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미세먼지 저감을 위한 특허기술들

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Patent Technologies for Reducing Micro-Dust

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Abstract Four developed patents have applied for a new type of Composite Cyclone Scrubber followed by the previous research (Cho and Kim, 2017), including dust reducing fan with filters. Regarding target installation and maintenance cost, 64% reduction for investment costs (6.2 billion won vs. 17 billion won) compared to existing road pollution reduction system, while social benefit costs increase by 43% compared to existing road pollution reduction measures (72.6 billion won vs. 50.8 billion won). The composition of the device is an air blower type spiral guide vane, and an injection pressure collecting dust efficiency. A nozzle varies Injection angle and contact range, spray liquid species (waterworks, salty water). The proposed patent tests are circulation water Time-by-Time Spray and collected 41.4% more increased micro dust since the sprayed water meets contaminated gas due to the 45^0 degree colliding, which is 141% increased conventional dust collector. (Ratio of collection over 85%). As regards the source of collection liquid, circulated rainwater and well water, we expect a huge amount of energy and economically saved eco-friendly system in our patent. Finally, the guided vane and metal filter reduced over 90% micro-dust, while sprayed water cleans the vane and filters, resultantly minimizing the maintenance budget. The preliminary evaluations of the developed design make it possible to reduce not only cheaper maintenance budget due to the characteristic water spraying but the cost of water comes from mainly rain and underground.

Keywords: Composite clone scrubber, road pollution reduction system and air blower type spiral guide vane, reuse of rainwater

1. Introduction

1.1 Worldwide Air Pollution Management Market

The most urgent task regarding reducing micro-dust on the roads is "STOP" of spraying water on the road "day time". Since the secondary micro dust as by-product, resulting from combined with sunlight and water, lessen the effect of reducing dust significantly. The second problem is treating NO_x, from car and truck. It causes critical health problems to the human body but not filtered even if flow into DPF.

Fine mode aerosol (PM2.5 or less) divided into a primary generation due to combustion and a condensation of particles in the atmosphere. It divided into ones that generated in the condensation. The finer I-mode (nuclei or Aitken) is directly discharged or a relatively large j-mode, meaning less matured (i.e., a fresh particle) produced by condensation (accumulation) means aged particles; these two modes interact through aggregation, and it grows through condensation of gaseous precursors such as NO_x, SO_2, NH_3, etc., and is wet and dry deposited. Chemical components of the aerosol taxonomic micro modes are sulfate, ammonium salt, nitrate, natural and artificial vegetation organic carbon, elemental carbon (EC), etc., and the coarse mode component related to (KECO2015-ER03-14, 2015).

Meanwhile this black (carbon) market is growing in high speed, however world widely 8% increasing death ratio due to air pollution, which needs the most urgent research and policy. The forecast for growth of 5.2% during 2014-2019 (BCC, 2015), but BCC Research 2017, which shows more than double the expected growth rate of 64 trillion won since 2015.China invested 288 trillion-won March 2014, averagely 32 percent decrease in urban fine dust concentration over four years (KECO2015-ER03-14, 2015).

Beijing has allocated $120 billion (128 trillion won) to improve air quality, bans new thermal power plants, controlling the number of vehicles and reducing steel production capacity, but still 9 times the air pollution level based on WHO (BCC, 2015). In Japan,

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•본 논문에 대한 토의를 2020년 5월 31일까지 학회로 보내주시면 2020년 6월 호에 토론결과를 게재하겠습니다.

Nozzle-type road water spray fine dust reduction (350 m section between the Japanese National Assembly and the National Assembly Hall).

Europe reduced average AEI (Air Environmental Index) of PM2.5 to 20% by 2020. France utilize rainwater on roadside as a waste cleaning facility (Using Heavy Water Supply Facility in Roadside). Finally, the United States, the United Kingdom and Taiwan, etc.). Most of the surveys have conducted on road cleaning, mainly water-cleaning vehicles. They did significant jobs to reduce micro-dust; however, still is it the largest cause of death in the world (BCC, 2015).

1.2 Constraints for direction of the scrubber

The reason for a design of a modified Day-to-Night Spraying System in a modified method based on the side effects of the pollution. To remove the effect according to the temperature and (solar) luminance, it can generate smog, according to the increase of the solar temperature and luminance with "the second level fine dust generation" in the daytime application of the sprinkling cleaning removal method. Which increased density of NO_2 nitrogen dioxide and ozone and HCHO formaldehyde (smog) by NO_X nitrogen oxide and SOx sulfur oxide in exhaust gas; see NO_2 nitric oxide (NO_X: nitric oxide, NO plus nitrogen dioxide, NO_2) (Shin, 1996).

Therefore, the following shape of scrubber and schedule of watering are proposed:

1) Direct road injection only at night when the concentration of fine dust is getting worse.
2) In the daytime, the internal circulation type cleaning collection performed in the circulation type cyclone scrubber.

2. The goal of research

2.1 The objectives and scope

The final goal of this research is development of composite cyclone structure utilizing reserved water in order to reduce micro dust, range from 2.5 nm to 10 nm size.

For this purpose, we develop a revised cyclone scrubber, in which having guided vane and mesh type filter. Since sprayed water clean vane and mesh type metal filter, the maintenance period and cost would be much cheaper.

In addition to that, regarding target installation and maintenance cost, over 60% reduction in the investment costs compared to existing road pollution reduction measures.

In terms of quantitative estimation, the micros dust would collect over 90% for CO, CO_2, PM, SO_x, and NO_x, in the developed 30 meter spacing columns utilizing 20 m^3 of circulating water per day. It may notable that the range of working form -20^{o}C to 50^{o}C due to the lessen potential of water, resultantly working 4 seasons, different with other conventional ones.

In general, if compared the gas and water in the same direction show less performance of collecting dust than in the opposite direction between dust and water, already proved in many experiments. Therefore, gravity direction (downward) spraying collects a normal efficiency Test. Regarding our spiral guide vane may show best performance, an air blower type vane with an injection pressure collecting efficiency due to their 45-degree angle spraying collision with vanes.

2.2 Comparison with conventional patents

There is at least one type of similar technology for reducing micro-dust via sprayed water. This gadget contains several similarities in terms of 1) Spraying water, 2) Providing water for cleaning and 3) inlet gas to be cleaned.

However, the following progressive differences have proved in our advanced cyclone system.

1) The proposed system could work on the roadside or in the basement as a vertical type and horizontal type.
2) The proposed system could work in the subway in a horizontal type.
3) Collecting droplet shows the maximum ratio when they meet directly (0 degree), which is 141% larger pressure value than the conventional one in which water flow upper and lower directions only.
4) The proposed patent utilizes circulating rainy water and well water, which are not used in general.
5) In fact, the hydrophilic between vane and water is not so high; hence, we add metal filter, in which dust reduced 10% more while passing through (Fig. 1). The conventional dust remover use guided vanes as well.

2.3 Process of development for composite cyclone scrubber

Two main functions of collecting micro-dust have suggested shown in Fig. (1). The contaminated gas goes in the scrubber due to the fan in outlet. Over 60% of the gas meets with three fans, which combined with water and drop to the reservoir. The reserved water pumped and move into the scrubber again. After passing the guided fans, the approximately 25% of remain gas meet with metal filter. Resultantly, over 85% contaminated gas changed to clean gas, which process will start cyclically when contaminated water drained and clean water added from waterworks, rainwater or inlet well.

Therefore, the water and the sprayed metal filters are passed through the fine dust flowed in through the blower and the scrubber type cleaning device washing dust and separates water and air. The next room facility system is necessary for separating clean gas and contaminated water. The key design variables might be

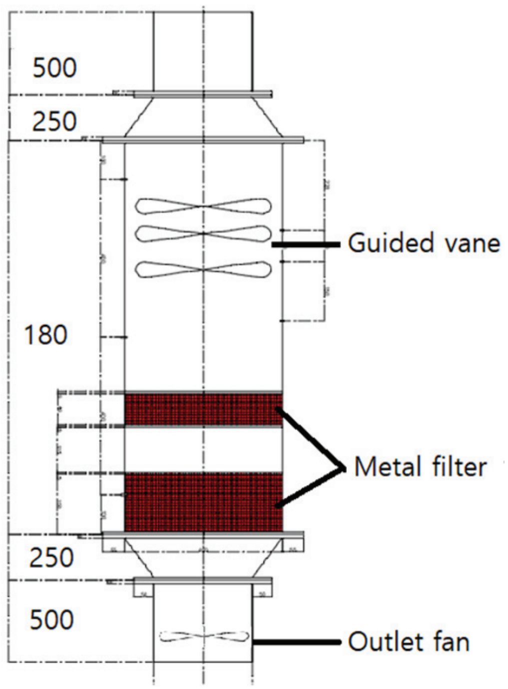
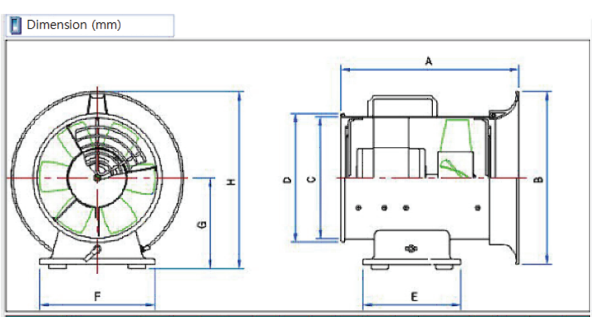


Fig. 1 Connected members of Model 1



Model	A	B	C	D	E	F	G	H
TIP-200S	315	ø279	ø185	ø198	200	188	159	320
TIP-250S	315	ø355	ø235	ø248	200	238	197	375
TIP-300S	325	ø368	ø265	ø298	220	240	218	408
TIP-350S	370	ø435	ø335	ø348	220	240	218	455

Fig. 2 The dimension of outlet fan

1) The pores of metal filter
2) Optimal space flow shape
3) Flow velocity and air volume of fine dust
4) The length and diameter of the cleaning device
5) Comparison of air vortex and cleaning degree.

14 inch CF-14D Guided vanes attached as the first circling filter, which are rotated by sprayed water and out let fan. The second filters are two metal filters cleaned by the sprayed water as well. Dimensions of outlet filter and the system of model is illustrated in Fig. 3 and Fig. 4. In this system, the following variables are considered.

The structure and location of duct do not prevent flow of water

Air duct should be filtered

Inlet emissions, e.g.CO, CO_2, NO_x, and PM, meet on the vane with spraying water in a short duration

After meeting, contaminated air should have to flow into reserved water tanks via bent.

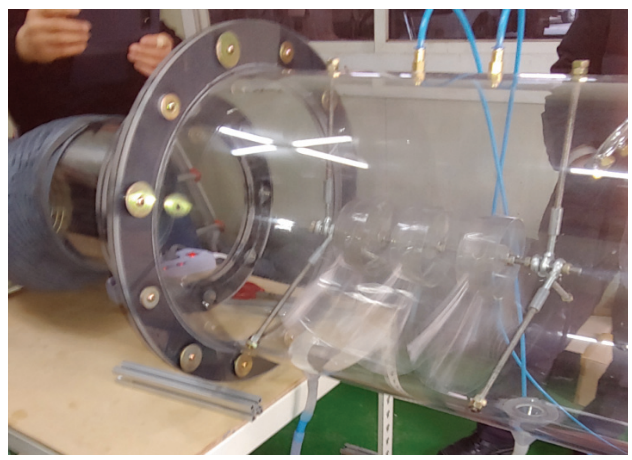


Fig. 3 Connected members of Model 1

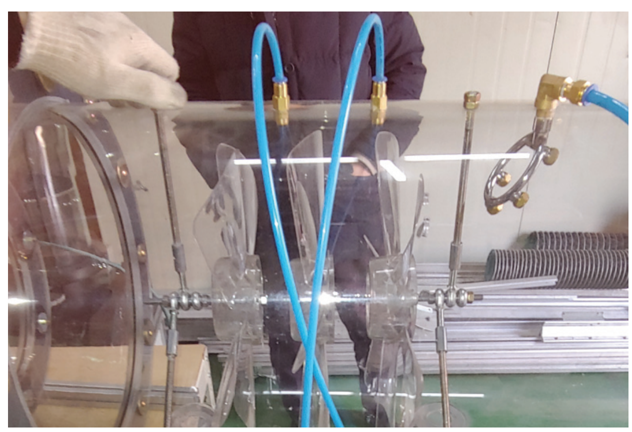


Fig. 4 The dimension of outlet fan

While the above 1-4) processes, capacity of pump is important, as to be selected optimum one.

2.4. Capacity of pump

To maximize cleaning effect, the process from suction with pump to spraying to vane directly related with reduction of energy. Assembled vane, fan, circular body and outlet fan as presented in Fig. (5).

2.4.1 Inlet Emissions & Fan

- Casing: 100cm x 40cm x 100cm= 400,000c㎥ (Initial value)
- Volumetric flow rate(Q) = 400,000cm^3/s = 0.4㎥/s (1)

- Massive flow rate

$$\acute{m} = \rho Q = \left(\frac{1.2kg}{m^3}\right)\left(\frac{0.4m^3}{s}\right) = 0.48\,kg/s \tag{2}$$

- Mean velocity into duct;

$$v_2 = \frac{Q}{A} = \frac{0.4}{0.4\times 0.4} = 2.5\,m/s v_2 = 2.5\,m/s \tag{3}$$

- Quantity of the fan:

$$\acute{W}_{fan} - \acute{E}_{mechanical\,loss} = \acute{m}\left(\alpha_1 \frac{V_2^2}{2}\right) = 1.5\,W \simeq 2\,W \tag{4}$$

2.4.2 Scrubber Pump

- Let Well=1, location of sprayed by a nozzle in the scrubber as 2, then
- ($\boldsymbol{p_1 \cong p_2 p_1 \cong p_2}$), $\boldsymbol{v_1 \cong 0 v_1 \cong 0}$),

$$\acute{m}\left(\frac{p_1}{\rho} + \alpha\frac{v_1^2}{2} + gZ_1\right) + \acute{W}_{fan} = \acute{m}\left(\frac{p_2}{\rho} + \alpha\frac{v_2^2}{2} + gZ_2\right) + \acute{E}_{mechanical\,loss,\,fan} \tag{5}$$

$$p_1 = p_2 = p_{atm}$$

$$p_1 = p_2 = p_{atm}\ , z_1 = z_2 z_1 = z_2,$$

$$v_1 \ll v_2 (v_1 \approx 0) v_1 \ll v_2 (v_1 \approx 0)$$

$$\acute{W}_{fan} - \acute{E}_{mechanical loss,\,fan} = \acute{m}\left(\alpha_1 \frac{v_1^2}{2}\right) \acute{W}_{fan} \tag{6}$$

$$-\acute{E}_{mechanical loss,\,fan} = \acute{m}\left(\alpha_1 \frac{v_2^2}{2}\right) = \left(\frac{0.48kg}{s}\right) \times 1 \times \left(\frac{0.48kg}{s}\right)\left(\frac{1\,N}{\frac{1kgm}{s^2}}\right) = 1.5\,W \simeq 2.0\,W$$

Let Reserved water tank ①, Scrubber: location of spraying via nozzle= ②,

p1 ≈ p2 (Assumed as atmospheric pressure), v1 is zero on the free water surface v1 ≈ 0

- Provided water Q = 0.0015m/s, and diameter of nozzle is 1cm

$$v^2 = \frac{Q}{A_2} = \frac{Q}{\pi(0.01)^2} = \left(\frac{0.0015}{\pi(0.01)^2/4}\right) = 19.1 m/s \tag{7}$$

$$h_{pump,u} = 10 + \frac{24.5^2}{2(9.8)} = 40.6 \tag{8}$$

$$w = \rho Q g h_{pump,u} = \left(\frac{1000kg}{m^2}\right)\left(\frac{0.0015m^2}{s}\right)\left(\frac{9.8m}{s}\right)(24.6m) = 0.36\,kW \tag{9}$$

Hence, the minimum pump quantity (Efficiency of the pump, =0.7, assumed)=

$$\dot{W} = \rho Q h_{pump,\,u} = (1000kg/m^3)(0.002m^3/\sec)(9.8m/\sec^2)(40.6m)\frac{1kN}{1000kg/s^2}\frac{1kW}{1kNm/s} = 0.795\,kW \tag{10}$$

Therefore, when water quantity Q = 0.0015m/s, the quantity of the pump is calculated as 0.795KW. Hence we selected the pump as 1.5KW, considering mechanical energy loss.

3. Conclusion

As illustrated in Figs. 6 to 9, we have changed the filtering conditions as water, vanes and metal filter (Fig. 7), water with vane and metal filter (Fig. 8), and no filters (Fig. 9). As the results presented in Table 1, the water, vanes and metal filter case showed largest filtering over 10 PM of micro-dust with 87% cleaned during 20 minutes in 10 times of tests.

Due to the cyclic function of the proposed scrubber, the accumulated gas would show higher values for the removing micro-dust in the outlet air.

Table 1 Collected micro-dust (scale;100/0.01g)

	Base Weight	Water with Filter	Water only	Sprayed Carbon
Measured (g)	0.81	1.16	1.78	3.47
Collected Carbon (g)	NA	0.35	0.97	2.66
Cleaned (%)	NA	86.5	63.5	NA

17,000 people are dead by the contaminated air per year [6]. This dirty air kills people by cancer as well. For problem solving

Fig. 5 Zero Setting

Fig. 6 Water and filter (1.16g).

Fig. 7 Water only (1.78g).

Fig 8 Sprayed Carbon (3.47g).

the first proposed water spray nozzle method is to compensate for the disadvantage of rapid deducting effect due to the increase of secondary fine dust sulfur dioxide (SO_2), nitric oxide (NO_x: nitric oxide, NO plus nitrogen dioxide, and NO_2 in daytime (sunrise-sunset time: 12 hours). The additional plan change of the helix vane type cyclone chamber is raised to the average 70% (PM10: 95%, PM2.5: 45%) of the cleaning collection efficiency.

In order to solve current significant challenges of air pollution of roads, four patents have submitted to compose the composite cyclone scrubber system, which will provide cyclic water for cost efficiency (Cho et al., 2017(a), (2019)(b)). The proposed structural system is composed of integrated composite cyclone scrubber structure having reserved rainwater or inlet well, hence additional cost benefit comes.

The preliminary evaluations of the developed design make it possible to reduce not only cheaper maintenance budget due to the characteristic water spraying but the cost of water comes from mainly rain and underground. The calculated results are possible to be designed over 85% reduced micro dust results. However, the optimum nozzle size and spraying angle with pressure are sensitively dependent with angle of attached guided vanes and the number of metal filters, which needs additional experiments.

Acknowledgement

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References

1. T. Cho, T. Kim, (2017)"Patent Technologies in an Artificial Tree". Recent Patents on Engineering. Vol. 13, Issue 4, pp.125 - 133.
2. KECO2015-ER03-14 (2015), Korea-China collaborative study. Abate monitoring air pollution in China, p.40.
3. (BCC, 2015) BCC (2015), Market Research Reports and Industry Analysis.
4. Shin (1996), The updated environmental engineering. Free Academy.
5. Kim S. et al., (2014), Development of Clean road system. Environmental Research of Metropolitan Area.Vol.23 No.12 pp. 2029-2034
6. WHO(2013)(International cancer institute, IARC). Lyon, France, from http://www.ecowatch.com [Accessed: Aug. 28, 2017].
7. T. Cho,(2017), "Assembly Type Road Support Structure Having Rain Water Reserving Function" Korean Intellectual Property Office Patent 1019505850000.
8. T. Cho,(2019),"Rain Water Automatic Spraying System. Korean Intellectual Property Office Patent 1019648550000.
9. T. Cho(2017), "Collection and recycling system for evaporation water at room temperature used in sewage passage using potential energy, Korean Intellectual Property Office Patent 1019351560 000.
10. T. Cho, (2017), "Collection and recycling system for evaporation water at room temperature used in sewage passage", Korean Intellectual Property Office Patent1019351550000.

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요 지 : 필터가 장착 된 먼지 감소 팬을 포함하여 새로운 유형의 Composite Cyclone Scrubber를 개발하고, 목표 설치 및 유지 보수 비용에 대해서는 기존 도로 오염 저감 시스템 대비 64 %의 투자비 절감 (61 억 원 vs. 170 억 원), 기존 도로 오염 저감 조치 (72.6 억 원) 대비 사회 적 비용 편익이 43 % 증가 , 50.8 억 원)가 예측되고 있다. 장치의 구성은 송풍기 형 나선형 가이드 베인이며 , 분사 압력은 미세먼지를 포집한다. 분사 각도 및 접촉 범위가 다양한 노즐, 스프레이 액체 등과 순환 수를 이용한 스프레이이며, 분사 된 물이 Guide Vane과 45도 각도로 충돌로 인해 오염된 가스를 만나기 때문에 41.4 % 더 많은 미세 먼지를 포집한다. 이는 기존의 집진기보다 141 % 증가한 것이다. 포집 액체, 순환 빗물 및 우물 공급원과 관련하여 우리는 특허에서 막대한 양의 에너지와 경제적으로 절약되는 친환경 시스템을 기대한다. 가이드 베인 및 금속 필터는 90 % 이상의 미세 먼지를 줄였으며, 분무 된 물은 베인과 필터를 청소하여 유지 관리 예산을 최소화했다. 개발 된 설계의 예비 평가를 통해 특징적인 물 분사로 인하여 유지 보수 예산을 줄일 수 있다.

핵심용어 : 복합사이클론스크러버, 도로변 오염원 제거, 나사선모양의 가이드베인