Influence of particle size on the high solid performance coatings with BOF dust as Fillers

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Abstract
The converter dust of different particle sizes was used as fillers for preparing high solid coating, to study the surface morphology and particle sizes of dust on the coating film properties. The results show that: with the converter dust particle diameter in 20~60μm, the particle size < 20 μm dust accounted for 50%, and the grain size meet the size of pigments and fillers for general coating (multi control in 50~60μm) requirement; when the dust particle size was 250 mesh, the coating surface shrinkage is smaller, the performance is best.
Key words: CONVERTER DUST, HIGH SOLID, SALT SPRAY TEST, THE DUST PARTICLE SIZE
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Introduction

To develop the low-carbon economy is the urgent requirement of human existence and the sustainable development of social economy, the global annual 1/10 steel scrapped because of corrosion, obviously, the development of efficient anticorrosion coating has become a pressing matter of the moment[1]. High solid anti-corrosive coating[2,3] is a kind of low volatile organic compounds (VOC) emissions and less solvent coating with excellent adhesion, corrosion resistance, and good construction performance, which make it environment-friendly and energy-saving, nowadays, it has become the best choice for steel anti-corrosion coating field[4].

The basic oxygen furnace（BOF） dust has the characteristics of large quantity, fine particle size and high iron content. In addition, converter dust contains rich oxides, such as SiO_2, CaO, MgO etc[5]. Therefore, it is appropriate for the BOF dust as pigments and fillers to prepare environmental friendly coating.

In coating products, pigments and fillers are mainly the powder. The particle size, distribution, shape, surface morphology, body (internal) structure and microstructure, as well as the mechanical strength of various kinds of particles, influence the powder greatly, especially on the secondary processing products, such as paint performance, among which, the grain size distribution and the particle size of powder are the most significant influence factor. The converter dust as high solids coating salt packing, and the dust of different particle size ratio are analyzed, compared the surface morphology and performance of coating, to study the effect of particle size on the properties of the coating.

Experimental methods

The converter dust from Tangshan Iron and Steel Plate was used as the pigments and fillers of high solid coating, containing Fe_2O_3, SiO_2, CaO, MgO, MnO, Na_2O, K_2O, Al_2O_3 etc. Other materials included E-51 epoxy resin, curing agent YF-350, benzyl alcohol, talc, mica, quartz powder (2000 mesh), leveling agent, dispersing agent and silane coupling agent.

After filtration, drying and grinding, the BOF dust was screened with the standard sieve to150 mesh, 200 mesh and 250 mesh. Converter dust filling quantity of three kinds of sizes was 110g. Pigments and fillers: epoxy resin = 1.1:1, and the amount of diluent for epoxy resin was 15%.The pigments and fillers mainly contained converter dust and a certain amount of mica powder, quartz powder and talcum powder were added to adjust. The experimental formula was shown in Table 1.

Table1. The ratio of raw materials

No.	The dust particle / mesh	Pigments and fillers					Epoxy resin /g	Diluent /g
		BOF dust /g	Mica powder /g	Quartz powder /g	Talc /g	The total /g		
1	150	8.93	0.41	0.41	0.41	10.15	9.23	1.38
2	200	8.93	0.41	0.41	0.41	10.15	9.23	1.38
3	250	8.93	0.41	0.41	0.41	10.15	9.23	1.38

Paint and coating with different particle sizes analysis test preparation, experimental equipment: The JL-1177 type laser particle size analyzer and fluorescence spectrometer, Quanta650 type field emission scanning microscope, Zeisss microscope, NK-2 viscosity cup, mal Axiovert200MAT metallographic microscope, salt fog test box etc.

Results and discussion

1) Analysis of dust particle morphology

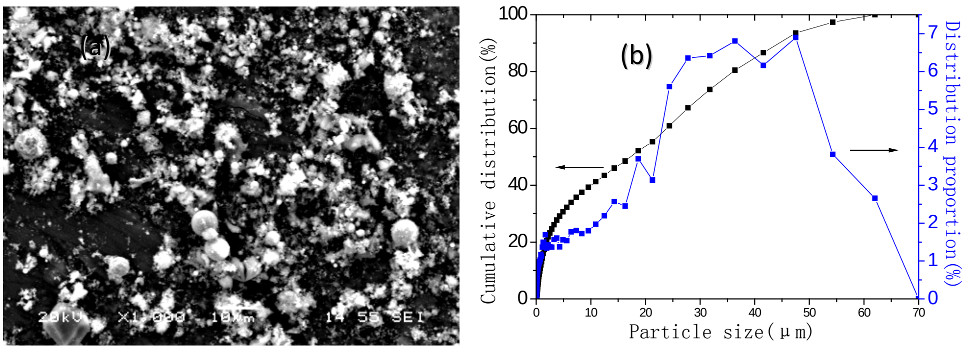

Figure1. Morphology and laser particle size distribution of converter dust

The dried converter dust sample morphology and laser particle size distribution (Fig. 1) shows that there are spherical particles and agglomeration in BOF dust. In addition, the converter dust particle size concentration is in micron or smaller, so the particle size needs to be analyzed. As is shown inFig.1(b),converter dust particle size is mainly in the range of 20~60μm;20% of the dust particle sizes is less than 2μm; and particle size < 20μm dust accounts for 50%. Through calculation, converter dust mean diameter is only 19.68μm. Because converter dust particle is spherical, and the grain size is very fine, general paint pigments and fillers size controls in 50~60μmfor taking into account the grinding cost. Therefore, the dust completely meets the requirements of using as pigments and fillers in the size.

2) Effects of dust particle size on the coating microstructure

The film is uniform, no impurities, no obvious defects, but small shrinkage existing. Figure 2(a) shows that when the dust grain size is -150 mesh, there exists coated on shrinkage of about 5μm, and the film is out-of-flatness. Figure 2(b) shows that when the dust grain size is -200 mesh, the unit area of film decreases in the quantity of shrinkage. And there is no shrinkage with patches in flat area and uneven coating. Figure 2(c) shows that when the dust grain size is -250 mesh, shrinkage is reduced to about 1μm, and shrinkage porosity increases in the unit film area. The surface tension gradient is the main factor causing shrinkage in film surface. And the no uniform of the surface tension is due to the fluid flowing from low to the high surface tension that is caused by changes in coating composition and temperature. At the last, depressions are formed on the surface of fluid, and the substances of the low surface tension present in the shrinkage center[6]. The shrinkage formed in the coating processis affected by the droplet of coating, which flows from low to high in direction to form the center concave holes shrinkage. With the decrease of dust particle size, the particle surface activity increases, and the surface tension of coating decreases, which makes surface tension difference become small between the low surface tension materials and materials around the paint, in consequence, film shrinkage is reduced and the coating surface becomes more smooth.

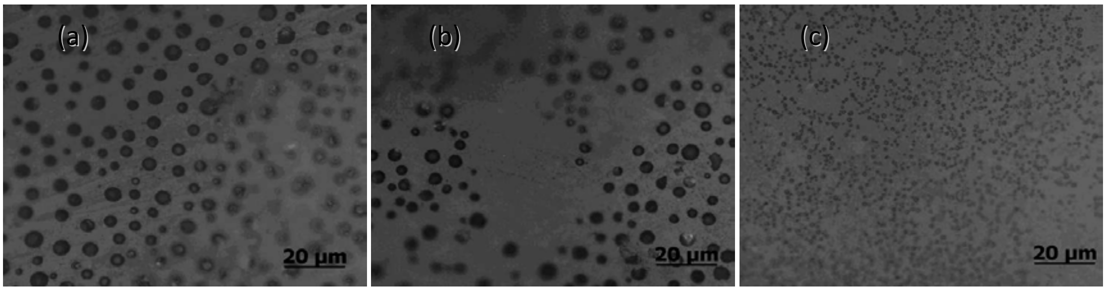

Figure 2. Influence of dust particle size on the coating appearance(a) -150mesh(b) -200mesh(c) -250mesh

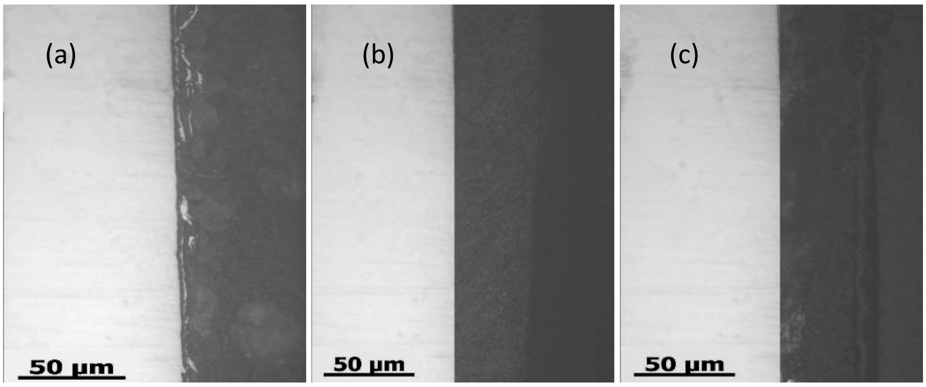

Figure 3. Influence of dust particle size on the sample sections(a) -150mesh(b) -200mesh(c) -250mesh

Fig.3shows that the coating is closely combined with the bright white matrix, and the sample holder is positioned at the outside. It can be seen that the film thickness is about 50μm, and the thickest film is prepared by -150 mesh converter dust, besides, the stratification with5μm gap consists in coating near the substrate. This shows that fine particles of dust can improve the combination with the coating and matrix.

3) Effects of dust particle size on the properties of coating film

(1) The adhesion and hardness

Preparation and results of adhesion and hardness test of the film with different dust particle sizes are shown in table 3.

Table 3. Influence of dust particle size on the adhesion of coating

The dust particle size /mesh	The remaining number of squares	Abscission rate /%	Hardness
150	98	2	6H
200	100	0	5H
250	100	0	5H

With the decrease of the size, adhesion of coating increased, and hardness decreased. After hundred lattice method inspecting, the loss rate of coating prepared by the 150meshof dust was 2%.And the hardness of film was tested as 6H by the pencil hardness. However, abscission did not happen in the film produced by 200 mesh and 250 mesh of dust, and the coating hardness was5H. When the pigments and fillers of paint was large particle dusts, the surface of the film was roughness, and pencil broke easily during the hardness test. It shows that the smaller the dust particle size is, the better binding force between substrate and coating is. But due to different levels of surface roughness, the film hardness was slightly changed. According to the research, coating adhesion depends not only on the surface of base material, but also the interaction between the coating and the substrate[7]. Thus to get good adhesion coating, enough wet-ability on coating surface is required, that is to say, the tension of the coating surface should be lower than the surface tension of matrix material. Therefore, the different average particle sizes of converter dust lead to the different paint adhesion, cohesion and liquidity. The finer the particle size is, the greater the surface area and cohesion is. In addition, with the size of the powder particle decreasing, particle surface defects increased, which resulted in an increasing activity in particle surface to the internally generated, especially the surface activity. In conclusion, the surface activity and the surface tension of coating become stronger and lower respectively, along with the decrease of dust particle size, and the adhesion of the films is better.

(2) Coating resistant to salt water

The coating was prepared by converter dust of different particle as fillers, and magnified 200 times in the Zeiss microscope after 120h neutral salt spray test[8-10]. Fig.4 shows coating corrosion condition.

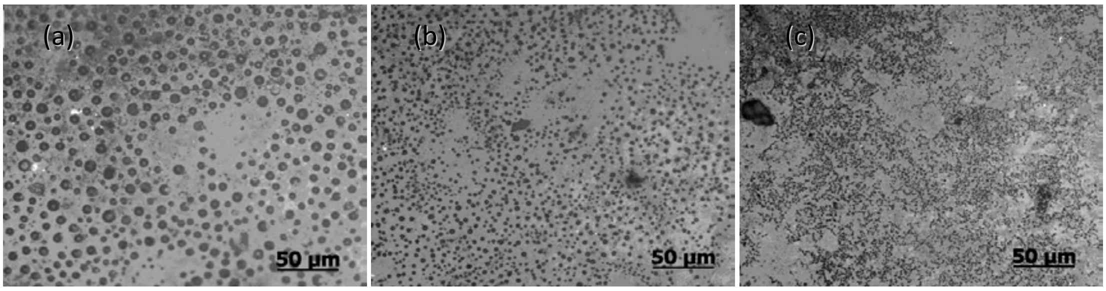

Figure 4. NSS result in films of different dust particle(a) -150mesh(b) -200mesh(c) -250mesh

After coating corrosion by salt spray test, there appears corrosion pits on the surface. This is because of the film surface shrinkage cavity connected with the outside, corrosive gas outside has easy access to corrode the film surface shrinkage. For this reason, the existence of film surface shrinkage is facilitated by the presence of corrosion outside. Namely the corrosion is gradually initiated by the surface shrinkage hole. Fig. 4 (a) and (b) show that the coating films of -150 mesh and -200 mesh are obviously damaged with bad points on the coating surface because of exposing the substrate. However, there are a few slight corrosion points on coating prepared with-250 mesh of dust, as is shown in Fig. 4 (c).In other word, size, numbers and distribution of pore have a direct affect on the corrosion degrees of salt spray test. With the decrease of dust particle size, the coating is not easy to be damaged, and coating anti salt corrosion becomes stronger.

(3) Acid resistance of paint film

The coatings prepared by different sizes of dust are conducted by acidic salt spray in condition of pH 3 and 120h. Then the coating corrosion was observed in the Zeiss microscope by magnifying 200 times(as shown in Fig.5).

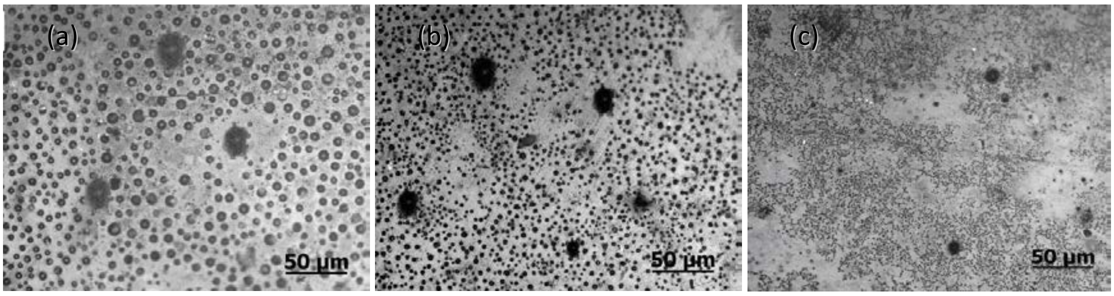

Figure 5. ASS results on different dust particle film(a) -150mesh(b) -200mesh(c) -250mesh

Fig.5 shows that surface shrinkage of the coating is corroded with acidic salt spray corrosion, and corrosion pits appear obviously on the surface. When the dust grain sizes are -150 mesh and -200 mesh, a few large pits appear on the film surface. But when the dust grain size is -250 mesh, the corrosion pits are small on the film surface. Thus, corrosion resistance of the coating changes with dust particle size, and the better is with the decrease of dust particle size, corrosion resistance of the coating is better.

Conclusions

Different sizes of converter dust was used as filler to prepare high solid coating. It is found that the smaller dust particle size is, the better comprehensive performance coatings are.

1）That the dust in the size during 20~60μm as high solid coating pigments and fillers is not only practicable, but also good for resource conservation and environmental protection.

2）The smaller the dust particle size is, the better the combination of coating and substrate is; With the decrease of the dust particle size, the shrinkage film decreases, and the film is more and more smooth.

3）The film prepared with different dust particle sizes has an excellent corrosion protection. When the particle size in the range of -150~-200 mesh, the smaller the dust particle size is, the more uniform the coating is, and the better the anticorrosion performance is.

Acknowledgements

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References

1. J. G. Xu, G. F. Zhang, J. Wang, X. F. Xu, J. J. Lv, Y. Zheng, A. W. Li: 'Preparation and properties of heat-reflective insulation thin layer anti-corrosion coating', New Chem. Mater., 2010, (8), 168-171.
2. Z. Y. Zhan: 'Research and development of anti-corrosion coatings', Henan Chem. Ind., 2011, 28(2), 19-21.
3. G. Lu: 'The trend of high solid anti-corrosion coatings development and product promotion and application', Chem. Ind., 2013, 31(4), 35-40.
4. N. J. Zhu, S. Y. Pan, X. J. Lan, Q. L. Yuan: 'Preparation of high solid anti-corrosion epoxy coating for steel structure', Ningbo Chem. Ind., 2009, (3), 22-25.
5. J. C. Gao, M. X. Fang, Y. Wang, A. X. He, L. Xiao: 'Extracting iron powder from revolving furnace sludge', Powder Metall. Technol., 2002, 20(1), 24-27.
6. J. X. Dong, J. W. Cao: 'Preventing and controlling of waterborne coating surface defects-shrinkage', Henan Build. Mater., 2011, (3), 23-24.
7. L. Xie, A. Freytag, M. Mutha: 'Novel adhesion promoter used for heavy duty coatings', Electro. Finish., 2011, 30(12), 53-56.
8. F. H. Zeng, H. M. Chen, X. J. Xie: 'Study on the salt-fog resistance of water-borne epoxy anticorrosive coatings', China Paint, 2006, (12), 26-28.
9. X. D. Cao, J. Z. Sun: 'Discussions and analysis on bubbling around crossut of film in neutral salt spray test', Paint Coat. Ind., 2006, 36(3), 55-57.
10. B. S. Huang: 'Salt spray test standard and its implement', Paint Coat. Ind., 2002, 32(12), 39-41.