Creating optimal cleanable stainless steel surfaces

In the food industry, all food contact surfaces must be frequently and thoroughly cleaned. This is also valid for food contact surfaces made out of stainless steel. The efficiency of the cleaning process is related to the cleaning process itself, as well as to the hygienic characteristics of the surface being treated. However, those specific surface characteristics – in short, the 'cleanability' – often pose problems due to the traditional surface treatment methods that are applied after fabrication of the stainless steel components. But scientific research proves that there is an innovative alternative for those traditional methods: the SUBLIMOTION-process®.

By Pieter Haers[1] and Dr. Nicolas Rossi[2]

[1] Phibo Industries, Ronse, Belgium, e-mail: pieter.haers@phibo.be, www.sublimotion-process.com

[2] ACTALIA, Center of expertise for the food industry, Villers Bocage, France, www.actalia.eu

Hygiene demands permanent and special attention in the food industry because consumers expect high-quality products that are safe for consumption. Through its guidelines and other publications, the European Hygienic Engineering & Design Group (EHEDG) provides a number of hygienic design tools that help food producers meet these consumer expectations. One essential objective of hygienic design is to keep all food contact surfaces (and thus also the food) safeguarded from chemical and microbial contamination. Cleaning and disinfection is therefore essential.

The effectiveness of the cleaning and disinfection process not only depends on the technique and specifications of the process, but also on the characteristics of the surface being cleaned and disinfected. In particular, characteristics such as the roughness, topography, hydrophobicity and surface energy, each which have an impact on its suitability for getting rid of food and dirt (i.e., its cleanability).[1,2] Moreover, as already stated in a previous version of the EHEDG Yearbook, for food processing machines that do not meet the 'easy to clean' requirements of the Machinery Directive 2006/42/EC and other relevant standards, conformity to the CE mark is not valid.[3]

The downsides of traditional stainless steel surface treatments

When stainless steel is processed (bent, cut, welded etc.) into parts and components that are destined to be used in food production facilities, several functional problems and deficiencies can appear, including:

- An unfinished, unclean surface that is visually not uniform.
- Surfaces with all kinds of contamination and imperfections generated during handling and fabrication such as the typical oxidation and discolourations in welding zones that are associated with the onset of corrosion, microscopic surface damage, grease spots, impurities, etc. (Figure 1).[4] As a result, these surfaces do not possess good hygienic characteristics according to EHEDG guidelines Doc. 8. Hygienic Equipment Design Criteria, and Doc. 32. Materials of Construction for Equipment in Contact with Food.[1,5] More specifically, the cleanability of those surfaces can and must be significantly improved.

Figure 1. A stainless steel component that shows the typical welding discolourations, imperfections, impurities and contamination generated during fabrication.

Traditional surface treatment processes that are used today to remove discolourations in welding zones, grease spots and similar contamination of stainless steel surfaces on an industrial scale include chemical pickling and passivation, electropolishing, mechanical grinding, brushing and polishing, and conventional bead blasting. All of these methods, however, leave the door open for further improvement with regard to environmental impact, safety of the process itself, and the resulting hygienic characteristics and cleanability of the food contact surfaces.

A mechanically polished surface, for example, can result in a surface with a low roughness but can also be damaged and contain micro-cavities, tears or laps, which lead to a reduction of its cleaning properties.[6,7] Also, the remaining overall surface topography and quality strongly depend on the process parameters, such as belt speed, pressure, etc.[8] When examining a stainless steel surface at the microscopic level after grinding and polishing, one can observe considerable amounts of remaining grease, oil and polishing paste residues on and within the surface. This contamination might affect the food products with which they come into contact, and in certain cases might quickly become the starting point for corrosion (e.g., definitely when the contamination comes from carbon steel).

The widely applied bead blasting treatment, on the other hand, is known to result in ruptured surfaces (Figure 2).[5] In addition, these types of treated surfaces possess a surface roughness that exceeds the maximum roughness values advised by EHEDG for large surface areas (i.e., R_a<0,8 µm).[8]

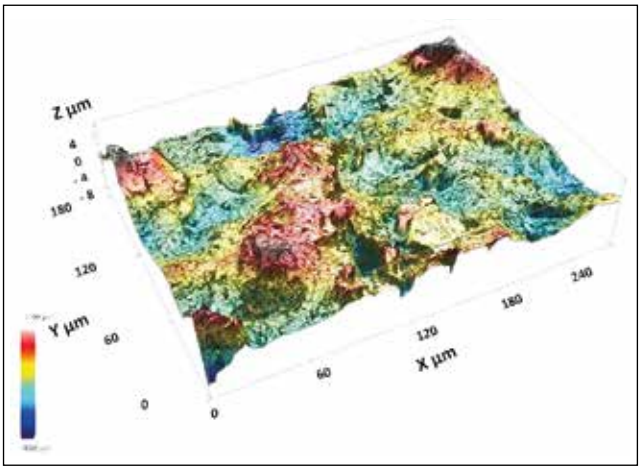

Figure 2. Microscopic 3D image of a standard 2B stainless steel surface treated with conventional glass bead blasting. The topography is very rough, with many alternating high peaks and valleys.

Chemically pickled and passivated stainless steel surfaces may, in some cases and strongly depending on the initial surface state before pickling, obtain an average surface roughness that falls below the advised 0,8 µm. Even then, the disadvantage is that high peaks and deep valleys are created on the surface, which remain difficult to clean.[8] This lack of thorough cleaning on the micro level, was shown in research conducted by Actalia, as discussed later in this article).[12]

Focusing on R_a values alone can lead to misjudgement of the cleanability of a surface and/or its susceptibility to accumulating contamination. Even surfaces with the same R_a values can have totally different topographies. For example, they can exhibit large differences in the number of peaks and valleys along the measured sample lengths (Figure 3).[6]

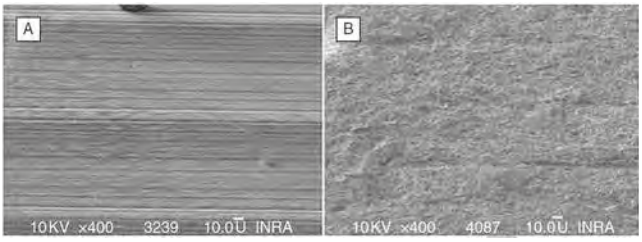

Figure 3. SEM observation of stainless steel characterised by similar Ra values (A: R_a = 1.17 µm, B: R_a = 1.12 µm) but with quite a different topography.[9]

As commonly known, and certainly within the EHEDG, cleanability strongly depends on the total surface topography, of which the R_a value is only one of many parameters.[1,6] Every surface imperfection, from pits, holes and crevices to grooves and grain boundaries, makes removal of adherent bacteria more difficult (Figure 4).[9]

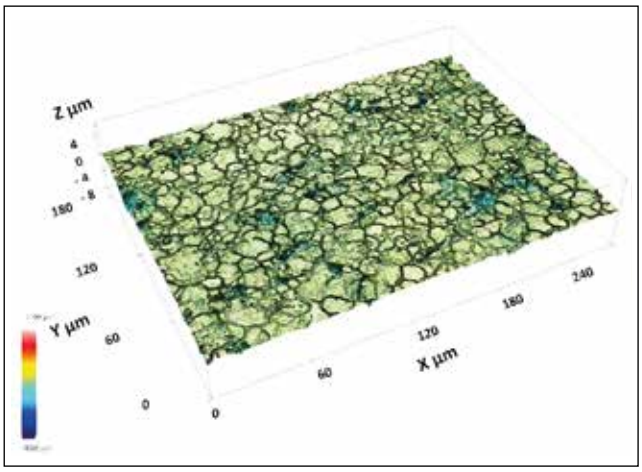

Figure 4. A standard 2B finished stainless steel surface shows, that although the surface possesses a low R_a value and gives the impression of being a smooth, ideal hygienic surface, there are deep micro-cavities, cracks and clear grain boundaries when examined under the microscope.

Figure 5 shows that these grain boundaries are optimal points of attachment for bacteria. So even standard 2B finished stainless steel shows there is still room for improvement in terms of hygienic characteristics.

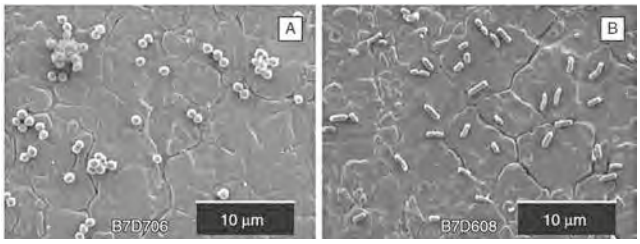

Figure 5. Adhesion of various microorganisms on stainless steel surfaces: adhesion of *Staphylococcus caprea* (A) and *Pseudomonas fluorescens* (B) under static condition on stainless steel with a 2B finish (horizontally immersed).[9]

One could say that one of the practical problems is that there is no explicit, straightforward legislation or regulation regarding surface roughness, topography and/or cleanability of stainless steel food contact surfaces. However, the European Union's Machinery Directive does state clearly that all surfaces in contact with foodstuffs or cosmetics or pharmaceutical products must:

- be smooth and have neither ridges nor crevices that can harbour organic materials, and
- be easily cleaned and disinfected.[10]

To independently examine whether something is cleanable or not in a straightforward way, the EHEDG developed the standardised method for assessing the in-place cleanability of food processing equipment, which is outlined in EHEDG Doc. 2.[11]

The SUBLIMOTION-process

Following extensive internal research and development at Phibo Industries to create a surface treatment process that results in optimal cleanable surfaces, an innovative alternative to traditional surface treatments is now available. The SUBLIMOTION-process is a monitored surface cleaning and conditioning process for stainless steel, based on a distinctive projection of a well-determined and specific colloidal suspension that removes contamination from the fabrication of the surfaces (Figure 6). This method results in a visually appealing and uniform finish, and reconditions the complete surface topography (including, amongst others, the roughness) and energy (Figure 7).

Figure 6. The same stainless steel component as shown in Figure 1, but now after treatment with the SUBLIMOTION-process. All contamination or impurities resulting from the fabrication are removed and at the same time the surface topography is reconditioned.

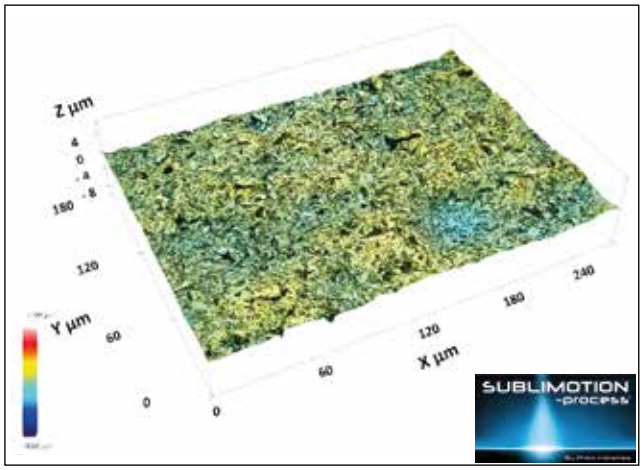

Figure 7. The SUBLIMOTION-process reconditions the surface topography, creating a surface with optimal cleanability.

Independently proven optimal cleanability

ACTALIA, an officially authorised test and certification institute, was employed to carry out the EHEDG cleanability test according to EHEDG Doc. 2 and to deliver EHEDG certificates in case of compliance.[12] In first instance, the institute conducted a scientific study inspired by EHEDG Doc. 2 with specifically adjusted parameters to compare the cleanability of a stainless steel surface finished with the SUBLIMOTION-process to surfaces finished with traditional surface treatment methods. Having submitted all of these differently finished stainless steel surfaces to the cleanability test, the remaining contamination was compared. Testing showed that the stainless steel surface treated with the SUBLIMOTION-process showed no remaining contamination and was determined to be at least equally cleanable as an electropolished surface. This in contrast to the results of the reference pipe, the standard surface with 2B finishing and the surfaces treated with glass bead blasting and chemical pickling and passivation, as these last four types of surfaces all contained remaining contamination after completing the cleanability test.[13]

In the second phase of the study, ACTALIA verified the conformity of the SUBLIMOTION-process with Regulation (EC) 1935/2004 on materials and objects that come into contact with food and evaluated a tube of stainless steel with SUBLIMOTION-process finishing for compliance with the hygienic equipment design criteria of EHEDG according to the test method of EHEDG Doc. 2. The process also has been declared EHEDG Certified Type EL Class I for wet in-place cleaning of closed equipment, without dismantling.[14,15]

As previously noted, these optimal characteristics regarding cleanability are very important for all the surfaces in the food industry in general and for both direct and indirect food contact surfaces in particular, as these characteristics lead to a reduced risk in microbiological contamination. As a consequence and according to EHEDG Guideline 35, this reduces the need for cleaning cycles, which enhances the efficiency of the food processing plant.[16]

Conclusion

The SUBLIMOTION-process is an alternative to conventional stainless steel surface treatment processes. Based on scientific research, testing has shown that the SUBLIMOTION-process conditions stainless steel surfaces in such a way that they possess better hygienic characteristics, which significantly improves cleanability after treatment (Figure 8).[13,14] Moreover, the cleaning and conditioning of the surface is simultaneously realised in one single step.

Figure 8. Large stainless steel container before and after treatment with the SUBLIMOTION-process.

References

1. European Hygienic Engineering & Design Group (EHEDG). EHEDG Guideline 8, Hygienic equipment design criteria, 2nd Ed. April 2004, p. 12.
2. European Hygienic Engineering & Design Group (EHEDG). EHEDG Guideline 35, Hygienic welding of stainless steel tubing in the food processing industry. July 2006, p. 5.
3. Bellin, Hans-Werner. Legal requirements for hygienic design in Europe. *EHEDG Yearbook 2013/2014*, pp. 17-19.
4. European Hygienic Engineering & Design Group (EHEDG). EHEDG Guideline 35, Hygienic welding of stainless steel tubing in the food processing industry. July 2006, pp. 5 and 28.
5. European Hygienic Engineering & Design Group (EHEDG). EHEDG Guideline 32, Materials of construction for equipment in contact with food. August 2005, p. 13.
6. European Hygienic Engineering & Design Group (EHEDG). EHEDG Guideline 32, Materials of construction for equipment in contact with food. August 2005, p. 14.
7. Faille, C., J.M. Membré, J.P. Tissier, M.N. Bellon-Fontaine, B. Carpentier, M.A. Laroche, and T., Benezech. (2000). Influence of physicochemical properties on the hygienic status of stainless steel with various finishes. *Biofouling*, 15(4), pp. 261-274.
8. European Hygienic Engineering & Design Group (EHEDG). EHEDG Guideline Doc. 8. Hygienic equipment design criteria, 2nd Ed. April 2004. Table 2 p. 12.
9. Faille, C. and B. Carpentier. (2009). Food contact surfaces, surface soiling and biofilm formation. In: *Biofilms in the Food and Beverage Industries*. Eds. Pina Fratamico, Bassam Annous and Jack Guenther. Cambridge, UK. Woodhead Publishing Limited.
10. European Union. EU Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery. Amending Directive 95/16/EC (recast).
11. European Hygienic Engineering & Design Group (EHEDG). EHEDG Guideline 2, A method for assessing the in-place cleanability of food processing equipment, 3rd. Ed. July 2004. Revised June 2007.
12. European Hygienic Engineering & Design Group (EHEDG). List of test and certification institutes. Accessed at www.ehedg.org.
13. ACTALIA. Report No. 14.834.1. September 2015.
14. ACTALIA. Evaluation Report No. 001ACT2016.
15. European Hygienic Engineering & Design Group (EHEDG). EHEDG Certificate of Compliance, Type EL-Class I for welded stainless steel pipe with SUBLIMOTION-process® finishing for application in the food industry. Certificate number ACTALIA-1/2016.
16. European Hygienic Engineering & Design Group (EHEDG). EHEDG Guideline 35, Hygienic Welding of Stainless Steel Tubing in the Food Processing Industry. July 2006, pp. 5.

Photos and source for figure 1, 2, 4, 6, 7 and 8:
© Phibo Industries