Selecting an Aqueous Cleaning System

By Edward H. Tulinski

This belt spray system is configured for wash, rinse, rust inhibit, recirculating hot air dryer, oil coalescor, and wash filtration.

Proper equipment configuration for aqueous cleaning systems is process driven and must satisfy all issues associated with the acceptible cleaning of parts. This presentation, from SUR/FIN® 2001—Nashville, identifies process parameters that must be end-user driven and identified.

Aqueous washing systems have become the dominant method of cleaning in the industrial marketplace as manufacturers strive to become environmentally compliant. It is a trend that will continue.

Aqueous systems clean better, meet higher cleanliness tolerances, and have higher production rates than solvent cleaning systems, which were formerly used. Parts cleaned by aqueous methods are film- and residue-free.

For an aqueous system to be successful, proper equipment configuration is necessary for maximum cleaning capability. This is best achieved by interaction between the end user and the chemical and equipment suppliers.

It is important that the end user establish some ground rules or definitions for the design of the equipment. The end user must define the following:

Parts

The user should define the part or parts, including the minimum and maximum size and geometry. It also should be determined whether, during the cleaning cycle, parts can come in contact with one another, or whether parts must be maintained in a proper geometry, or even fixtured.

Productivity

The end user must determine the productivity level, in terms of parts-per-hr or cubic feet-per-hr, that the system is to generate. If multiple parts are to be processed—depending upon the equipment utilized—the equipment should also be sized and designed to ensure that product flow through the machine does not cause any part mixing.

Material Handling

Define how the parts are to reach the aqueous system. The manner of delivery of components, whether they are in baskets, totes, on blue steel, egg crated, or in large hoppers, may determine equipment configuration, as well as the degree and need for automation. Parts can feed into systems directly in bulk, in baskets, or in line.

Acceptable Cleanliness Standard

Establish and communicate an acceptable cleanliness specification. Various types of aqueous systems are geared for large particulate and oil removal only, while other systems are more capable of achieving high-precision, low-Millipore, or low total molecular weight cleaning criteria. By specifying the cleaning requirement and acceptable cleanliness level, it will help determine the type and configuration of the aqueous system to be utilized.

Once the end user has defined part geometry, productivity, product delivery, and cleanliness specifications, the type of aqueous system to be utilized can be defined.

Mechanical Interaction

The defined parameters are important to determine the type of mechanical interaction that the aqueous system is to develop. Mechanical interaction is the most important part of system design and can determine the success or failure of the system. Various forms of mechanical interaction can be employed simultaneously. The standard types of mechanical interaction are defined as follows:

1. Soak
2. Spray
3. Soak and spray
4. Soak with turbulation
5. Soak with ultrasonics
6. Vertical agitation

7. Vertical agitation with ultrasonics
8. Vertical agitation and rotation
9. Vertical agitation and rotation with ultrasonics

The least capable level of mechanical interaction is soaking alone. The most capable level of mechanical interaction is vertical agitation and rotation with ultrasonics. By determining the type of mechanical interaction to be employed, the end user can understand the degree of cleanliness or consistency of cleaning specifications that the machine will be capable of achieving.

Other factors to be defined by the end user and the system supplier include:

This rotary drum system features a wash, rinse, dry with soak and spray zone.

Chemistry

Mechanical interaction will establish the chemistry to be employed, its pH and concentration level or ratio, and the ability of the chemistry to interact and remove the soils and oils on the parts. Most chemistries are alkaline, and the percentage of chemistry to maintain a uniform process must be controlled. Mechanical interaction will dictate whether the chemistry must be non-foaming, and whether soil splitting or soil emulsification will occur.

Temperature

The temperature is critical to ensure that the chemistry is working at its maximum capability. The heat source should be specified to maintain consistent temperature and compensate for spray or pumping heat loss (*i.e.* electric, steam or gas). Enough heat recovery is necessary to allow cold parts to be introduced while maintaining solution temperature for chemical interaction, and for drying.

Time

Determine the time that the components will be involved with mechanical interaction and chemistry to achieve an acceptable production level, and an acceptable cleanliness specification.

Drying

A drying specification should determine how dry components must be after cleaning, or whether they have to be dried spot-free.

Summary of Cleaning Parameters

Part geometry, productivity, part delivery, and cleanliness specifications are normally defined by the end user. The type of mechanical interaction, the chemistry, its concentration and pH, temperature, time, and drying are normally derived through product testing and interaction between suppliers and end users. It should be understood that satisfying all of these requirements is necessary for the success of an aqueous system. Parts should be tested in large volumes to ensure repeatable results.

Since the most important part of the aqueous cleaning cycle is mechanical interaction, the following are some definitions for the standard types of mechanical interaction available.

Soak

Soaking of parts in chemistry relies solely on the mechanical interaction of chemistry to attack, dissolve, and/or emulsify soils. For soaking to be successful, it is imperative that chemistries be aggressive, and that adequate time be utilized to ensure that the chemistry has the ability to interact effectively with soils. Even in soaking, some form of part movement normally takes place, usually as parts are either introduced to a soak tank or withdrawn. It is likely that this small amount of mechanical interaction or part movement will, in effect, do more work than the soak cycle itself.

Spray

Spray is probably the most widely used form of mechanical interaction in aqueous systems. Spray is used on belt systems, monorail systems, cellular and centralized washers, and with cabinet systems that use low-, medium-, or high-psi delivery of solution.

Spray systems are designed to direct solutions so that the solutions impinge the parts from above, from the sides, and below. The solution is normally directed by spray headers utilizing nozzles to generate overlapping spray patterns. Parts are typically drawn through spray zones by some form of conveyance, such as belts, monorail, rotating turntable, or rotating baskets. The spray mechanical interaction is designed to impinge the part surfaces at high pressure and high volume. Spray impingement loosens and removes soils. It is necessary to understand that high volume is as important as high pressure, because it is the volume of solution that causes dirts and soils that are removed by the spray impingement to float away or be removed from the parts. The combination of pressure and volume, in conjunction with heated chemistry, is effective in removing soils, oils, dirt, chips and other by-products associated with manufacturing.

In most cases, spray can only be delivered from four axes, while most parts have a minimum of six geometric axes. Likewise, spray can be easily deflected or masked. Spray is not well suited for cleaning blind holes or complex geometries. If parts are processed in baskets, parts positioned on the outside of the basket may mask effective cleaning of other components in the middle of the basket, because parts on the surface of the basket will be the ones effectively engaged by spray, while parts in the middle of the basket must rely on solution volume and drippage for effective cleaning. For this reason, parts in baskets in cabinet cellular washers are rarely filled more than 60 percent. This allows parts in the middle of the basket to eventually migrate to the exterior of the basket, if the basket is rotated.

Spray systems can also be used as in-line manufacturing cleaning systems. The same belt used to transport the parts through

A five-tank vertical agitation and rotation system with material handling and closed-loop wastewater treatment system. It utilizes a wash, ultrasonic wash, three counterflow rinses, and rotation of baskets in a recirculation hot air dryer.

the washer can also transport them from one location to another, thereby acting as a material-handling unit.

Spray systems should be designed to ensure that the various spray chambers are shrouded with baffles—both before and after spray zones—to minimize overspray and solution drag-over. A belt can act as a natural pump, and an adequate drain area is necessary on belt systems to minimize carryover of wash solution to rinse zones, or as the belt returns, from rinse to wash zone. In all instances where spray systems are employed, sufficient drain area before and after spray zones is required to allow the parts, belt and baskets to adequately drain, to minimize contamination of subsequent spray zones, or to maintain rinse tank clarity. Drain areas before spray zones (also referred to as vestibules) prevent deflected spray from entering a previous tank drain area.

Soak & Spray

Belt or monorail systems can be equipped with soak zones, which are areas where the part is drawn through a soak stage prior to being sprayed. The soak area will ensure that all areas of the component are exposed to chemistry that can initially loosen and emulsify some soils and oils as parts are transported through the soak zone. This greatly assists the ability of the spray to flush and remove soils. Rotary drum systems also typically employ soak and spray.

Rotary drums are designed to move parts through various operations in a horizontal cylinder, with the interior of the cylinder equipped with a helix. This automatically advances parts forward as the drum rotates, and allows a large quantity of parts to be effectively engaged by the mechanical interaction generated by the machine. This is a combination of soak and spray impingement, as well as high-volume solution delivery. The parts are soaked to loosen soils and contaminants, and simultaneously sprayed clean. Spray headers are positioned so that the spray engages the parts as they are lifted out of the soak solution. After the soak section, the parts continue to be engaged by spray. The spray uses a combination of spray impingement and high volume solution delivery.

The high-pressure spray impingement is generated by directed stainless steel spray nozzles, and is designed to dislodge contaminants from the parts. In short, the combination of soak and spray impingement dislodges soils, then the high-volume delivery flushes away the soils, oils, and other contaminants.

In a rotary drum system, the mass of parts is gently tumbled in the aqueous cleaning and rinsing solutions. This gentle tumbling action provides an effective method of completely exposing all edges and surfaces of components to the action of the soak, impingement spray, high-volume solution delivery, rinsing solutions, and the drying action. The rotation of the drum causes parts to rotate and move. The movement within the drum causes all surfaces and edges to be exposed to the cleaning action. All areas of parts, therefore, are engaged by the cleaning capability of the system. It is the combination of part movement, soak immersion, high-pressure spray, and high-volume solution delivery that is more effective than spray alone in dislodging contaminants and soils from all areas of the parts.

Because of part movement, more uniform cleaning is realized in rotary drum systems than in belt or monorail part transport systems.

Parts come in contact with one another in a rotary drum system. If no part contact is permitted, this would not be the system of choice.

Soak with Turbulation

Turbulation is, in essence, exciting the cleaning bath, causing fluid movement within the bath. This is accomplished by using aerators or impellers to cause the cleaning solution to become a fluidized bed of continuous movement. When parts are introduced to a turbulated bath, the solution moves around areas of the components. This rapid movement of solution has the ability to emulsify oils and dislodge soils.

In turbulated systems, care should be taken to ensure that parts do not mask one another. Turbulation moves tremendous volumes of solution, but lacks any driving force to penetrate a basket or a layer of parts. Turbulation can easily be defected or masked. This masking is sometimes off-set by ensuring that there is part movement in the turbulated bath.

Part exposure to turbulation is accomplished by either rotating or articulating the part. Small components placed in baskets require this rotation movement. The basket itself and the parts in a basket will act as a mask for the turbulation solution. By rotating the basket, parts in the interior may eventually be drawn or positioned at the exterior of the basket, where they may be somewhat engaged by the turbulated solution. Therefore, full baskets (or even baskets three quarters full of parts) cannot be effectively cleaned with turbulation, because of minimal or no part movement. Similar to a rotary drum system, there is some part-to-part contact caused by partially full baskets that are rotating.

Turbulated systems, like spray alone, typically are not as effective as other forms of mechanical interaction for cleaning I.D. or blind hole areas.

Vertical Agitation & Rotation

Vertical agitation develops the highest degree of mechanical interaction between parts and chemistry. The vertical agitation movement produces a natural hydraulic cleaning action, generating cavitation in the tank. This cavitation forces the cleaning solution between parts, and in and out of recesses and cavities. This vertical agitation movement of parts in an aqueous solution generates a flushing action that scrubs clean all parts surfaces, crevasses, holes, and recesses. The agitation movement forces solution between components and in and out of holes.

In many instances, parts are cleaned in baskets. Unlike spray or turbulation systems, however, parts in baskets do not mask themselves, allowing full baskets of components to be effectively cleaned because of the agitation movement. The mechanical action of agitation removes oils and greases, while loosening and removing metallic fines and chips. Complete immersion of baskets in and out of the solution is much more effective than partial immersion.

Adding rotation to the agitation further enhances this capability by allowing all holes, recesses, and cavities to fill and drain effectively with the aqueous chemistries.

With the vertical agitation concept, the amount of agitation can normally be adjusted for each tank in a process. With the advent of programmable controllers, systems can be programmed to agitate and rotate baskets under solution, while occasionally raising the baskets out of solution to drain, then totally immersing the baskets in solution again. Baskets can effectively rotate out of solution for complete draining prior to transfer to subsequent tanks. This drain cycle greatly reduces chemistry drag-over and prolongs rinse tank clarity.

Vertical agitation systems are also very effective for chip removal, as turbulation can also be added. The turbulation in vertical agitation systems also serves a second purpose by keeping chips and fines in suspension in the solution until they can be evacuated by high-volume pumps and filters. Because baskets are normally full, turbulation only marginally improves cleaning capability.

Cellular vertical agitation and rotation system that accepts up to six baskets approximately 12 in. x 18 in. x 6 in., for a total work envelope of 36 in. x 18 in. by 12 in. The system is configured for wash, rinse and dry.

The vertical agitation movement also makes this concept readily adaptable for use with ultrasonics. The agitation can be programmed to move slowly up-and-down while moving through a focused ultrasonic field. This slow up and down movement exposes the entire workload to the full power of the ultrasonic scrubbing action, allowing full cavitation, generated both by ultrasonics and agitation, to effectively engage components. In agitation systems, ultrasonics are side-wall and bottom-tank, bulkhead mounted. This will guarantee that the parts will pass through the high concentration ultrasonic field. Slow rotation through the ultrasonic field also ensures 100-percent exposure, allowing blind holes to be effectively filled with solution and engaged with the ultrasonic energy.

Drying

What differentiates an aqueous system from solvent systems is the need to dry components. Newer dryer designs incorporate the principles of high velocity, and high-volume recirculating hot air convection drying concepts. High-volume air dries more effectively than high pressure or high temperature. Dryers should be designed to allow for maximum air movement at minimal operating temperature. Systems that employ high temperature to flash-dry parts can cause spotting on components, and discoloration of certain alloys.

Good dryer design employs louvers that will direct the air flow against the components and/or baskets. The dryer design should contain an internal duct system that directs the air flow from multiple directions against the parts or baskets. This design will ensure uniform exposure of all surfaces, edges, and recesses of components to the air flow.

As with interaction of chemistry and components, time is a variable in the drying process. End users should be aware that shortening drying time to save space can be detrimental, and can compromise the effectiveness of dryer design.

On belt or monorail type systems, air knives can be used prior to drying to remove puddled water from recesses and cavities. Air knives are important when parts cannot rotate, either prior to or in the drying process.

Air knives on belt or monorail systems can also be used between wash and rinse stages to minimize cross-tank contamination. This will effectively remove chemistry residues from the belt and part hangers, as well as from parts. Newer style air knives can employ either low pressure and volume shop air, or self generated air delivery systems.

The Aqueous Process

Most aqueous processes require, at a minimum, a wash, rinse, and dryer. There may be multiple wash and rinse stages, depending upon the cleanliness level desired.

Typically, wash requires a mild alkaline cleaner that is heated. Care should be taken in the selection of the cleaner to ensure that it is compatible with alloys being cleaned, and that it has the ability to emulsify, or split oils and remove other contaminants.

The purpose of a rinse is to remove residual chemistry remaining on parts. If only one rinse is employed, a flow of clean water into the rinse tank on a continual basis to an overflow dam is necessary to maintain rinse clarity. A system employing two rinses should consume half the water required by a single rinse system. Likewise, three rinses will utilize half the water required by a two-rinse system to maintain final rinse tank clarity. Depending upon cleanliness specification, and whether spot-free drying is necessary, RO or DI waters may be necessary for final rinses.

If RO or DI water is employed, consideration should be given to prevent flash rusting on ferrous components. It may be necessary to add rust inhibitors or wetting agents to rinse tanks to prevent flash rusting while rinsing ferrous components.

Water Quality

If incoming municipal waters contain a high level of chlorine, sulfur, salts or other contaminants, it may be necessary to treat the water prior to use. Water hardness and poor quality of water can affect the ability of the aqueous chemistries to work. Likewise, poor water quality can affect drying and cause water spotting.

System Construction

All aqueous cleaning systems should be constructed with stainless steel for tanks and wetted surfaces. Although mild steel construction was acceptable in the past, the greatest cost factor in manufacturing an aqueous system is labor. Stainless steel, although three times the cost of mild steel, should have a cost impact of less than 20 percent on the overall system. Mild steel construction will always oxidize over time, causing degradation of baths, compromising the ability to clean, and causing rinsewater to contain ferrous oxides. Stainless steel construction overcomes these shortcomings and should give an aqueous system a minimal 20 year life.

Filtration

Filtration will greatly prolong bath life and allow for a more uniform cleaning process. Aqueous chemistries are designed to remove soils. Most chemistries are designed to emulsify or suspend soils in the wash bath. In time, these soils will build up in the wash tanks.

For spray type systems, filtration should be in line between pump and spray headers. Filters should be constructed of stainless steel and sized to be a minimum of 20 percent above pump GPM rate.

For bath type systems, filtration should be designed to exchange the total volume of the bath every three to five minutes. A tank bath of 200 gal should have, as a minimum, a 40 GPM pump and 50 GPM filter system. Filtration is designed to remove suspended fines, particulate, soils, dirt, etc. Good filtration will prevent redeposit of the soils on the parts.

Oil Removal

Most chemistries are designed to split petroleum and tramp oil and cause the oil to float to the tank surface. Many types of oil-removal systems are available, and they vary in price, complexity and efficiency. Disc, belt and decant systems are marginally effective. Coalescing and ultrafiltration are the most effective. Coalescing systems with surface skimmers or spargers are required for soak or agitating systems, to ensure that the top surface of the water is free of oil prior to the removal of parts.

Oil coalescers are normally free-standing units constructed of stainless steel. A coalescer is designed with perforated partitions, making it multiple tanks. The first area is a still tank. The second area is normally filled with polypropylene tubes. The polypropylene tubes are efficient in their ability to collect oil. The tubes attract oil globules as small as 20 microns. When the oil globule builds and reaches a dimensional size of between 100 and 200 microns, it breaks free from the polypropylene tube and floats to the surface of the tank, where it is skimmed. Therefore, the coalescer is effective in removing oil as small as 20 microns. The coalescor collects only oil, but not water and chemistry.

The coalescer then pumps clean water to a sparger pipe positioned to skim the top surface of the tank to an overflow weir. The overflow weir is connected to the coalescer, and the system operates on a closed-loop basis.

Emulsified oils must be handled differently. Membrane or evaporation technologies must be incorporated to deal with the emulsified oils in solutions.

Waste Treatment

Alkaline chemistries and rinsewaters, by themselves, are not normally an environmental issue. Chemistries are designed to remove soils and oil from parts. If the soils are heavy-metal laden, they will have to be treated accordingly. If petroleum-based oils are used, coalescing and other oil extraction systems can readily remove them from baths prior to discharge.

If emulsified oils are present in the bath, they will have to be dealt with as regulated by local environmental authorities. Either evaporation or membrane technologies, such as ultrafiltration, should be employed to remove emulsified oils prior to solution discharge.

Normally, rinsewaters are sufficiently free of heavy metals and emulsified oils, and may be readily dischargeable.

Local sewer authorities may dictate the type of treatment required for alkaline baths, and how these baths are to be disposed. In all instances, cost of disposal is normally far less costly than dealing with, or disposing of, solvents.

Equipment Selection

End users have to define part geometry, productivity, material handling, and cleanliness specification. Once these are known, tests can be conducted to determine which type of system and the mechanical interaction that is best suited to meet end users' needs. Although cost is always a consideration, to determine the proper selection of the type of aqueous cleaning system to be used, capability should be the driving force. It is important that the system achieve cleanliness specifications at the production levels required.

Good interaction must be achieved between the end user and equipment supplier to ensure that any proposed system is equipped with adequate mechanical interaction to achieve the desired level of cleanliness; that there is adequate rinsing to ensure removal of residual chemistries, with a minimal level of acceptable water usage; and that dryer design will achieve the level and quality of dryness desired.

The equipment costs for aqueous systems normally are higher than solvent systems, but the operating costs are less. The purchase costs for aqueous chemistry and chemistry disposal are a small fraction of the purchase and disposal costs of solvent-based chemistries.

Aqueous cleaning systems have come of age. They can more effectively clean to a higher cleanliness level than is achievable with solvent systems. Aqueous systems leave no residue on parts. They are environmentally friendly, end-user friendly, and can consistently achieve desired results.

Aqueous systems are effective and considered environmentally compliant. With new environmental guidelines and restrictions, you can be assured that aqueous systems will become even more dominant in the 21st century. ***P&SF***

About the Author

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