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Research Article

Research of the Dust Removal Technology with Multiphase Flow Water Mist

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Abstract: In order to eliminate the hot steam and dust when the quicklime is slaking, the dust removal technology with multiphase flow water mist is provided in this study. The mechanism of dedusting, working principle and structure composition are introduced and the practical results show that dust removal technology is simple, feasible and effective, can effectively solve the long-standing problem of enterprise green production.

Keywords: Multiphase flow, quicklime; strong cohesiveness, wet dust removal

INTRODUCTION

Sintering with addition of quicklime is a remarkable economic effect of technical measures, in the mixed process of sintering it will improve the ball forming rate of the mixture (the ball forming rate increased about 15%), thereby improving the permeability in the process of sintering; at the same time, quicklime meets with water, it reacts with water and generates Ca (OH)2,expands and emits a large amount of heat, it can increase the mixture temperature in the process of sintering, which has the effect that cannot underestimate. And in the process of sintering eliminates the appearance of white point, improves the oxygen content in the material layer, promotes the generation of calcium ferrite in sintering ore, greatly improves the strength and metallurgical properties of sinter (Lin, 2004). But quicklime after slaking generated a lot of hot steam and dust, the dust removal problem has not been effectively solved (Zhao and Long, 2008).

THE CHARACTERISTICS OF QUICKLIME DUST

The solid particles suspended in the gas called dust (Wu, 2003). Quicklime is also known as calcium oxide and its chemical formula is CaO.

Strong cohesiveness: The phenomenon which dust attached to the solid surface or dust mutual attachment is called adhesion. Its adherent strength is the force required to overcome the adhesion phenomenon and also known as adhesion. The bigger dust sticky is, the easier adheres and coagulates into larger particles in the process of collision. In general, adhesion of the dust is measured by tensile stress. Tensile stress of quicklime dust is more than 600 pa, so it belongs to the strong cohesiveness dust.

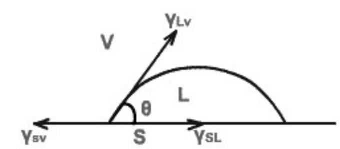

Fig. 1: Wetting angle of the droplet on the smooth solid surface

High hydrophilicity: Liquid phase (L) is adsorbed on the Solid phase (S) surface and the phenomenon which reduces the surface energy of the solid phase is defined as wetting. Hydrophilicity is defined as wettability which the liquid make the solid particle wet when solid dust particles contact with liquid interface. It depends on wetting angle θ (Angle between the solid-liquid phase interface and liquid phase surface tangent which containing liquid phase, as shown in Fig. 1). Wetting angleθ≤90°, the performance of materials are hydrophilic, such as wood, quicklime, sandstone, etc.; when the wetting angle θ > 90°, the performance of material are hydrophobic, such as asphalt, paraffin wax, etc.

From the thermodynamics point of view, a droplet falls on a clean smooth solid surface, while ignoring the effects of gravity and viscosity of liquid, the droplet in the solid surface spreading depends on three interfacial tension, such as YSV [solid-vapor phase (SV)], YSL[solid-liquid phase (SL)] and YLV[liquid-vapor phase (LV)] , its balance relationship can be determined by the following formula:

$$Y_{SV} = Y_{SL} + Y_{LV}\cos\theta \quad (1)$$

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Then: $$\cos\theta = \frac{Y_{SV} - Y_{SL}}{Y_{LV}} \quad (2)$$

High dispersion: Chemical equation of quicklime in the process of slaking can be expressed as:

$$CaO+H_2O = Ca(OH)_2 +64.9 \text{ KJ} \quad (3)$$

The reaction gives off a lot of heat, generating extremely fine slaked lime colloid particles, the volume expands (its volume is about 1~2.5 times of that of the original), average specific surface area reached 300000 cm 2/g(it increased about 100 times after slaking). Thus the process of quicklime slaking with high dispersion, diffusion range is larger, the difficulty of dust collection is high.

Hydraulicity: From the formula (3), it is known that after slaking the quicklime will generates Ca(OH)2 particle and then reacts with the CO^2 and absorbs heat generated in the front and generates $CaCO^3$, a large number of $CaCO^3$ form hard scale and harden after precipitation, namely for hydraulicity.

To sum up, dust produced in the process of quicklime slaking easily bonding, humidity, light weight and high dispersibility, not easy to capture. According to these characteristics, we can consider to apply with multiphase flow water mist dust removal technology.

THE DUST REMOVAL REMOVAL MECHANISM WITH MULTIPHASE FLOW WATER MIST

Multiphase flow is refers to the vapor-solid-liquid three phase flow. Dust removal technology with multiphase flow water mist is similar to filter deduster in mechanism, that is, using inertia collision, intercept and diffusion effect (Xiang, 2006).

Inertial impaction effect: When dust flow along the streamline and flow around, streamline buckle. The mass of dust for m due to the effect of inertia and deviate from streamline and collide with dust arrester then the dust is arrested. Trajectory that dust can be arrested in the most distant is called limit trajectory, as shown in Fig. 2.

Interception effect: Interception effect is first assumed that the dust has size without mass and then under this assumption, different size dust flow along the streamline of the vapor, as shown in Fig. 3. The trajectory of dust in the Fig. 3 is limit trajectory, all the dust bellow this trajectory which the range for b, size as dp will be intercepted.

Diffusion effect: When the diameter of dust is less than 1 μ m, due to the thermal motion of surrounding gas molecular, the trajectory of dust is always inconsistent with streamline of the vapor, Therefore it no longer abides by the mechanism of impaction effect

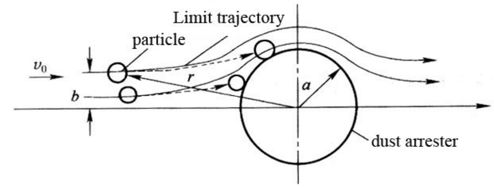

Fig. 2: Inertial impaction effect

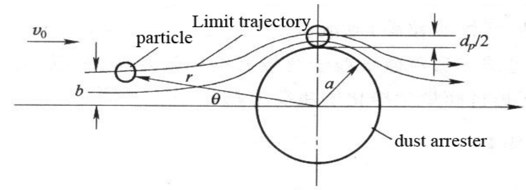

Fig. 3: Interception effect

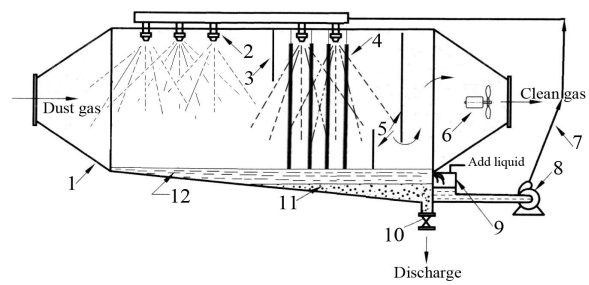

Fig. 4: The dust removal device with multiphase flow water mist
1-case; 2-atomization nozzle; 3-choke plate; 4- water film dust removal tube (Steel pipe); 5- mist baffle plate; 6-induced draft fan; 7-pipeline; 8-pump; 9-water tank; 10-valve; 11-mud; 12-pool

or interception effect, when the vapor moves around the droplet, because of Brown diffusion and deposited in the droplet. The mutual diffusion of dust and the behavior of dust spreading to dust-arrester are extremely complex physical phenomenon (Xiang, 2006).

THE STRUCTURE AND WORKING PRINCIPLE OF THE DUST REMOVAL DEVICE WITH MULTIPHASE FLOW WATER MIST

As shown in Fig. 4, the dust removal equipment mainly consists of the case 1, atomization nozzle 2, Choke plate 3, water film dust removal tube (Steel pipe) 4, mist baffle plate 5, induced draft fan 6, pipeline 7, pump 8, water tank 9, valve 10 and pool 12, etc.

Its working principle is as follows: the dusty gas enters the case from collecting inlet under the negative pressure suction of induced draft fan, a group of atomization nozzle is installed near top of the collecting inlet. The atomization nozzle connected steelmaking wastewater. The main reason of using the steelmaking wastewater is that it includes iron materials, iron material in the process of digestion can absorb a lot of heat and reduce the steam produced in the process of assimilation, thereby reducing the dust which steam brought out; At the same time it can also be recovery of iron material in steelmaking wastewater, decrease the cost of sinter (Lin, 2004). In order not to influence the fluidity of wastewater, so as to ensure atomization effect, the concentration of steelmaking wastewater must be controlled, firstly, steelmaking wastewater flows into a concentration regulation pool (figure not shows), its concentration is controlled below 20% and then sent to the pool and then supply atomization nozzle. The wastewater is recycling, but there is lossy in the dust removal process, so must be added.

Steelmaking wastewater after atomizing by the first group of atomization nozzle, using inertia collision effect, being the first dust removal measures, at this stage can be regarded as vapor-liquid two phase flow; Then gas containing dust continue to flow to the water film dust removal tube, water film dust removal tube is actually a group of staggered steel pipe (the quantity can be adjusted according to actual situation), The upper end is fixed on the upper part of the case by a hinge, can carry out 360 degrees of rotational freedom and small angle swing back and forth, its length extends a short distance into the pool. On the top of the water film dust removal tube is decorated with another group of atomization nozzle, this group of atomizing nozzle spray angle can be adjusted and the spray droplet size is slightly larger than the front, in order to flush the adhesive content on pipe. Part of wastewater by atomization directly to capture dust, this is the second dust removal measures, at this stage can be regarded as vapor-solid-liquid three-phase flow; another part of wastewater by atomization spray on steel tube, thus the pipe surface is adhered with a layer of water film. Due to the steelmaking wastewater itself has certain viscosity, in addition atomization wastewater adsorb some quicklime dust when enter into dust collector, for its viscosity increased after chemical reaction generating $Ca(OH)^2$, so the viscosity of steel pipe surface wastewater membrane is very strong. When dust and vapor go through the staggered arrangement of steel area, because of the dust also has good adhesion, it is extremely easy to adhere to the surface of the water film and is arrested. The atomization nozzle located on the top of steel pipe to spray this area and flushing the steel pipe, washing away adhesion things of steel pipe surface and then making it clear, collected in the pool, discharged through the lower sewage outlet of the case, this is the third dust removal measures. At the same time, steel pipe can be rotated, thereby ensuring from multiple angles to wash and steel pipe can also be carried out within the scope of small swing, to make the steel pipe slightly impact each other, make its surface adhesion of the content is more easy to be cleared.

The role which settings choke plate is to prevent the vapor containing dust from going directly to the outlet without going through water film dust removal tube. Mist baffle plate is located in the hind of water film dust removal tube, the air supply areas of this area is bigger than that of the water film dust removal tube, according to the fluid mechanics theory, it is known that the wind speed will reduce, thus forming dehydration cavity, flowing through mist baffle plate, removing mist for the dust removal vapor, in order to reduce the moisture which wind will take away, so as to ensure the gas from the outflow is clean gas.

RESEARCH OF INFLUENCE FACTORS ON DUST REMOVAL PERFORMANCE

There are many influence factors on dust removal performance, mainly from the following several aspects to analysis and study.

Atomization nozzle: Atomization nozzle is one of the most critical part of dust removal device, it is direct decided to the liquid refining degree and coverage, etc. From the interception effect point of view, under the condition of the amount of spraying water is a certain, the finer the sprayed liquid droplets is, the more opportunities the dust is arrested; But from the inertia collision effect point of view, because inertia collision efficiency and the relative speed v_R (between dust and droplets) is proportional and droplet diameter D_f is inversely proportional, accordingly, to increase collision efficiency, have to increase v_R, decrease D_f. And the effective value of v_R is the gravity free fall speed difference between dust and droplet, because of the dust are much smaller than droplet, so v_R is equal to the gravity free fall speed of droplet. This appeared to the contradiction between the two requirements of increasing v_R and reducing D_f. Therefore, there is an optimum diameter of droplet (Hu *et al*., 2002). Reference (Wu, 2003) gives the relationship between collision efficiency and the droplet radius in the spray tower, as shown in Fig. 5, it shows that the most effective droplet size in the spray tower relying on inertia collision to collect dust is the range of 500~1000 μm. Through the different nozzle spray experiments show that: for the gas containing dust after assimilation, the extrusive droplet diameter is thicker, the dust removal effect is well and it can be controlled in 1000 μm~2000 μ m is appropriate. But it should be clear, because the influence of the droplets agglutination and the collision between the droplets and the case and the droplet size in contact with the gas containing dust is difficult to predict. Therefore, in the selection of atomizing nozzle, it should be chosen according to the actual situation of its basic characteristics, especially the spray angle, penetrating and flow coefficient, etc. In addition, the higher the injection pressure is, the smaller

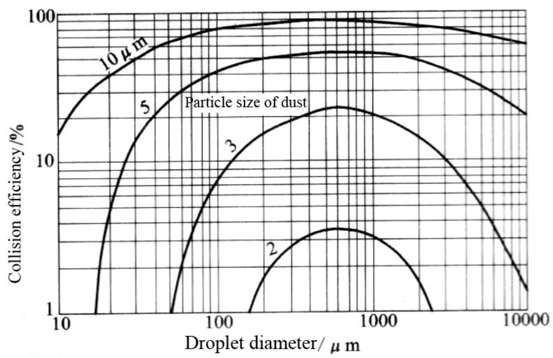

Fig. 5: Relationship between collision efficiency and the droplet radius

the mean particle size of the droplet is, therefore, the injection pressure should be adjustable, so as to be carried on the adjustment in the field and to get the best removal effect. Of course, we still should consider its layout rationality; avoid the existence of jet blind angle.

Water film dust removal tube: Water film dust removal tube is internal staggered steel pipe in the precipitator. Obviously, the number of steel pipe and diameter directly affect the dust removal efficiency, the experiments also proved that: to increase diameter and quantity of the steel pipe all can improve the dust removal effect. But it should consider the precipitator actual layout, diameter of the steel pipe should not be too big, otherwise it will affect its rotation and swinging. In the conditions of steel pipe diameter has been selected, appropriately increase steel pipe row number is a good choice within the scope of certain.

Influence of gas containing dust parameters: The influence factors including: the gas flow rate, dust of concentration, moisture content, gas density, gas viscosity, gas pressure, gas temperature, etc. Through the experiment shows that: in a certain enterprise actual circumstances, wind speed should be controlled in 1.5~2 m/s, wind pressure about 2000 Pa, air volume should be controlled about 10000 m 3/h.

CONCLUSION

- The dust removal technology with multiphase flow water mist is one kind of a wet dust removal system for gas purifying including water mist dust condensed, inertia settlement and separation etc, the practical application shows that this technique has solved the problems of dust removal for quicklime after digestion which distress enterprises over the years, to help the enterprise became efficiency, environmental friendly and green production; at the same time also provides references for strong cohesiveness dust removal.
- The dust removal technology with multiphase flow water provides a guarantee for the sintering burden with good slaked lime, so as to improve the quality and production of sinter.

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REFERENCES

Hu, M., Y. Zhao and Z. Liu, 2002. Dust Removing Technology [M]. Chemical Industry Press, Beijing, pp: 6, (In Chinese).

Lin, W., 2004. Improvement of digestion effect of quicklime [J]. Sichuan Metall., 5: 31-32, (In Chinese).

Wu, C., 2003. Chemical Suppression of Dust [M]. Central South University Press, ChangSha, pp: 6, (In Chinese).

Xiang, X., 2006. Modern Aerosol Particle Collection Theory and Technology [M]. Metallurgical Industry Press, Beijing, pp: 6, (In Chinese).

Zhao, X. and Y. Long, 2008. A new device for burnt lime hydrating and de-dusting [J]. Sinter. Pell., 33(2): 34-36, (In Chinese).