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Effects of Velocity and Particles Load on Efficiency of Cyclone in the Stone Crushing Units at Azendarian Area

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Abstract

Background: The traditional cyclone has been developed for the removal of airborne silica particles from local exhaust ventilation (LEV). The objective of this research was to evaluate the effects of velocity and particles load on efficiency of cyclone in the Stone Crushing Units at Azendarian Area.
Methods: After the designing and installing the traditional cyclone, downstream and upstream samples of the apparatus were obtained. The mass of all samples collected was determined gravimetrically using EPA method with cascade Impactor.
Results: The relation between inlet total and respirable dust concentration to cyclone and cyclone overall efficiency is statistically significant (P= 0.005) and the relation between inlet air velocity to cyclone and cyclone pressure loss is statistically significant (P= 0.002). There was a significant correlation between the inlet concentration loaded to cyclone and the efficiency of cyclone.
Conclusion: Increase of respirable dust concentration and also total concentration cause to increase efficiency of cyclone.

Keywords: *Cyclone, Velocity, Particle, Concentration Load*

Introduction

Cyclones are among the oldest types of industrial particulate control equipment and are still one of the most widely used of all industrial gas-cleaning devices. The main reasons for the widespread use of cyclones are that they are inexpensive to purchase, they have no moving parts, and they can be constructed to withstand harsh operating conditions (1). Typically, a particulate-laden gas enters tangentially near the top of the cyclone; the gas flow is forced into a downward spiral simply because of the cyclone's shape and the tangential entry. Centrifugal force and inertia cause the particles to move outward, collide with the outer wall, and then slide downward to the bottom of the device. Near the bottom of the cyclone, the gas reverses its downward spiral and moves upward in a smaller inner spiral. The cleaned gas exits from the top through a "vortex-finder" tube, and the particles exit from the bottom of the cyclone through a pipe sealed by a spring-loaded flapper valve or rotary valve (1). The most commonly used cyclone designs are the 2D2D (2). Evaluations of cyclone performance have long been studied to better understand and improve cyclone design theory. Lapple (3) developed the Classical Cyclone Design process (the CCD process) for designing cyclones and predicting their performance (emission concentrations and pressure drop). This model incorporated the number of effective turns, cut-point diameter, and a "generalized" fractional efficiency curve. For many situations, the Lapple model has been considered acceptable. Previous results from research conducted at Texas A&M University (TAMU) (4) indicated that the Lapple methodology for

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predicting number of effective turns and the use of the “generalized” fractional efficiency curve in the CCD process yielded inaccurate results.

We installed the LEV equipped with conventional cyclone with spray scrubber for the twenty nine factories from March 2004 to July 2006.

The objective of this research was to evaluate the effects of velocity and particles load on efficiency of cyclone in the Stone Crushing Units at Azendarian Area

Materials and Methods

Isokinetic sampling probes were used to measure the representative upstream and downstream particle concentrations of the cyclones. The inlet and outlet concentrations of dust particles were measured using a probe connected to cascade impactor. For each test, the sampling time was 2 minutes. The mass of all samples collected was determined gravimetrically using EPA method (5). Filters were equilibrated in desiccators for a minimum of 24 hours prior to tare and final weighing. A pitot tube with a manometer was used the monitoring of static pressure and velocity pressure in the site of sampling. Cyclone collection efficiency is one of the main parameters considered when evaluating cyclone performance. There are two ways to calculate the overall collection efficiency of a cyclone. Four parameters were required to develop cyclone fractional efficiency curves. They were 1) inlet concentration, 2) inlet particle size distribution (PSD), 3) emission concentration for each cyclone test, and 4) the PSD of dust emitted. The inlet and outlet concentrations for various size ranges were calculated using inlet and outlet dust concentrations and the fraction of particulate in those size ranges obtained from the Cascade Impactor. The outlet concentration was divided by the corresponding inlet concentration for each particle size range and subtracted from one with the resulting values being the fractional efficiency for each particle size range.

For comparing concentration of particle before and after installation of local exhaust ventilation paired *t*-test was performed. ALSO pearson correlation coefficient was used to show the relationship between efficiency of cyclone and inlet concentration to cyclone. Data analysis was performed using SPSS for windows.

Results

Fig. 1 shows the scatter diagrams between concentration load to cyclone and the efficiency of the cyclone. There was a significant correlation between the inlet concentration loaded to cyclone and the efficiency of cyclone with the increase in inlet concentration, the efficiency was also increased ($P< 0.05$). Fig. 2 shows the scatter diagrams between inlet velocity to cyclone and the efficiency of the cyclone. There was a significant correlation between the inlet velocity to cyclone and the efficiency of cyclone with the increase in inlet velocity, the efficiency was also increased ($P< 0.05$). Fig. 3 shows the scatter diagrams between respirable dust concentration and the efficiency of the cyclone. There was a significant correlation between the respirable dust concentration and the efficiency of cyclone with the increase in respirable dust concentration, the efficiency was also increased. The results show that relation between inlet total and respirable dust concentration to cyclone and cyclone overall efficiency is statistically significant ($P= 0.005$). The results show that relation between inlet air velocity to cyclone and dust collection efficiency is statistically nonsignificant ($P= 0.116$). However, the relation between inlet air velocity to cyclone and cyclone pressure loss is statistically significant ($P= 0.002$). The results show that mean concentration of total dust before and after starting ventilation system equal to 1628±322 mg/m^3 and 8.33± 3.81 mg/m^3 respectivly. Free silica rate of respirable dust in different workshops is from 81.3% to 97.5%.

Table 1 shows the mean of total dust before and after of installation of LEV in different sites of stone crushing units. Results show that the efficiency of LEV to control of particles is greater than 99%. The average value of total dust emission from sources was 9.46 mg/m^3 as compared to 1.24 mg/m^3 respirable dust showing that 13.18% of total dust is respirable. No significant difference was observed for emission of particles among stationary sites after installation of LEV.

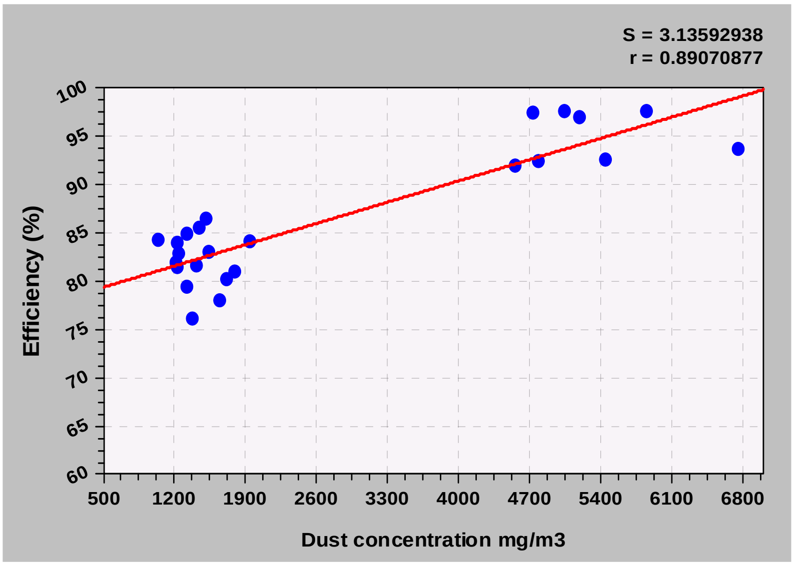

Fig. 1: The scatter diagrams between concentration load to cyclone and the efficiency of the cyclone

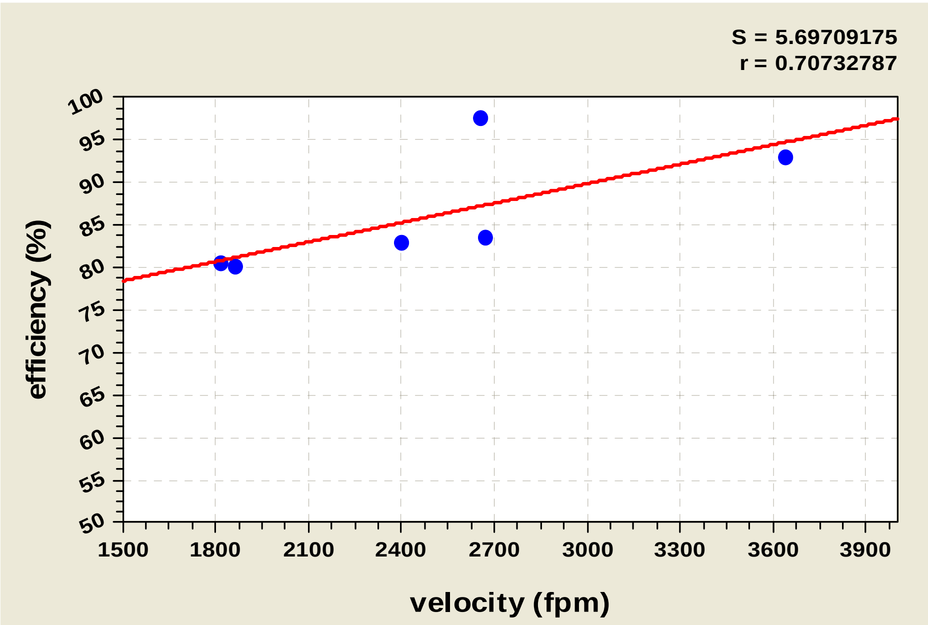

Fig. 2: The scatter diagrams between inlet velocity to cyclone and the efficiency of the cyclone.

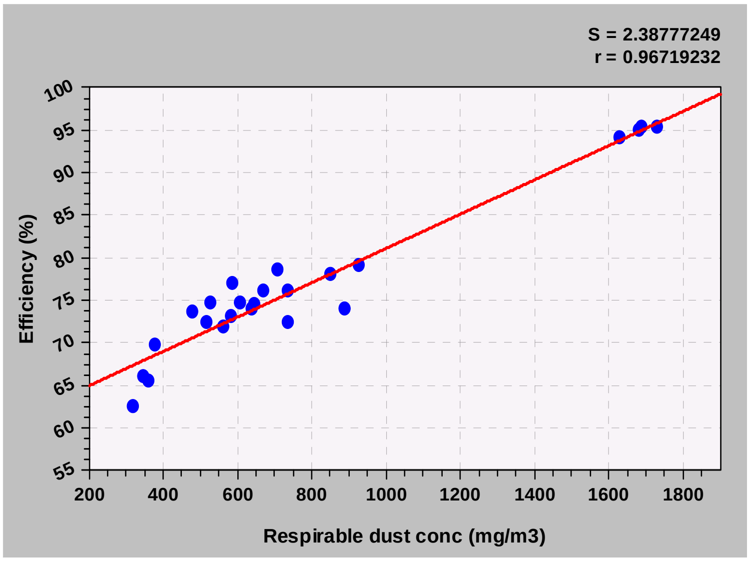

Fig. 3: The scatter diagrams between respirable dust concentration and the efficiency of the cyclone.

Table 1: The mean of silica concentration before and after of LEV in different sites of grinder stone units

Site of sampling	**No LEV n=20**		**With LEV n=20**			**ϕ1**
	Total dust Mean±SD	**Respirable dust Mean±SD**	**Total dust Mean±SD**	**Respirable dust Mean±SD**	**Respirable quartz Mean±SD**	
Hopper	1257.4±72.43	111.12±10.23	8.44±1.37	1.48±0.65	1.33±0.59	99.33
Rotary Grinder	2007.5±567.4	179.23±71.45	11.07±6.96	1.44±0.83	1.30±0.75	99.45
Screening I	1900.1±558.63	170.12±60.24	9.34±5.8	1.30±0.62	1.18±0.60	99.5
Screening II	1787.5±449.77	152.56±58.34	9.00±6.5	0.77±0.48	0.69±0.44	99.49

ϕ1 efficiency of LEV

Discussion

The cyclone fractional efficiency curve (FEC) relates percent efficiency to the particle diameter and can be obtained from test data that include inlet and outlet concentrations and particle size distribution (PSD's).

There was a significant correlation between the inlet concentration loaded to cyclone and the efficiency of cyclone with the increase in inlet concentration, the efficiency was also increased. This can be related to striking of more particles to the walls of the cyclone (6) and probably the striking of particles together inside the cyclone. Impaction of particles to each other causes to lower velocity of particles and therefore their settlement in the bin of cyclone.

Cyclones, as the most cost-effective air pollution device for particulate matter removal, have been studied for decades. Although many procedures for calculating collection efficiency have been developed, current design practice either emphasizes past experience rather than an analytical design procedure, or cannot accurately predict cyclone collection efficiency.

In the literature, theories to predict cyclone efficiency have been reported for many years. Lapple (3) developed a theory for cut-point (d_{50}) based upon a force balance and representation of residence time with the air stream number of turns within a cyclone. The Lapple model is easy to use, but it cannot accurately predict cyclone collection efficiency. In 1972, Leith and Licht presented another theory (back-mixing) for the study of cyclone collection efficiency (7). Their back-mixing theory suggests that the turbulent mixing of uncollected particles in any plane perpendicular to the cyclone axis produces a uniform uncollected dust concentration through any horizontal cross section of a cyclone. According to the research conducted by Texas A & M university (TAMU) the 2D2D cyclone (traditional cyclone) are the most efficient collectors for fine dust in another research, Wang et al reported that 2D2D cyclone had high efficiency for fine dust and large trash (8).

The inlet gas velocity of the cyclone was the variable with the greatest stronger influence on its efficiency: the higher the velocity, the higher the overall collection efficiency within the studied range. According to Hoffman et al. (1995), vortex length increases with the increase in gas velocity, for a fixed cyclone geometry. Therefore, besides increasing the centrifugal force, an increase in gas velocity also increases the effective collection area in the cyclone, and both effects result in an appreciable improvement in collection efficiency (9). Yoshida et al. (1991) report an experimental and theoretical study of the collection efficiency of a reverse-flow cyclone, and they verified that large particles are collected in the upper part of the cyclone and small particles in the conical section. This conclusion can be an indication that the increase in ratio highet of cyclone decreases the collection area for fine particles (conical section), thereby affecting overall efficiency (10).

It is concluded from this study that increase of respirable dust concentration, velocity, and total concentration cause to increase efficiency of cyclone.

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