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Development of Anti-Scaling Technology in Spraying Water System

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Scaling is the deposition of mineral solids on the interior surfaces of water lines and on equipment surfaces that cause clogging of water pipelines and a reduction of equipment efficiency. There were scaling problems in the spraying water system of China Steel (CSC) including on the Top Gas Pressure Recovery Turbine fans (TRT fans) in the Blast Furnace Facility, on the Induced Draft fans (ID fans) in the Basic Oxygen Furnace Facility, and on the nozzles of the bloom marking machines. The efficiency of TRT fans and ID fans were decreased, and the markings on the blooms were unclear due to scale deposition. Three strategies were approached separately or in combination to reduce the scale level. First, the concentration of suspended solids in spraying water had to be controlled under 10 ppm. Second, the most suitable scale inhibitors were selected and applied. Third, the magnetic anti-scaling devices developed by CSC were applied on to the water pipelines. The efficiency of TRT fans and ID fans was increased and the consumption of operating power was reduced after the application of the anti-scaling technology. After improvement, the clogging frequency of nuzzles on the bloom marking machine was reduced and the markings on the blooms were clearer.

Keywords: Anti-scaling, Scaling prevention, Spraying water system

1. INTRODUCTION

Scale is the deposition of minerals that form on surfaces due to the saturation of inorganic salts(1). The major categories of scale are: carbonates, sulfates, oxides and hydroxides, sulfide and silicates. Scale deposition often causes many technical and economical problems in industrial plants by blocking the flow of water in pipes or reducing the efficiency of equipment. Operators are often forced to shut down production to solve the scaling problems. Scale removal techniques not only have to not cause damage to tubing or equipment, but also have to solve scaling problems in a short time. Both chemical and physical approaches have been proposed to remove or prevent scale. Each approach has its advantages and disadvantages depending on the physical properties as well as the location of the scale. A bad choice of removal techniques lead to the rapid recurrence of scale.

In general, the use of chemical agents is low cost and is easier in gaining access to scale surfaces or places beyond the reach of physical removal methods(2,3). However, the chemical agents change the water composition. Ion exchange technology is also a successful method to prevent scale but the installation cost is high and requires regular regeneration with high maintenance fees(4). Conventional mechanical cleaning can be used when pipes become clogged by scale but it is expensive and time consuming(1). Electromagnetic and ultrasonic waves have been used for scale removal but they did not work in all situations(5-7).

Three methods were approached at China Steel (CSC) to reduce the scale level on the equipment. First, the concentration of suspended solids was controlled to below 10 ppm in spraying water by increasing the draining frequency or with pretreatment equipment. Second, the scaling inhibitors were selected based on the scale composition and used in sprayed water. Third, the magnetic anti-scaling devices developed by CSC were installed to prevent scaling. These three methods were used alone or in combination depending on the physical properties and the location of the scale. Three examples, including scale level reduction on TRT fans, on Induced Draft Fans (ID fans), and on the nozzles of bloom marking machines, would be discussed.

TRT fans in the Blast Furnace Facility are important equipment in generating power. TRT fans had scale problems even with the use of a scaling inhibitor from Cinyea together with the application of magnetic anti-scale devices. The scale problems of the TRT fans led to an increase in the level of vibration resulting in the TRT fans consuming more operating power. It has been determined that the scaling inhibitor from Cinyea was still the most suitable chemical agent however the dose concentration needed to be increased two times more to have better effects. On the other hand, the suspended solid concentration of the water was reduced by increasing the draining frequency of the water pipeline. The CSC magnetic anti-scale devices with higher magnetic fields were installed. With the application of these three approaches, the vibration level of TRT fans was reduced and the power generation efficiency of TRT fans was increased by 5%.

ID fans in the Blast Oxygen Furnace Facility are also important equipment in generating power and had scale problems even with the use of a scaling inhibitor from Kurita. The scale problems of the ID fans led to an increase in the level of vibration resulting in the ID fans consuming more operating power. In addition, the maintenance frequency of the ID fan was six times per year. The scale deposition was analyzed and a more suitable scaling inhibitor from Ecotek was selected. After switching the scaling inhibitor, the maintenance frequency was reduced to 3 times per year and the power consumption was reduced by 5%. In addition, the magnetic anti-scale devices developed by CSC were used, and the operating power consumption was reduced a further 4%.

There were scaling problems of the nozzles on the bloom marking machines causing the markings on blooms to be indistinguishable. Operators had to mark the blooms by hand and the operation process would be delayed. The scaling inhibitors would interact with the paint used in the marking machines therefore scaling inhibitors cannot be used. The suspended solid concentration of the spraying water was reduced by increasing the cleaning frequency of the pretreatment filter. On the other hand, the CSC magnetic anti-scale devices were installed on the water pipelines. The clogging frequency of the nozzles was reduced after the application of these two approaches. The markings on blooms were clear and easily tracked with the improvement.

2. EXPERIMENTAL METHOD

2.1 Scale deposition analysis and scaling inhibitor selection

X-ray Fluorescence (XRF) analysis was used to determine the composition of scale deposition. Scaling inhibitors were selected based on the composition of scale deposition. A jar test was performed to determine the best scaling inhibitors from the selected candidates and the best dosing concentration. The scale deposition was filtered by a 35 mesh filter. 0.2 g of filtered scale deposition was poured into two litter jars. Each jar was filled with 1,000 ml distilled water. Selected scaling inhibitors with different dose concentrations were added respectively into each jar and stirred at 300 rpm for 5 minutes. The mixed solution was settled for 30 minutes and the turbidity was measured. The one that produced the highest turbidity after settlement was the most suitable scaling inhibitor and dose concentration.

2.2 Water quality analysis and reduction of suspended solid concentration

The water quality analysis results were compared with XRF results to determine the reasons for scaling. Conductivity, pH, calcium, chloride, sulfate, and Suspended Solid (SS) concentrations, were examined in water used in the plants. A pH/water quality analyzer LAQUA F-72 from HORIBA was used to measure conductivity and pH. A Dionex ICS-1100 (Thermal Fisher) equipped with AS22 column was used to mea-sure calcium, chloride and sulfate concentrations. Suspended solids were measured using the following procedure. The samples were filtered through pre-weighted 0.45 μm filter paper and the filter paper was dried in an oven at 100℃ for 2 hours. The dried filter paper was weighted and the concentration of suspended solid was obtained with proper calculation. If the concentration of suspended solid was over 10 ppm, the water quality needed to be improved with pretreatment or a draining process of water pipelines.

2.3 Application of magnetic anti-scale devices developed by CSC

Magnetic anti-scale devices developed by CSC were installed on the spraying water pipelines. The magnetic fields of the devices were between 6,100-7,300 gauss. The diameters of the devices were customized base on the caliber size of the water pipelines. Four sets of magnetic anti-scale devices with magnetic fields of 7,200 gauss were used on the water pipelines to TRT fans and the diameter of the devices was 1.5 inches. On the other hand, there were four sets of magnetic anti-scale devices on the water pipelines to the bloom marking machines. The diameter of these were 0.5 inches and the magnetic field was 6,400 gauss.

2.4 Field test assessments

There is one criterion to assess the scaling level of the TRT fans which is the vibration level. The vibration level is required to be less than 100 μm. There were two criteria to assess the scaling level of the ID fans including the vibration level, and maintenance frequency. The limitation of the vibration level is 60 μm and maintenance frequency should be less than 6 times per year. There are two criteria to assess the scaling level of the nozzles on the bloom marking machines including the clogging frequency and the clarity of markings on the blooms.

3. RESULTS AND DISCUSSION

3.1 Scaling level reduction of TRT fans in Blast Furnace Facility

TRT fans are turned by Blast Furnace Gas (BFG) to generate electricity. The scaling inhibitor from Cinyea was sprayed on to the TRT fans with a dose concentration of 10 ppm. Magnetic anti-scale devices were installed on the water pipelines to prevent scaling and the magnetic field of each magnetic anti-scaling device was 6,000 gauss. However, the TRT fans still had scaling problems and the vibration level of the TRT fans in Fig.1 increased over the 100 μm limit. The higher vibration level caused the TRT fans running at high speed to consuming more operating power. In order to keep the vibration level of the fans below the 100 μm limit, the scaling problems needed to be solved.

XRF analysis showed that the main component of the scale deposition was Fe_2O_3 in Table 1 therefore the most effective scaling inhibitor and dose concentration were selected. The jar Test determined that the best scaling inhibitor was still from Cinyea but the best dose concentration was 20 ppm in Table 2. Water analysis showed that the suspended solid concentration of water used in the water sprayed on the TRT fans was 15 ppm which is above the 10 ppm limit.

Three strategies were used to improve the scaling level of the TRT fans. First, the water pipeline was drained for 30 seconds every day to reduce clogging. After this improvement, the suspended solid concentration decreased from 15 to less than 2 ppm. Second, an increase in the concentration of the scaling inhibitor from 10 to 20 ppm. Third, the CSC magnetic anti-scale devices with an increased magnetic field from 6,000 gauss to 7,200 gauss were installed on the pipelines. Field tests showed that the scaling level was decreased. With the application of these three strategies, the vibration level of the TRT fans were reduced from 45 μm to 20 μm achieving the set out requirement in Fig.2. In addition, the power generation efficiency was enhanced by 5 % with a 10,000 kWh increase per day.

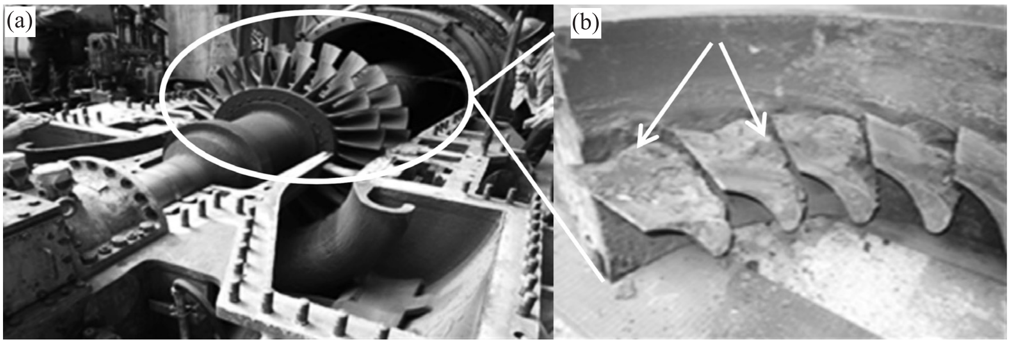

Fig.1. Scaling of TRT fans in Blast Furnace Facility.

Table 1 XRF analysis results of scaling on TRT fans, ID fans and nozzles of bloom marking machine

Scaling items	XRF Analysis Results
TRT fans	90.67% Fe_2O_3 、1.34% MnO_2 、1.16% SiO_2 、1.07% CaO 、1.07% MgO 、0.58% ZnO
ID fans	88.5~91.0% Fe_2O_3 、2.3~3.1 %MgO 、1.6~2.0 %CaO 、1.5~2.9% SiO_2 、1.3~1.4 % MnO_2
Nozzles of bloom marking machine	35.4% Fe_2O_3 、53.7% $CaCO_3$ 、4.6% MgO 、3.6% P_2O_5 、2.0% SO_3 、0.2% Al_2O_3 、0.2% SiO_2 、0.2% Na_2O

Table 2 Jar Test determined that the best concentration of scale inhibitor was 20 ppm from Cinyea to treat the scale deposition of TRT fans

Concentration (ppm)	0	5	10	20	40	80
Turbidity (NTU)	49	78	87	112	119	120

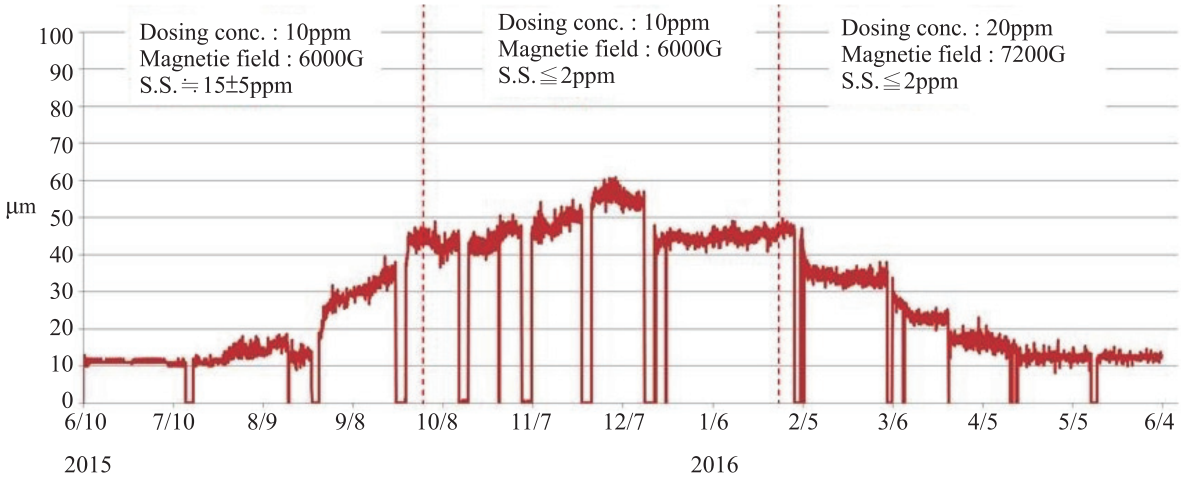

Fig.2. The vibration level of TRT fans before and after improvement.

3.2 Scaling level reduction of ID fans in Blast Oxygen Furnace facility

ID fans are turned by LD convertor gas (LDG) to generate electricity. The scaling inhibitor from Kurita was sprayed on to the ID fans to prevent scaling. However, the ID fans still had scaling problems Fig.3(a) causing an increase in the vibration level. The higher vibration level caused the ID fans turning at high speed to consuming more operating power during the production of molten steel. Once the vibration level reaches over 60 μm, the ID fans needed to be stopped for maintenance and sprayed with silica sand. The maintenance frequency of the ID fans was six times per year before improvements. In order to decrease the maintenance frequency and reduce the vibration level of the ID fans, the scaling problems needed to be solved.

XRF Analysis showed that the main component of the scale deposition was Fe_2O_3 in Table 1 and five scaling inhibitors were selected for test. The jar Test determined that scaling inhibitors from Nalco and Ecotek were the best candidates in Table 3. CSC chose the scaling inhibitor from Ecotek because the scaling inhibitor of Nalco was more expensive than that from Ecotek. Field tests showed that the vibration level increased at a slower rate when the scaling inhibitor was switched from Kurita to Ecotek. Also the maintenance frequency was reduced from six to four times per year. And the power consumption was reduced from 1,267 to 1,204 kWh per month when using the scaling inhibitor from Ecotek.

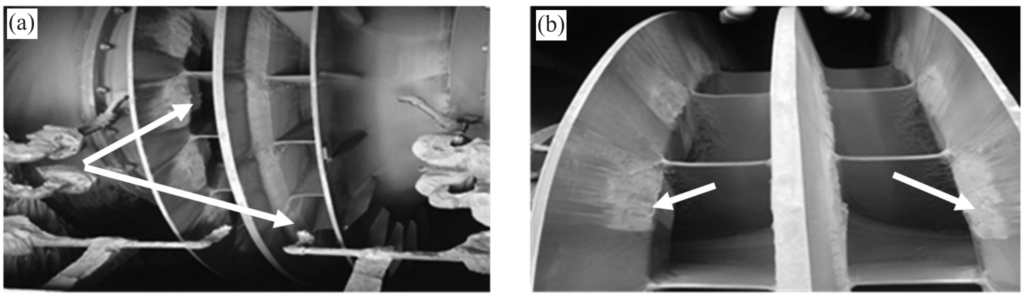

Fig.3. (a) Scaling on ID fans in Blast Oxygen Furnace facility before and (b) after improvement.

Table 3 Jar Test determined that scaling inhibitors from Ecotek and Nalco were the best candidates to treat the scale deposition of ID fans

Anti-Scaling Agents	Nalco	General Electric (GE)	Kurita	Ecotech
Turbidity (NTU)	38	36	33	38

Furthermore, the scale problems of the ID fans decreased in Fig.3(b) with the additional application of the magnetic anti-scale devices developed by CSC. After four months of operation, the vibration level of the ID fans decreased further from 54 μm to less than 40 μm in Table 4. The power consumption was reduced further from 1,204 to 1,161 kWh per month. Overall, the maintenance frequency of the ID fans was reduced from six to three times per year. The amount of produced molten steel was increased to 8,100 ton/yr and recycled BOG was increased to 750,000 Nm^3/yr with an extended maintenance cycle.

Table 4 Vibration level of ID fan was decrease and maintained below 40 μm after improvement

	month	Vibration level (μm)
Before improvement		50
After improvement	1st	32
	2nd	32
	3rd	30
	4th	9

3.3 Scaling level reduction of nozzle on bloom marking machine

Marking machine uses a mixture of water and paint to mark numbers to each bloom so the product source and purchase order can be traced in Fig.4. There was a filter to pretreat the water used in the marking machine with a cleaning frequency of once a month. During the process of marking the blooms, there were scaling problems with the nozzle on the marking machine. The scaling clogged the nozzles and caused the markings on blooms to be indistinguishable in Fig.4~5. In this case, operating personnel needed to mark the blooms by hand and the operation process would be delayed. The clogging frequency of the nozzles was eight to ten times per day. In order to decrease the clogged frequency and increase the efficiency of the marking machine, the scaling problems needed to be solved.

XRF Analysis showed that the main component of scale deposition was $CaCO_3$ and Fe_2O_3 in Table 1. Scale inhibitors cannot be used in this case because they would react with the paint making the markings unclear. Water analysis showed that the calcium concentration was 100 ppm. The calcium would easily form calcium carbonate crystal in a high temperature environment[8]. On the other hand, water analysis also

Fig.4. (a) Markings on the blooms before and (b) after improvement.

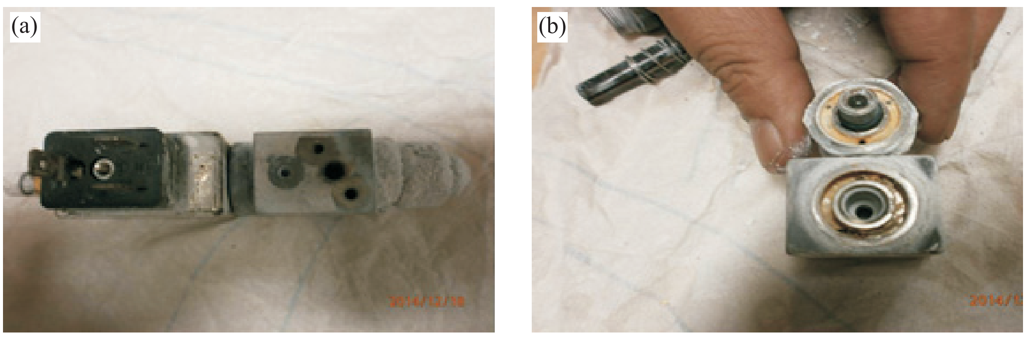

Fig.5. (a) Scaling of nozzle on bloom marking machine before and (b) after improvement.

showed that the suspended solid concentration of water used in the marking machine was 20 ppm which is above the 10 ppm limit so by causing the scaling problems of the nozzles.

Two strategies were used to improve the scaling level and reduce the clogging frequency of the nozzles. First, the cleaning frequency of the pretreatment filter was increased from one time per month to one time per day. The suspended solid concentration decreased from 20 to 1.5 ppm. Second, the CSC magnetic anti-scale devices were installed on the water pipelines. A field test showed that the clogging frequency reduced from eight to ten times per day to once every 3 weeks. With the application of these two strategies, the scaling level was decreased. The markings on blooms were clear and easily tracked in Fig.4(b).

4. CONCLUSION

Scaling problems of water pipelines and equipment are common issues in many industrial plants. Three different directions were approached to solve the problems at CSC. First, to analyze water quality and decrease the concentration of suspended solids to less than 10 ppm. Second, to choose an effective scaling inhibitor to prevent the formation of scaling if there is no other side effect. Third, to install magnetic anti-scaling devices developed by CSC on the water pipelines. These three strategies were used alone or in combination depending on the different scaling scenarios. There were three examples of how the scale level was reduced in different facilities at CSC. With the improvement of water quality, the increased concentration of scaling inhibitor from Cinyea, and the increasing of the magnetic field of the magnetic anti-scaling devices, the vibration level of TRT fans was controlled to below 100 μm and the power generation efficiency was enhanced. With the use of the scaling inhibitor from Ecotech and the application of the CSC magnetic anti-scaling devices, the vibration level of the ID fans was controlled within limits and the maintenance frequency decreased. The power consumption of the ID fans was reduced and the production of molten steel and BOG was increased. With the decreased concentration of suspended solids in water, and the application of magnetic anti-scaling devices, the clogging frequency on the nozzles of the bloom marking machines was reduced and the markings were clearer. CSC has developed anti-scaling technology in spraying water systems to solve scale problems of different plants.

REFERENCES

1. M. Crabtree, D. Eslinger, P. Fletcher, M. Miller, A. Johnson and G. King: Oilfield Review, 1999, vol. 11, no.3, pp. 30-45.
2. M. M. Reddy and G. H. Nancollas: Desalination, 1973, vol. 12, no.1, pp. 61-73.
3. P. Shakkthivel, R. Sathiyamoorthi and T. Vasudevan: Desalination, 2004, vol. 164, no.2, pp. 111-123.
4. T. Vermeulen, W. T. Badawi and G. Klein: Desalination, May 1983, vol. 47, issue1-3, pp. 149-159.
5. C. Y. Tai, M. C. Chang, R. J. Shieh and T. G. Chen: Journal of Crystal Growth, 2008, vol. 310, no.15, pp. 3690-3697.
6. D. Hasson and D. Bramson: Industrial & Engineering Chemistry Process Design and Development, 1985, vol. 24, no.3, pp. 588-592.
7. C. Gabrielli, R. Jaouhari, G. Maurin and M. Keddam: Water Research, 2001, vol. 35, no.13, pp. 3249-3259.
8. M. Chaussemier, E. Pourmohtasham, D. Gelus, N. Pécoul, H. Perrot, J. Lédion and O. Horner: Desalination, Jan. 2015, vol. 356, pp. 47-55. □