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# Influence of processing Parameters on Rust Removal Performance when Cleaning Steel with Ultrasonic Assistance

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**ABSTRACT**

Ultrasonic steel surface cleaning technology is increasingly playing an important role in many different fields. The determination of the influence of the machining parameters on the amount of removed rust on the steel surface is important in the selection of these parameters to increase the machining productivity. In this study, we conducted tests to determine the influence of machining parameters on the amount of removed rust on the steel surface. Tests were performed according to Box-Behnken matrix in two cases: Acids are used or not used in cleaning solutions. In the absence of the use of acids, the selected parameters were the input parameters of the test including machine power, cleaning time and the distance from the steel surface to the ultrasonic head (referred to as the machining distance). Four parameters have been selected as the input parameters when using acids in the detergent solution, including machine power, machining distance, solution concentration and machining time. Finally, orientation for the next research has also been proposed in this paper.

**Keywords :** Steel Surface Cleaning, Ultrasonic Machining, Machining Productivity.

## I. INTRODUCTION

Today in the mechanical industry, in the field of mechanization of agriculture and forestry, in the field of defense, civil, etc., cleaning equipment plays an important role. Classic cleaning methods such as using hands in combination with solutions do not guarantee the cleanliness of the parts to be cleaned, the working environment is too toxic, people are always in direct contact with chemicals, so their health is not guaranteed. Especially for details with complex structures with high impurity adhesion, this cleaning method is difficult to guarantee. For the electrolytic cleaning method, the energy consumption is quite large, so the surface of the parts will not remain intact when the cleaning time is long [1].

Ultrasonic cleaning equipment is quite appreciated for its superior cleaning ability thanks to the application of ultrasonic technology. The mechanism of this equipment is quite simple, mainly thanks to the elasticity of the solvent, creating thousands of microscopic air bubbles that creep into each corner, when these bubbles burst, they will create a huge energy source that helps to remove all stubborn stains. An outstanding advantage of the ultrasonic surface cleaning method is that it does not cause any disadvantage to the object's surface [2]. Besides, this method is also known as the only method that can clean extremely complex or very small surfaces that cannot be cleaned by other methods. The ultrasonic cleaning technology also saves the product drying time than other methods. This technology can remove most types of materials getting on the surface of objects such as oil, dust, rust, fungus, calcification, blood and biological contaminants, etc. [3].

Statistical data shows that with conventional cleaning methods, the dirt of part surface is 70%; washing by vibrating method will reduce the dirt of part surface by 50%; when washing parts by hand, the dirt of part surface is 20%. In the ultrasonic cleaning method, the dirt level is only below 5% [4]. With the trend of using technologies that reduce energy consumption, do not pollute the environment, and do not cause harmful effects on human health as today, the ultrasonic cleaning equipment is the first choice in the cleaning field in the industry. The use of ultrasonic energy will provide superior cleaning performance compared to previous cleaning solutions especially for objects with complex shapes. The study [5] also suggests that ultrasonic surface cleaning is at least 10 times cleaner than manual cleaning. Another example also show that ultrasonic cleaning is more dominant than cleaning with a scrub when it is necessary to clean uneven surfaces [6].

There are many parameters that affect the cleaning efficiency of the ultrasonic cleaning process such as the ultrasonic frequency, the size and the shape of the object to be cleaned; the size and shape of the tank; the type of ultrasound head to be used; cleanliness of solution, temperature of solution, concentration of solution, etc. [7], [8].

The temperature of the solution is a factor that has a great influence on the surface cleaning process of object. Because temperature affects the viscosity and solubility of the gas in the liquid as well as the diffusion rate of the gases in the liquid, when the temperature of the solution increases, the viscosity decreases, and the diffusion rate of the gas in the solution also increases. However, when the solution temperature is close to the boiling temperature, the bubble-forming intensity is reduced, which is due to the fact that the liquid begins to boil at the aggressive sites. With purified water, the best temperature for machining is 160$^o$F (corresponding to 71.11$^o$C) [6]. However, according to document [2], in order to ensure the productivity of the steel surface cleaning process as well as ensure the health of the equipment operator, it is necessary to use the equipment when the liquid temperature is in the range of 50 ÷ 70$^o$C.

When the ultrasonic frequency increases too high, the radius of the bubbles and the bubble pressure decrease, thereby affecting the surface cleaning speed of the material [9], [10]. If the ultrasonic frequency is high, the bubbles will quickly burst when the difference between the pressure of the solution and the pressure of the bubbles is not large enough. The ultrasonic frequency suitable for application in cleaning is between 20 kHz and 50 KHz [27].

According to documents [11] and [12], the position of the object at which the highest machining productivity is met is not the position closest to the ultrasonic head and also not the position not farthest from the ultrasonic head, but at the center of the tank.

In this study, we will examine the influence of some machining parameters on rust removal performance on steel surface when cleaning with the ultrasonic assistance.

## II. TEST PROCESS

### A. Test equipment

The cleaning equipment used in this study is the cleaning tank as shown in Figure 1. The inner length, width and height of the tank are 700 mm, 400 mm and 400 mm respectively. The material of the tank (pot) section is made of stainless steel to ensure it is not affected by chemicals in the cleaning solution [3, 13]. The power source with ultrasonic frequency is provided by an ultrasonic generator with a frequency of 40 KHz, which has the symbol AC220V50HZ +/- 10%. The ultrasonic generator cluster used in this study is the generator cluster with 32 IBL emitters.

Figure 1. Test equipment

### B. Test sample and test solution

Test process is performed on steel samples with length, width and thickness of 96 mm, 96 mm and 2.5 mm, respectively (figure 2). The acid used in this study is $H_3PO_4$.

Figure 2. Steel sample

### C. Measuring devices

Micro-electronic balance, type AJ203 with number 140211043 (by Shinko Denshi Company – Japan) is used to determine the amout of removed rust. This balance is capable of weighing a maximum of 200 (g), with an accuracy of 1/1000 (figure 3). The temperature of solution is determined with a thermomerter called TP 101 (also known as thermometer TP 101). This device is capable of measuring temperatures in the range of $50^o \div 300^o$ with an error of $\pm 1^o$.

### D. Test process

The Test process is as follows:

- Step 1: Weigh the mass $m_1$ of steel sample before testing.
- Step 2: Conduct the test in accordance with the value of input parameters.
- Step 3: Weight the mass $m_2$ of the sample after the test (the test sample is weighed after it is dry).
- Step 4: Determine the amount of removed rust by the formula $m = m_1 - m_2$.

**E. Test design and results**

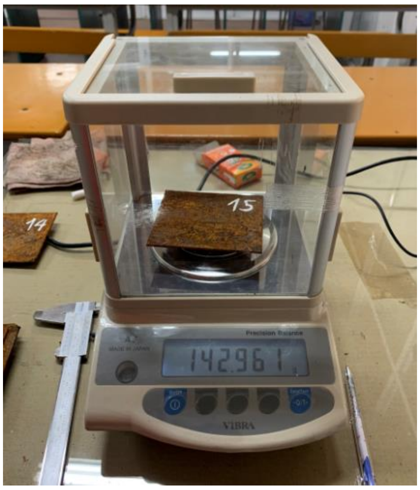


Figure 3. Micro balance AJ203, No. 140211043

Box-Behnken experimental design will be applied to design the Test. In accordance with this design, each input parameter will have 3 value levels corresponding to the three coding levels of -1, 0, 1, which are shown in Table I. The values of input parameters in Table I are determined after conducting input single-parameter parameters. The test process is carried out in two cases: (1) Without using acid – in this case, the test matrix consists of 15 tests and the results are shown in Table II; (2) With acid – in this case, the test matrix consists of 27 tests and the results are shown in Table III.

TABLE I. VALUE OF PARAMETERS AT THE LEVELS

| **Parameters** | **Notation** | **Unit** | **Value at the levels** | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Without using acid** | | | **With acid** | | |
| | | | -1 | 0 | 1 | -1 | 0 | 1 |
| Machining time | T | min | 30 | 40 | 50 | 3 | 4 | 5 |
| Machine power | Q | % | 60 | 65 | 70 | 60 | 65 | 70 |
| Machining distance | L | mm | 250 | 300 | 350 | 250 | 300 | 350 |
| Acid concentration | C | % | - | - | - | 0.3 | 0.4 | 0.5 |

TABLE II. TEST RESULTS WITHOUT USING ACID

| **No.** | **T (min)** | **Q (%)** | **L (mm)** | **$m_1$ (g)** | **$m_2$ (g)** | **m (g)** |
|---|---|---|---|---|---|---|
| 1 | 30 | 60 | 300 | 156.614 | 156.434 | 0.180 |
| 2 | 50 | 70 | 300 | 159.043 | 158.618 | 0.425 |
| 3 | 40 | 65 | 300 | 165.119 | 164.830 | 0.289 |
| 4 | 30 | 65 | 350 | 158.869 | 158.710 | 0.159 |
| 5 | 40 | 60 | 250 | 165.390 | 165.193 | 0.197 |
| 6 | 40 | 65 | 300 | 152.379 | 152.164 | 0.215 |
| 7 | 50 | 65 | 250 | 158.450 | 158.193 | 0.257 |
| 8 | 40 | 60 | 350 | 168.538 | 168.390 | 0.148 |
| 9 | 40 | 65 | 300 | 160.109 | 159.841 | 0.268 |
| 10 | 50 | 65 | 350 | 157.866 | 157.755 | 0.111 |
| 11 | 40 | 70 | 350 | 173.305 | 172.923 | 0.382 |
| 12 | 50 | 60 | 300 | 156.322 | 156.082 | 0.240 |
| 13 | 30 | 70 | 300 | 164.239 | 163.864 | 0.375 |
| 14 | 40 | 70 | 250 | 160.587 | 160.304 | 0.283 |
| 15 | 30 | 65 | 250 | 161.222 | 161.071 | 0.151 |

TABLE III. TEST RESULTS USING ACID

| No. | T (min) | Q (%) | L (mm) | C (%) | $m_1$ (g) | $m_2$ (g) | m (g) |
|---|---|---|---|---|---|---|---|
| 1 | 3 | 60 | 300 | 0.4 | 156.614 | 155.899 | 0.715 |
| 2 | 4 | 70 | 350 | 0.4 | 159.043 | 158.299 | 0.744 |
| 3 | 5 | 65 | 300 | 0.3 | 165.119 | 164.379 | 0.740 |
| 4 | 4 | 65 | 300 | 0.4 | 158.869 | 158.119 | 0.750 |
| 5 | 4 | 60 | 250 | 0.4 | 165.390 | 164.635 | 0.755 |
| 6 | 4 | 65 | 300 | 0.4 | 152.379 | 151.629 | 0.750 |
| 7 | 3 | 65 | 300 | 0.3 | 158.450 | 157.71 | 0.740 |
| 8 | 4 | 70 | 300 | 0.5 | 168.538 | 167.743 | 0.795 |
| 9 | 4 | 65 | 350 | 0.5 | 160.109 | 159.39 | 0.719 |
| 10 | 5 | 70 | 300 | 0.4 | 157.866 | 157.081 | 0.785 |
| 11 | 4 | 70 | 250 | 0.4 | 173.305 | 172.48 | 0.825 |
| 12 | 3 | 65 | 300 | 0.5 | 156.322 | 155.591 | 0.731 |
| 13 | 5 | 65 | 250 | 0.4 | 164.239 | 163.479 | 0.760 |
| 14 | 4 | 60 | 300 | 0.5 | 160.587 | 159.89 | 0.697 |
| 15 | 3 | 70 | 300 | 0.4 | 161.222 | 160.467 | 0.755 |
| 16 | 4 | 65 | 250 | 0.5 | 156.614 | 155.845 | 0.769 |
| 17 | 5 | 65 | 300 | 0.5 | 159.043 | 158.312 | 0.731 |
| 18 | 5 | 65 | 350 | 0.4 | 165.119 | 164.437 | 0.682 |
| 19 | 5 | 60 | 300 | 0.4 | 158.869 | 158.182 | 0.687 |
| 20 | 4 | 65 | 250 | 0.3 | 165.390 | 164.64 | 0.750 |
| 21 | 4 | 65 | 350 | 0.3 | 152.379 | 151.706 | 0.673 |
| 22 | 4 | 65 | 300 | 0.4 | 157.866 | 157.152 | 0.714 |
| 23 | 3 | 65 | 350 | 0.4 | 173.305 | 172.629 | 0.676 |
| 24 | 4 | 70 | 300 | 0.3 | 156.322 | 155.584 | 0.738 |
| 25 | 4 | 60 | 300 | 0.3 | 164.239 | 163.568 | 0.671 |
| 26 | 4 | 60 | 350 | 0.4 | 160.587 | 159.945 | 0.642 |
| 27 | 3 | 65 | 250 | 0.4 | 161.222 | 160.47 | 0.752 |

From the test results in Table II and Table III, we build a Pareto chart of the influence of the input parameters on the amount of removed rust as shown in Figure 4 and Figure 5, in which the selected significance level is α = 0.05.

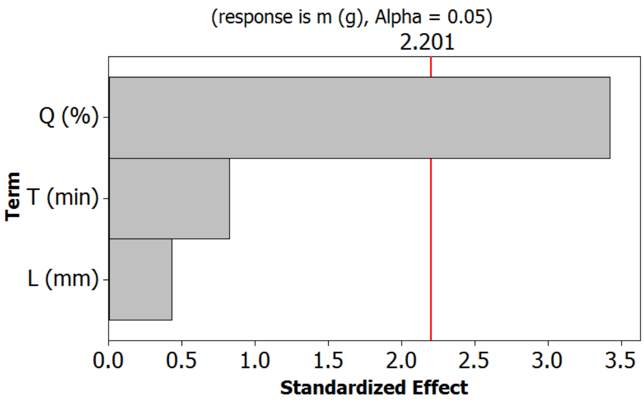


Figure 4. The Pareto chart of the influence of the parameters on the amount of removed rust without using acid

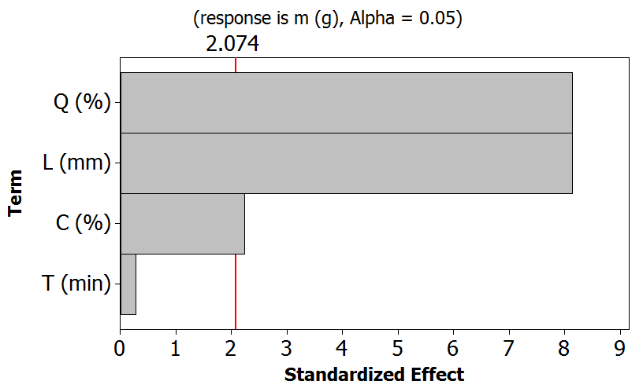


Figure 5. The Pareto chart of the influence of the parameters on the amount of removed rust using acid

Observing Figure 4, it shows that: Machine power is a parameter having a significant influence on the amount of rust removal on the steel surface. Meanwhile, the cleaning time and machining distance do not significantly influence the amount of removed rust. However, should it is considered in detail, the machining time influencing the amount of removed rust is greater than the influence of the machining distance.

From the results of Figure 5, it shows that: Machine power, machining distance and solution concentration are parameters having a significant influence on the amount of removed rust on the steel surface. In which, the influence of rust removal decreases in the order of machine power, machining distance and solution concentration. The machining time does not significantly influence the amount of rust removal.

## III.CONCLUSION

Ultrasonic steel surface cleaning process was carried out in this study. Tests were performed to investigate the influence of some parameters of machining process on the amount of rust on the steel surface in two cases of using and not using acid in the detergent solution. Some conclusions are drawn as follows;

- When not using acid in the detergent solution, the machine power is the only parameter having the significant influence on the amount of removed rust on the steel surface. Meanwhile, the cleaning time and machining distance do not significant influence.
- When using acid in the detergent solution, the machine power is the parameter having the greatest influence on the amount of removed rust on the steel surface, followed by the influence of machining distance and solution concentration. The machining time does not significantly influence the amount of rust removal.
- The study for determination of optimal value of the input parameters in order for the amount of rust removal on the steel surface to reach the maximum value is the work that the authors of this study will perform in the next time.

## IV.APPRECIATION

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