Preparation of the surface of used cylindrical steel cases for zinc recoating

Abdulrasoul Salih Altaei
Electrochemical Eng. Dep. / College of Engineering
University of Babylon,
E- mail : abdtaey@hotmail .com

Abstract:

Used cylindrical steel case usually plated with zinc, to reuse these cases, dirt, oil, grease, rust and old layer of zinc coat must be removed and again replated.

In an mechanical complex, cleaning and surface preparation of used steel case was carried by mechanical method. Sanding lathe machines with an emery sandpapers were used to do this job, this method has many disadvantages, some of are the low production rate , the need for large manpower , original metal damage , it is expensive and dust occur during sandering cause environmental problems at the jobsite.

In this case study cheap, and high production rate chemical method was proposed and executed to clean and prepare steel case surface for recoating as alternative to the mechanical method, the production rate increased more than ten fold compared with mechanical method. . The concentration of the consistent of the chemical solutions and operation conditions were determined as a result of several experiments. Eight steps technological procedure was suggested.

الخلاصة

يقدم هذا البحث دراسة حالة تنظيف وازالة الصدأ وطلاء الزنك التالف من اسطوانات فولاذية مستعملة وذلك لغرض اعادة استخدامها مرة ثانية بعد طلاؤها بالزنك . تنظف هذه الاسطوانات من الاوساخ ، الزيوت، الشحوم، الصدأ وطبقة طلاء الزنك القديمة التالفة في مجمع صناعي بطريقة ميكانيكية، مكائن خاصة مجهزه بورق صنفرة تستخدم لانجاز هذا العمل . هذه الطريقة فيها مساوئ كثيرة منها انتاجيتها قليلة ،تحتاج الى ايدي عاملة كثيرة ، غالية الثمن ، تعرض العمال الى استنشاق غبار الزنك واكاسيد الحديد بالاضافة الى تغير أبعاد الاسطوانة, ولغرض زيادة الطاقة الانتاجية يتطلب شراء مكائن من السوق العالمية مما يزيد من كلفة الانتاج .

في هذه الدراسة تم اقتراح وتنفيذ طريقة كيمياوية لتنظيف هذه الاسطوانات بدلا من الطريقة الميكانيكية مما ادى الى زيادة الطاقة الانتاجية الى اكثر من عشر مرات ضعف ، بالاضافة الى انها ارخص واقل خطورة على العاملين مقارنة بالطريقة الميكانيكيه . اجريت عدة تجارب لغرض تحديد تراكيز المحاليل الكيمياوية وكذلك ظروف التشغيل الملائمة لهذه الحالة وبالنهاية تم وضع مسلك تكنولوجي من ثمان عمليات لتنظيف وتهيئة سطح الاسطوانات الفولاذية المستعملة لغرض إعادة طلاؤها واستخدامها مرة ثانية.

Preparing a surface includes removing the contaminants that inhibit coating adhesion and providing a surface profile for tight bonding of the coatings. The objective of all surface preparation is to present as clean substrate as possible to the coating system. The type of surface preparation required will depend on the condition of the surface and the performance of the coating in its particular environment.

Grease and oil will prevent tight bonding of coatings, as will loose dirt, dust. Oxide film,(rust, scale) which is present at normal conditions on the steel surface, prevents the achievement of good adhesion between the substrate and protective metal coating (zinc, nickel, copper and so on). [1]. There are many different methods of cleaning metal surfaces. The most commonly used cleaning methods are: mechanical cleaning, flames (thermal), steam cleaners, and chemical cleaning.

1.1 Mechanical surface cleaning :

Various methods have been used to clean steel surface mechanically, Abrasive blast cleaning is the most widely used method of surface preparation for steelwork. This method involves mechanical cleaning by the continuous impact of abrasive particles at high velocities on to the steel surface either in a jet stream of compressed air or by centrifugal impellers [2] Abrasive blasting can effectively remove rust, mill scale and paint but is not effective at removing soluble salts such as chlorides from contaminated surfaces [3], dust can create visibility problems during blasting and cause environmental problems at the jobsite.

Surface cleaning by hand tools such as scrapers, sanders and wire brushes is relatively ineffective in removing mill scale or adherent rust. Hand tool cleaning removes only loosely adhering paint, rust, and mill scale. It is slow and produces a burnished rather than a textured surface that permits only limited coating adhesion, It will not remove surface contaminants and soluble salts. Thus, it is used mostly for spot cleaning.

Power tool cleaning method (electrical and pneumatic) offer a slight improvement over manual methods. Power tool clean much faster than comparable hand tools. They include sanders (sandpaper cleaning), grinders, wire brushes, hammers, scalers, and needle guns. They clean by impact, abrasion, or both. Cleaning of metal surfaces is less expensive using power tools than using hand tools, and less particulate contamination occurs than when abrasive blasting. Thus, they are used mostly for spot cleaning, where contamination of adjacent areas by abrasive blasting is unacceptable [4].

1.2 Flame cleaning

Flame cleaning uses an oxy/gas flame that is passed over the steel surface. The sudden heating causes rust scales to flake off as a result of differential expansion between the scales and the steel surface. All loose rust can then be removed by scraping and wire brushing followed by dust removal.

Flame cleaning is not an economic method and may damage coatings on the reverse side of the surface being treated. Also the technique is not very effective in removing all rust from steel.

1.3 Steam cleaning:

Steam cleaning effectively removes grease, oil, and dirt by a combination of detergent action, high pressure heated water (138 °C to 149 °C at 0.189 to 0.315 liters/sec and impact. It is used on both coated and uncoated surfaces. The equipment consists mainly of a pressure jet steam cleaner [3].

1.4 Chemical surface cleaning.

Chemicals can often be used to clean metals for coating. Organic solvents are widely used to remove organic contaminants from the metal substrates. But they are toxic and flammable nature and need to be used in large quantities, which is uneconomical. Alkaline cleaning provides an economical and effective alternative to the use of organic solvents to remove greases, oils and waxes. They are also used in conjunction with surface active (wetting) agents and emulsified hydrocarbon solvents. Alkaline cleaners are particularly efficient when used hot (approx. 79 °C). While alkaline cleaning is free from the fire and toxicity hazards associated with organic solvent cleaning, the corrosive effects of alkaline materials on the skin and on ordinary clothing must be guarded against.[2] Alkaline cleaners remove grease, oil, and oil-based coatings from steel. Solvent strippers are appropriate for removing other coatings. Baths can be used for dip cleaning of some metals.

Acid cleaning or pickling using acids such as HCl, H_2SO_4, and H_3PO_4 is a very effective method for the removal of rust and mill scale Dilute solutions (5-10% by weight) of H_2SO_4 and HCl are used in presence of inhibitors to remove the inorganic contaminants by converting them into their ferrous salts. Pickling in H_2SO_4 is usually performed at high temperatures (about 60 °C). H_3PO_4 is an excellent time-tested cleaning agent which not only removes organic and inorganic solids present on the metal but also causes chemical etching of the surface by reacting with it to produce a mechanically and chemically receptive surface for subsequent coating formation , acid pickling is widely used in the pre-treatment of steel products prior to their coating with other materials such as zinc ,tin and paint. Acid pickling will only remove iron oxides (rust) and mill scale. It has little effect on organic contaminants.

Starting in 1964, numerous steel pickling facilities changed from sulfuric acid to hydrochloric acid. Besides the advantage of lower costs, HCl pickling offers faster and cleaner pickling, lower acid consumption and greater utilization of the acid, less steam consumption and reduced quantities of waste pickle liquor, and more uniform product quality than sulfuric acid pickling. However, the only significant disadvantage of HCl acid is its volatility, which is greater than that of sulfuric acid. When HC1 is used as the pickling solution to clean steel surface iron oxide, the following reactions occur: [5]

$Fe_2O_3 + Fe + 6HCl => 3\ FeCl_2 + 3H_2O$

$Fe_3O_4 + Fe + 8HCl => 4FeCl_2 + 4H_2O$

$FeO + 2HCl => FeCl_2 + H_2O$

HCl acid react with zinc layer of zinc coated steel as follow:

$Zn + HCl => ZnCl_2 + H_2$ (forming bubbles)

HCl acid also reacts with the base steel by the following mechanism:

$Fe + 2HCl => FeCl_2 + H_2$ (forming bubbles)

Therefore, an inhibitor is usually added to the acid solution to inhibit or lessen acid attack on the steel itself while permitting preferential attack on the iron oxides.

The rate of pickling is affected by several variables, including the base steel constituents, the type of adherence of oxides, acid concentration and ferrous chloride

concentration in the solution, temperature of the solution, agitation, time of immersion, and the presence of inhibitors. Pickling rate increases as acid concentration or temperature increases.

As pickling continues, free HCl depletes and ferrous chloride builds up in the pickle liquor to an extent that pickling cannot be accomplished effectively and the quality of the treated metal surface deteriorates. At that point, the pickle
Liquor is discharged from the pickling tank to a storage tank, and the pickling tank is replenished with fresh acid solution.
In pickling process steel is immersed in an acid solution for 10 to 30 minutes until the scale or oxide film is removed, lifted from the bath, allowed to drain, then rinsed by subsequent immersion in one or more rinse tanks or by spraying to remove HCl residue . Generally, the acid solution is maintained at ambient temperature for surface cleaning or etching and at an elevated temperature for oxide removal.

Typical HCl concentrations in the batch pickling process range from 12 percent at the beginning of a fresh batch to 4 percent before acid replacement. A fresh batch of acid solution is prepared; then the pickling is performed until the iron concentration of the acid solution reaches the maximum allowable concentration (about 13 percent by weight) or until the free HCl becomes insufficient for proper scale removal. [6],[7]

2. Case study

In an mechanical complex, used zinc plated cylindrical steel case which is opened from one end and there is a small hole in the other end was required to reuse. To be able to reuse these steel case again, oil, grease, dirt, rust, and old coatings must be removed in order to replate with zinc coat. Removing rust and zinc coat was carried out by mechanical method; the drawback of this method was the low production rate, large manpower, base metal damage and the toxicity. Chemical cleaning method was suggested as alternative high production rate, very less base metal damage and less toxicity than the mechanical cleaning method.

3. Experimental

3.1. Chemical treatments

Small rectangular plates with an overall surface area of 25 cm^2 were cut from used cylindrical carbon steel alloy and were used in this study as the sample material.
Specimens were immersed in hot water in order to remove any mud or dirt, to remove grease, oil the samples were treated by hot degreasing solution containing sodium hydroxide , sodium carbonate , sodium phosphate , sodium silicate , and emulsifying agent 0П-7 (Russian origin) . They immersed in hot water and then HCl acid pickling solution to remove zinc coat layer, rust and scale and after that they washed in cold flowing water.
Finally the specimens were immersed in sodium nitrite passivation solution in order to prevent rerusting before zinc plating process, dry surface samples were inspected visually and by ring gauge to insure that there is no damage in the outer diameter due to the pickling process. Many experiments were performed to find a suitable mixture of chemicals with suitable concentration and treatment conditions to clean used steel case samples from dirt, grease, oil, rust, and damaged zinc coat as shown in the table (1)

bellow. According to the experiments results eight steps technological procedure was proposed.

Table (1)

Operations	Chemicals	Concentration, gm / l	Temperature, O C	Time, min
Alkaline solution degreasing	NaOH , $Na_3 PO_4$. 12 H_2 O , $Na_2 CO_3$, $Na_3 SiO_3$. n H_2O , Emulsifying agent(0П-7)	50 - 100 30-60 20 - 50 3 -10 3-5	60 - 95	1 - 3
Pickling and old zinc coat removing solution	HCl acid , inhibitor kc (Russian origin)	10 -25 % W 3 - 5	Room temperature	10 - 25
Passivation solution	$NaNO_2$	30 - 50	Room temperature	0.5 - 3

3.2 Technological procedure details

In general chemical cleaning method of used cylindrical steel case comprises of eight operations as indicated in flow chart as given in figure (1). Following is the details of these operations:

Step 1: Hot water washing

Rinsing in hot water bath (60 - 85) ^{0}C for (0.5 - 1) min duration to remove dirt from used steel case.

Step 2: Alkaline solution degreasing

Rinsing in hot alkaline solution bath (60 - 95) ^{0}C for 1 - 3 min in order to remove oil and grease, solution compose of the following constituents: sodium hydroxide NaOH , (50 - 100) gm / l ,sodium phosphate, Na_3PO_4 . $12H_2O$, (30 - 60) gm /l, sodium carbonate, $Na_2 CO_3$, (20 - 50) gm/l, Sodium silicate, $Na_3 SiO_3$ .n H_2O, (3 -10) gm/l. Emulsifying agent (0П-7), (3-5) gm/l

Step 3: Hot water washing

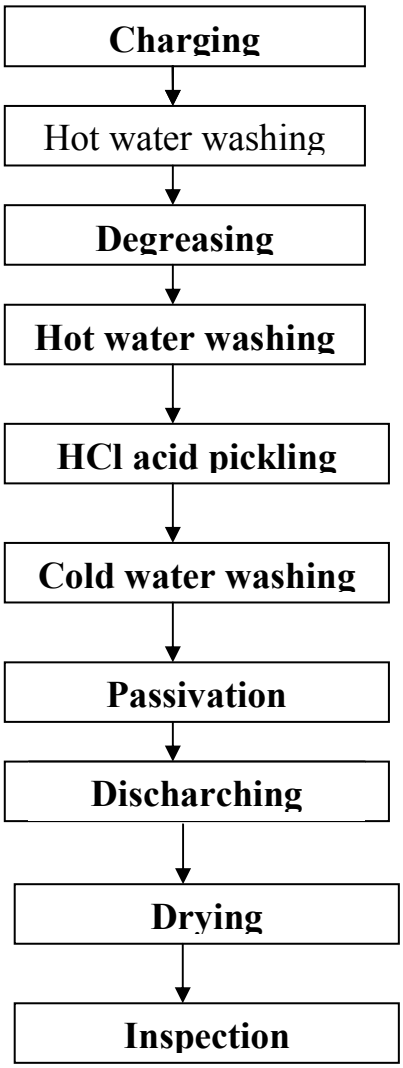

Figure (1)

Rinsing in hot water bath as in step 1 in order to remove any chemical residue on the surface from the previous step.

Step 4: pickling and old zinc coat removing

Immersion used steel case in cold pickling solution bath for (10 - 25) min in order to remove old zinc coat and rust. Pickling solution consist of HCl acid, (10 -25 %w) and inhibitor kc (Russian origin), (3 - 5) gm/l.

Step 5: cold flowing water washingRinsing in flowing water for (0.5 – 1) min to remove acid residue from the steel surface.

Step 6: passivation

Rinsing in cold sodium nitrite solution bath, (30 - 50) gm/ l for 0.5 - 3 min in order to prevent cleaned surface from rerusting during the transportation.

Step 7: Drying

Drying by air at room temperature till dry surface.

Step 8: Inspection

Visual inspection on inspection table to insure that all used steel case are free from dirt , oil , grease , rust, and other contaminants, the surface must be bright steel surface.

4. Results and discussion

In this paper chemical method to clean used cylindrical steel case from dirt , oil , grease , iron rust and old zinc coat was suggested . The concentration of the consistent of the solution and operation conditions were determined as a result of several experiments. Production rate of cleaning of used cylindrical steel case using already exists mechanical machines in cleaning workshop was about 100 piece per shift (shift = 8 hr), so to increase the production rate more expensive cleaning machines must be purchased from abroad and workshop building must be extended. By chemical method the production rate can be increased to ten fold or more depending on the tank size. Tanks line consist of six tanks already exists in the cleaning workshop was used to clean more than 1000 piece per shift, to increase the production rate tanks with large size from local market can be used with out any need to extend the workshop building, rejection percent due to dimension damages decreased to less than 1% compared with mechanical method .

5. Conclusions

Technological procedure for chemical cleaning , pickling and old zinc coat removing from used cylindrical steel case surface was found and executed in already existing tanks line in pickling workshop in the mechanical complex. The production rate increased more than ten fold.

In mechanical method the workers are very close to the machines which may they expose to the risk of inhaling metal dust. In chemical method the workers not need to be near the degreasing and pickling bath and good ventilation can remove the dangerous vapors come from these baths.

Acceptable clean surface of used steel cases for zinc recoating was achieved by using chemical method and there was no effect on the base metal dimensions compared with the mechanical method.

References

1. Yume Gerenrot and David Leychkis Ferrotech, ' steel surface oxidation after pickling', Applied Research Center, Pittsburg, PA, U.S.A.
2. Dr. R. Hudson,' surface preparation for coating', crown copyright 2000
3. John Robinson, ' what lies beneath surface preparation, the key to coating performance', corrosion management may 2003
4. Tyler J. Fox, Craig D. Randall, David H. Gross,' Steel Pickling: A Profile, Draft Report', Center for Economics Research, Research Triangle Institute, Research Triangle Park, NC 27709
5. R. Y. Chen, and W. Y. D. Yuen, ' on the pickling mechanisms of hot rolled steel strip', 44th MWSP Conference Proceedings, Vol. XL, 2002, page 1077.
6. T.S.N. Sankara Narayanan,' surface pretreatment by phosphate conversion coatings ' . Sankara Narayanan, Rev.Adv.Mater.Sci. 9 (2005) 130-177
7. Jeleel K. Ahmad "Surface preparation For Finishing Industries "2009