UDC 620 . 197 . 6 : 621 . 869 : 669 . 1

Low Cost and Long Lifetime Painting Methods for Ore Unloading Machines of Steel Works

Takehide AIGA*[1] Shigeaki TAUCHI*[2]

Abstract

The corrosion of ore unloading machines, for example unloaders, stackers, reclaimers, and belt-conveyers, has become a serious maintenance problem in Nippon Steel Corporation. Most of the machines have been operating for more than 30 years, and full maintenance painting should be carried out to avoid the replacements and to continue to be operative. Accordingly, two low-cost and long-lifetime painting methods for these machines have been examined, using our special modified epoxy resin paint NB Coat 3000GW (produce of Nippon Steel Chemical Corporation). It has been ensured that these painting methods demonstrate very durable characteristics on JIS Z 2371 Salt Spray Test. The first method is 1 coat thick(200μm) spraying method for the machines which have wide surfaces, such as unloaders, reclaimers etc. By this method, a 25% cost reduction for the reclaimer maintenance painting is actually realized at Nagoya Works. The second is 1 coat thick(120-200μm) brushing method by new thick-brushing paint, NB Coat Super 3000GW for the steel truss structure equipment, such as belt-conveyers. An adequate amount of flake pigments is blended into the base modified epoxy resin paint, so that this new paint enables the 120-200μm 1 coat brush painting.

1. Introduction

A very important maintenance task for the steel industry is how to deal with equipment deterioration for steel industries. Particularly, most of the ore unloading machines of the steel works, as shown in **Fig. 1**, were installed when the steel works was constructed in the 1970's, and have been running for over 20 years. Concretely, the ore unloading machines include an unloader which unloads raw materials for iron manufacture, such as iron ores and coal, from the ship, a belt conveyor for carrying them, a stacker for piling them mountain-high, and a reclaimer which picks out raw materials from the pile. Since they have been exposed to the seaside environment for many years, they have been significantly deteriorated due to corrosion in recent years. Overall film scaling and corrosion were found in progress, and a decrease in wall thickness was observed locally

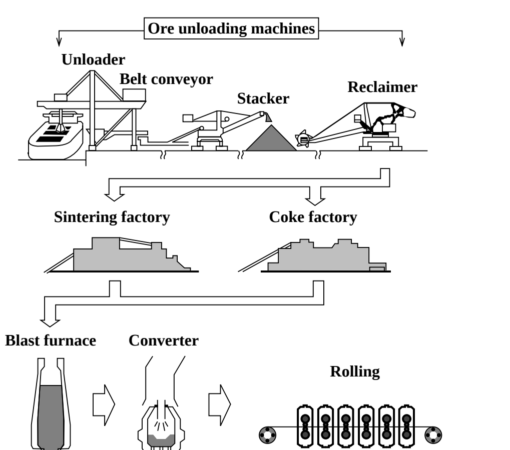


Fig. 1 Ore unloading machines in the steel manufacturing process

*[1] Nagoya Works
*[2] Nippon Steel Chemical Co,. Ltd.

where falling ores are piled.

This makes it urgent for the maintenance department of the steel works to make plans and implement them on how to prolong the life-time of the equipment by preventing the progress of corrosion while controlling the repair cost. It has therefore been earnestly desired that a method of maintenance painting be developed, by which anticorrosion performance can be expected at low cost.

A technical study was made of low-cost and long life-time anticorrosion painting to answer the above need. This resulted in proving the effectiveness of thick layer modified epoxy resin paint, which was then actually applied to the repainting of the reclaimer. Another new paint was also developed, which enables to apply thick layer paint by one brushing.

In this report are introduced the contents of the study of the technique of low-cost heavy anticorrosion painting.

2. Viewpoints of the study of low-cost heavy anticorrosion painting

2.1 Check points regarding the corrosion of ore unloading machines

The ore unloading machines, including the unloader, the belt conveyor, and the reclaimer, are installed within about 500 meters from the seashore, a comparatively corrosive environment exposed to airborne salt. In addition, they are manufacturing equipment, and therefore considered difficult to shut down for a long period over several months. This makes it necessary to adopt anticorrosive measures that can be readily taken in a short repainting period. Furthermore, the unloader and other machines are large-scale equipment as high as tens of meters above the ground. A gigantic scaffold is therefore required for overall repair.

As an inexpensive and effective anticorrosive method, a study was made from the standpoint of rendering anticorrosive painting less expensive and more effective, because it is considered almost difficult to adopt a surface treatment method other than the replacement of the material with stainless steel or anticorrosion thermal spray in the light of the cost and relative difficulty of work.

2.2 Viewpoints of rendering anticorrosion painting less expensive and more effective

Before studying how to render anticorrosion painting less expensive and more effective as realistic and effective measures, the details of the cost of repainting the unloader in the past were first investigated. **Fig. 2** shows the findings. It was then found that the cost of painting accounts for about 10% in overall cost, while the cost of labor, including scaffolding, rust removing surface preparation, and painting work, accounting for a large portion. Emphasis was therefore placed on the reduction of labor cost for total cost reduction, and the following items were studied for the improvement of anticorrosion performance.

(1) Full utilization of an overhead cradle for scaffolding

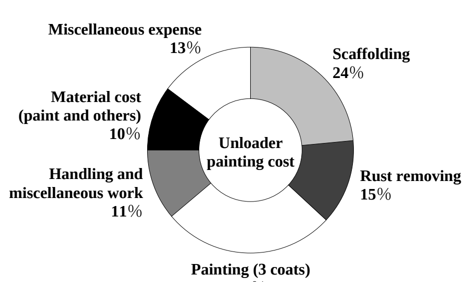


Fig. 2 Example of the details of painting expenses

Scaffolding is useful for multi-layer coating at the working site for a long period, but rather expensive for short-term work and thin layer coating. In addition, a scaffolding man is required for rust removal and coating at a high place with due attention paid to safety control. An overhead cradle should therefore be utilized to the utmost to reduce scaffolding.

(2) Trying to reduce the number of coats

Three-layer coating has usually been applied, that is, prime coating, intermediate coating, and top coating. However, in reference to the recent trend of two-layer coating without intermediate coating, 1- to 2-layer coating was studied for further reduction in labor cost.

(3) For paint is used modified epoxy resin paint[1)] excellent in anticorrosive performance even for bad surface.

(4) Study of optimal film thickness for modified epoxy resin paint

A salt spray test (JIS Z 2371, hereinafter abbreviated to SST) is expected to be carried out for this study using three kinds of film thickness, that is, 120, 180, and 240 μm. For evaluation of the effectiveness of maintenance painting at the working site, a rusted steel plate is to be used for a test piece. Furthermore, the paint film is to be cross-scratch-marked 55 mm long with an edged tool for fear of film defects, such as painting failure and scratches.

3. Details of the study

3.1 Investigation of optimal film thickness of modified epoxy resin paint

In consideration of the actual conditions of equipment corrosion, test pieces significantly rusted (field exposed for 3 years) were used, adjusted to St2, sprayed with modified epoxy resin paint (Nippon Steel Chemical-made, NB-Coat 3000GW) for respective film thicknesses, cross-scratch-marked, and investigated by the SST.

Figs. 3 and 4 show the findings. Fig. 3 is a photograph showing how the film was deteriorated, while Fig. 4 is a graph representing

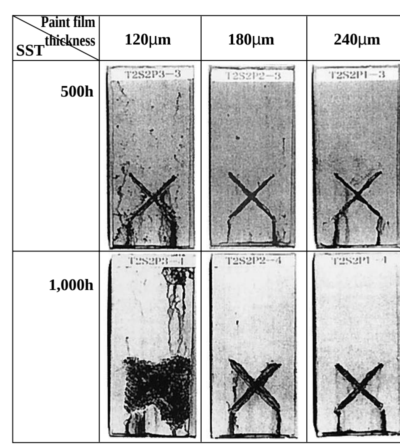


Fig. 3 Influence of the film thickness of modified epoxy resin paint (photograph of SST test pieces)

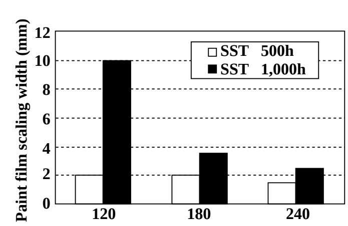


Fig. 4 Influence of the film thickness of modified epoxy resin paint

the width of film scaling from the cross-scratch-marked line. The film scaling width is the maximum one of film scaling from the cross-scratch-marked line as measured after removing the film with no adherence force left. It was confirmed from Fig. 4 that anticorrosion performance improves in proportion to an increase in film thickness. However, the detailed study of the findings of the 1,000 hours SST revealed that a big difference was observed in scaling width between 120-μm and 180-μm test pieces, whereas there was only a slight difference in scaling width between 180-μm and 240-μm test pieces.

The above results lead us to think that a paint film thickness of about 180 μm is desirable for the modified epoxy resin paint offered for the test in terms of profitability and durability in maintenance painting for ore unloading machines. However, in the actual maintenance painting with only 1 coat high-build painting applied without weatherproof top coating, a paint film thickness of 200 μm was considered optimal in anticipation of a chalking allowance provided that the equipment requires no embellishment. After investigating the durability of paint film under marine exposure conditions, Japan Railway Technical Institute also reported[2)] that a paint film thickness of over 200 μm is effective. The above specification can therefore be considered appropriate.

3.2 How to apply 1 coat high-build painting

The following two methods were studied relative to the application of 1 coat 200-μm thick high-build painting to the actual equipment:

(1) Spraying of the existing modified epoxy resin paint in cases where the subject machine has many flat parts like an ore unloading machine in the stock yard and where the scattering of a small quantity of paint is allowable.

(2) Development of thick layer paint[3)] enabling to coat as thick as 200 μm with one brushing, a thickness that usually requires 3 coats, for steel truss structure equipment and in case the scattering of only a small amount of paint is not allowed.

3.3 Actual examples of 1 coat high-build painting

On the occasion of applying one 200 μm thick spray coat to the actual machine, check points of the work were clarified by carrying out beforehand test painting in the laboratory and small-scale outdoor painting of about 30 m^2. The details are as follows:

(1) Setting up of a slightly lower ratio of dilution of thinner to avoid a run.

(2) Spray coating a little slowly while confirming the wet film thickness to be over 360 μm with the wet film thickness gauge so that a dry film thickness of 200 μm can be obtained.

(3) Implementing touch-up painting (preceding brushing) for an edged or narrow part where sufficient film thickness can hardly be achieved by spray painting.

This painting method was applied to the overall repainting of the reclaimer with a surface area of about 3,150 m^2 as shown in **Photo 1**. The surface was sand-blasted to Sa1, and partly treated to St3 with the power tool. After touch-up painting of the edged and narrow parts, 1 coat 200-μm thick high-build painting was applied as **Photo 2** shows.

Fig. 5 shows the field-proven repainting schedule. About one month was required for the work because of many rainy days. However, the painting work was completed in 8 days, so the number of days usually required for 3 coats reduced to half. As **Fig. 6** shows, the construction cost was about 25% lower than the conventional one in which 3 coats were required. This is considered due not only to the effect of reduction in painting cost, but also to the reduction in the costs of scaffolding and transportation as a result of the shortened construction period. On the other hand, however, many parts were found unfit for spray painting in the actual equipment, such as handrails and conduit tubes. To those parts it was necessary to apply one coat on the other with a roller to attain 200-μm film thickness.

This repainting work proved that inexpensive heavy anticorrosion painting work can be achieved with one 200-μm-thick spray coat for the ore unloading machines. At the same time, the necessity was reconfirmed of thick-layer brushing paint.

Photo 1 Reclaimer

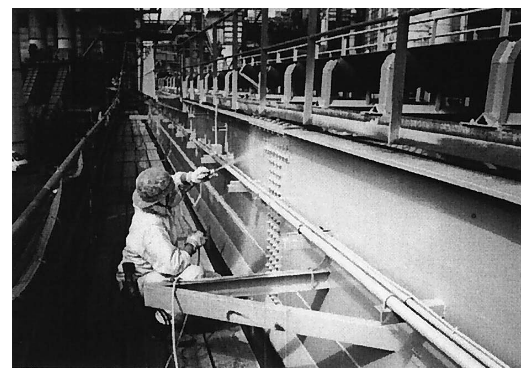


Photo 2 1 coat high-build spray painting

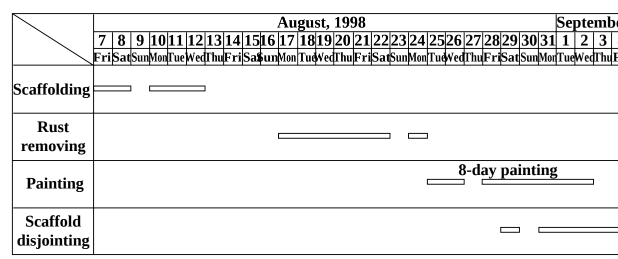


Fig. 5 Actual schedule of reclaimer repainting work

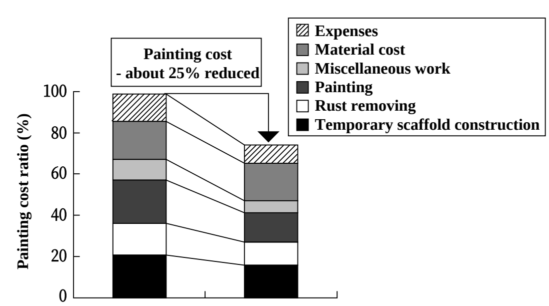


Fig. 6 Comparison of repainting cost

3.4 Development of thick-layer brushing paint

As described above, the necessity of thick-layer brushing paint is so great for the actual machines that emphasis was placed on the following two points as the performance of a new paint for development:

(1) To enable to achieve by wet on wet painting a maximum thickness of 200 μm with one brushing.

(2) To aim at an anticorrosive performance equal to or more than that of the existing modified epoxy resin paint by improving it into a high-build paint.

As **Fig. 7** shows, thick coating cannot be expected of general paint, because wet on wet painting by brushing tends to scoop up the undercoat with the brush. In the case of the newly developed paint, however, flake pigments are added in proper quantity to prevent the undercoat from being turned over due to their orientation, thus enabling to apply thick coating. **Photo 3** shows a section of 200-μm-thick paint film by one brushing of the newly developed paint. Striped flake pigments can be observed inside the film.

After repeated trial manufacture and improvement, and after thinking out how to blend flake pigments properly in the process of development, this paint was highly valued relative to its anticorrosion performance as **Fig. 8** shows. It has already been marketed under the brand name of NB Coat Super 3000GW. It is now widely used for maintenance painting in the steel works. To the equipment requiring no embellishment, such as a conveyor frame, 1 coat high-build painting is applied, while 2 coats are applied with the weatherproof top coating added to the unloader for which discoloration is undesirable in terms of appearance.

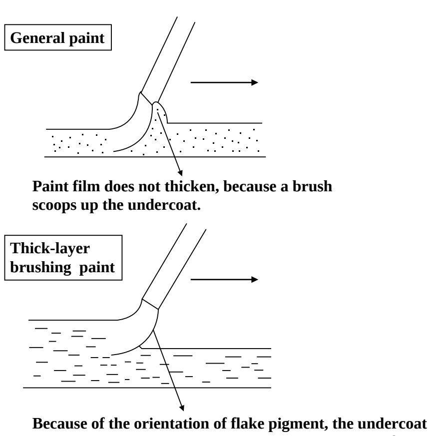


Fig. 7 Mechanism of film thickening

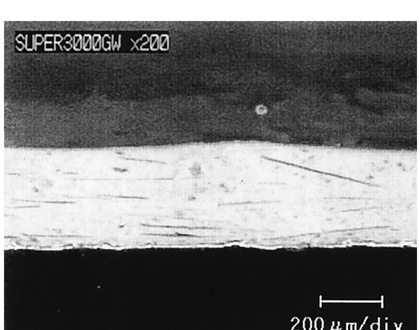


Photo 3 Section of paint film of thick-layer brushing paint

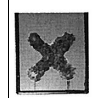
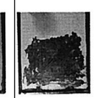
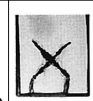
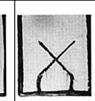
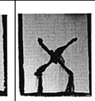
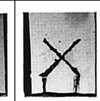
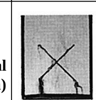
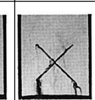
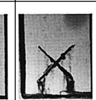
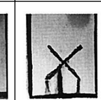
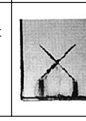
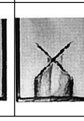
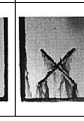
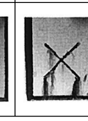
	SST 1,000h		SST 2,000h	
	Sand-blasted steel plate	Rusted steel plate	Sand-blasted steel plate	Rusted steel plate
Oil paint (JIS K 5621) (30μm×3) + phthalic acid top coating (total thicknss 120 μm)				
Modified epoxy resin paint (60μm×2) + polyurethane resin paint (total thickness 150 μm)				
Modified epoxy resin paint 1 spray coat (total thickness 200 μm)				
Developed paint (thick layer paint for brushing) 1 brush coating (total thickness 200 μm)				

Fig. 8 Results of the SST of developed paint (thick layer paint for brushing)

4. Consideration

From the data of paint film performance evaluation by the SST as given in Fig. 8, how film deterioration developed was put in order. The findings of the investigation of the steel road bridge[4)] were reported relative to the influences of the degree of rust removing surface preparation and the difference in paint bases on paint film life. It is difficult, however, to represent the degree of deterioration in consecutive quantity. It is therefore general to represent it with the evaluation guideline by Japan Paint Inspection Association. In this test, the rate of a film scaling area as given by the following formula was used as an index of film deterioration by utilizing the findings of the SST for which cross-scratch-marked test pieces were used:

$$\text{R (film scaling area rate)} = \frac{4t \times L - 8t^2}{B^2} \times 100\ (\%)$$

As **Fig. 9** shows, the above formula gives the rate of an area of film scaling in the range of a square connecting the 4 terminals of the cross-scratched lines. Here, t is an average film scaling width, L is the length of a cross-scratched line (55 mm), and B is the length of one side of the square (38.8 mm). From the data of the sand-blasted steel in Fig. 8, R was calculated by substituting the value measured of t into the above formula, and represented graphically as the curve of film deterioration in **Fig. 10**.

Fig. 10 shows how the difference was made in the progress of film deterioration in accordance with the kind and film thickness of paint. That is, 120-μm-thick oil paint film was already in the state of total scaling in the 2,000 hours SST, while 200-μm-thick modified epoxy resin paint film was confirmed to show a tendency of leveling off at below 40% of the m scaling area rate even in spray

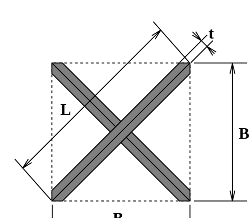


Fig. 9 Corroded part from cross-scratched SST test piece

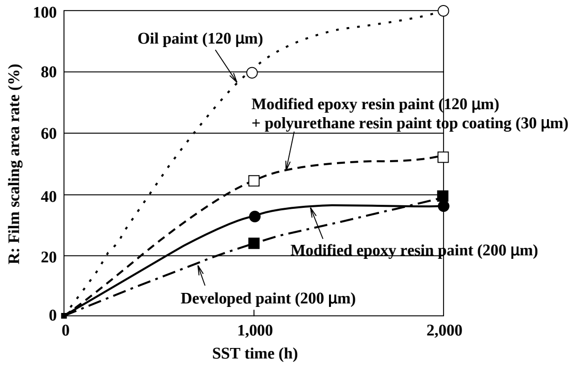


Fig. 10 Comparison of film deterioration condition (results of the SST of sand-blasted steel plate)

painting and in one brushing of the developed paint. Accordingly, it is very important to properly select the kind of paint and paint film thickness.

5. Conclusion

For the prevention of corrosion of ore unloading machines in the steel works, inexpensive heavy anticorrosion painting has been studied. As a result, 1 coat 200-µm film thickness was realized by the following two methods:

(1) A method of spray painting
(2) A method of using thick-layer brushing paint

The above two methods have respective characteristics, and should therefore be employed depending on the kind of subject equipment to be painted. In other words, the spray painting method is effective for the equipment with a large flat area, enabling to achieve a uniform paint thickness in a short construction period. On the other hand, the method of using brushing thick-layer paint enables to apply efficiently thick layer painting when the scattering of paint is not allowed or when the equipment is unfit for spray painting, such as steel structure equipment. Moreover, those two methods enable to carry out inexpensive heavy anticorrosion painting when embellishment is required by applying 1 weatherproof top coat after 1 coat thick film painting.

Furthermore, how anticorrosion performance differs depending on the kind and film thickness of paint could be proven by representing graphically the rate of an area of film scaling from the cross-scratched line. This enabled to confirm that high-build painting with modified epoxy resin paint is higher in anticorrosion performance than that with oil paint.

References

1) Kato, K.: Rust Prevention & Control. 32(1),9(1998)
2) Kirimura, K. et al.: RTRI Report.1070,1(1978)
3) Aiga, T. et al.: Rust Prevention & Control. 45(5),11(2001)
4) Teraoka, H. et al.: NKK Technical Report.131,55(1990)