DEVELOPMENT OF AN OPTIMAL SYSTEM
TO PREVENT WASTE REFRACTORY DUST SCATTERING IN HYUNDAI STEEL

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1. INTRODUCTION

With the emergence of ESG management worldwide, interest in preventing environmental pollution has increased rapidly, away from productivity-oriented management in the past. In the European Union and the United States, it has already become an important criterion for evaluating companies. The installation of discharge facilities was insufficient due to the very low interest of the people involved in dust generated in open spaces rather than specific process facilities. Due to the recent issue of dust and fine dust, the environmental improvement of dust in the workplace is gradually taking place.

Generally, refractory is a material resistant to high heat, high pressure, or chemical action, and is mainly composed of an oxide or non-oxide of a non-metallic material such as silicon, aluminum, etc. In particular, steel refractories used in steelmaking processes, which mostly have a high heat environment, are used as interior materials or repair materials according to operational characteristics in various processes for containing, transporting, and treating iron as well as steel. The replacement of refractory takes place according to the life of the refractory by process and operation situation. The removed waste refractories are crushed to an appropriate size and then recycled as aggregates, but the amount is very small and most of them are buried as waste. Most steel factories consist of a system in which crushed refractories are temporarily collected from temporary Yards and then taken out. At this time, dust scattering generated during transportation and collection in Yard causes respiratory diseases of workers such as pneumoconiosis, and causes various problems such as delays in operation due to obstruction of vision caused by dust.

In the case of Hyundai Steel, the tilting process of the ladle containing waste refractories was carried out in an open space inside the factory, and the resulting ultra-high concentration of dust scattered and spread throughout the factory. To solve this problem, Hyundai Steel developed a dust scattering prevention system using air flow control and air purification technology to prevent waste refractory dust from scattering.

Fig 1. Scattered dust in the tilting process

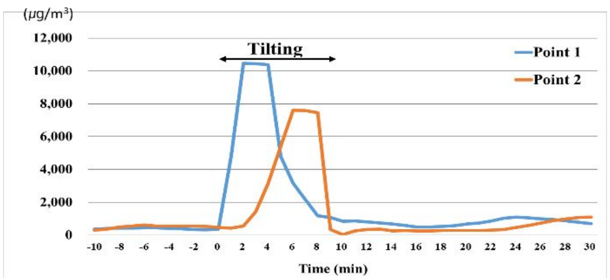

Fig 2. Dust concentration in the tilting process (Max. 10455 $\mu g/m^3$)

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2. DUST SCATTERING PREVENTION SYSTEM

2.1 PRINCIPLE

The dust scattering prevention system is a system that prevents dust generated from scattering when tilting ladles containing waste refractories. It consists of a cube structure with an open hole for waste refractory fall, supply/exhaust facilities (Diffuser, Hood, Duct, etc.), and a cyclone & filter type. The exhaust flow rate was adjusted to form a negative pressure inside the housing, and the air flow using an air jet was controlled to prevent dust from escaping to the outside of the structure through the open hole. Air sucked into the hood installed inside the housing passes through the cyclone (without a filter device) and most dust in the air is removed. Afterwards, some of the cyclone-purified air (circular air) is supplied into the structure through a diffuser, and the rest of the air passes through the HEPA filter and only clean air is discharged into the factory.

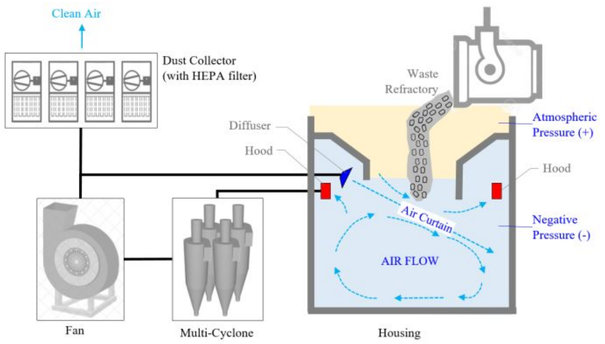

Fig 3. Schematic Diagram

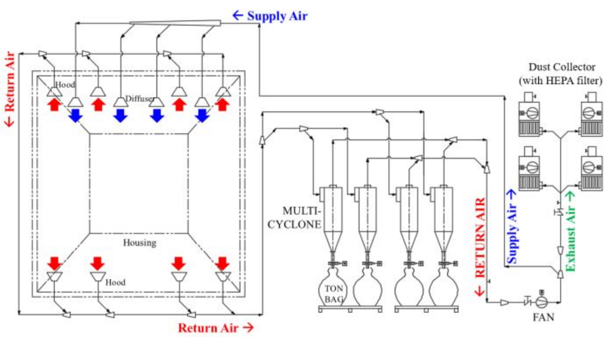

Fig 4. Process Flow Diagram

2.2. ENGINEERING AND DESIGN

2.2.1 Negative Pressure in the housing

It is designed such that the amount of exhaust air through the hood is greater than the amount of air supplied through the air supply device so that negative pressure is formed inside the housing so that air can flow only in one direction from the outside to the inside of the housing.

2.2.2 Air Curtain at open face

In order to trap dust that rises vertically at a high speed after dropping waste refractory in the housing, air jet was sprayed from the air supply port to form an air curtain on the open hole surface.

2.2.3 Efficient dust capturing in the housing

The hood was designed so that dust trapped inside the housing was collected as efficiently as possible. As a result, it was possible to minimize dust scattering generated in the dumping operation, which is the last process of disposing of waste refractories.

2.2.4 Filterless Air Purification Facility

Since the air collected through the hood has a very high dust concentration, the filter-type air purification facility is blocked by dust in an instant. For this reason, a dry cyclone separator(no filter) which capable of capturing 99.9% of PM10 or higher dust was applied. And, a total of four single cyclones were applied as multi-cyclones composed of 2 rows*2 columns because the air volume to be processed was large and the space for installation of facilities was limited.

The pressure loss values for each duct section were calculated and balanced so that the total processed air volume could be accurately and evenly distributed into quarters.(If the air volume is distributed disproportionately, the dust purification efficiency of the single cyclone that distributed less air volume is significantly lowered.)

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2.2.5 No Stack

Since installing a chimney was not possible, collected dust had to be discharged inside the factory. Most of the dust was removed by the multi-cyclone, but Dust Collector with HEPA Filter was installed to remove even fine dust.

2.3 Erection

The facilities (hood, diffuser, duct, multi-cyclone, etc.) manufactured according to the design was installed on site.

Fig 5. On-site installation

3. Simulation with CFD (Computational fluid dynamics)

Simulation was performed using ANSYS Fluent (ver. 2019 R1) to predict the airflow inside the housing. It was modeled identically to the specifications (size, layout, etc.) of actual facilities. The flow analysis was performed in a steady state, and a realized k-ε turbulence model was used to analyze the overall air flow inside the housing. Atmospheric pressure, gravity, air at room temperature (Density 1.225kg/m3, Viscosity 1.7894e-5 kg/m-s) were set as conditions.

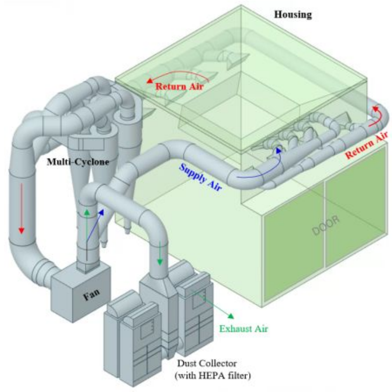

Fig 6. Geometric

For the mesh, an inflation layer was applied to the part where the air flow changed rapidly, and Tetrahedra and Hexahedra were applied to the part where the change was relatively small.

- Quantity of Nodes: 5,661,631ea
- Quantity of Elements: 32,219,501ea

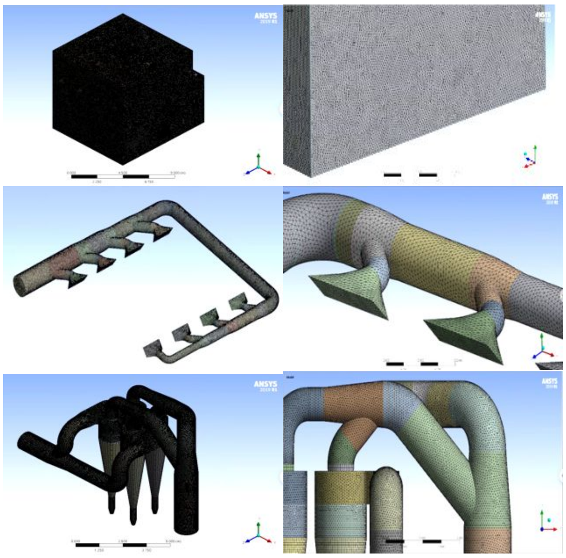

Fig 7. Mesh

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When the flow rate of return air is 1500CMM (m3/min), the flow rate of supply air was compared with 300CMM (case1), 500CMM (case2), and 700CMM (case3). As a result of simulation analysis, the most optimal result was shown in the supply air volume of 500CMM (Case 2). (hood collection efficiency 99.2%, dust scattering rate 0%)

Table 1. Result for each air supply flow rate

Items	Unit	Case 1	Case 2	Case 3
Supply Air volume	m^3/min	300	500	700
Total number of particles	EA	66,415	66,415	66,415
Particles captured by the hood	EA	63,970	65,911	29,522
Scattered particles	EA	557	0	36,317
Particles spinning inside	EA	1,888	504	576
Difference between supply and exhaust	m^3/min	1,200	1,000	800
Capture rate	%	96.3	99.2	44.5
Scattering rate	%	0.8	0.0	59.2

A flow field was formed in which the air from the diffuser formed an air curtain, circulated inside the housing, and then collected through the hood.

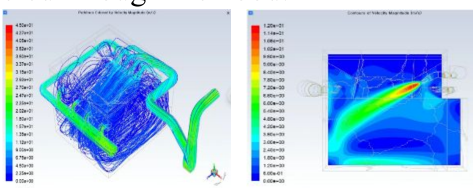

Fig 8. Air flow in housing

It had a low-pressure distribution at the hood opening, and a negative pressure was formed throughout the housing.

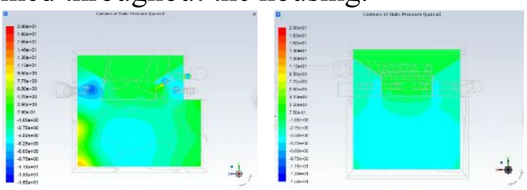

Fig 9. Pressure in housing

Air flow was formed from the outside of the housing to the inside, so the inside air did not go out. At this time, the average surface velocity at the inlet is 1.01 m/s.

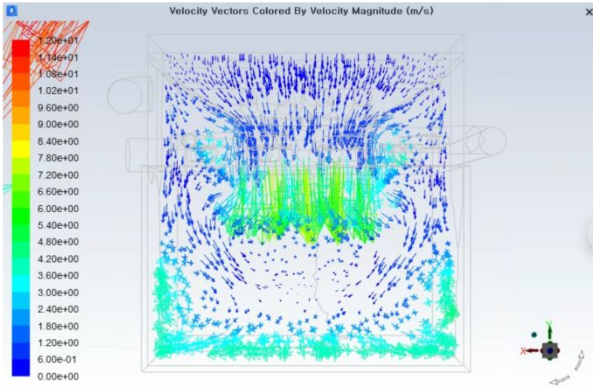

Fig 10. Air velocity vector in housing

The air volume distribution for each of the air diffuser and hood as well as the four single cyclones was uniformly formed.

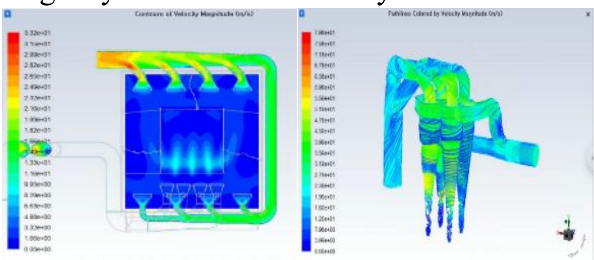

Fig 11. Air volume distribution

4. RESULTS

As a result of applying the dust scattering prevention system to the site, it was confirmed that the dust scattering was reliably improved with the naked eye.

Before	After
	

Fig 12. Improvement effect

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Before installing this system, dust concentrations were measured at two points near the housing. It was tilted a total of 2 times. After the system was installed, the dust concentration was measured in the same way.

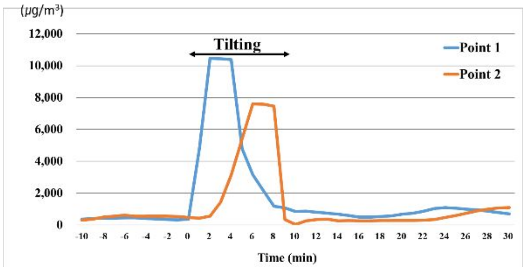

Fig 13.1. Measurement concentration of dust @ 1st tilting before improvement

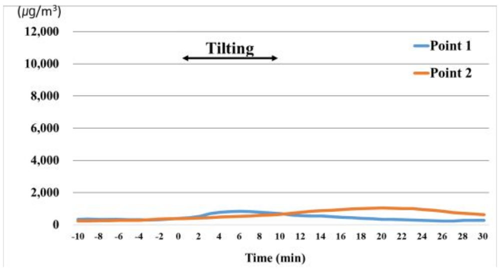

Fig 13.2. measurement concentration of dust @ 1st tilting after improvement

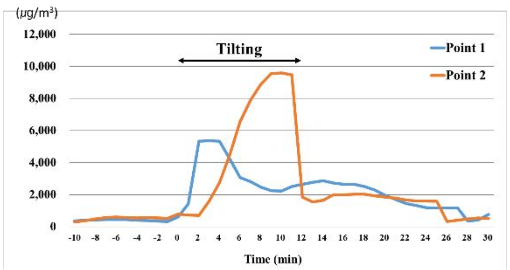

Fig 13.3. measurement concentration of dust @ 2nd tilting before improvement

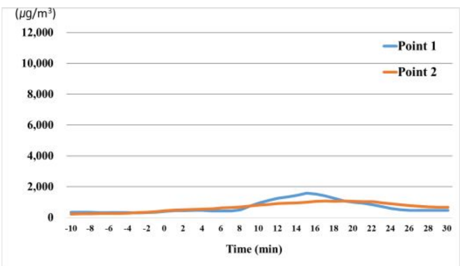

Fig 13.4. measurement concentration of dust @ 2nd tilting after improvement

Table 2. Average(1st & 2nd) dust concentration

Division		1st & 2nd Average dust concentration (μg/m³) Before Tilting	After Tilting	Reduction rate
Point 1	Before Improvement	389	6,253	96.4%
	After Improvement	342	552	
Point 2	Before Improvement	581	4,848	96.9%
	After Improvement	414	546	
Total				**96.7%**

This system reduced the average dust concentration near the housing by 96.7%.

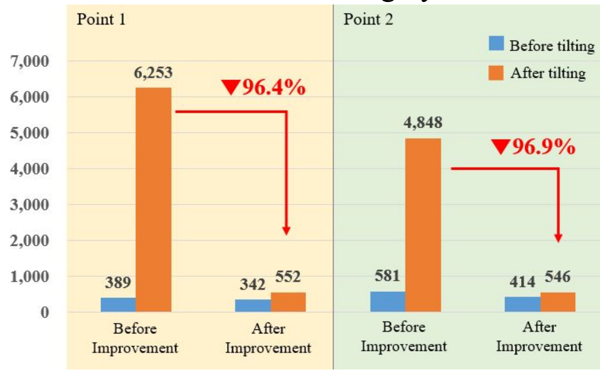

Fig 14. Dust scattering reduction efficiency

5. Advantages

The dust scattering prevention system has the following characteristics in various aspects.

5.1 Increase productivity

Productivity can be increased by eliminating the scattered dust from interfering with operating activities in the factory.

5.2. High economy efficiency

Since a separate chimney installation is not required, initial facility cost and construction cost will be reduced. In addition, by applying a high-efficiency multi-cyclone air purification facility, the facility size can be minimized, installed simpler, and workability

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is better than when only air purification facilities using filters are applied (based on the same throughput). In addition to reducing the initial construction cost, the maintenance cost is reduced because filter management (cleaning/replacement) is not required.

5.3 Protect workers' health.

It prevents deterioration of workers' health (respiratory diseases, vision loss, etc.) due to scattered dust.

6. APPLICATION

Nowadays, there are many requests for cleaning air polluted by dust in many industrial sites, but it is true that the improvement activities have been slow due to the absence of legal standards, inadequate air flow design, or realistic limitations of manufacturing. Through this Hyundai steel case, a stepping stone has been laid to improve the environment of the dust scattering site, and it is thought that it can be applied to this system, especially open area conditions, which was a blind spot, and it can be expanded furthermore.

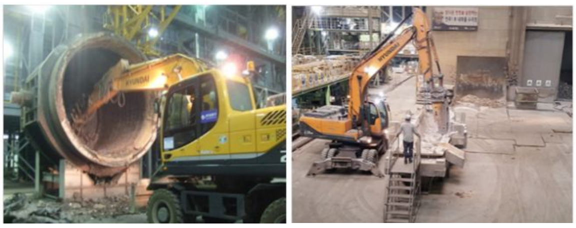

Fig 15. Example of dust scattering site

6. 1 Treatment of Ladle waste refractory

In the steel making process, most of the molten steel is transported using a ladle. Ladle refractories are frequently repaired such as partial repairs and full-scale reconstruction, and the waste refractories generated at this time. Waste refractories are transferred to a construction vehicle or transported to a ladle and dumped to a collection treatment site through tilting. In a similar case, dust scattering prevention system can be applied

6. 2 Treatment of Tundish waste refractory

In the continuous casting process of steel, tundish is an intermediate facility that is exported to the mold after stabilizing the molten steel flow between the ladle and the mold, and productivity and steel quality are directly affected depending on the quality of refractories and how they are used. After use, the tundish is transported to the tundish repair shop and repaired through the process of dismantling and reconstructing refractory materials. In this process, a dust scattering prevention system can be applied.

Refractories that are inevitably used in the steel manufacturing process are generally subjected to a crushing process during treatment after use, which is the main cause of dust scattering. However, it is very difficult to standardize work method as the details of the work process are different for each site. Therefore, the direction of improvement should be derived through consultation with working-level personnel after an accurate on-site inspection so that the contents of improvement do not interfere with the work.

6. 3 Dumping site of slag

The slag generated in the upper process of steel making, is collected in the dumping site and crushed for recycling or waste disposal. Most of the slag dumping sites are using wide and open yard for slag cooling, and there is no separate dust collecting facility, so they are very vulnerable to dust scattering. Accordingly, a dust scattering prevention system using an air curtain can be an alternative that can control dust scattering in a large space.

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