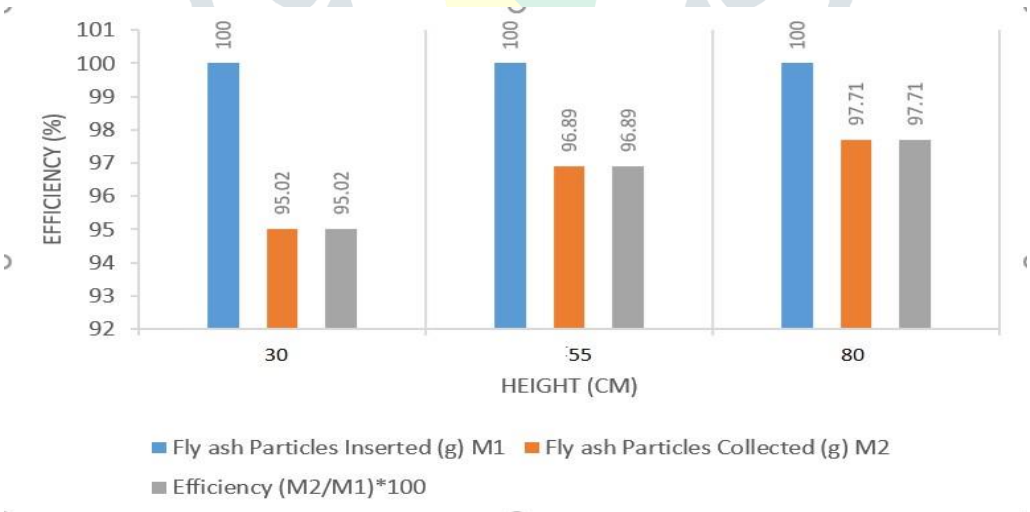

Fig.7. Collection efficiency

IV.Conclusion

The main conclusions can be summarized as:

1. With increase in water head above the venturi scrubber pressure drop across venturi scrubber decreases.
2. Collection efficiency of self-priming venturi scrubber increases with increase in water head above the venturi scrubber.

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