**MECHANICAL AND CAUSTIC CLEANING**

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**INTRODUCTION**

An important step in the galvanizing process is preparing the steel surface. The steel needs to be properly cleaned for the metallurgical reaction between the clean steel and molten zinc to occur. Failure to remove contaminants (i.e. soils, oils) reduces the efficiency of the acid in the pickling process, but can also lead to defects and bare spots in the galvanized coating. Surface preparation includes caustic cleaning to remove dirt and oil; pickling to remove rust and scale; and fluxing to remove oxides and protect the steel as it enters the zinc bath.

Mechanical cleaning methods can also be included in the steps for preparing the steel. This method is helpful in removing tough coatings, such as paint and lacquer, before pickling. The first chemical surface treatment in the galvanizing plant is caustic cleaning. The caustic bath is designed to remove oils, dirt and other contaminants encountered on steel parts to be galvanized so that the rust and scale are exposed.

In a recent process survey, galvanizers were asked questions about their caustic bath and if mechanical cleaning methods were used at their plant. Of the 86 respondents, only seven did not have a caustic bath and 18 used some type of mechanical cleaning. Results from the process survey will be discussed in the appropriate sections for mechanical and caustic cleaning.

**MECHANICAL CLEANING**

The main purpose of using a mechanical cleaning method is to remove rust, scale, mold sand, slag from welding operations, and paint or lacquer coatings. Mechanical cleaning methods are often used as the first surface preparation step because it helps reduce the amount of time the work is immersed in other surface preparation solutions (i.e. caustic and pickling). Mechanical cleaning methods can also replace the costly practice of burning-off paint and varnish by immersing parts in the zinc bath before they are cleaned. The part is then stripped of any adherent zinc in an acid bath. This method is very costly since valuable working time in the galvanizing bath is lost and zinc and acid are wasted.

**TYPES OF MECHANICAL CLEANING**

There are several methods of mechanical cleaning. The most common mechanical cleaning methods in galvanizing are abrasive blasting, barrel and vibratory finishing, brush and hand finishing, and grinding and polishing. Mechanical cleaning methods can be used together or stand alone. According to the process survey, the two most popular mechanical cleaning methods among galvanizers are both abrasive blasting, techniques using shot and grit. The other mechanical cleaning processes are wire brushing, wheel abrasion, and vibration tumbler.

In abrasive blasting, a forceful stream of abrasive particles, either shot or grit, is forced against the work surface. The process is particularly suited for thorough and effective removal of mill scale from hot-rolled steel products or of scale produced during the casting, heat-treating and annealing processes. There are two basic abrasive blasting methods used. The first is mechanical blasting, or airless centrifugal blasting, where the abrasive media is propelled by a power driven, rapidly rotating, bladed wheel. The second method is air blasting. Air blasting uses compressed air to propel the abrasive media through a nozzle toward the work to be cleaned. The abrasives used...
include angular metallic grit, spherical metal shot and sand.

Metallic shot tends to peen the surface using a stream of rounded pellets called shot. The advantage of using shot is the particles can be re-used many times before fracturing. If the shot does fracture, continued use will smooth out the rough edges of the shot, resulting in smaller round particles. Grit particles are angular metal pellets and are more aggressive than shot. In contrast to shot, grit tends to fracture in use before the sharp surfaces have an opportunity to smooth over. The type of contaminants and extent of iron oxide buildup determines the size of the abrasive and the relative coverage of the mix.

Barrel and vibratory finishing are two types of multiple-part finishing operations. Barrel finishing improves the surfaces of a large number of smaller parts by tumbling or rolling them along with a finishing medium in rotating containers called barrels. This process is also referred to as tumbling. Vibratory finishing imparts an oscillation motion to the parts and finishing medium. This motion produces a constant scrubbing action. Vibratory finishing can readily clean hard-to-reach areas. In comparing these two multiple-part finishing operations, vibratory finishing is usually completed in less time than barrel finishing. For both barrel and vibratory processes, compounds such as soaps, synthetic detergents and acid or alkaline cleaners can be used with water along with the finishing medium. Finishing media include a wide variety of materials and shapes. Finishing media are employed to separate the pieces, prevent them from being damaged, provide the finishing action, and influence the tumbling characteristics of the parts during barrel finishing.

Brush and hand finishing are other mechanical cleaning methods. For dry or wet surface cleaning operations, power driven rotary brushes may be used at various speeds. These brushes can be filled with wire or non-metallic fibers and are available in many dimensions and densities. Hand operations with wire brushes, abrasive papers and files can also be used. Usually only very small areas are economically cleaned by hand finishing.

The last mechanical cleaning methods are grinding and polishing. Grinding is an abrading operation that uses abrasive media bonded to either a power-driven belt or wheel. Grinding usually produces a rough surface, so it may be necessary to finish with a polishing operation if the final surface appearance is important.

ADVANTAGES AND DISADVANTAGES

Mechanical cleaning methods have advantages and disadvantages for cleaning steel to be galvanized. The most important advantage is the removal of difficult coatings on steel, such as paint and lacquer. A secondary advantage includes a reduction in pickling time. A third significant advantage is that the resulting roughened surface minimizes the thickness of the zinc coating for steel containing high silicon. Mechanical cleaning methods have other advantages. They include:

- energy efficiency – power consumption is limited to only the time when the system is actually in operation
- for castings – effectively and safely removes the sand, produces a uniformly cleaned surface and uniform coating; malleable iron castings are candidates for mechanical cleaning since their irregular surfaces require excessive pickling times and could produce an uneven galvanized coating
- versatility – welds are readily cleaned, including the removal of lightly adhering weld spatter. Different thicknesses of steel on a single fabrication that would require different pickling times can be cleaned uniformly with mechanical methods.
- reduction in acid disposal – pickling time is greatly reduced, which results in less acid waste and the lowering of volume of pickle liquor which must be disposed

There are few disadvantages to using the mechanical cleaning methods. They include additional cost because of increased usage of zinc, the difficulty of reaching some areas on fabricated parts, and dimensional accuracy. Increased usage of zinc results from roughening the surface of the steel. Mechanical methods can only clean the external surface of the steel. Internal surfaces of tubes and pipes cannot be
cleaned using mechanical methods. The removal of underlying steel is another disadvantage if there is an issue of critical dimensional problems.

CAUSTIC CLEANING

In the hot-dip galvanizing process the first chemical surface treatment is usually caustic cleaning. Figure 1 shows an example of parts being immersed in a caustic bath. At the fabricator’s plant, stamping, drawing, forming, and machining operations coat the steel with oils, greases and lubricants. Paint and identification markings are other types of contaminants which can be found on metal surfaces. Some of these materials may be covering heat-treating oxides or scales, as well as rust formed during long-term outdoor storage. Caustic cleaning involves the use of a hot alkali solution to remove organic contaminants like dirt, paint, markings, grease, and oil from the metal surface. The main component of the caustic bath is sodium hydroxide, also known as caustic soda.

Figure 1. Immersion of parts in the caustic bath

An alkaline cleaner removes organic contaminants in five different ways.

1. Dispersion by washing soil from the work surface
2. Emulsification by breaking up the soil and suspending it in the solution
3. Film shrinkage by forming beads of oil to remove oil films
4. Saponification by converting animal and vegetable oils to water-soluble soaps
5. Aggregation by collecting soil particles away from the work so that they can be more easily removed from the solution

There are many operational procedures for a caustic bath. The most important variables to monitor are concentration, temperature, cleaning time, and agitation.

CONCENTRATION

The concentration of a caustic bath ranges from 7 - 15 % sodium hydroxide. According to the process survey, the most common range was between 10 - 15%. Concentrations were reported from a low of 4 % to over 20 % sodium hydroxide. The high concentrations of caustic may be due to the type of work, such as painted or refinished articles that may need the extra cleaning strength. In the process survey the pH for the cleaning baths ranged from 10 to 14. The values for pH were widely spread due to the differing amounts of soil and organic matter that are carried into the bath on the steel parts. The most common pH values were 12 and 14. The high pH of the caustic solution is to clean steel effectively.

Many caustic solutions consist of a mixture of basic sodium salts in water. Water is an essential element in the composition of a caustic cleaner. It transmits heat and agitation to the work; carries the ingredients of the cleaner to the work; flushes the work; and carries the soil away from the work. A typical example of the solids portion of a caustic solution is:

- 20 % sodium hydroxide (caustic soda)
- 30 % sodium silicates
- 20 % sodium phosphates
- 20 % sodium carbonates
- 5 % sodium sulfonate
- 5 % sodium resinate

Sodium hydroxide provides the necessary alkalinity and improves saponification. Sodium silicates provide active alkalinity, emulsification and hold soils in suspension. Sodium phosphates provide some alkalinity, rinsability and emulsification, but serve primarily as water softeners. Sodium carbonates provide some alkalinity and act as water softeners,
although their primary purpose is to keep the cleaners dry and free flowing in storage before use. Sodium sulfonate and sodium resinate are used primarily as wetting agents, but also provide some emulsification.

TEMPERATURE, AGITATION AND CLEANING TIME

Caustic baths are usually heated and agitated with air to help remove soils and organic material from the surface. The bath temperature is maintained between 130 - 180 F. In the process survey, the temperature ranged between 140 and 180 F. There were few caustic baths that had temperatures over 180 F. The high temperature bath may be due to work that had paint or lacquer coatings, as cleaning action goes up very rapidly with temperature. If the temperature is increased or the concentration is increased, the cleaning is accelerated.

Steam coils or immersion burners are used to heat a caustic bath. These are located on one side of the tank so that a rolling action imparted to the solution by convection currents will agitate the bath. Other heating methods include using a boiler, carbon stick, electric, fire tube, and live steam.

Agitation is an important factor in speeding contaminant removal, particularly on irregularly shaped parts. Agitation helps to bring fresh solution in contact with the soil to be removed. This can be obtained as a side benefit from heating with steam injection or by movement of the work during the cleaning cycle. A degree of agitation can be obtained by installing a sheet-metal shield in front of the tank steam coils to make use of the convection currents. The shield directs the flow of solution upward and keeps it in steady circulation throughout the tank. Motor-driven mixers or mechanical agitation of the work pieces are also effective. Agitation stronger than the convection currents caused by the steam coils and burners can be obtained with mechanical stirring, recirculation pumps or by an air sparge at the bottom of the tank. Excessive agitation may cause alkaline cleaners to foam, but can be controlled by proper selection of surface-active agents. In the process survey, one third of the galvanizers used some type of air agitation.

The cleaning time can vary according to the amount of contaminants on the work. The average time to degrease in a still bath is between 10 - 13 minutes depending on the nature and degree of contamination. Normally less than five minutes of treatment is required when using an agitated bath.

MAINTENANCE

Since the strength of the caustic solution is essential to an effective degreasing operation, it is important to keep accurate records of the concentration of the bath and to establish the operating strength of the cleaner as a range. Caustic cleaners are weakened by reactions with acid solids, hard water, sludge resulting from common ion absorption on solid soils or emulsified oils, and by dilution resulting from water additions made to replenish dragout losses. Periodic tests should be made as a basis for controlling solution strength. Small additions of blended ingredients should be added to the bath at regular intervals. It is good practice to establish a schedule for adding cleaner consistent with the soil load and quantity of work being cleaned. The additions of blended ingredients should be spread over a large bath area and stirred completely. These are safety precautions against an eruption of hot caustic materials. Appropriate personal protective equipment should also be used when preparing these or any other metal treating solutions. Soft water should be used for the bath make-up and in-house titration used to monitor the pH of the solution. In the process survey, in-house laboratories were the most common method of testing and analyzing the caustic solution.

TANKS

There are several equipment requirements for the caustic bath. Most caustic baths are constructed from hot rolled mild steel plate at least ¼ inch thick. Tanks are also constructed out of polypropylene or of rubber-lined steel and plastic. The tanks that are six feet deep or more require thicker walls, horizontal braces and buttresses to brace the sides. All tanks should have a rim of angle iron or structural shape welded to the upper edge of the sides for reinforcement and for supporting equipment and accessories. Tank joints should be double welded and the bottoms should
be pitched to assist draining and washing out of solids and sludge. An overflow dam located on one end of the tank provides a means of skimming soils off the top of the cleaning solution. A valve should be placed in the drain for the overflow dam.

OTHER CLEANING TECHNIQUES

There are other cleaning techniques besides using a caustic bath. Acid cleaning is a process in which a solution of a mineral acid, organic acid or acid salt is used in combination with a wetting agent and detergent.

Emulsion cleaning is a process using common organic solvents dispersed in an aqueous medium with the acid of an emulsifying agent. Vapor degreasing is a cleaning process employing hot solvent vapor.

Solvent cleaning is a process using immersion at room temperature. Wiping with the solvent may also clean large items. Care should be taken to wipe the surface completely clean; otherwise, it may be found that the result of the treatment has been merely to spread the contaminant over a large area. Drawing lubricant can be removed effectively from some hollowware articles by furnace treatment at a temperature sufficient to decompose the oil. Paraffin-based emulsion cleaners are available which operate without heating and give efficient degreasing. These cleaners have a low flash point and caution must be given to the design of the installation.

Cold caustic baths are also used. These baths will remove a thin film of oil. Solutions are usually phosphate based and the supplier gives full working instructions. Such processes are useful in works where a consistent mild degree of surface contamination has to be removed with simple equipment. Subsequent rinsing is important in all of these cleaning methods to prevent carryover to the pickling bath.

REQUIREMENTS FOR A GOOD CLEANER

A good alkaline cleaner should have characteristics.

• Easily wet the metal being cleaned, as well as the soil being removed.
• Provide alkalinity. Most soaps and synthetic detergents are more efficient at pH values between 7 and 13. High alkalinity is required for saponification reactions.
• The cleaner should provide buffering action. Buffers tend to preserve the original pH of a solution when an acid or base is added to it. The buffering action and available alkalinity give long life to a cleaner at constant pH.
• The cleaner should soften hard water. Hard water components may form insoluble films on the work that are difficult to remove and that negate other cleaner characteristics.
• The cleaner should also disperse, emulsify and deflocculate removed soils. These properties will prevent resoiling of the work as it is removed from the cleaning tank.
• Readily rinsed off the work. All cleaner components must be readily soluble in cold water, with no significant affinity for the object being cleaned.
• The cleaner should contain stable components that are compatible with each other. Sodium salts are most commonly used together and also provide lowest costs.
• The cleaner should clean the work in a reasonable time and produce a surface that can be pickled satisfactorily.
• Does not cause excessive foaming when used in a spray application.

INSPECTION OF PART

Work should be suspended in the degreasing bath to allow free circulation of liquid over all surfaces. The surface of the solution should be cleaned of any scum that may collect, but the sludge that settles to the bottom of the tank can usually be left until the solution is replaced. Immediately after degreasing, the work is rinsed. If the work is not rinsed, alkali carried over neutralizes the pickling solution and causes unnecessary waste of acid. According to the recent process survey, only a few galvanizers did not have a rinse tank before the pickling bath. Most rinse tanks were maintained at ambient temperature. Only three
galvanizers used a heated rinse tank. After the work is finished in the caustic bath and the rinse, a visual inspection of the work should be the next step. A visual inspection should include checking for oil, soil, paint and lacquer removal. If there is paint and lacquer still remaining on the work, a mechanical cleaning method can be used to remove the tough coating.

DISPOSAL

In disposing of the spent caustic solution, the most common method of treatment was to neutralize it and send it to a landfill. Only 20 galvanizers reported having a source for recycling the spent caustic or the caustic sludge that develops at the bottom of the tank. The common method of removal was to decant the liquid and remove the bottom sludge.

SUMMARY

Surface preparation is an important step in producing quality galvanized coatings. Inadequate surface preparation prior to coating the steel will result in poor bonding of the coating – perhaps, complete failure to bond – and poor quality. Proper surface preparation can include mechanical or caustic cleaning, then pickling and fluxing.

Mechanical cleaning helps to reduce the cleaning times of the chemical surface treatments. There are various mechanical cleaning methods that can be used to effectively remove contaminants. By removing the tough coatings on the steel, less time is spent cleaning the material in the other steps.

Caustic cleaning is usually the first chemical surface treatment. The caustic solution removes oil and soils that are left on the work. The concentration, temperature and agitation should be adjusted to meet the soil load going into the caustic bath. Good record keeping can also help to determine when the caustic solution needs to be adjusted or when it must be disposed.

Proper cleaning of the steel can lead to less coating failure. By using the first cleaning methods effectively, the end result will be a quality galvanized coating.

BIBLIOGRAPHY