

Review of the Hot Rolling Steel Strip Rust Removal Technology

He Zhu, Min-Liang Zhang*, Guo-Kui Zhu

(College Of Mechanical Engineering, Shanghai University Of Engineering Science, Shanghai 201620, China)

Abstract : Iron and steel has become an indispensable material for the development of industry. Among those ,hot rolling steel strip has a good toughness, ductility and price economy.The demand of hot rolling steel strip is strong and there is a trend of gradually replacing the cold rolled strip.Because of the hot strip production process and the storage environment make the oxidation of steel surface then produce the oxide layer. Based on the oxidation of the hot rolled strip, corrosion and rust removing ,this paper introduces the composition and the influence of the oxide layer of the hot rolling steel strip; some mature technologies in hot rolling steel strip rusting are introduced; the advantages and disadvantages of different technologies ,their applicability and their development status are summarize. Through the development of these technologies, the law of development and the outlook for the future are summarized.

Keywords: Rust Removal Technology; Hot Rolling Steel Strip; Oxide Layer; Law of Development

I. INTRODUCTION

Iron and steel as the most common in the engineering, the most widely used, the largest amount of metal material is known to people. However, the chemical properties of iron and steel are easy to be oxidized and easily corroded by acid and alkali.The economic loss caused by metal corrosion and corrosion in the developed countries of the world is about 2% ~ 4% of its gross national product. By metal corrosion and corrosion every year, the annual steel 20% ~ 10% output is wasted and the loss value is more than \$70 billion by metal corrosion and corrosion in the world^[1]. Hot rolling steel strip has good obdurability, easy processing and good welding and so on. It is widely used in ships, automobiles, bridges, buildings and pressure vessels and so on^[2]. As Fig. 1 is shown , the surface of hot rolling steel strip will lead oxide and need to remove the rust for reusing during this storage period.

II. RUST OXIDE PROCESS AND INGREDIENTS

The reasons for the corrosion of metal materials are;Humidity of environment;environmental temperature;oxygen;Toxic and harmful gases and microorganisms.Combining with the corrosion reasons,Combining with the Actual conditions of the process of Hot Rolling Steel Strip from production to storage to use, Analysising will be the specific reasons for corrosion.

Hot rolling Is a high temperature production process, The main steps of Including the slab heating again,roughing,finishing,Laminar cooling,coiling and cooling steel coils^[3]. Compared with the production process of cold rolled strip, The production process of Hot Rolling Steel Strip is more likely to produce oxide scale. When producing Hot Rolling Steel Strip, the material needs to be heated.

The surface temperature is very high,Initial oxidation in the furnace,In roughing and finishing and winding process Contact with air And respectively happens again, oxidation and high times,In Hot Rolling Steel Strip during transportation and storage of oxidation will happen again, Surface is very easy to severe

corrosion, Because the surface of Hot Rolling Steel Strip use fewer measures to prevent oxidation, For example, greased or tight packing.

The whole production process of Hot Rolling Steel Strip is in a state of high temperature. And participate in oxygen is present in the production process, Inevitably, the surface will produce oxide. Produce what kind of scale will become one of the main factors that affected surface properties and corrosion resistance. Which in the process of generating decided the cooling system of Hot Rolling Steel Strip scale is different.

As shown in Figure 2, Is made of SS400 Hot Rolling Steel strip as raw material after heated to 600 °C. Respectively simulated with furnace cooling, canning and natural cooling air cooling in three different cooling ways, Different microstructures of the oxide coating produced by Hot Rolling Steel Strip. Analysis can be known, The uniform and smooth oxidation of the material for the follow-up of the corrosion of the barrier.

At the same time, The change of stress state is small. Uneven corrosion of the oxide skin barrier corrosion ability is poor. Meanwhile, it has a great influence on the mechanical properties. According to the figure 2, the results are compared with the microstructure of the oxide skin of the three cooling modes. Along with the furnace cooling is best, canning cooling times, air cooling is the worst.

Research shows that in different oxidation layer of structure of each found Fe_3O_4 , Fe_2O_3 and Fe. Three different ways of cooling the formation of the oxide layer of the main substances are Fe_4O_3 . The oxide scale of Hot Rolling Steel Strip is mainly composed of Fe_4O_3 under different cooling ways. Another contains Fe_2O_3 and Fe. With the decrease of cooling rate, Increased Fe_3O_4 content in the oxide skin. But did not find FeO ^[4]. The scale with furnace cooling with a, b two layer thinner Fe_2O_3 outer respectively and the lining of the thicker Fe_3O_4 +Fe. The structure of Fe_3O_4 is more compact, the nature of the crystal is more stable, and the adhesion is strong. Play the role of protective film. There are also studies that the substrate surface still exists Rich austenite that is FeO . This difference is actually determined by the cooling rate of Hot Rolling Steel Strip. When the cooling rate is fast enough, a part of the FeO will be below 570 degrees Celsius is decomposed into Fe_3O_4 +Fe, and a part of the FeO will be saved. Known by exposure to the surface of a thin oxide skin Fe_2O_3 , layer of Fe_3O_4 + Fe, accompanied by fine seam to substrate. The substrate protective effect of the Crack and Partially broken oxide is very small. It also makes the Hot Rolling Steel Strip easily corroded. So Hot Rolling Steel Strip as a material to be used to remove the surface of the oxide and has been corroded parts. Depending on the way and time of storage, the thickness of the oxide skin is different. The thickness of oxide layer formed on the surface of Hot Rolling Steel Strip was 7.5μm~15μm . FeO can be retained within a few microns of the mother, as rust.

III. RUSTING PROCESS of HOT ROLLED STRIP

3.1 Acid Pickling Process

Acid pickling is a once used more as the hot rolled strip rust removing technology, but the process slowly being replaced by other processes. The principle of acid pickling is the use of chemical properties of the oxide layer and the substrate. Oxide layer contains three kinds of products. The outer thinner layer of the Fe_2O_3 and the inner layer of Fe_3O_4 which content is maximum are more difficult to soluble in acid solution. But Fe which exists in inner layer and the matrix itself will produce a chemical reaction with acid, producing molisite and hydrogen. As mentioned above, the surface of the oxide layer has cracks and pores. These cracks and pores become the earliest reaction sites. That is to say, the pickling process starts from the inner layer and the substrate. The first effect is to enlarge the crack and pore, which is the combination of hydrogen atom and hydrogen molecule. The second effect is the reduction of high iron and its oxides, produced can dissolve in acid solution of low oxide and low iron salt. Gradually, the combination of the substrate and the oxide layer is loosened until the final oxide layer is separated from the surface of the substrate. Dissolution, mechanical stripping and reduction of three in one completed pickling.

The pickling efficiency is high, the process is not complicated, simple and easy to operate. But in the process of pickling rust will consume a lot of acid solution and part of the iron and steel materials. Hydrogen will cause hydrogen embrittlement into the steel, which will affect the mechanical properties of steel. Hydrogen embrittlement phenomena tend to make the structure sudden fracture which is in a lower load than that of the normal design load, so the hydrogen embrittlement is difficult to predict^[8]. Production of different varieties and specifications of the steel are needed to control the production process and production environment, which will waste time and are inconvenient. The most important reason for the gradual elimination of the pickling process is the serious environmental pollution problem. Treatment of waste gas, acid mist, sewage and iron salt during acid pickling process has been plagued by technicians.

3.2 Shot Peening Process

Shot peening process is a relatively common rust removal process. Through the medium of against rust substrate surface, using the impact of the media and the matrix of friction remove the matrix of the oxide layer and other impurities. Obtaining a certain degree of roughness, the matrix has a metallic color.

Hardened steel particles is the selection of injection medium of Shot peening, which the hardness is about HRC49. The shapes of the particles are columnar, pill and block, in which the diameter of the pellet is 0.6mm ~ 3.5mm, and the size of the other shapes is similar to that of the size of the pellet. After the quenching, prismatic abrasive easily clean oxide layer up because of sharp edges and its edges are not easy to be polished. Pellets are easily broken, affecting the treatment effect. The power of the abrasive is provided by the compressed air. High air pressure will cause the line pressure increased wear or pits occurred on the surface of the workpiece, however the pressure is too low will cause inefficient or abrasive can not be normal ejection. For the general steel parts, compressed air pressure of 0.4 ~ 0.8MPa is appropriate. For alloy and light metal alloy 0.1 ~ 0.3MPa is appropriate^[9].

Effectively improving the mechanical properties of the workpiece is being shot peening in derusting effect outside of significant additional advantages. Shot peening can produce a large number of plastic deformation on the workpiece surface. The introduction of high density dislocation and slip band, without changing the overall mechanical properties of the matrix corrosion susceptibility and resistance to intergranular^[10]. Based on the impact of the projectile, the metal surface is formed by the hardening layer of 0.1mm ~ 0.4mm. The fatigue strength of the workpiece at the position where the stress is constantly alternate will be enhanced by hardening. But the shot peening also has its own limitations. The inner diameter of the nozzle is generally about 4 times the diameter of the abrasive, so the range of the jet is very limited. The width of hot rolled strip is generally between 600mm ~ 1300mm. To clean up a roll of strip, it needs a row or several rows of nozzles working at the same time after the rolling of strip. Certainly can not guarantee this production efficiency. At the same time, the recovery of the whole system design and installation of shot peening and abrasive recycling is very complex, the recovery rate is not high. Sandblasting working environment can be open, big noise and dust which will damage workers' health. Shot peening can not remove the matrix film, also increasing the risk of matrix deformation. The process of shot peening is widely used in shipbuilding industry. The plate on the old paint and rust removing, re-coating. Shot peening process as pretreatment used in hot rolled steel, still need to solve the problem of efficiency and economy.

3.3 Blasting Process

Blasting technology is the use of more advanced derusting technology in industry at present, by which machine parts can be surface cleaning, removal of burr, polishing and strengthening. The principle of blasting derusting process and shot peening cleaning process are the same. Through shot blasting equipment in

high-speed rotation of the impeller, the shot is the abrasive to a certain speed and a certain angle along the curved track of workpiece of collision and impact to make the oxide layer occurred off.

Compared with the shot peening process, blasting process more used in the heat treatment of steel structure on the surface. The reason is that compared to the shot peening process, blasting technology has the following advantages. Blasting process has full pipeline facilities, and a high degree of automation. Closed studio to reduce the dust on the workers' physical damage. Blasting blasting abrasive loss is very small and closed environment after the recovery of abrasive. Blasting process of shot peening process is less than the energy consumption in hand. At the same time, derusting quality also improved by blasting process. Cleanliness can be guaranteed to reach Sa2 ISO8501-1 level (equivalent to Sa2 8923 - 1988 of the GB/T), and can obtain a uniform surface roughness ^[11]. The most important is the efficiency of blasting process is higher than that of shot peening process. Shot line is mainly composed of steel plate conveying, dust removal system, spray coating device, drying workshop primer composition. The plate is driven by a motor transport conveyor, also can realize frequency control (2m/min ~ 8m/min). For the steel width of 1300mm ~ 3000mm, blasting blasting requirements were chosen as 4 ~ 12 ^[12]. The disadvantage is that the blasting, spray nozzle in the angle of 70 degrees to 90 degrees, in some surface rust will be dead. Unlike the shot blasting process will be more thorough removal of the oxide layer. Like shot peening process, shot blasting process need to paint in steel, or steel will expose in the air. Blasting process, influenced by many factors, it is not too easy to adjust.

3.4 SCS^[13-14]

SCS is a highly advanced mechanical derusting Technology. The technology was developed by the United States TMW in 2003, and used to clean the surface of hot rolled strip. TMW company in March 2003 has been applied in its own production line. The surface is smooth and clean technology by mechanical grinding oxide grinding roll and wash away surface residue, but retain the bottom oxide layer 7 μm as a protective layer. SCS grinding through the pinch roll uncoiling and leveling of the hot rolled strip into the grinding and grinding, and then by clip send and send. As shown in Figure 3 grinding is mainly made of stainless steel wire brush for grinding, in the appropriate pressure and suitable feed rate of the oxide layer will break off or weak binding in the surface. Subsequent to the circulation of water washed off the weak binding of the oxide and residual in the surface has been separated from the substrate of the oxide.

SCS has several advantages compared to not rust removal. Firstly, without the use of chemical methods rust, SCS does not produce waste acid wastewater, which is different from pickling. Secondly, compared with mechanical derusting shot peening and shot blasting, SCS don't need using any external abrasive. That is not dust pollution. This technique is very clean. You can recycle cleaning water, oxide layer is removed from the new can also be collected by. The entire SCS pipeline covers an area of only about 20% of the ordinary Vera type pickling line. After the cleaning of the strip in the SCS system is dry, and the strip surface after SCS treatment is a protective oxide layer of 7 μm . No anti oxygen protection on the strip surface oil is in need. This kind of non-oil strip will not produce oil fume in the subsequent welding and laser cutting, and the welding intensity is enhanced. This kind of processing will destroy the surface of the FeO, so that the product lost corrosion protection function. As the raw material of the post process, if the coating time is short, such as continuous hot dip galvanized, electro galvanized is more difficult ^[15].

At present, SCS as a mechanical descaling method of hot rolled strip advanced, is currently in use in Europe and the United states. This technology in Chinese has not yet begun to use for the study of this technology is now the focus of mechanical descaling.

3.4 Eps

EPS is to develop and promote mechanical descaling technology. Its principle is the use of liquid carrying liquid with abrasive together through the high-speed rotation of the slurry jet jet out, across the need to clean the steel strip or steel, to achieve the mechanical cleaning. The first surface ecological pickling line is also developed by the United States TMW company in 2007, put into operation in 2008. EPS production line consists of uncoiler, the board embryo dressing table, straightening machine, injection device, drying bed, electrostatic oiler and volume take machine. The surface of hot rolled strip after EPS treatment is superior to that of hot rolled strip. EPS hot strip surface rust as an advanced technique, there are many technical details are confidential. In order to get better, the mechanical pickling effect, need to study a lot of important parameters, such as mortar abrasive type, grain size, hardness, shape and thrown at speeds; slurry flow; angle of incidence of the mortar projectile to strip; running speed of steel belt. The key technology of EPS is to make the abrasive uniformly sprayed on the strip surface moving and cover strip width^[16]. From the current data, it can be known that the abrasive is generally used in stainless steel or carbon steel projectile particles or angular particles, the particle diameter of 0.3mm ~ 0.7mm between. The carrier solution is basically composed of water, at the same time, adding the anti rust additive to prevent rust. The TMW company by two sets of ejection device, up and down a total of eight ejection device mechanical pickling line, thickness of pickling 3.57mm, 1524mm wide hot strip, used is carbon steel abrasive LG-40 unit speed 39.6m/min.

ESP as a mechanical derusting process one kind of environmental protection to the protection of the environment is very good. In the political strategy of economic transition, such a process will no doubt be extremely popular. The surface roughness Ra of the strip after EPS treatment had no difference between the basic and pickling. The production efficiency of the production line is also huge, TMW company's second EPS production line annual production reached 360 thousand tons. EPS production costs are much lower than that of acid, which consumes a large amount of acid. EPS production line covers an area of just pickled and oiled production line of about 2/3. Like SCS, EPS processing of hot rolled strip don't oiling; but SCS outperforms, EPS treatment of hot rolled strip can be cold rolling and continuous hot dip galvanizing. EPS in fact, in our country to promote the need for a lot of efforts, the introduction of the technology from abroad, the need for a large number of funds, but also the various restrictions on the seller. To break the technical monopoly to the technical researchers to understand the basic principles of EPS, and then the key parameters of the theoretical and experimental demonstration.

3.5 Loose Shell Paint Rust Removal Process

The loose shell painting process is a process which is aimed at the rise of hot rolling strip in recent years. This process is a kind of pure mechanical process. Loose shell paint type descaling process principle is according to the different material properties of hot rolled strip the oxide layer and the base material, the use of bending deformation under the precondition of ensuring the quality of the base metal, the combination between the oxide layer and the base material to become loose. According to this principle, we can see that, for serious rustiness of hot-rolled strip steel derusting effect is rusty slightly hot rolled strip rust removal effect is better. This is different from the other derusting, derusting corrosion more serious difficulty should be greater. Loose shell paint process efficiency and the corrosion degree of the curve should be as shown in Figure 5, before the specific degree of corrosion, efficiency is gradually improved, then efficiency with the increase of corrosion degree decreased gradually, efficiency and tends to a constant value. The oxide layer, which is combined with the base material, is easily removed under the cleaning of the paint roller. At present, the loose shell paint rust removing technology is not very mature, the research and experiment of shell theory are still loose. The difficulty of loose shell technology is how to control the deformation of the bending deformation, so that the

oxide layer and the base material to reduce the degree of combination, how to control the effect of the removal of the oxide layer in the process of painting. There is no special mechanical equipment for loose shell paint rust removal process used. Figure 6 is the idea of painting on the shell of rust removal process. These processes can be cleaned on the oxidized layer on the hot rolled strip, which can be cleaned by Figure 6.

Loose shell paint rust removal process does not produce pollution to environment, the process is not purely mechanical complex. In the enterprise practice effect is good and bad, mainly at home and abroad for this aspect of the theoretical research is still lacking, need to support the loose shell theory. In the pursuit of environmental protection, in order to replace high pollution of rust removal, pine shells painted rust research is a research hotspot. At present, the loose shell paint rust removing technology research is still at the starting stage, this paper argues that the process has great prospects for development, in particular, is more suitable for hot rolled strip rust.

IV. CONCLUSION

Hot strip rust is a common problem in actual production, the solution to this problem many. For cleaning, we should first clear the strip oxide basic structure and its characteristics. Understanding the morphology of oxide layer by microstructure. From the existing for hot rolled strip rust removal process, summed up the development trend of rust removal is: 1. Chemical derusting is gradually replaced by the physical, mechanical derusting method for. The development of the 2 Mechanical derusting process conforms to the green concept, pay attention to environmental protection and harmless treatment method. The development process of 3 mechanical descaling technology is the result of deepening the theoretical research of oxide layer material. The same basic principle 4 rust, increase the control parameters of rust removal, more complex technology. For future of the rust process, should be on the basis of mechanical descaling continuous development according to sheets of different oxidation can regulate the operation and device miniaturization. At the same time, we should into the robot technology, laser technology and high-end technology, increased automation, intelligent, shorten the cleaning time and improve the efficiency.

REFERENCES

- [1]. Enchong Dong.Exploration and protection of corrosion of meta[J].China Educational Technique & Equipment, 2013(9):144-145.
- [2]. Aihua He.The effect of Oxide Film on the Electrochemical Corrosion Behaviors of Hot Rolled Steel[D].Thesis of Ocean University of China, 2007.
- [3]. Academic Committee of Hot Rolled Strip of Metal Committee of China.Roller Machine of Hot Rolled Broadband Steel and Production Technology of Roller Machine[M].Beijing:Metallurgy Industry Press, 2002.
- [4]. Xianliang Zhou,Min Zhu,Xiaozhen Hua,Zhiguo Ye,Xia Cui,Aihua Zou.Different Ways of Cooling of Hot Rolled Strip Scale structure and Corrosion Resistance[J].Journal of Chinese Society for Corrosion and Protection, 2010, 30(4):323-328.
- [5]. Hua Zhang,Yuhai Qian,Huabin Qi,Wei Wang.Rusting Behavior and Preventing Measures of Hot-rolled Steel Plates for Automobile[J].CORROSION&PROTECTION, 2008, 29(6):316-318.
- [6]. [6] Changhui Wang.Application Study of Process Control method of Laminar Cooling for Hot Strip Mill[D].Northeastern University, 2005.
- [7]. Meishuang Li,Li Xin,Yuhai Qian. A Review on Studies of Internal Stress in Oxide Scales[J].Corros.Sci.Prot.Technol.1999,11(5):300-305
- [8]. Xinmin Fang.The Hydrogen Embrittlement and its Control in the Process of Electroplating[A].China Surface Engineering Association Electroplating Branch of the Fifth Annual Meeting[C].China Surface Engineering

- Association, 1998.1.
- [9]. Shiping Huang,Xiang Li.The process factors affecting Blasting Derusting [J].Transformer, 1994(1):16-17.
 - [10]. Zengwu Yue,Xingeng Li.Effect of Shot Peening and RE Containing oxide Coating on Oxidation Resistance of Super304H steel[J].RARE METAL MATERIALS AND ENGINEERING,2013, 42(Suppl.2):326-329.
 - [11]. Shengjie Qian ,Xiang Ding ,Minfeng Li.Steel Structure Mechanical Injection Processing Technology and Equipment[J].Electroplating & Finishing, 2011, 31(4):75-78.
 - [12]. Huixian Wang.Analyse the Steel Structure Mechanical Injection Processing Technology and Equipment[J].Chian New Technologies and Products, 2014(1).
 - [13]. Kevin Voges,Alan Mueth.Eco-picked Surface:An Environmentally Advantageous Alternative to Conventional Acid Pickling[C]//AISTech 2007 Proceedings.Indianapolis:Association for Iron & Steel Technology,2007.
 - [14]. Eric Hi.ER EPS:The Superior Replacement for Acid Pickling[OL].(2013-08-30) <http://www.epsprocess.com>
 - [15]. Bin Kang ,Linxia Niu .The Foreign Ecological Picking Technology Research and Development Status Quo of Hot Rolling Steel Strip[J].Metallurgy Control, 2012(5):56-60.
 - [16]. Ning Tan,Jun Li.Development of Acid Free Pickling Technology for Hot-rolled Strip[J].STEEL ROLLING, 2014, 31(1):47-50.