PARTS CLEANING IN HEAT TREATMENT

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1) Introduction

About twelve years ago AICHELIN recognized the necessity and importance of an environmental friendly washing alternative and began development of a washing machine, which was based on the use of slightly alkaline washing agents. In the last eight years a significant increase of governmental restrictions concerning the use of halogenated hydrocarbons caused a replacement of old machines with water-based cleaning systems in many heat treatment shops.

Nowadays we can conclude that the water-based washing is well accepted in the field of heat treatment; nevertheless, there are special applications where fully capsulated cleaning machines working with chlorinated hydrocarbons are still offered. Also aliphatic HC cleaners, known as cold washing agents, become of interest, but - due to their flammability - there is a safety risk for the hardening shop.

Usually the washing is not recognized as a separate operation; the result is that - in comparison with other operations - it is considered to be not important.

Very seldom we find the necessary surface cleanness of parts or the most appropriate washing process and agent for the soiling to be defined for the subsequent process.

The most important parameters of the cleaning process are shown in Fig. 1.

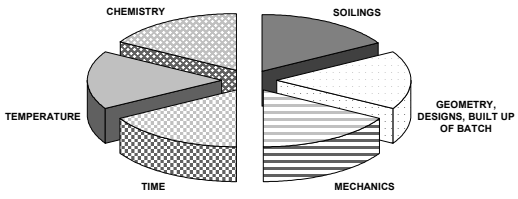

Fig. 1: Parameters of the cleaning process

2) Soilings

In practical application the washing problem is determined by prior operations or processes, as well as the subsequent demands of the heat treating and/or by the demands of final cleaning. Before heat treatment the parts have to be cleaned from sliding oils or fats, cooling lubricants (CL), emulsions, grinding or lapping pastes, slivers and chips or corrosion inhibitors, whereas the soilings from the heat treatment are mainly hardening oils or hardening salts and furthermore dirt, pigmental residues or soot. Further applications are the cleaning of assembling parts or the final cleaning for sale.

The most important representatives of cutting and machining residues are the cooling lubricants. These agents are of decisive importance for cutting or machining operations. Besides the primary demands, such as lubrication and cooling of the parts, they must offer sufficient environmental and working place safety, have to be easy to wash and rinse off, and should not form any diffusion inhibiting layer during the heat treating and have to be stable against micro-organism. To fulfill all the demands, the cooling lubricants usually show a very complex composition. An addition of graphite, sulphur or sulphured compounds, chlorine compounds, organic silicon compounds, phosphates or borates could cause difficulties in connection with subsequent heat treatment. So several well-known cooling lubricant manufacturers intend to mark their products with references regarding their suitability for diffusion processes.

However, the following heat treatment operation significantly determines the neccessary washing quality. PVD processes show the highest demand, followed by nitrocarburizing processes, brazing, nitriding, carbonitriding, plasma processes and vacuum heat treatment. For the washing quality after the heat treatment the highest demands are set on a final cleaning for sale (optical impression) followed by lacquering or painting, cleaning for assembling, tempering and annealing processes. Further demands are the removal of pigments, soot, slivers and chips. In general, a long storage time of soiled parts enhances the desired effort for cleaning.

It has to be mentioned that a water-base cleaning system should be mainly used for degreasing. If the degreasing is successful, contaminations such as pigments, swarfs, slivers, etc. could be removed depending on the geometry of the parts and the arrangement of the batch. The removal of chips can be done just due to mechanics of the machine and therefore the position of the chips, the built up of the batch and other parameters are responsible for the quality of the result.

3) Temperature and time

The influence of temperature and time on the degreasing result is shown in Fig. 2.

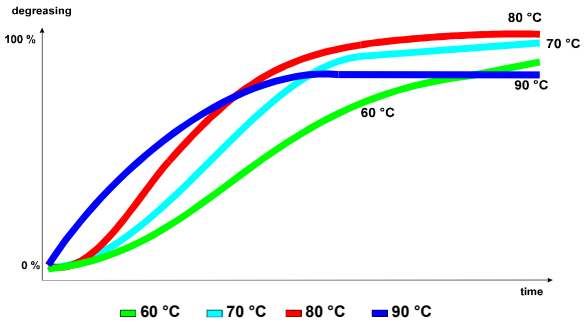

Fig. 2: Influence of temperature and duration on the degreasing (scheme)

Since the cleaning agents usually show a cloud point of 55 to 60 °C the minimum temperature for the washing is 60 °C. As it can be seen in Fig. 2, the enhancement of temperature both increases the degreasing capability and shortens the operation time. A further increase of washing temperature up to 90 °C leads to a reduction of the maximum degreasing capability due to the demulgating behaviour of the tensides, leading to separation from the water-based cleaning bath. Therefore, the detergents separate upon the surface of the washing agent and the washing capability of the agent is reduced.

4) Mechanics

The design of a horizontal single chamber Flexiclean® washing machine is shown in Fig. 3. The concept is based on the requirement of replacing degreasing with chlorinated HC by water-based washing technology. The machine is equipped with two or more media tanks for storage and heating of washing and rinsing fluid. A washing chamber, usually positioned above the media tanks, is equipped with a gas injection, filling and vacuum drying components. Furthermore, the media tanks are equipped with an external oil separator which enables a permanent or non-permanent bath maintenance.

Fig. 3: Flexiclean® type EKFE-3

The Flexiclean® with horizontal washing chamber can be easily incorporated into a production line. For parts cleaning before and after hardening in a pusher-type furnace, Flexiclean® is also available in a pushing-through modification. Fig. 4 shows such a machine for washing after heat treatment in line with a pusher-type carburizing furnace for gears with a capacity of 750 kg/h. Furthermore vertical washing chambers are designed to cover the demands of pit-type nitriding or carburizing furnaces.

Fig. 4: Pusher-type Flexiclean® in the production line

After loading the washing chamber is filled with the washing fluid from the tank below. By injecting air into the washing chamber below the batch, small gas bubbles cause flotation, leading to enhanced bath motion, removal and transportation of the soilings. For the patented Vacupearl system a

sufficient vacuum is generated, leading to a low pressure boiling with steam bubbles on the work-piece. This operation improves the removal of pigments and also allows the cleaning of blind holes, nuts or gaps. Steam bubbles are also generated in bulk material, leading to an enhanced agitation and better cleaning. Afterwards the washing fluid is drained back into the media tank and the whole process should be repeated with one or two rinsing fluids by shortening the agitation time. When the last rinsing is finished, the drying process is started by evacuating the washing chamber. Since the residual heat of the charge is utilized, no additional energy consumption is required for vacuum drying. This process is preferably used for solid walled parts, containing no or just small blind holes, or for bulky material which can be charged in a washing drum. Thin-walled parts or parts with big blind holes or buckets need a convective drying with an additional heating, which is also available on request.

5) Chemistry

Very high demands are set on industrial water-based cleaning agents. Two groups of cleaning agents are mainly used:

a) alkaline cleaners, which are based on hydroxides or inorganic salts like phosphates or borates.

b) organic neutral cleaners, which are based on non-ionic or anionic tensides, also including sequestering agents and additives like corrosion inhibitors or biocides.

LUBRICATIONS AND SOILINGS	REAGENT BASE FOR REMOVEMENT	
	TENSIDES	BUILDER/ SEQUESTERING AGENTS
1. SAPONIFIABLE ANIMAL AND VEGETABLE FATS	●	●
2. NON-SAPONIFIABLE MINERAL OILS AND FATS	●	
3. EMULSIFYING AGENTS AND LUBRICATION COMPONENTS; COOLING LUBRICANTS	●	
4. ANORGANIC DRAWING AUXILIARIES AND METAL SOAPS		●
5. RUST PREVENTING AGENT	●	●
6. PIGMENTS, METAL ABRASION, GRAPHITE, MoS_2		●
7. REACTION PRODUCTS OF LUBRICATION AND SOILING POLYMERIZATES	●	●
8. SLIVERS, CHIPS	-	-
9. WHEEL SWARF/ABRASIVE RESIDUES		●
10. OXIDE / CORROSION PRODUCTS	-	-

Fig. 5: Overview of the soilings

The preferred application of both product lines is shown in Fig. 5. For degreasing of moderate soiled parts before heat treatment organic cleaners (tensides) are preferably used. Alkaline cleaners (builders) should be mainly used for high cleaning requirements. Residues of some inorganic components can cause passivating layers for the following thermochemical treatment. However, it could be found that a combination of builders and tensides enhances the washing quality, leading to best results for universal use.

Due to the high demands on the washing agent, the importance of rinsing and the demands on the rinsing fluid are often underrated. The rinsing enables the removal of residues of the washing fluid, the removal of tenside/oil agglomerates which are still on the surface of the parts, furthermore the removal of dirt or pigmental residues is continued. In addition to that, the last rinsing fluid is responsable for a temporarily corrosion inhibition and a stain free drying. All components which remain on the parts should be invisible, showing complete evaporation at low temperatures without generating any visible smoke.

To fulfill the requirements on the rinsing fluid, a fully demineralized water should be used - at least for the last rinsing. The corrosion inhibitor should be maintained at a very low concentration and the drag-over of the washing agent should be minimized. Furthermore, a sufficient bath maintenance of the washing and the rinsing agent has to be assured.

6) Bath maintenance of water-based washing solutions

For achieving a constant washing quality and a long life time of the bath a faithful bath maintenance is necessary.

a) Oil removal

A sufficient oil removal is depending on the demulsifying ability of the cleaning agent. Corresponding to the input of oil, the separation has to be done continuously or in an intermittent process. For most applications a separation by gravity or coalescence is sufficient for a reduction of the residual oil content of the washing fluid to avoid a regreasing of the parts. Furthermore, the oil separator is easy to handle, not expensive and shows only a moderate depletion of tensides.

For enhanced separation quality a centrifugal separator can be used. Besides significantly increased investment costs, the risk of micro emulgation and increased depletion of tensides should be mentioned.

Micro- or ultra filtration leads to perfect oil separation with a residual oil content of less than 10 ppm. If the ultra filtration is used for a permanent bath recycling, expanded examinations and optimization of the diaphragm and the tenside

composition have to be done to avoid a high depletion of tensides. However, a permanent regeneration with tenside-rich cleaners is necessary. Furthermore the investment costs of the ultra

filtration are rather high, therefore it usually cannot be used for economical bath recycling.

b) Removal of pigmental soilings and soot

Pigmental soilings, soot, and other small particles which are floating in the washing fluid can be removed by a mechanical filter system with a porosity of 50 - 100 micron. For high demands, an external centrifugal separator can be achieved.

c) Removal of slivers and chips

The mechanical filter system is also sufficient for the removal of slivers and chips. In addition, a magnetic separator can be attached in the washing chamber.

However, it has to be mentioned that the bath maintenance starts before washing. A reduction of different types of cooling lubricants and the optimization of the cooling lubricants in correlation to the washing agent is the first step in solving the washing problems. A reduction of cooling lubricants or oil remaining on the parts will both reduce the costs for machining and washing. Suitable measures are a sufficient trickle down of the oil before the washing, a centrifugal separation and recycling of oil or cooling lubricants or a rinsing with clear water prior to the washing. Also the removal of slivers or chips by magnetic separation or blowing off before loading of the parts significantly reduces the costs of bath maintenance of the washing machine.

d) Supervision of the bath quality

The following measurements can be easily done in the hardening shop:

- determination of the bath concentration by titration
- determination of the pH-value
- measurement of the electrical conductivity (correlation to the salt content)
- measurement of the hydrocarbon content

These measurements indicate the condition of washing and rinsing fluids. Nevertheless, the correlation between the alkaline titration and the washing quality looses it's accuracy with increased life time of the washing fluid.

7) Disposal of washing fluids

If the required cleaning quality cannot be obtained anymore, even though a proper bath maintenance was done, the bath content has to be exchanged and the washing fluid has to be disposed. An ultra-filtration can be used to reduce the oil content of the washing fluid below 10 ppm. Afterwards the permeate can be dumped into the sewer system. The generating concentrate has to be disposed.

To save process water, an ultra-filtration can be used for regeneration of the rinsing fluid, too. Afterwards a regeneration concentrate and/or a washing agent is added and the rinsing fluid can be made the washing fluid. Therefore the costs for disposal and water consumption will be reduced significantly.

8) Optimizations

In accordance with the soilings and the customer's demand on the washing quality the washing process should be individually analized and adapted. Therefore, an application laboratory had been installed at Aichelin Mödling some years ago. This laboratory is equipped with an industrial Flexiclean® washing machine, which isw used for customer's application, development and optimization of the washing technology in accordance with the customer's requirements. Furthermore, a small model unit allows developmental test runs with new washing agents, basic investigations and optimization of washing through a built-in ultrasonic device.