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DESIGN AND EXPERIMENTAL ANALYSIS OF DUST CONTROL SYSTEM FOR IMPROVING THE TOTAL DUST REMOVAL EFFICIENCY OF A MELTING BRONZE FURNACE

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ABSTRACT

A small foundry usually produces air pollution causing problems in the working area and environment. This project aimed to remove the total dust emitted from a melting bronze furnace and decrease total dust concentration based on the principles of particle control unit construction and the budget of small a foundry. The current study started with preliminary sampling, where total dust concentration average and particle size distribution were determined. Those results were considered for the design and construction of a local exhaust ventilation system and a packed bed scrubber type counter current to remove total dust from the melting bronze furnace. The local exhaust ventilation system was constructed by galvanized steel for drawing total dust emitted from the melting and pouring bronze process. Total dust was transferred into the packed bed scrubber type counter current flow, afterward clean air would be released to atmosphere. The packed bed scrubber type counter current flow had a removal total dust efficiency average (η) of 44.00% and removal of total dust larger than 2µm efficiency average (η ≥2µm) of 89.96%.

Keywords: Bronze, Dust Concentration, Foundry, Local exhaust ventilation system Partical Size distribution, packed bed scrubber type, Efficiency

1. INTRODUCTION

Increasing in the number of industries in Jimma (Ethiopia) improves the economic and the quality of life of people, but at the same time those industries emitted pollutions into atmosphere. They were produced from fuel, poor production process, poor safety management and poor air pollution control. So it is essential to construct air contaminants control unit necessity for removal the air contaminants before emit to atmosphere. A bronze product manufacturing unit is selected for collecting the data's and analyzing a removal of total dust efficiency. Packed bed scrubber is selected in current study.

2. LITERATURE REVIEW

2.1. Health Issues and Environmental Issues

Kuo et al. (1998) investigated the prevalence and factors related to pneumoconiosis in foundry workers. They found, the prevalence of pneumoconiosis was significantly related to high concentrations of dust, especially with a high proportion of free silica, however, smoking and length of exposure were also contributing factors [1].

M. Holtzer (2005) states dust is a major issue, since it is generated in all process steps, in varying types and compositions. Dust is emitted from metal melting, sand moulding, casting and finishing[9].

C. Vijayananda,P. Rajagurub,K. Kalaiselvi a, K. Panneer Selvamc and M. Palanivel (2008) states Industrialization and urbanization are the two major causes of deteriorating air quality. To evaluate the ambient air quality of the Coimbatore city, suspended particulate matter (SPM) was collected at ten stations and analysed for the heavy metals content. The concentrations of seven heavy metals (Zn, Fe, Cu, Pb, Ni, Cr and Cd) were estimated [12].

R. Masike, M.J. Chimbadzwa (2013) describes Cleaner Production and its opportunities to minimize material consumption, optimize production yield and to prevent polluting the air, water and land [18].

G. S. Patange , M. P. Khond, S. J. Prajapati, H. J. Rathod (2013) describes need of air pollution control in a foundries in india and suggests the model for control the emission in medium and small scale foundries [19].

Jong-hyeon Jung et al. (2015) analyzed emission characteristics and concentrations of hazardous pollutants generated in unit processes (casting, molding, core, welding and finishing) of a foundry industry. They found that workers have non-tuberculous diseases, thickening of the pleura, circulatory diseases, hypertrophiacordis, and pulmonary insufficiency. When compared with workers in general manufacturers, the rates of health problems of workers in the foundries are relatively high [20].

2.2. Dust Control System Design

Croteau, Guffey, Flanagan and Seixas (2002) studied the effectiveness of local exhaust ventilation system for capturing dust is dependent on the proximity of the contaminant source to the shroud, face velocity and the magnitude and direction of competing air current .

Murugesan and Sivakumar(2002) describes pressure drop is dependent on all the variables viz., phase flow rates, physical properties of the gas and liquid systems (density, viscosity and surface tension) and structural parameters of the porous medium (packing size, shape and bed porosity) used [4].

Sindhu and Sai (2003) states that pressure drop increased when increased gas flow rate and liquid rate. On comparison of values for up flow with that of down flow, it is observed that the contribution towards total pressure drop due to bubble formation is more for up flow compared to that of down flow [5].

Yuan, Han, Wang, Wang and Jin. (2004) investigated mass transfer coefficient for two-phase counter current flow in a packed column with a novel internal [6].

Belmira Netoa, Carolien Kroezeb, Leen Hordijk and Carlos Costa (2009) presents an overview of options aiming to reduce emissions to air, soil and water from an aluminium die casting plant located in Portugal [13].

A. Yu. Val'dberg, t. N. Kuzina, and yu. V. Bykova (2009) discusses a hollow sprayer scrubber and cooler involving complete evaporation of the irrigating liquid [14].

J. Koo,J. Hong ,H. Lee and S. Shin (2010) founds a new type of scrubbing system equipped with air-atomized spray nozzles, full cone type spray nozzles and the maze shape channels has been developed and the mass transfer mechanism to remove sub-micron particles is analyzed [15].

2.3. Removal Dust Efficiency

Kim, Jong, Oh and Lee (2001) studied particle removal efficiency of gravitational wet scrubber considering diffusion, interception and impaction [2].

S. V. Entin et al. (2004) developed fine filter for treatment of dust-laden gases in the production of refractories. The aerodynamics of the filter equipped with rotary impellers is discussed [7].

Anne-Gwenaelle Guezennec et al. (2005) developed an experimental device for studying this phenomenon. As in the case of the air–water system, the bubble-burst gives birth to two types of droplets: film drops and jet drops [8].

Li, Klausner, Mei and Knight. (2006) determined direct contact condensation in packed beds. It is observed that, the counter current flow stage condensation effectiveness is significantly higher than that for the co-current stage. The condensation heat and mass transfer rates were found to decrease when water blockages occur within the packed bed [10].

Prosanto Pal et al. (2008) focus on the process by which the SDC-TERI partnership developed and demonstrated an energy-efficient divided-blast cupola (DBC) and a highly effective pollution control device [11].

Jonathan M. Cullen and Julian M. Allwood (2010) claims that using energy more efficiently is a key strategy for reducing global carbon dioxide emissions[16].

Bashir et al. (2012) describes an analytical method for design and prediction of spray tower scrubber performance based on cement dust particle removal efficiency. Then it is validated using the World Health Organization (WHO) air quality standard [17].

3. PROBLEM DEFINITION

The current work aims to design and construct the local exhaust ventilation system consisted of low enclosure hood, capturing hood, ducts, blower and stack. The construction was performed by using materials low price, tolerate and local available material. The current work determined the removal total dust efficiency average of the packed bed scrubber type counter current flow only, not

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included the efficiency of removal gas.

The numbers of samples were 5 samples. It was few because of the limitation of customer order and high price of copper. The production procedure of each batch is similar. The budget for stack sampling is high. The sampling process required many technicians and the instruments were not available. The parameters needed to be control were gas velocity, gas flow rate, and pressure drop and liquid/gas ratio. The removal total dust efficiency average of the packed bed scrubber type counter current flow was analyzed.

4. METHODOLOGY

The current work is aimed to design and experimental analysis the local exhaust ventilation system and the packed bed scrubber type counter current flow for removal total dust. The removal total dust efficiency of the packed bed scrubber type counter current flow from melting bronze furnace was determined in this project.

4.1. Particles Concentration:

Data of preliminary sampling including particles concentration (Table 1), particles size distribution (Table 2). The determined particles concentration included total dust concentration, copper fume concentration and tin fume concentration, which shown in table 5. The sampling period was melting bronze process.

The sampling conditions:

Sampling time average = 57 min,

Air volume average = 85.88l (0.086 m^3),

Temperature average = 59.8°C and

Atmosphere pressure average = 1012.8mbar

The total dust concentration determination: The filters were absorbed humidity by desiccators least 24 hours after sampling. The filters were weighed in weighing apparatus. The total dust weigh calculated by blank weigh and air volume for determining total dust concentration in samples.

4.2. Metal fumes concentration analysis:

This method is following NIOSH 7300. The filters were digested by ashing acid and heat on hotplate (120°C) until the solution was clear. The solution was diluted by dilution acid. Solution was analyzed by Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES) for copper and tin fume concentration. The metal fume concentration was calculated from blank concentration, sample solution volume, blank solution volume and air volume for determining metal fume concentration in samples.

The table 1 shows the results of particles (total dust, copper fume and tin fume) concentration emitted from melting bronze furnace. The samples were collected particles while melting bronze process.

Total dust Concentration (mg/m^3)	Copper fume Concentration (mg/m^3)	Tin fume Concentration (mg/m^3)
13.41 (15)*	0.82 (0.1)*	0.162 (2)*

Table 1- Dust & fume concentrations

*: Exposure limits standards

- Total dust : OSHA = 15 mg/m^3

- Copper fume : OSHA. ACGIH, NIOSH = 0.1 mg/m^3

- Inorganic tin : OSHA. ACGIH, NIOSH = 2 mg/m^3

Total dust and tin fume concentration were compared with exposure limits standards. Christo Ananth et al. [3] proposed a system, this fully automatic vehicle is equipped by micro controller, motor driving mechanism and battery. The power stored in the battery is used to drive the DC motor that causes the movement to AGV. The speed of rotation of DC motor i.e., velocity of AGV is controlled by the microprocessor controller.This is an era of automation where it is broadly defined as replacement of manual effort by mechanical power in all degrees of automation. The operation remains an essential part of the system although with changing demands on physical input as the degree of mechanization is increased. Thus, the working area should be construct particles control unit appropriately for decreasing and controlling particulates emitted from melting bronze furnace.

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4.3. Particles size distribution:

The steps for size distribution measurement were as follows:

Size distribution sampling: Andersen One ACFM Ambient Cascade Impactor was installed outside melting bronze furnace. It was connected to vacuum pump. Sampling time covered melting and pouring bronze process. The sampling condition were,

Sampling time average = 264.7 min,

Temperature average = 48.7°C and

Atmosphere pressure average =1005.7 mbar.

Analysis of samples: The aluminum plates and filters were weighed. The mass frictions in each stage were the total dust weigh on the aluminum plates and filters. *Anderson one ACFM Ambient cascade Impactor is used to measure particle distribution.* . The table 2 shows the particles size distribution from melting bronze furnace. From the results, the most size range was 0-0.4 µm (43.40%) and 5.8-10.0 µm (33.91%) respectively. The particles size average was 3.32µm. The particles size larger than 2 µm was 48.91% of all total dust.

Stage	Size range (µm)	Mass friction average (%)	Cumulative Mass friction average (%)
Filter	0 - 0.4	43.40	43.40
7	0.4 - 0.7	2.23	45.63
6	0.7 - 1.1	2.21	47.84
5	1.1 - 2.1	3.25	51.09
4	2.1 - 3.3	3.51	54.60
3	3.3 - 4.7	4.04	58.64
2	4.7 - 5.8	7.45	66.09
1	5.8 - 10.0	33.91	100.00

Table 2- The particles size distribution from melting bronze furnace

5. DESIGN THE LOCAL EXHAUST VENTILATION SYSTEM

The principle of the design the local exhaust ventilation which was constructed by galvanized steel. The local exhaust ventilation system was consisted of low enclosure hood (uses for drawing total dust from melting bronze furnace), capturing hood (uses for drawing oil smoke from pouring bronze process), duct (uses for transferring air contaminants into and out from the packed bed scrubber type counter current flow), blower (uses for drawing air contaminants into the local exhaust ventilation system and the packed bed scrubber type counter current flow) and stack (uses for releasing clean air to atmosphere).

Figure 1 shows Layout chart of the local exhaust ventilation system. The local exhaust ventilation system would consider each segment: A-B, B-C, B-D and D-E (Position A is low enclosure hood, Position B is joint ducts of hoods, Position C is capturing hood, Position D is outlet duct of scrubber and Position E is stack). Figure 2 describes the conceptual Model for the system.

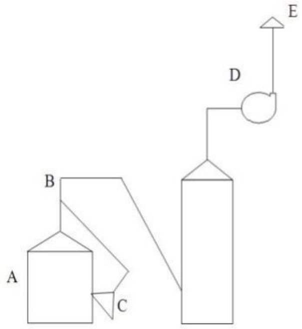

Figure 1- Layout of the local exhaust ventilation system

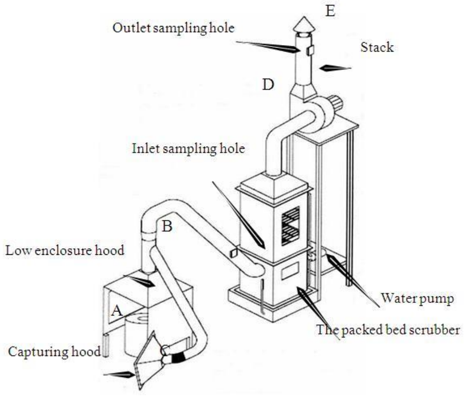

Figure 2- Conceptual Model

5.1. Design of Packed Bed Scrubber

The packed bed scrubber type counter current flow operation was gas stream moves upward in direct opposition to the scrubbing liquid steam, which moved downward though the packed bed. The packed bed scrubber was constructed by stainless steel.

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The packed bed scrubber had rectangular column shape, the total dimensions was 600 x 600 x 2200 mm, which was separated into 3 parts:

Bottom part: It dimensions was 60 x 60 x 80 cm. This part was gas inlet and recirculation tank (Figure:3).

Figure:3 Bottom Part

Middle part: It dimensions was 1.97 x 1.97 x 3.61 ft (600 x 600 x 1100 mm). This part occurred contacted between contaminants upward with liquid downward, which was impaction and diffusion mechanisms for total dust removal within the packed bed scrubber type countercurrent flow (Figure: 4).

Figure: 4 Middle Part

Top part: It had trapezoid shape, the dimensions was 600 x 600 x 300 mm. This part was filled packing for eliminating mist (Figure: 5).

Figure: 5 Top Part

Stock: It used to release the cleaned dust to atomsphere. (Figure: 6)

Figure: 6 Stock

Figure: 7 Packed Bed Scrubber

Equipments of the packed bed scrubber (Figure: 7) included;

Sponge filter was used for trap particles moving downward with droplets for plugging protection in suction head of water pump and spray nozzles. It was installed at the middle of the bottom part.

Suction head was used for suction water in the bottom part into water pump. It was installed inside the bottom part.

Water pump was used for suction and discharge water recirculation within the scrubber. The water pump of this project had specifications: electric centrifugal pump (YOSHIMA, model CPM-158), motor 1 HP (750 W), 220 volt, head max 114.8 ft (35 m), capacity max 110 l/m, 2,850 RPM. It was installed beside the bottom part.

Sieve plates dimension were 29 x 58 cm, which were constructed by ingot stainless steel. They were used for support packing and sponge filter (Figure-8).

Water volume scale was used for indication water volume in the scrubber. It was installed outside the bottom part

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(Figure-9).

Figure: 8 Sieve plate

Figure: 9 Water volume scale

Drain valve was used for draining water outside the scrubber. Spray nozzle ejected water droplet, which had water flow rate 1.5/m/nozzle. It could adjust water distribution, which were installed 60 pieces within the top of the middle part. (Figure-10).

Figure: 10 Spray Nozzle

Packing selected square rings, this was made by polyethylene. The specifications were: high temperature resistant 80°C, void ratio 90%, cylinder shape, height 0.07 ft, diameter 0.23 ft, density 3.4 kg/ft^3 and 170 pieces/ft^3 of packing. The packing was used for impact between particle and water droplet.

Sample	**Temperature At environment/duct (C°)**	**Pressure (mm Hg)**	**Air Volume (m^3)**	**Total dust weight on filters (mg)**	**Total Dust weight in beaker (mg)**	**Total Dust weight (mg)**	**Total dust Concentration (mg/m^3)**
Inlet 1	**29.0 / 77.8**	**758.0**	**0.4252**	**4.37**	**1.57**	**5.94**	**13.97**
Outlet 1	**34.7 / 37.1**	**758.0**	**0.8651**	**5.10**	**2.02**	**7.12**	**8.23**
Inlet 2	**30.1 / 70.3**	**757.0**	**0.4119**	**4.53**	**1.34**	**5.87**	**14.25**
Outlet 2	**33.9 / 33.9**	**757.0**	**0.8865**	**5.97**	**1.67**	**7.64**	**8.62**
Inlet 3	**29.8 / 82.0**	**758.0**	**0.4220**	**3.41**	**2.24**	**5.65**	**13.39**
Outlet 3	**32.9 / 35.8**	**757.5**	**0.9563**	**5.11**	**1.67**	**6.78**	**7.09**
Inlet 4	**33.1 / 71.3**	**757.5**	**0.4123**	**4.46**	**1.00**	**5.46**	**13.24**
Outlet 4	**38.5 / 37.3**	**758.0**	**0.9691**	**4.66**	**1.69**	**6.35**	**6.55**
Inlet 5	**30.6 / 61.7**	**758.0**	**0.4421**	**4.71**	**1.39**	**6.10**	**13.80**
Outlet 5	**34.3 / 37.1**	**758.0**	**1.0144**	**6.52**	**1.63**	**8.15**	**8.03**

Table -3 Stack sampling

6. EXPERIMENTAL ANALYSIS OF THE SYSTEM

The stack sampling was for collecting particles at 2 positions (inlet and outlet duct of system). Each position was for 5 sampling. Each sample was collected in 2 sampling period: The first period was done at 40th minute after start the burner of the first batch or 10th minute after started melting bronze process of the second batch. The second period was done at 15th minute of pouring bronze process.

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This step presented inlet and outlet total dust concentration of the packed bed scrubber type counter current flow, which were calculated for determining the removal total dust efficiency average (η) and removal total dust larger than 2 µm efficiency average (η ≥2µm) of the packed bed scrubber type countercurrent flow.

Total dust concentration determination: The total dust concentration can be calculated using total weight of total dust in filters, total dust in beakers, air volume, air and stack temperature, air and stack atmosphere pressure, temperature and atmosphere pressure at NTP and other constants using the equipments Gas Analyzer, Pitot tube, Dry Gas Analyzer. The analysis of removal total dust efficiency average (η) and removal total dust larger than 2 µm efficiency average (η ≥2µm), as shown in equation in

$$\eta_{\geq 2\mu m} = \frac{\eta}{48.91^{*}} \times 100$$

Table 3 describes the Total Dust Concentration in 5 Sampling stages. It needs various parameters like Temperature at Environment and Duct, Pressure, Air volume, Total Dust weight on filters, beaker.

7. RESULTS AND DISCUSSIONS

7.1. RESULTS

7.1.1. Removal Total Dust Efficiency of the Packed Bed Scrubber

Samples	Total dust concentration (mg/m^3)		Efficiency (%)
	Inlet	Outlet	
1	13.97	8.23	41.08
2	14.25	8.62	39.51
3	13.39	7.09	47.05
4	13.24	6.55	50.53
5	13.80	8.03	41.81
Average	13.73	7.70	44.00

Table 4 - Removal total dust efficiency

7.1.2. Removal Total Dust Larger Than 2µm Efficiency

Removal total dust larger than 2 µm efficiency (η ≥2µm) is calculated from:

$$\eta_{\geq 2\mu m} = \frac{\eta}{48.91^{*}} \times 100$$

48.91*: Mass of particulate larger than 2 µm from the particles size distribution of melting bronze furnace

$$\eta_{\geq 2\mu m} = \frac{44.00}{48.91^{*}} \times 100$$

$$= 89.96\%$$

7.2. DISCUSSIONS

7.2.1. Discussion Of Removal Total Dust Efficiency of The Packed Bed Scrubber

The packed bed scrubber type counter current flow had removal total dust efficiency (η) 44.00% , which includes 51.09% of particles size smaller than 2µm and 48.91% of particles size larger than 2µm. But, the objective of current study is to remove very fine dust particles. So the final Efficiency is calculated for Removal of total dust larger than 2µm.

7.2.2. Discussion of Removal Total Dust Larger Than 2µm Efficiency

The current study had fine particles size. The result shows, when increased the efficiency of removal contaminates the particle size range will be increased. The packed bed scrubber type counter current flow had removal total dust larger than 2µm efficiency (η ≥2µm) 89.96%. The removal total dust efficiency was increased, when the particles size was large.

8. CONCLUSION

The Design and Experimental Analysis of a Control Unit for Dust and Metal Fumes from a Melting Furnace was performed in the small scale bronze foundry. The control system was designed, fabricated and installed in a melting furnace. Finally, the stack sampling is performed, total dust concentration inlet and outlet duct were range 13.24-14.25 and 6.55-8.62 mg/m^3 respectively. The results were calculated for the removal total dust efficiency average (η) and the removal total dust larger than 2µm efficiency, average (η≥2µm) of the packed bed scrubber type counter current flow. The packed bed scrubber type counter current

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flow had removal total dust efficiency average (η) 44.00% while removal total dust larger than 2 µm efficiency average (η ≥2µm) 89.96%.

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