Effectively Using Non-Chelating Materials in Mass Finishing Compounds

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Mass finishing is the art of accomplishing processes such as cleaning and degreasing, deburring, surface improvement, corrosion inhibition, or burnishing on a large number of parts. The equipment, the media, and process fluid work together to achieve acceptable parts. The nature of the mass finishing process lends itself to the generation of wastewater. Mass finishing compounds are designed to meet very specific goals and selection of raw materials depends greatly upon the desired end result of the process and the anticipated waste stream. Chelating materials, which are widely used in mass finishing compounds, chemically react with metal atoms to form large, complex, water-soluble molecules. Once reacted, the chelating materials do not let go of the metal atom causing waste treatment concerns. Instead, non-chelating materials can often be used with comparable results while not interfering with the waste treatment process.

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INTRODUCTION

Mass finishing is the art of accomplishing processes such as cleaning and degreasing, deburring, descaling, surface improvement, corrosion inhibition, or burnishing on a large number of parts. There are four main elements in the mass finishing process: the part, the machine, the media, and the process fluid. The four elements work together to achieve acceptable parts. This paper is about chemistry but it is impossible to discuss chemistry without including the other three elements of mass finishing because the most important aspect of mass finishing is to make sure that the four elements' variables are taken into account when establishing a mass finishing process. Once the variables have been dealt with, the proper components of the mass finishing process can be selected. Only then can it be discussed if non-chelating compounds can be used in place of chelating compounds.

PARTS

Almost any type of part can be mass finished. Sometimes there are limitations with very delicate parts and very large parts; but many times mass finishing processes can even be developed for these. The list of parts in which mass finishing can be utilized seems endless and includes: nuts and bolts, medical instruments and implants, knife blades and handles, pens and pencils, clothing rivets as well as clothing itself, manufactured metals and alloys (copper, aluminum, magnesium, brass, bronze, etc.), door and window components, coin and precious metal artifacts, auto, boat, motorcycle, snowmobile, and bicycle components, aircraft components, guns and ammunition components, dishes and cutlery, and toys. Obviously the mass finishing process must be developed around the part.

MACHINES

There are three basic types of mass finishing machines: rotary, vibratory, and centrifugal. Rotary is probably the oldest form of mass finishing and consists of a barrel (usually hexagonal or octagonal) that rotates along a fixed horizontal axis. Vibratory finishing is the most popular form of mass finishing. It consists of a bowl or tub setting on springs. An electric motor drives a shaft with offset weights that cause the shaft to wobble. The bowl or tub then vibrates on the springs as a result of the wobble. Centrifugal finishing consists of a bowl with stationary walls and a disk at the bottom of the bowl that spins causing the media and parts to spin as well. Most mass finishing machines run on principles of these three basic concepts.

MEDIA

Media is the term used for substance put in the machine that rotates or vibrates and does the work on the part. There are some applications where no media is used (part-on-part); usually general cleanup or light deburring or if media is going to cause separation problems. There are two general types of media: abrasive and non-abrasive. Abrasive media is used when heavy burrs exist, heavy cut lines must be removed or significant stock removal is required. Abrasive media usually contains some cutting material usually aluminum oxide or silicon carbide bonded in ceramic using water with pressure and heat. Ceramic media is available in a plethora of shapes and sizes.

Non-abrasive media is used in applications where stock removal is not required or not desired such as general cleaning, burnishing, and surface preparation for plating, painting, or adhesion. There are three general types of non-abrasive media: porcelain, plastic, and steel. Steel is the most common non-abrasive media used and can be normal carbon steel or stainless steel. Steel media is normally used with acidic compounds utilizing the weight of the steel media with the acidic pH of the compound to provide a very bright luster. Indeed, in some cases using steel media and the proper acidic compound can produce a part which appears plated.

Porcelain media is normally used with alkaline compounds but can be used with acidic compounds as well. Porcelain media can be very dense to provide similar action as steel media with reduced cost. Not as much care is required for porcelain media as is required with carbon steel media which has to be protected from rust overnight and over long shut downs. Plastic media because of its lightness is normally used in processes with very delicate parts or were a very smooth surface is required.

PROCESS FLUID

The process fluid or compound works with the media to provide acceptable parts. Compounds have very specific functions which include: control foam, control pH, control water hardness, wet surfaces, emulsify oils, remove tarnish, suspend soils, control lubricity, control part color, inhibit corrosion, and provide cooling. Once we understand how each function works, we can discuss how and if non-chelating materials can be used in lieu of chemically reactive chelating compounds.

Most mass finishing compounds contain some level of foam. It is important to control the level of foam in the process mainly for the cleanliness of the finishing department. The rule of thumb is that if the foam is not overflowing out of the machine there is not too much foam. Not only is foam desirable in most mass finishing applications, but in some cases it is a necessity. Foam tends to help machines, especially larger machines with steel media, feed and roll better and helps in unloading of parts.

Controlling the pH of the process fluid is probably the most important function of a compound. What's more, it is the process pH (usually 1% for process compounds and 5-20% for inhibiting compounds) not the concentrate pH which is important to monitor. So much of the process depends on the pH that it is critical to maintain a consistent pH. Compounds are typically built with buffers to combat changing water quality as well as changing compound concentration if the compound pump gets turned up or down.

Most compounds are designed to be used with normal tap water which usually contains some hardness as calcium, iron, magnesium, etc. This means some of the compound is used up just in controlling the hardness of the water. Remember, most process compounds are used at 1% (99% water) so in some cases water hardness can have a significant impact on the process. It is becoming more common for shops to use specially treated water such as soft water, deionized water, or reverse osmosis water. These types of water, although more pure than tap water can cause more problems than they cure. These types of water usually add more slip to the media mass causing decreased feed and roll as well as significant foaming issues. It is recommended to use tap water in mass finishing unless extremely hard water – over 50 grains (850ppm) is present.

Many times compounds are required to remove cutting, cooling or other types of oil that are petroleum- (or other solvent-) based and not water-soluble. Compounds contain materials that wet the surface of oils or make them more water-like to help them become water soluble. This is accomplished with the help of surfactants which are molecules that contain a water-soluble portion and an oil-soluble portion. Once the process fluid wets the surface of the oil, other components work to keep the oil emulsified in the aqueous solution. This is accomplished by the process fluid creating little temporarily water-soluble droplets called micelles.

Once the oil (or other soil contaminant) is wetted and/or emulsified the process fluid must be able to suspend the soil until it can be carried away from the part to the waste stream. Foam is extremely helpful in accomplishing this task. This is one reason foam is so important to the mass finishing process.

Controlling lubricity, or the amount of slipperiness in the process, is another function of mass finishing compounds. In some cases, with harder metals less lubricity is required since it is desired that the media do more work on the part. However, with lighter and more delicate parts, more lubricity is desired. If there is too much lubricity, the function, especially deburring may not be carried out; or longer run times may be observed.

Part color is important in some mass finishing applications especially with copper, brass, bronze or other colored metals. With ferrous metals and some non-ferrous metals like aluminum certain compounds can affect the part color. For example, if the compound is too acidic (acid descaler where pH 1% < 3) it may be too active for said metal. Both steel and aluminum react at that low of a pH to form oxides (iron oxide or aluminum oxide) which can literally plate back onto the metals. This causes steel parts to turn black and aluminum parts to get white spots.

A compound can be purposefully selected to affect the color of a metal. This is especially true with copper and is directly proportional to the pH. The common bright orange copper color associated with plumbing copper is obtained by running the process at a pH of 3.5 - 4.5. A lower pH (1-3) will give the copper a pink tint while running the process at a higher pH (above 7) will give copper a deeper orange color.

The mass finishing process works on the surfaces of the parts. While obtaining a clean, smooth, or burnished surface it makes the part susceptible to oxidation. All metals corrode. It is very important that compounds contain materials which inhibit the parts (and media when using carbon steel media). Most compounds contain sufficient corrosion inhibition to curtail oxidation during process but will not offer shelf life. To get extended corrosion protection, a compound designed specifically for rust protection must be used.

In most mass finishing processes, cooling is not required. A warm mass can sometimes be beneficial as many oils clean easier at elevated temperatures. However, cooling is necessary in some applications using large machines with steel media. Steel media averages 300 pounds per cubic foot. Vibratory machines have been built to 50 -100 cubic feet of working capacity. With this much weight the mass can run very hot and in this case cooling is extremely important.

CHELATING MATERIALS

Chelating materials are large molecules that chemically react with a metal atom or ion to form a very stable water-soluble complex molecule. Many large molecules exhibit chelating properties naturally, but ethylendiaminetetraacetic acid (EDTA) and other large amine molecules and citric acid are the most common materials used specifically for their chelating properties. To picture how chelating agents function use this analogy. Think of a chelating material as a large snapping turtle and a metal atom or ion a small pea. The large snapping turtle grabs the small pea in its mouth and will not let go of it until its head is chopped off. This is very similar to what chelating agents do. They are much larger than the metal atom or ion and once they chemically react with the metal they don't want to let it go.

The tetra sodium form of EDTA is normally formulated into alkaline compounds including: deburring, burnishing, and inhibiting compounds. Deburring is enhanced by tetra sodium EDTA's chelating ability by reacting with metal atoms on the surface burr of the part. It works similarly in alkaline burnishing compounds by reacting on the surface metal to form a smooth lustrous surface. In alkaline inhibiting compounds the tetra sodium EDTA and other amines (especially amine carboxylates and amine borates) chemically attach themselves to the surface of the part through their chelating properties. This causes a film to develop on the part keeping oxidation away from the part.

Citric acid is used widely in formulation of acid burnishing compounds and acid descaling compounds as well as some cleaning and inhibiting compounds. Citric acid has some very good properties: it is environmentally friendly (it is the acid in citrus fruits and used in processed foods as a preservative), it is plentiful and can be manufactured easily, and it has some natural cleaning ability. In addition, citric acid tends to passivate the surface of a part especially a ferrous part. Passivate is a term used for the chemical process of removing iron from the surface of a part. This has the added benefit of rust protection as there is no iron present on the surface of the part to take place in an oxidation reaction.

Phosphonic acid and some of its derivatives have been developed as mildly chelating agents. These were developed to have some chelating properties similar to EDTA and its derivatives but let go of the metal ion easier to ease treatment concerns. However, these materials are not used as commonly as the EDTA because of the decreased chelating abilities and because they contain phosphorus. Many manufacturers have gone away from using phosphorus containing materials because of the environmental impact they show.

NON-CHELATING MATERIALS

In contrast to chelating materials, non-chelating materials are usually smaller molecules that don't chemically react (or at least not to the extent of chelating materials) with a metal atom or ion. Non-chelating acid burnishing and acid descaling compounds use other acids to lower their pH's. The biggest disadvantages of using non-chelating acids to build these compounds is that the passivation activity is usually lost. The end result is that metals run with non-chelating compounds typically tarnish if not treated with a rust inhibiting compound. In addition, some other acids selected may have environmental or health concerns.

Alkaline deburring compounds have the highest impact of using non-chelating materials since chelating compounds, because of their reactive nature, really enhance deburring. Deburring is usually accomplished with non-chelating materials by decreasing the lubricity and foam level causing the media to do more work on the part. Many times a more aggressive media is required to do the same amount of deburring. Unfortunately, more aggressive media tends to break down faster causing more particulate matter in the waste stream as well as increased cost of replacing worn out media.

Inhibiting compounds suffer from using non-chelating materials. As stated before most water-soluble inhibiting compounds work when their chelating materials attach themselves to the surface of the part keeping any oxidation from occurring on the surface of the part. There are some materials specially formulated to offer rust protection while being non-chelating - these are normally very viscous liquids that stick to the surface of the part similar to oil-based inhibiting compounds. Because of their physical characteristics and unique chemical abilities, these materials are often harder to formulate into aqueous inhibiting compounds and more expensive. Most people opt to deal with chelating materials in their aqueous inhibiting compounds.

WASTE TREATMENT

Mass finishing lends itself to the generation of waste water. Many mass finishing compounds when diluted to processing concentration (1%) are mild enough to dispose of directly into septic systems or sewage plants. Unfortunately there are deeper concerns with typical mass finishing waste streams than the compound used in the process. Indeed, most of the waste streams that are out of compliance are because of elevated oil and grease levels, elevated particulate matter, elevated dissolved or total metal content, or elevated biological oxygen demand (BOD) levels.

Many aqueous mass finishing compounds are labeled as biodegradable. It is important to note that biodegradable does not mean, "Dump it down the sink". Biodegradable simply means that bacteria or some other living organism will consume the constituents of the compound completely to water and carbon dioxide along with trace elements. The negative side of using biodegradable constituents in mass finishing compounds is that living organisms love most biodegradable elements in the mixture. In this environment with essentially unlimited food supply bacterial growth can take place at an incredible rate. The bacteria (or other living organisms) use oxygen while consuming the biodegradable food source. Therefore, a high BOD level signifies significant bacterial growth.

Typical waste treatment is based on the fact that particulate matter and metal fines are not tied up with anything and will react with standard treatment chemicals to drop out. For example, a traditional waste treatment process would include: lowering the pH, adding a competing ion such as ferric chloride, raising the pH with sodium hydroxide, adding flocculant to increase particle size, and filter. Ferric chloride is frequently used since iron is not as hazardous to humans and the environment as some other metals that may be in the waste stream such as chromium, nickel, zinc, lead, etc. When chelating agents are present in the waste stream they often don't allow the competing ion to react and thus stay in solution with the metal they have tied up.

It is incorrect to say, "This waste stream contains chelating agents so it cannot be treated." True, most waste streams that contain chelating agents are more difficult to treat but often the stream can be treated. In our analogy of the snapping turtle and pea, the snapping turtle grabbed the pea and didn't want to let it go. There are two options: cut its head off or deal with it as one entity. It is easier to deal with a complex, chelated molecule than it is to try to get the molecule to chemically let go of the metal ion. Treating the chelated entity can often be accomplished by adding additional quantities of flocculants and other treatment chemicals.

CONCLUSION

Mass finishing has specific functions. As a result, compounds designed to be used in mass finishing have very specific functions. Chelating agents are often formulated into mass finishing compounds to enhance the abilities of the compounds. Many times chelating agents are tolerated because of their abilities in compounds especially inhibiting compounds. In some cases chelating agents are not all that bad and can be treated from the waste stream. Many times, a sample process can be run on a small scale to determine if the stream can be treated and if so how easily.

It is extremely important to take into account all four elements of mass finishing - the part, the media, the machine, and the process fluid before making any decisions about a mass finishing process. After investigating the four components of the mass finishing process, decisions must be made to set up the process properly. Once the system is set up properly, then the question, "Can non-chelating compounds be used in this process?" can be asked. If the answer is yes, one can be selected from the many non-chelating compounds that exist that have been proven to be quite effective and successful in the mass finishing process.