Designing the Proper Cleaning System for the Substrate

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Proper cleaning of metals prior to some form of finish treatment is very important and specific. The basis metal, the soils that may be on the metal when received for finishing, and the finish treatment must be known in order to design the appropriate cleaning system, including the means of application.

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Introduction

Have you ever wondered why there are so many cleaners? If you go to your local grocery store and walk down the aisles, you find all kinds of cleaners for all kinds of applications. If you were to read the ingredients list, you would find some ingredients common to many of them, and you would find some serious differences.

Cleaners, which contact human tissues, have to be aggressive to clean body oils as well as acquired soils, and yet not harm the skin. They will have varying amounts of organic chemical agents known as surfactants (surface active agents). These chemicals must be able to remove oils and other soils without damaging tissue.

Other cleaners are more aggressive in their action. An example of this is laundry detergents. These are stronger mixtures of organic surfactants plus inorganic compounds, usually mildly alkaline with high ionic strength. They are designed to remove a variety of contaminants which get on clothing–oils, food residues, sweat, dirt, etc. The laundry detergent must be able to react with these many different contaminants without damaging the clothes. However, because fabrics are not as delicate as skin, laundry cleaners can be more aggressive. Sometimes they will have stain removers and/or fabric softeners.

A third level of cleaner is the dishwashing detergent. They must be formulated two ways. One type for immersion having contact with skin tissue (hands) and must be non-corrosive. The other type is for the dishwasher, which operates on spray impingement. These detergents are very alkaline and very aggressive. However, they are cleaning surfaces, which are generally inert to attack by them -such materials as ceramic, glass, and plastic. The detergents rely on uniform spray, high temperature, and chemical conversion of food substances to water soluble salts. After the cleaning cycle, sometimes additives (rinse aids) are used in the rinsing cycle to lower the surface tension of the rinse water so it will sheet off the dishes and allow the water to dry, spot free. This last additive is for aesthetics–no ugly spots.

Metal Finishing

So what do household cleaners have to do with metal finishing? Primarily when you clean metal, you are essentially accomplishing the same thing, only the substrate is different. However, the metal substrates are as varied in sensitivity and reactivity as the few household examples discussed above. The difference in purpose however, is that the cleaning of the household items is the end result, while with metal finishing the cleaning process is just one step in several that will lead to a product having a coating that is both protective and aesthetically pleasing. As a result, cleaner development is somewhat more complex, especially when dealing with the potential variety of metals.

Basis Metal

Knowing the metal to be treated is very important. It may be obvious that you are treating steel rather than titanium or aluminum and that is a beginning. However, it is necessary to know more about the metal; such as the alloy, the temper, and the forming method–cast, rolled, extruded, or machined–which determine the surface quality, and metallurgical characteristics.

Each basis metal has a variety of alloys. Each of these alloys will have varying amounts of alloying ingredients, which will exist at the surface of the part. For instance, for Iron-based alloys there is mild steel with varying amounts of carbon. Carbon is a nonreactive material, which, if on the surface, will leave residues that will make subsequent treatments nonadherent. With low carbon steels, which are generally considered the stainless steels, carbon is not the issue, but the surface quality is a function of nickel and chrome. There are several types of stainless steel, and the problem is that in many instances the stainless steels are not totally nonreactive. These alloying materials are finely disbursed, yet still exist in a crystallized form called grains. While the general metal may have a certain quality to it, the grain structure can vary depending on size, which can be determined by the method used to form the metal and/or the temper of the metal. The higher the temper usually the finer is the grain structure and more finely disbursed the alloying ingredients.

These same metallurgical principles apply to aluminum, which is more sensitive than mild steel, and to titanium, which is generally less reactive than stainless steel. Aluminum is like the human skin we discussed in that it will react with strong alkaline or acid cleaners. Therefore, the cleaners have to be designed so as not to attack the aluminum, except when desired for special cleaning and activation requirements. Titanium, on the other hand, is like the dishes that are generally nonreactive with more aggressive chemicals (keeping in mind that titanium is not totally inert).

Soils

In the process of forming, machining, and handling the metal, various protective agents, such as lubricants and antioxidants, or contaminants, such as dust, dirt, moisture, ambient chemicals, and skin oils and moisture, can get on the surface of the metal. Left on the metal such materials will definitely affect substrate protection and finish adhesion. It is the job of the cleaner to remove these surface soils. In order to accomplish this it is necessary to thoroughly know the types of soils that are to be dealt with. There are so many ways that metal surfaces are contaminated prior to reaching the process line that we can't consider them all here. Some have already been mentioned. However, it can't be stressed enough the importance of an inventory of all the ways that lubricants are used with the metal and of the handling procedures which can deposit foreign material.

There are four basic types of lubricants which are used–fatty acids (animal fat), unsaturated polyesters (vegetable oil), synthetic oils (with polar characteristics), and good old motor oil (mineral oils). Each of these has different characteristics that require different cleaning agents.

- Alkaline inorganic compounds can be used with fatty acids to form saponified by-products, which are simply soaps that are water-soluble.
- Unsaturated polyesters will not react with alkaline compounds to form salts, but they tend to have polarity. This polarity allows them to combine with oppositely charged species to form either water-soluble molecules, which couple with the polarity of the water, or water-emulsifiable molecules, which become finely dispersed in the aqueous solution. This is accomplished with ionic surfactants that attack and break up the oils and remove them from the surface.
- In recent years, because of the continued pressure to use environmentally friendly cleaning methods, especially aqueous solutions, synthetic lubricants are regularly developed which are already water miscible or emulsifiable and therefore more responsive to simple aqueous cleaning products.
- The last type of lubricant (which is commonly used for lubrication and antioxidation protection of Iron-based metals) is mineral oil. This is a long, straight-chain or branch-chain, saturated hydrocarbon, which is generally nonreactive and nonpolar. It does not react well with the cleaning compounds mentioned previously. Mineral oils require a combination of organic, nonionic surfactants, which will attack the mineral oil and reduce it from a film to discrete particles. These particles can be lifted off the surface by the presence of strong inorganic salts that contribute ionic strength to the aqueous bath, as well as scour the surface of the metal to cause the oil to release. However, once released into the aqueous solution, it is not stable and will eventually find similar oil particles and recombine into larger particles and eventually will reform the oil as an immiscible floating layer. To finish the cleaning job and not allow the oil to

redeposit on the metal, the surface of the solution, along with the floating oil, is pulled off to an oil skimmer and the cleaned solution is recycled back to the bath to continue removing more oil. Although this method is more complicated, it is often necessary, as mineral oil is so nonreactive and neutral that not much will impact it.

Finish Treatment

The end use of the part must be known. Will it be for outdoor or indoor exposure and what is the vigorousness of the environment in which it will be used? Is there concern about abrasion resistance or is the concern mainly about corrosion resistance? Iron-based alloys obviously are very susceptible to oxidation and require serious protection from rust and corrosion. Aluminum is also prone to oxidation and corrosion, and although its corrosion product is colorless, it is still unacceptable. Stainless steel and titanium oft times are used in the mill finish condition or even polished but need no further treatment, because they are not affected by environmental exposure. If some sort of coating is applied, it is usually for decorative reasons rather than for protection of the metal.

The finish treatment depends on the final use of the product. This may be anodizing of aluminum or titanium, painting of aluminum and steel, powder coating of aluminum, steel, and titanium, and plating of steel and several other metals. In every case the surface of the metal to be treated must be cleaned and activated to offer a uniform surface that will react with the steps following the cleaning. Doing this correctly will allow for some sort of pretreatment prior to the final coating.

- In the case of anodizing, it is the final coating. It can be followed by imparting color to the anodic film, if desired. Then the coating is sealed to finish the protection characteristics.
- In the case of painting or powder coating, it is necessary to convert the aluminum surface into a more inert surface with adhesive properties over which the paint or powder coat will be applied. This underlying protection may be chromate conversion or non-chromate conversion of the aluminum, but is necessary because the painted surface is a semipermeable membrane, which over time will allow environmental moisture and chemicals to migrate through to the metal surface. Without the corrosion protection the aluminum would start to become powdery under the paint or powder coating causing a loss of adhesion. Eventually the paint would begin to separate and flake off the part, losing both protection and attractiveness.
- With steel products the process is usually accomplished with phosphates which have an affinity for forming a stable iron phosphate (or other phosphate) layer which is both protective and adherent.
- If any of the previously discussed lubricants, soils, or other contaminants are left on the surface, these conversion reactions can not take place properly and uniformly, and will result in failure of the finish coating on the metal.

Process Application

So how are we sure that we will be successful? This is accomplished by the above steps of knowing the metal, knowing the surface contaminant, knowing the correct combination of cleaner ingredients (this is the proprietary part), and last we need to discuss the method by which we apply the cleaner solution. The two primary methods of applying cleaners are immersion or spray. The conditions of time, temperature, and concentration of the cleaner are very important and must be maintained adequately and consistently. Just as in the examples of the household cleaner systems at the beginning, the method of cleaning determines the cleaner to be used. For instance, if the dishes are to be washed by hand, the cleaning solution can not be corrosive to skin tissues, but must be able to remove the contaminants. However, because the system is an immersion system with mechanical action on the surface–use of a dishcloth or brush–the cleaner will have a large amount of organic surfactants and detergents, which do not have to be aggressive. Also they can be foamy to some extent. However, in the case of the dishwasher, we now have a spray system. Often the surface contaminants have had a chance to dry or set on the surface. The use of a spray system requires a vigorous spray impingement action plus a more aggressive inorganic alkaline cleaner with only a small amount of low- or non-foaming surfactants to avoid the formation of lots of foam during the spraying action.

These same requirements occur in the cleaning of metal. An immersion system allows for variability of soak times, cleaner strength, and temperature. The important part of the immersion system is that it is not so aggressive that it attacks the metal surface, unless this is desired to help remove adherent contaminants, such as the carbon particles of the steel or reaction products that have bonded to the aluminum surface. The key to a successful immersion system is that it is a batch system and has the ability to vary the time for various situations or cleaning needs.

The spray cleaner system is usually a continuous system, which is not just for the cleaning, but includes the total process. That means that all of the steps from the cleaner step through the final finish is one integrated process. Exposure to each step is fixed in time to the final step, and the cleaning and pretreatment must be accomplished in that time period. This removes an important variable from the system - time - and puts a greater importance on the correct cleaner, its concentration, the uniformity of the spray to reach all surfaces, and the temperature of the cleaning solution. As stated already, the cleaner will need to be somewhat more aggressive and will usually be alkaline, especially with aluminum. The action with aluminum is more of microetching than emulsifying. With steel it is important that the system is alkaline since an acid solution will only serve to attack the steel surface. Since iron is not soluble in alkaline chemicals this would seem to be desirable in cleaning the surface of the steel. However, this is actually not a good system, and most steel cleaners will contain mild alkaline salts, which provide ionic strength, but will not attack the iron surface. Probably the most important part of the continuous spray system is remembering that it is a continuous system. The uniformity and consistency of the operation depends upon running the line continuously. Once the protective lubricants or contaminants are removed and the metal is exposed to a humid environment, if it stops in its progression, oxidation begins to occur. (This applies to both aluminum and steel although steel will react faster.) The oxidation products recontaminate the surface with undesirable reaction products, which will not respond uniformly to the subsequent pretreatment conversion coating. This will result in unacceptable performance of the final finish layer, because of poor adhesion. Many of the problems associated with spray systems is the difficulty of keeping them going continuously in spite of breaks, lunch, and unscheduled stops. Steel, once it has been cleaned of its protective oil and rinsed, will rust very quickly. Aluminum will reoxidize, also, even though the aluminum oxide is not as visible as that of steel.

Rinsing and Saturation

Two characteristic problems that occur on any metal treating line is the need to conserve water because of economical and/or environmental constraints and the desire to use the cleaner as long as possible. Both have had a serious impact on the performance of cleaners and finishing lines in general. Rinsing is so important. Without free rinsing of the cleaner and what it contains, material can be left on the surface, which will negatively impact the subsequent steps. The rinse water needs to be clean enough to leave the metal surface water break free which is the sign of a clean surface. If the rinse does not do this then you run the risk of contamination of the pretreatment solution, as well as, undesirable reaction products on the metal surface. This leads to nonuniform results and performance of the product coating.

The other problem is the desire to run the cleaner as "LONG" as possible. The problem with this thinking is that chemical solutions don't last based on time. They last based upon the amount of surface area treated and, in the case of cleaners, the amount of oils, soils, and contaminants removed from the surface. A cleaner that is not used will last indefinitely. Cleaners are bringing materials into solution or suspension in an aqueous media. There is a point at which the water can not hold any more. This is not a function of time but of use. When the cleaner bath has reached this point it is saturated. When it becomes saturated the amazing thing is that it will keep on trying to bring more material into solution. But what happens is that the material, which is already there, will be driven out of solution or suspension and will redeposit on the surface you want to be clean. This is not acceptable. It is important to be able to say that it is time to dump the cleaner and start fresh. Also, trying to save part of the saturated solution will not be successful, because once the falling-out process has started, it is hard to stop.

Conclusion

Successful cleaning is dependent upon knowing your system in all its aspects:

- The basis metal
- The surface contaminants
- The appropriate cleaner
- The proper conditions
- The method of application
- The final finish
- Rinsing and Replacement

With proper control of all these aspects of your process, you should be able to provide for a consistent and uniform finished product, which is the goal of any process.

