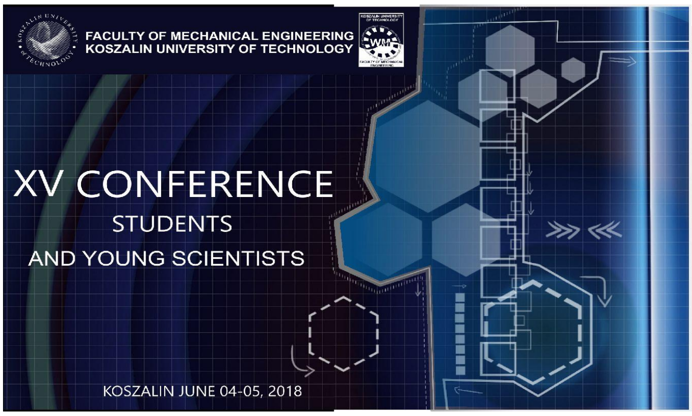


# Research on topography of stainless steel surfaces after abrasive treatment in a centrifugal smoothing container machine

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*ABSTRACT. The article presents the reaserch results of the geometric structure of the AISI 304L stainless steel samples treated in the abrasive smoothing process using loosely rotating or moving due to the centrifugal force Avalon ceramic fittings with parameters 06PP10 using the AVALON EC6 smoothing container machine. The top layer structure of the surface of steel samples was tested depending on the different exposure times of the treatment for the operation of ceramic inserts at a constant rotational speed of the rotational-cascade smoothing machine. The parameters of surface roughness, contact angle and adhesion energy values, surface isotropy were analyzed as well as a visual assessment of the gloss of the treated surface in relation to machining time was performed.*

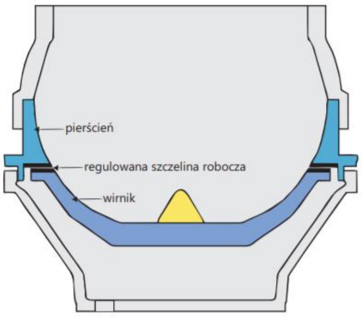
*KEY WORDS: rotational-cascade smoothinh machine, SGP, stainless steel, surface roughness, contact angle, adhesion energy*

# 1. Introduction

Surface treatment in container smoothing machines is nowadays a developing technology that is widely available due to low implementation costs. This type of smoothing machines of are easy to use and do not require special knowledge or protections (eg protective clothing) for their service compared to electrochemical treatment or sandblasting. Such features give this technology a very wide spectrum of use. There are many different types of container smoothing machines available on the market, which are widely used depending on the individual needs of the abrasive smoothing method using loose fittings. There are drum, rotary-cup, rotary-planetary, rotational-cascade, powder and vibratory smoothing machines (Woźniak, 2017). Choosing the right smoothing machine depends mainly on the dimensions and shape of the object that you want to process. The number of objects also plays an important role here, because depending on the size, form and volume of the elements and the effect we want to achieve, you can adjust the size and category of the smoothing machine, as well as the type and size of the inserts used. For example, one of the Turkish producers, in its offer of vibratory smoother machines, offers machines which working capacity container range is between 20 liters and 3200 liters, and the weight of these smoothing machines ranges from 90 to 6500 kilograms (Woźniak, 2017).

Smoothing containers have a wide range of applications. It is possible to remove surface layers - purification of deposits, rust, impurities; deburring, rounding of sharp edges, as well as reducing surface unevenness by abrasive, finishing or polishing. Various materials can be processed, such as metals (steels, aluminum, zinc, magnesium, copper or titanium alloys), gold, silver, plastics, articles made of wood and minerals, amber, as well as rubber elements. Depending on the desired effect, type of material, size and shape of the object, a suitably selected working medium is used, from ceramic, resin, porcelain, steel and natural plant media.

To carry out the research presented in the article, the Avalon EC6 smoothing machine was used. It is a rotational-cascade machine in which the working drum consists, among others, the fixed housing of the tank located above the ring and the rotating bottom of the container, which sets abrasive devices together with the workpieces (Fig. 1). Due to its relatively small size, this model is ideally suited for cleaning, grinding and polishing small-sized parts with a total weight of up to 0.5kg per one-off batch. This smoothing machine will find its application for the treatment of jewelery details, small screws or buttons.




a)

b)

*Rys 1. Stanowisko badawcze – wygładzarka AVALON EC6 a) Budowa bębna roboczego obrabiarki (www.avalon-machines.pl, 2018), b) Bęben roboczy w czasie wygładzania z użyciem kształtek ceramicznych*
*Fig. 1. Reaserch stand - AVALON EC6 smoothing machine a) Construction of the working drum (www.avalon-machines.pl, 2018), b) The drum during smoothing with the use of ceramic fittings*

## 2. Purpose of research

The aim of the research presented in the article was to obtain a non-targeted isotropic surface and to assess the condition of the surface layer of stainless steel samples subjected to the abrasive smoothing process in a rotational cascade smoothing machine depending on the processing time using one type of operating medium at a constant rotational speed of the machine drum. The analysis of the influence of the change of machining time on surface roughness values, adhesion energy and visual properties of the tested elements was analyzed.

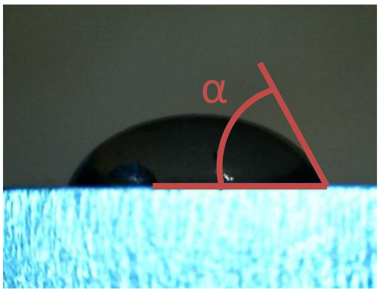
## 3. Research methodology

Six rectangular stainless steel AISI 304L samples with dimensions of 15 x 15 x 5 mm (length x width x height), cut from a rolled steel sheet with the use of Waterjet, were used for identification tests. The samples were processed in an AVALON EC6 container smoothing machine with the use of ceramic inserts 06PP10, used in the rough wet machining of steel and alloy steel details. (www.avalon-machines.pl, 2018).

Steel elements were machined at intervals of one order in succession: 1h; 1.5; 2h; 2.5; 4h; 6h at drum speed v = 300 rpm.

In the next stage, the samples were analyzed on a NANOVEA optical profilometer based on the chromatic aberration technique to determine their surface micro-geometry. The study covered the area of 2.5mm x 2.5mm from each sample, with measurement accuracy up to 0.001μm. As a result of the test, measurements were obtained, among others towards the surface structure, altitude and volume parameters. Samples were also analyzed under the Capture digital microscope to determine visual changes in the surface.

For each sample, the contact angle was calculated using the embedded drop method (Fig. 2), (Liber-Kneć, Łagan, 2014) using a specially made measuring stand (Kłonica).




*Rys 2. Pomiar kąta zwilżania osadzonej kropli wody destylowanej na powierzchni stali nierdzewnej*
*Fig. 2. Measurement of the contact angle of the deposited drop of distilled water on the surface of stainless steel*

The results of the contact angles were used to calculate the Wa adhesion energy for each sample according to the Young-Dupre formula (Rogowska, 2013):

$$W_a = \delta_L(1+\cos\theta) \quad (1)$$

Where:
$W_a$ - adhesion energy - work necessary to separate the solid-liquid surface
$\delta_L$ - value of surface water tension (he value was assumed 7,28 [$10^{-3}$ N/m] in a room temperature)
$\theta$ - value of the contact angle

The final stage was the analysis of each sample under the Cap-ture digital microscope. All surfaces were photographed at the same distance from the camera in which a uniform, unchangeable source of light was set.

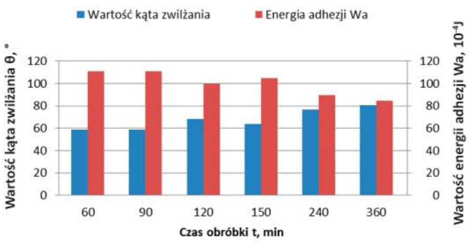
## 4. Reaserch results

A summary of the results of the tests carried out below. Table 1 presents the change in the value of various height parameters for steel surfaces (Sa - mean arithmetic deviation, Sq - mean square deviation of surface ordinates, Sk - core roughness height), significant in terms of surface roughness analysis (Oczoś i Liubimov, 2003) relative to the machining time. The change in the contact angle and adhesion energy for a given sample determined by the treatment time in a smoothing machine was also presented.

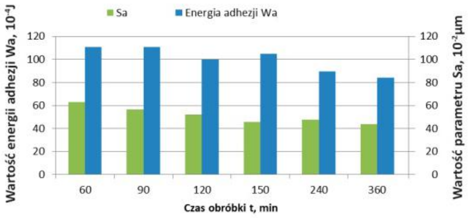
*Tabela 1. Wyniki badań zmiany struktury warstwy wierzchniej stali nierdzewnej AISI304L względem czasu obróbki z użyciem wkładek ceramicznych 06PP10 firmy Avalon*
*Fig. 1. The results of the research on structure changes of the surface layer of AISI304L stainless steel versus processing time with the use of ceramic inserts 06PP10 by Avalon*

| **Tooling time *t, min*** | **60** | **90** | **120** | **150** | **240** | **360** |
|---|---|---|---|---|---|---|
| **Parameter *Sa, µm*** | 0,631 | 0,565 | 0,519 | 0,455 | 0,447 | 0,439 |
| **Parameter *Sq, µm*** | 0,835 | 0,765 | 0,722 | 0,636 | 0,574 | 0,572 |
| **Parameter *Sk, µm*** | 1,938 | 1,679 | 1,516 | 1,373 | 1,41 | 1,329 |
| **Surface isotropy, %** | 19,404 | 33,703 | 59,381 | 49,152 | 19,738 | 41,076 |
| **Contact angle value *θ*,°** | 58,57 | 58,96 | 68,33 | 63,59 | 76,86 | 80,69 |
| **Adhesion energy *Wa*, $10^{-3}$ J** | 11,08 | 11,03 | 9,97 | 10,52 | 8,93 | 8,46 |

The results of the contact angle measurement indicate that the range for the tested samples is within the range $0^o < \theta < 90^o$, which means that the liquid moistens the solid well. However, after 6 hours of processing, the result is much closer to $\theta = 90^o$, where liquid molecules attract solid particles with a force equal to half of their mutual attraction (Thomsen, 2008; Żenkiewicz, 2000). Analyzing the above results and properties for the size of contact angles, it can be concluded that the surface after the longest processing time will be much less susceptible to water adherence, as a result of which higher corrosion resistance will be possible. This surface can be easier to clean and more resistant to dirt.



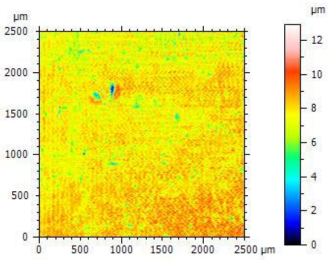

a) b)

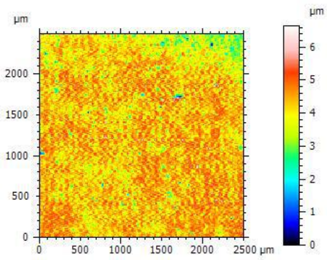



*Rys 3. a) Zależność między kątem zwilżania a energią adhezji względem czasu obróbki, b) Zależność między średnim arytmetycznym odchyleniem powierzchni Sa a energią adhezji względem czasu obróbki*

*Fig. 3. a) Relation between contact angle and adhesion energy versus treatment time, b) Relation between mean arithmetic surface deviation Sa and energy of adhesion with respect to machining time*

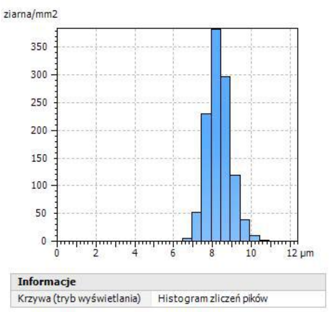
The graphs show the relationships between selected research results. In graph a), the relationship between the energy of adhesion and the surface parameter Sa is visible. On the other hand, in graph b) the relationship between the value of the contact angle and the adhesion energy for the tested samples is shown depending on the processing time.

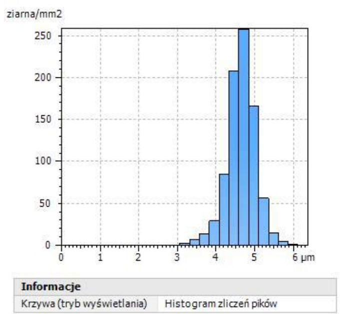
a) 


b) 

*Rys 4. Widok pseudokoloru powierzchni a) po 1 godzinie obróbki, b) po 6 godzinach obróbki*
*Fig. 4. View of the surface pseudocolor a) after 1 hour of treatment, b) after 6 hours of treatment*

The results of the tests carried out clearly show that the height of the surface unevenness along with the treatment time has changed (Rys. 4)

a) 

b) 


*Rys 5. Rozkład wierzchołków nierówności na powierzchni a) po 1 godzinie obróbki, b) po 6 godzinach obróbki*
*Fig. 5. Distribution of unevenness tops on the surface a) after 1 hour of treatment, b) after 6 hours of treatment*

Changes were also observed in the number of peaks occurring on the surface of the tested steel. After the first hour of treatment, the peak height ranged from approx. 6 µm to 11 µm, while after 6 hours the range changed to 3-6 µm. Peak grain size has also been reduced.

a)  b)  c)  d) 

*Rys 6. Widok powierzchni pod mikroskopem cyfrowym Capture a) po 1 godzinie obróbki, b) po 2 godzinach obróbki, c) po 4 godzinach obróbki, d) po 6 godzinach obróbki,*
*Fig. 6. Surface view under the Capture Digital Microscope a) after 1 hour of treatment, b) after 2 hours of treatment, c) after 4 hours of treatment, d) after 6 hours of treatment*

There were also visual changes that took place in subsequent stages of smoothing (Fig. 6), which could also be noticed without the use of specialized equipment.

## 5. Conclusions

The following conclusions can be drawn on the basis of the research and analysis of the results obtained:

1. The geometrical structure of the surfaces subjected to smoothing to a thinner in a container smoothing machine with the use of ceramic inserts undergoes changes as a function of time and shows a tendency to shape a non-targeted structure.
2. With the elongation of the machining time, the roughness of the surface decreases, eg Sa for t = 60 min is 0.631µm to Sa = 0.439µm with a 360 min machining time.
3. The longer the smoothing time, the greater the wetting angle of the workpieces being processed, and the adhesion energy is reduced, which may lead to increased corrosion resistance of the surface and more favorable cleaning conditions, as well as less tendency to adhere to contamination..
4. As the machining time increases, the greater glossiness of the stainless steel surface is visible.

## 5. Literature sources

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