BALANCING OF THE WET BLASTING PROCESS IN ORDER TO REDUCE THE TIME OF THE CLEANING CYCLE

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Industrial washing and cleaning of the components is an integral part of the business with the refurbished parts. The cleaning quality of the refurbished parts must be at the high level. One such technique for cleaning the components is the method of wet blasting using the chemicals at a certain temperature. Such process can be balanced by changes in the concentration of the chemical, the abrasive used and the temperature, resulting in time reduction of the cleaning cycle. It is especially important if the process is also a bottleneck.

KEYWORDS

wet blasting, washing, aluminium, alloy, corrosion, process, bottleneck, detergent, abrasive

1 INTRODUCTION

In the world of remanufacturing, the process of components cleaning is often the key. Depending how well we clean the component, we can identify its defects and prevent future complications during the applications of various lubricants or surface treatments [Cacko 2014, Flegner 2019 & 2020].

There are many ways to clean the components. It usually all depends on the type of the material we need to clean, the degree of its contamination that we want to remove, the allowable degree of component's damage as well as the speed of the component cleaning [Murcinkova 2013, Panda 2014 & 2022, Matiskova 2021].

In case we have the space and the time, then the key parameter in the cleaning process is the price of the process itself. But what if we do not have time due to the fact that in the complex system of refurbishment the cleaning process is a bottleneck? Then it is necessary to calculate not only the price, but also the time and the old well-known proverb "Time is money", can be applied literally. Imagine a cleaning process in which we do not have many options for cleaning methods due to required quality and price while at the same time we deal with the bottleneck.

In cases like that we have to balance the process so we can utilize its potential to the maximum while using the lowest price. In practice this means many measurements and analyzes to accurately determine the amount or the concentration of the chemicals, the number of tools or the amount of energy needed, the timing of the cleaning process to be as short as possible while achieving the maximum required effect and so on [Rimar 2016].

From the complex point of view this issue would be very lengthy, so let's try to focus on the specific process of the wet blasting of the brake calipers for the purpose of their refurbishment. This process deals with aluminum and cast iron calipers.

2 CONVENTIONAL METHOD OF ALUMINUM RECYCLING

At the first glance the actual process of wet basting seems very simple, but upon closer examination we will find out that it is not quite so. Since we will deal with a specific process, we can get specific output information.

Figure 1. Washing result, dirty and clean component

Equipment for the wet blasting process:

The device, where the brake calipers are cleaned by the wet blasting process is basically a large washing machine, where the dirty calipers are loaded in by operation and clean, non-greasy pieces without any damage are required to exit [Harnicarova 2019]. In order for the washing machine to be able to clean the calipers, it needs the water at a certain temperature, an abrasive material adapted to the essence and the properties of the cleaned material and chemicals, to which we will focus the most in this article. The washing machine itself ensures the agitation of the components during the supply of water, chemicals and abrasives and removal of the impurities [Krenicky 2022,].

Figure 2. Wash machine for wet blasting

Water and its temperature:

Water and its temperature represent a great influence as a support unit and the main carrier of the impurities, the chemicals and the abrasives. The purity of the water is not as important as its temperature, since the contamination is not caused by solid particles, but other chemicals. However, its temperature plays an important role as an enhancer of the effects of the chemicals and at the same time helps to dissolve greasy impurities from the surface of the components.

Abrasives:

Abrasive is an important part of washing, which plays an important role in the rapid removal of gross impurities [Monkova 2013]. However, we must choose the abrasive wisely, in order to be able to modify its material composition and the particle size according to the component that is being cleaned and so prevent the component damage during the washing process. We will briefly mention that for a specific application there will be an abrasive CrNi with the granule size from 0.150 mm to 0.425 mm used for aluminum and brown corundum with the granule size from 0.425 mm to 1.180 mm for cast iron.

Chemistry:

Ultimately, chemical is an equivalent medium in the wet blasting process, but unlike the mentioned media, it can vary the most [Gombar 2014]. Besides changing the type of the chemical, we can also change its concentration. Also, different properties of different chemicals bring the possibilities of their use at different temperatures and reactions with different materials, such as PH of the chemical depending on the material of the cleaned component [Pandova 2020]. After we specify the chemical of suitable composition and aggressiveness to the cleaned material, we can start adjusting its concentration so that it is suitable for the quality cleaning, while also affecting the length of the wash cycle, which is very important especially if it is a bottleneck process [Sukhodub 2018 & 2019].

The concentration of the chemical can be easily checked after each washing cycle with a device called refractometer, which is neither expensive nor maintenance difficult. It is easy to use and can provide immediate measurement results.

Figure 3. Refractometer SMC - 1000

3 DIVERSITY OF CHEMICALS AND THE CLEANING PROCESS WITH RESPECT TO THE MATERIAL BEING CLEANED

As mentioned before, the subject to cleaning are the iron cast and aluminum components both of which have been exposed to intensive contamination during their lifetime. As regards aluminum components, they are covered by a thick layer of oxidized aluminum and various greases [Straka 2018a,b].

In this case it is suitable to use an alkaline chemical which reacts with aluminum and gently dissolves the oxidized layer. The warm water together with the chemical on the basis of a detergent will cope quite well with the deposited layers of grease mixed with solid impurities [Mrkvica 2012]. Where the chemical itself is not enough, the abrasive will help. It constantly removes the part of impurities loosened by the chemical and that way enables new layers of the material to be always accessible to the chemical for further reaction. Because of its lower hardness in comparison to cast iron, the size of the abrasive granulate for aluminum is much smaller and since we want to keep the surface of the component undamaged, other granulate material is also suitable.

However, the cast iron is already more problematic because of the corrosion, which covers with the thick layer almost the entire component surface, including its folds, where the layer is most likely the most coarse [Nahornyi 2022]. Although it is possible to use a harder abrasive with a larger granulate, due to the nature of the material, it is more like a necessity [Pollak 2020a].

The case is more complicated as far as the used chemicals are concerned, because there are higher demands placed on them. The chemical must not only be able to clean, but after the cleaning and degreasing it must also sufficiently passivate the component so while in storage areas the corrosion process on the surface of the component does not occur again.

4 PARTICULAR APPLICATION WITH MACHINING

In the process of component refurbishment, it is very difficult to determine the correct concentration of the active chemical. The main factor preventing accurate determination, is the fact that each component is contaminated differently by the very amount of the contaminant as well as its composition. Let's assume we have a specified chemical with good cleaning and passivation properties. Now it is appropriate to determine its correct proportion, to avoid unnecessary waste of an expensive chemical while keeping the time of the washing cycle as short as possible.

The concentration measurement is monitored by a refractometer where the Brix value determines the concentration of the chemical in the solution. The volume of the washing machine tank is 200 liters. The sample to be measured must be of 20 °C temperature and must clear solid parts filtration. We start the cleaning process at 3% concentration, temperature 50 °C and time 60 minutes. With sufficient cleaning, we will then subsequently reduce the time and the concentration by 0.5%, while the priority for the process is the cleaning time since it is a bottleneck of the process.

For more accurate measurements during already such a demanding process of relevant data collecting, we will keep the concentration of the chemical at the required level for 10 working cycles before the concentration will be subsequently adjusted. This is due to the fact that the components do not come contaminated evenly and even the composition of the contaminant is not identical.

Table 1. Conversion of the chemical concentration to Brix values measured by refractometer

Concentration [%]	Result [%, Brix]
1	0.3
1.5	0.4
2	0.5
2.5	0.6
3	0.8

The first ten washing cycles showed that the length of the wash as well as the concentration of the chemicals are sufficient for high quality cleaning of the components from dirt and the rust. The standard concentration in the real process is 3.5% at a temperature of 50 °C and cleaning time of 60 minutes.

Table 2. Measurements record of when the chemical concentration reached its effective minimum

Concentration [%]	Concentration result [OK / NOK]
3	OK
2.5	OK
2	OK
1.5	NOK
1	NOK

As it can be seen from the records, it was possible to reduce the concentration of the cleaning chemical to a value of 1.5%, where however there were almost regular defects in sufficient removal of dirt and corrosion on some components in almost every batch intended for cleaning. Therefore, when setting the effective temperature, we will use a precise concentration of 2%. Although the manufacturer states a temperature of 50 °C, it is for general contamination. After consultation with the manufacturer of the chemical, the manufacturer recommends with sufficient cleaning to reduce the temperature by 5 °C until we get to undesirable values of the cleaning results.

Table 3. Measurements record of when the temperature reached its effective minimum

Temperature [°C]	Temperature result [OK / NOK]
45	OK
40	NOK
35	NOK
30	NOK
25	NOK

As the table shows, the first signs of insufficient cleaning occurred already at temperature of 40 °C, therefore the temperature for the test of time-consuming process would be set at the temperature of 45 °C. Also, it would be appropriate to mention the fact, that during the cleaning process it is impossible to check the state of component contamination, since the washing machine is full of dirty water, which prevents the removal and inspection of the component [Michalik 2014]. Inspection is therefore always possible only after the end of the washing cycle. We will reduce the time of the washing cycle in 5-minute intervals, and we will count as effective 10 consecutive washing cycles with the same parameters.

Table 4. Measurements record of when the time of the washing cycle reached its effective minimum

Time [min.]	Time result [OK / NOK]
55	OK
50	OK
45	OK
40	NOK
35	NOK

As can be seen from the table, the effective time of the washing cycle was reduced to 40 minute per cycle, before the first defects in cleaning quality started to appear. For this reason, the resulting wash cycle time is set to 45 minutes to minimize the rework of the components.

Table 5. Comparison of previous and future parameters

	Concentration	Temperature	Cycle time
Previous settings	3.5 %	50 °C	60 min.
New settings	2 %	45 °C	45 min.

After the overall testing and setting of the new parameters, we saved 1.5% of the chemical concentration, which can be easily reflected in the price. We can also include a 5 °C reduction in working temperature among our successes. It may seem negligible if we look at it from the point of view of saving electricity for water heating, but what is significant is the 7-minute time reduction in heating time. This is very crucial in the process that is referred to as a bottleneck. Finally, the biggest savings (if we look at the process as a bottleneck) is a 15-minute wash cycle saving, to which if we add 7 minutes saved in water heating time, it would represent in total 22 minutes of time savings, which constitutes about 1/3 of the total wash cycle. Additional test was carried out to refute the effect of the chemical concentration by increasing it to its initial value of 3.5% with water temperature of 50 °C and washing cycle set to 40 minutes. Surprisingly, the results were comparable to 2% chemical concentration and 45'C water temperature, which determines that unnecessarily high concentration of chemical has no desired effect.

5 DISCUSSION

As we can see, by proper setting of chemicals concentration, we can significantly reduce the amount of used chemicals which impacts the production cost and ecology [Zaborowski 2007]. We can also save on the amount of electricity needed to heat water. These are all financial benefits that we can talk about, if our process is not bottleneck. Of course, there are also some savings in the workforce, but it is usually reflected in higher production of components at a certain time.

Figure 4. Sample of insufficiently cleaned component

However, if we consider the cleaning process a bottleneck place, right then, the saving effects of these changes become more important and calculated savings taken into account are more than just savings for material and energy [Panda 2020 & 2021]. This kind of savings represents a much bigger financial contribution than just financial savings for material and energy.

6 CONCLUSIONS

Today's practice shows that very few processes are carried out almost to perfection under given conditions. This is an indication that there is always room for modifications and improvements. Such improvements and analyzes are sometimes avoided by people, especially in small companies, because they are not sure of their benefits. And even if they were, they are not sure of the amount of saving effect for their business activity. We can conclude from the real practice that the more emphasis is placed on the process productivity, the cheapest and the most effective way to achieve this, is its modification. Needless to say, we will not be able to avoid the situations where investment in a new and more productive machine is necessary [Pollak 2020b], but modification of the process itself should take place first.

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