CLEANLINESS OF VALVE COMPONENTS – RESEARCH OF BASIC WASHING PARAMETERS THROUGH MEASURING DYNAMIC SURFACE TENSION OF LIQUIDS

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The simplest way to control the quality of solution baths in water-based industrial washing is to track the concentration of detergent advised by detergent suppliers. Usually this is made indirectly by titration of total alkalinity of bath. These suggested limits of detergent concentration are usually relatively wide. Additionally, this method can sometimes give an incomplete picture of bath possibility to remove impurities. More detailed information about effectiveness of cleaning solutions could be given by measuring dynamic surface tension. In this paper, some basic measurements of dynamic surface tension done in real process are presented and discussed. Based on the results future developments of washing control and optimization of process parameters are foreseen.

Keywords:
hydraulic components,
cleanliness,
washing,
dynamic surface tension,
detergent

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1 Intruduction

Cleanliness of valve components is usually specified only in terms of technical cleanliness specification. In most cases it consists of total mass of impurities extracted from the part surface and the maximum size of the biggest particle found during analysis.

To provide a technical cleanliness value of a component a special method was developed. These analyses are relatively long so we cannot perform these tests on each component during mass production, but we rather rely on statistical process control. Furthermore, these analyses are usually done at final washing steps but not necessarily reflecting bad washing. The analyses are representing the whole manufacturing process of component, and not only washing itself. Often the root causes for impurities found on cleanliness test lie outside of the washing process steps.

To find root causes outside of washing steps, the best practice is that we run the washing process at best possible level or at least it must be as constant and controlled as possible.

Many parameters influence on washing efficiency. One of them is definitely the cleaning agent used in the process.

A cleaning agent for industrial, aqueous cleaning processes consists of builder and surfactant components. The cleaning process causes both components' concentrations to be used up differently due to different absorption of contamination particles and the carry-over effect. Dosing according to the consumption is necessary for ensuring high process reliability.

One possibility for controlling the cleaning agent concentration is titration of total alkalinity. But this method does not give you any insight of washing media contamination or/and its effectivity.

Additional or alternative method for washing media control is measuring surface tension with the bubble pressure method. This method is the most effective way of inspecting washing active surfactants. [1]

2 Surfactants

2.1 Dynamic surface tension

The following image shows the correlation between surfactant concentration and surface tension. Application-specific dosages of surfactant components are made possible by determining the limit and target values related to an individual cleaning process. [1]

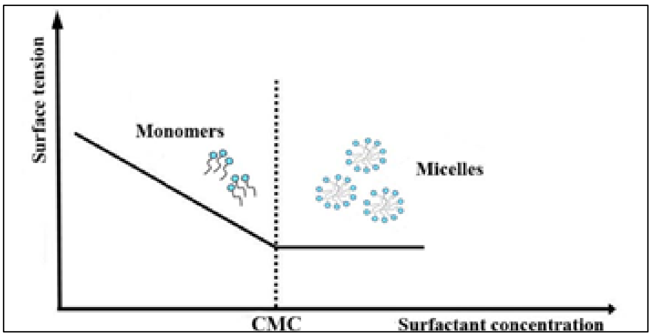

Figure 1: Correlation between surfactant concentration and surface tension.
Source: Pacwa-Plociniczak et al., 2011, CC-BY

2.2 Critical Micelle Concentration (CMC)

Critical Micelle Concentration (CMC) values are important indicators when considering which surfactant will provide optimal performance benefits for your formulation.

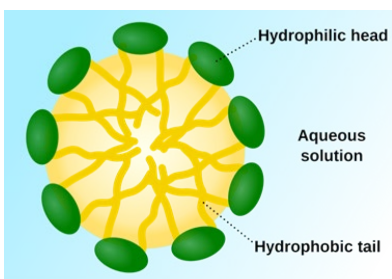

Figure 2: Agglomerates of surfactant molecules inside the liquid.
Source: SuperManu, Wikipedia.org, CC-BY-SA, 2007

When a certain amount of surfactant is added to water, the molecules will begin to form micelles. These consist of agglomerates of surfactant molecules inside the liquid and facilitate washing by storing hydrophilic substances (fats, oils, etc.) within the agglomerates.

The CMC value indicates the amount of surfactant required to reach maximum surface tension reduction. Expressed in wt/%, the lower the CMC, the less surfactant required to effectively emulsify, solubilize, and disperse soils at the surface. In sum, CMC measures the efficiency of surfactants. [2]

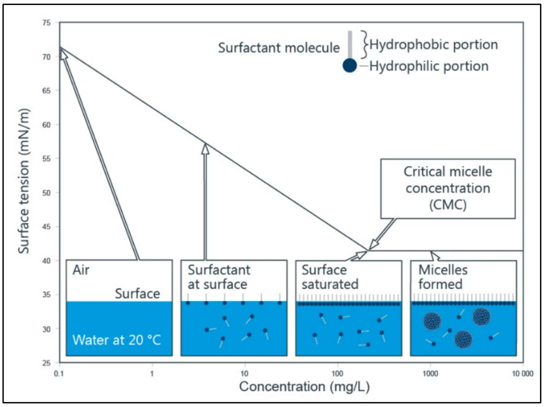

Figure 3: Surface tension of a surfactant solution with increasing concentration, formation of micelles.

Source: own.

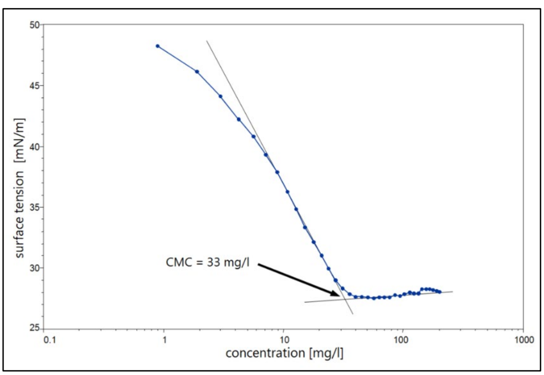

Figure 4: Determination of the CMC with a tensiometer.

Source: own.

3 CMC Study in real process

To define the state of our current process, we first investigated CMC value of our detergent. We made series of test in laboratory and in real process with an industrial washing machine. We found some significant difference between laboratory environment and real process. In laboratory the CMC value was achieved at around 1.5 % to 1.7 % of detergent concentration.

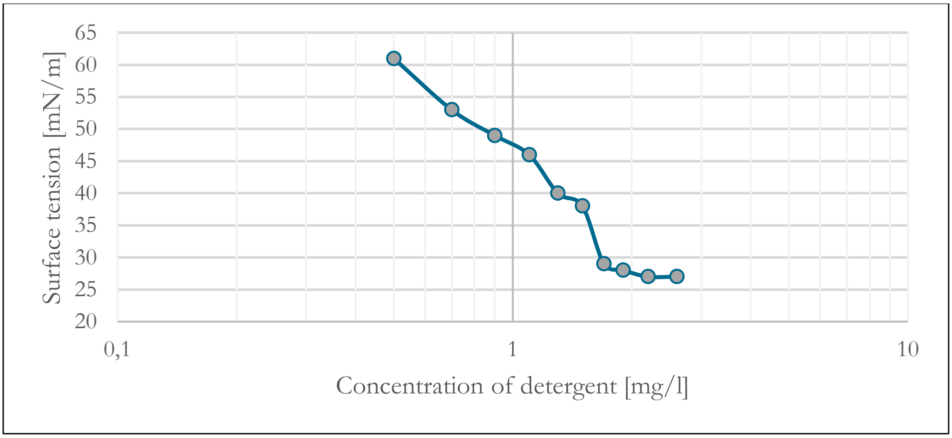

Figure 5: CMC in laboratory condition

Source: own.

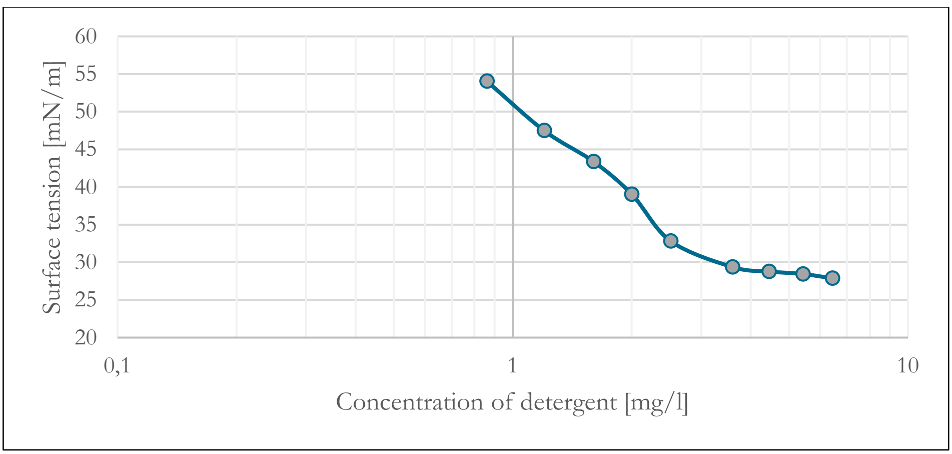

Figure 6: CMC at washing machine

Source: own.

In real process, the CMC value was higher – around 2.5 % to 3.0 % of detergent concentration. This means that we needed to have at least 3.0 % of detergent in our washing baths to reach the most effective cleaning. Adding more detergent was not improving the process. By adding more detergent, we only got an undesirable effect of excessive foaming.

4 Dynamic surface tension in real process

Since such a big difference between laboratory conditions and conditions in real process was observed, we decided to make further analysis on solutions taken directly from our process. Additionally, we know that surfactants activity is very much dependent on temperature. So, each sample taken from the process was measured instantly. Then we took measurements of the same sample during cool down phase to get an insight on this temperature dependency.

From figure 7, we can get similar conclusion about CMC value as in CMC study in previous chapter. We can see that adding more than around 3 % concentration of detergent does not improve the process anymore. The lowest surface tension reached is slightly below 30 mN/m.

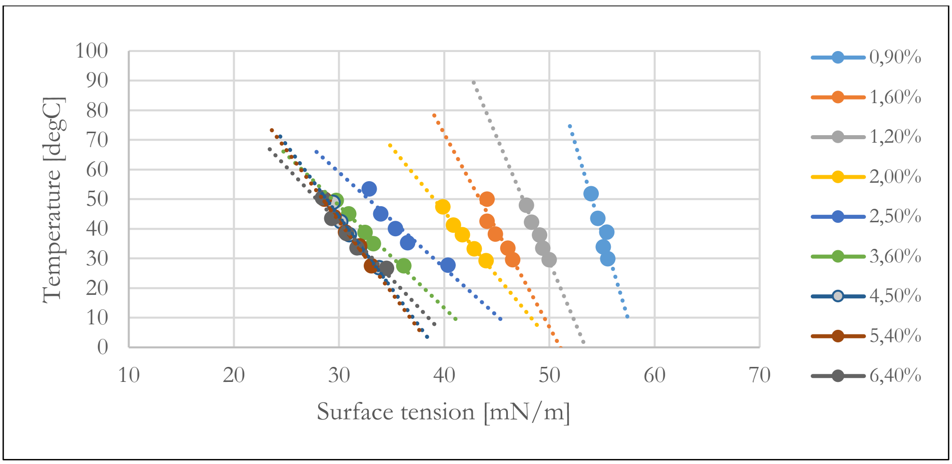

Figure 7: Surface tension in washing tank
Source: own.

In addition to the previous chapter, we can see another phenomenon in figure 7. The temperature dependency is significantly bigger at higher concentration. But it reaches its limits at CMC values when temperature dependency also loses its linear progression.

4.1 'Ageing' of washing media

In aqueous media industrial washing process, we reach a point when washing media is so contaminated that we need to empty the washing tanks and setup a new solution with fresh water and detergent.

Figure 8 presents washing media surface tension in first two weeks after new setup is presented by days. Concentration measured by titration was relatively constant – from 2.4 % to 2.5 %. On the other hand, we can see some significant difference in surface tension.

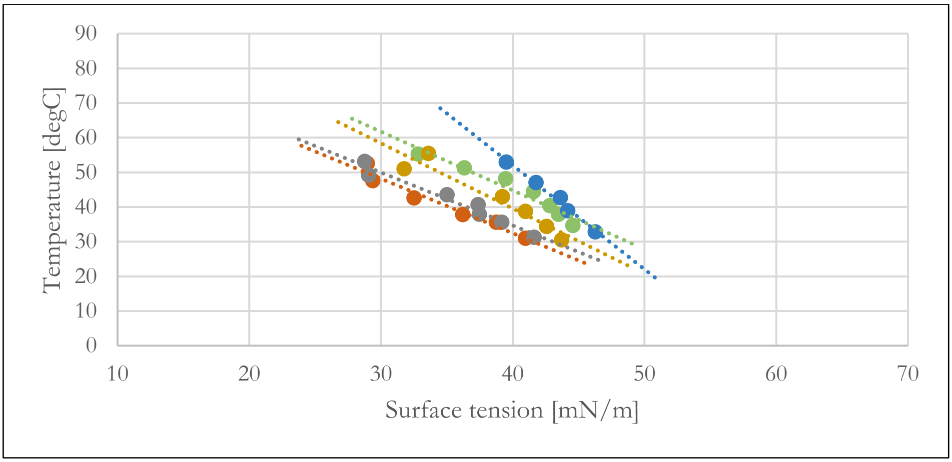

Figure 8: Relatively fresh washing media (1st and 2nd week after new setup)
Source: own.

After 2 to3 weeks the dynamics in our washing media changes. At the same concentration limits we get less temperature dependency but also some significantly higher values of surface tension at operating temperatures (approx. 60 °C).

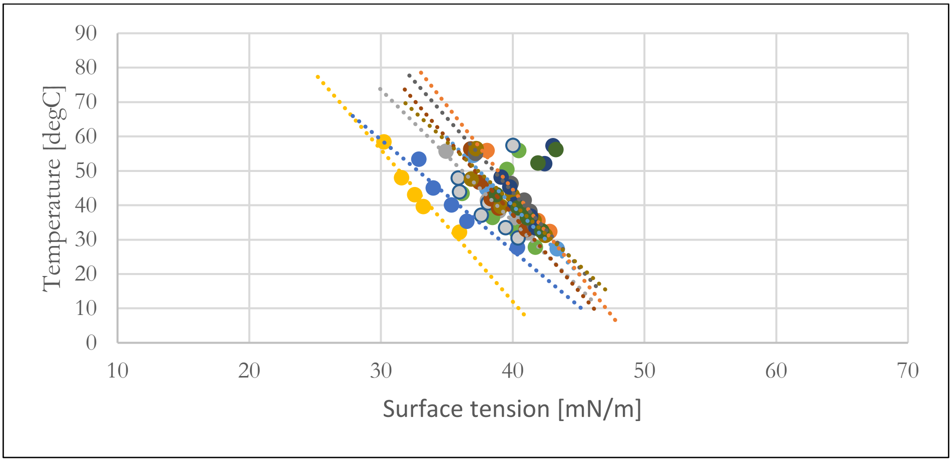

Figure 9: Washing media after weeks of operating (3rd-5th week after fresh setup)
Source: own.

4.2. Oil separator

One of the biggest contaminants in industrial washing media is oil. During washing of parts different kind of oils are removed from its surface. The oil contaminants are emulsified into washing media. For further effective washing these oils needs to be removed from washing media as much and as fast as possible. To do this an oil separator is usually added to the washing machine.

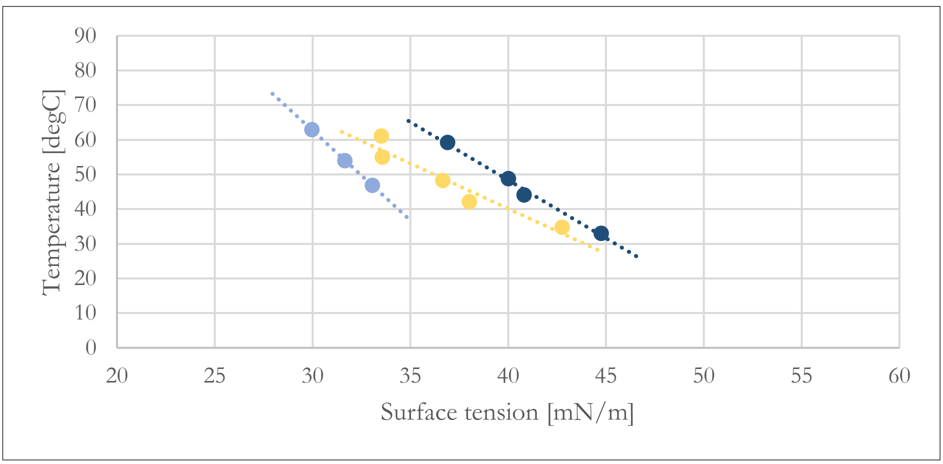

Figure 10: Role of oil separator in surface tension of washing media
Source: own.

In previous chapter we saw that our media is losing its effectivity through weeks of operating. One of possible cause for this is how effectively the oil removal process is set.

The samples shown on figure 10 were taken at some special periods in our process.

The yellow line represents a normal working without taking any focus on oil separator. The blue lines are representing two extremes found in our process. The light blue values were taken after careful continuous oil removal. When the oil separator was not doing well due to some excessive flows, we got values represented with dark blue colour.

5 Conclusions

In comparison to technical cleanliness test or titration of total alkalinity, measuring of dynamic surface tension of washing liquids gave us a faster and more precise data about quality of our washing process.

We managed to adjust parameters such as dosing of detergent, temperature of washing liquid etc. much faster than we would only by using previous methods. We got an insight into 'ageing' of washing liquids and when to setup a new, fresh liquid without relying only on daily period set by experience. Intake of oil and other oily contaminants are changing a lot and if we rely only on daily set period, we can sometimes make a fresh setup too soon or too late.

With these basic measurements we also found out that our oil separator was not working effectively. When the washing liquids were fresh, we did not detect bigger deviations but in few weeks, we found some significant deviations at operating temperatures. By detailed checking of possible root causes and measuring of dynamic surface tension we found out that oil separator was one of the main contributors to less efficient performance (deviations at operating temperatures mentioned in chapter 4.1.).

Together with two other control devices which are tracking only oily, greasy, etc. contaminants in washing liquid and on parts surface, a detailed analysis were made on one specific detergent with working on one specific washing machine. We compared data with other detergents and washing machines in production where we got some significant differences. By this we could set some approximate limits for each device. Based on this research a standard on a group level was issued. It includes suggestions for regular control of washing process to achieve the desired technical cleanliness level.

All this detailed data gathered on one washing detergent and on one type of washing machine will be used in future when testing other detergents and washing machines. Validation of both will be much shorter and less risky than validation only by using methods of technical cleanliness test and titration of total alkalinity.

References

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[2] https://www.jrhessco.com/critical-micelle-concentration-measuring-surfactant-efficiency/; last visited on 1.6.2023