Aqueous Parts Cleaning

Criteria for Selecting the Correct Cleaning System

What should users take into account when planning a new cleaning system and choosing a suitable process? Many different parameters need to be considered. A variety of different aqueous cleaning processes is available and these processes can be adapted to meet individual requirements.

Cleaning workpieces, components and assemblies is a multi-dimensional and complex process. In contrast, the result is easy to describe. The main aim of final cleaning processes is to comply with customers’ cleanliness standards, which relate primarily to the appearance and functionality of the parts. In the interim cleaning process, the focus is on ensuring that the workpiece quality meets the requirements of the subsequent processes and production phases. The surface properties of the substrate (roughness, topography, coating) must not be subjected to any further modifications.

The requirements for surface quality can vary considerably. The spectrum ranges from general specifications for parts which are free of grease and swarf and also clean and dry, through to detailed specifications based on ISO, DIN and VDA standards or customers’ own works standards which include specific values:

- Copper sulphate (Berlin blue) test. Active surface, no barrier layers before heat treatment. Specifications: Uniform deposition of copper and blue colouring.
- Complexometric determination of the zinc content. Residual zinc content on the surface from zinc phosphate, drawing soap before heat treatment. Specifications: Quantity.

Layers of contamination

Contamination or dirt on a metal surface, for example, is always made up of different layers (Figure 1). The first or lowest layer is the deformed boundary layer on the base material (layer thickness > 1 µm), which is caused by the machining process (milling, drilling, pressing etc.). It has the same chemical composition as the base material.

Above this is a reaction layer with a thickness between 1 and 10 nm. It consists primarily of oxides of the base material, but also contains reaction products from the additives in the machining oils (phosphates, sulphides). The reaction layer is covered by a very thin (0.1 to 10 nm) sorption layer, which is made up, for example, of surface-active additives from the emulsions and cooling lubricants or anti-corrosion agents. This is followed by the layer of contamination. This layer varies in thickness and consists of oils, cooling lubricants, greases and swarf.

The layers furthest from the substrate surface have the weakest bond. This means that to strip off the reaction layer, for example, aggressive processes such as blasting or pickling are needed, while the contamination layer can safely be removed using conventional cleaning processes. The reaction and
Sorption layers immediately reform on contact with the air. This means that components normally leave the cleaning process with some residues on their surfaces. From a cost and environmental perspective, it makes no sense to remove every trace of contamination and the remaining residues usually have no impact in practice.

The closed loop in the cleaning process
Four fundamental factors interact in the cleaning process to form a kind of closed loop (Sinner wash circle) that leads to the required results. These factors are mechanical energy (for example, ultrasound, spraying), chemical energy (cleaning agent), temperature and contact time (processing time). The term “closed loop” is the perfect description. If one of these factors is reduced, one of the others must be increased or modified to maintain the same level of cleaning.

Chemical energy produces chemical and physical cleaning effects which can be broken down into four main processes. These are removing and saponifying oils and greases, emulsifying the oils and greases that have been removed, removing and dispersing particles and removing and complexing metals and metal oxides and salts.

Structure of cleaning systems
The fundamental structure of aqueous cleaning systems is relatively simple. They consist of a builder and a surfactant. The builders are primarily inorganic salts, such as alkali hydroxides, silicates, borates and carbonates, which reinforce the effect of the surfactants synergistically (Figure 2). Among other things, they enable pigments and metal soaps to be removed, saponify the greases, help to disperse dirt and contribute to the emulsification process. Organic builders, such as alkanolamine fatty acid adducts, are also increasingly being used.

The generic term “surfactants” (meaning wash-active substances) is used to describe surface-active substances consisting of a polar (hydrophilic, water-loving) and a non-polar (hydrophobic, oil-loving) component. A distinction is made between non-ionic, anionic and cationic surfactants. The accumulation of surfactants at the interface between the water and the oily surface is a decisive factor in the cleaning process. They ensure that the contamination becomes water-soluble or water-miscible. Different surfactants are used depending on the process (spraying, immersion, ultrasound).

Different types of material and contamination
There are two criteria for the choice of a cleaning agent which relate to the component or workpiece that is being cleaned. These are the type of material and the type of contamination to be removed.

The base materials of workpieces consist of a wide variety of metallic and non-metallic substances. The metals have different requirements depending on their coatings (for example, hot-dip galvanised, galvanised and chromated, phosphated or bronzed).

The builder is the decisive substance in the choice of materials. In simple terms, ferrous metals and magnesium can be cleaned with alkaline cleaners. Amphoteric metals, such as zinc and aluminium, and galvanised surfaces are attacked by alkaline cleaning agents (the surface is stripped off, becomes discoloured or loses its gloss finish). For these substrates, neutral or weak alkaline cleaners or products containing silicates or borates that inhibit the alkaline attack are used. Acid cleaning agents are used to pickle steel, to strip layers of aluminium off and to brighten bronze. However, they are also suitable for use with non-metallic materials, such as plastic. The final choice of cleaning agent can best be made following appropriate pilot tests.

The chemical composition of the different types of contamination varies widely. Contamination generally takes the form of layers, coatings, films or particles. It has a range of different origins and, in the case of production-related contamination, comes from a variety of sources and substances. These include lubricants and cooling lubricants, hydraulic oils, greases, anti-corrosion agents, corrosion, particles, swarf and residues of cleaning products. Cleaners containing alkalis, silicates and surfactants are ideal for removing oily contamination. The combination of phosphates, silicates and surfactants is more widely used to remove particles. Tests can help users to
make the best choice for their application.

Cleaning machines: The decisive factor
An important aspect of the cleaning process is the design of the cleaning machine. Mechanical methods, including moving the parts that are being cleaned, pumping the cleaning solution around them and spraying, high pressure, pressure flooding, brushing, ultrasound and electrolytic processes, can remove the laminar boundary layer on the surface of the workpiece, significantly reduce the diffusion time and, therefore, accelerate the cleaning process considerably.

These processes are used to rinse the workpieces. This involves removing the contamination that has been dislodged and washing the parts with new, unused cleaning solution. An important consideration when choosing the cleaning agent is whether or not the process can accommodate the formation of foam. In the case of spray cleaning and also pumping processes, foam can cause problems which, in the worst case, may lead to the pump being permanently damaged.

When ultrasound and high-pressure blasting methods are used, the cleaner must remain stable. With ultrasound systems, the surfactant system in particular must support and not inhibit the spread of the sound waves. In the case of interim cleaning, the subsequent process is a decisive factor. It is important to understand which of the substances in the cleaning agent could affect the next production phase, because interim cleaning is often not followed by rinsing and, in some cases, the parts are still covered with a temporary coating of anti-corrosion agent. When choosing a cleaning machine, it is also important to carry out pilot tests to identify whether the process and the chemicals are suitable.

Cost-related factors: Bath maintenance and service life
Another aspect which influences the choice of cleaning agent is the bath maintenance programme. In order to ensure that the cleaning bath has a long service life, it is important to use a demulsifying cleaning formulation, which means that the contamination can easily be removed. The cleaning agent must also be easy to analyse, so that its concentration can be kept stable and the cleanliness of the parts guaranteed. Two-component systems (consisting of a builder and a surfactant) are ideal when it comes to topping up the cleaning bath, because the different levels of consumption of the two components can be accommodated during the cleaning and recycling process. Experience shows that the most effective bath maintenance method is to avoid all types of dirt on the parts that are being cleaned.

An overview of the most common forms of contamination, how to avoid them and remove them from the bath and the possible analysis methods is given in the table.

<table>
<thead>
<tr>
<th>Type</th>
<th>Avoidance</th>
<th>Removal</th>
<th>Analysis method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particles</td>
<td>Rinsing with cooling lubricants in the cutting machine and/or blowing off</td>
<td>Filters, cartridge filters, scrapers, magnetic separators, sedimentation tanks, membrane filtration, adsorption filtration</td>
<td>Filtering the bath solution and counting or weighing particles. Measuring in accordance with VDA Volume 19.</td>
</tr>
<tr>
<td>Oily and greasy contamination</td>
<td>Draining, blowing off, centrifuging</td>
<td>Skimmers, oil extractors, separators, centrifuges, membrane filtration, electroflotation, adsorption filtration.</td>
<td>Babcock test. Analysis in accordance with DIN 38409-H18</td>
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<tr>
<td>External ions</td>
<td>Deionised water</td>
<td>Ion exchangers, reverse osmosis (RO) depending on the ions</td>
<td>Photometry, atomic absorption spectrometry (AAS), inductively coupled plasma (ICP) spectroscopy</td>
</tr>
<tr>
<td>Special substances from the machining oils</td>
<td>Change the machining oil</td>
<td>Possible, but only if the contents are known</td>
<td>Possible, but only if the contents are known</td>
</tr>
</tbody>
</table>

This table gives an overview of how different forms of contamination can best be avoided.