STAINLESS STEEL

The cleanability of stainless steel used as a food contact surface: an updated short review

John J. Milledge reviews the effect of surface roughness on the cleanability of stainless steel as used in the food industry

Introduction

A previous review of the cleanability of stainless steel concluded; that if surface finish had an effect on the cleaning process, it is probably small in relation to other factors during cleaning (1). The object of this paper is to briefly review subsequent information so that an update assessment can be made.

Measurement of surface roughness

The costs of different surface finishes can vary considerably and the cost of imparting a highly polished finish can be expensive (2, 3).

The roughness of a surface has been most commonly measured by an instrument in which a stylus travels across the surface, the movement of the stylus being amplified and the signal recorded. The result is generally expressed as Ra or average roughness in "microns ra" (μm ra) which is the arithmetic average value of the deviation of the trace above and below the centre-line (4). Although Ra is a useful average it does not differentiate between peaks or valleys and very different profiles can have the same Ra value, for example, rolling and jagged profiles of the same amplitude (2, 5). Other expressions of surface roughness are available and have been suggested as better descriptions of the profile, such as Rz (the sum of the maximum highest peak and lowest valley within the sampling length) and may give additional insight regarding surface character (6).

Stainless steel surface finishes are very often described by a numbering system representing a processing method rather than its roughness in terms of Ra values (3, 7, 8) (Fig.1). Estimates of surface topography as indicated by Ra value for standard finishing process descriptions have been given, but Ra values of a given material can vary (2, 5, 9).

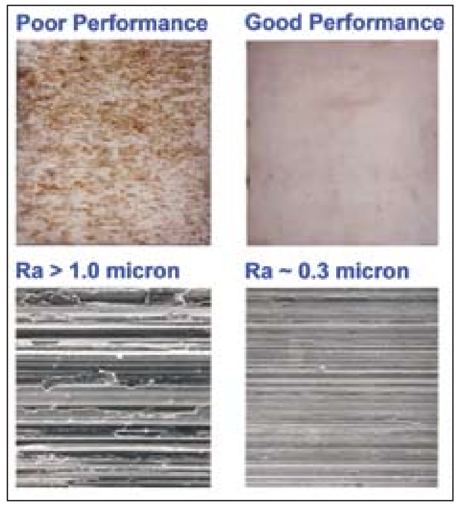

Fig. 1. Effect of surface on corrosion. Course polished surfaces Ra 1µm> showed more staining in a cyclic salt spray test (7). Courtesy of the British Stainless Steel Association (BSSA).

Current regulations and recommendations

Regulations normally only give general guideline on food contact materials and surface finishes (10-13).

European legislation requires that handling, preparation, processing, packaging etc, of food is done hygienically, with hygienic machinery in hygienic premises. How to comply with these requirements, however, is left to the industry (14).

The EHEDG (European Hygienic Engineering and Design Group) is a consortium of equipment manufacturers, food industries, research institutes, universities and public health authorities, founded in 1989 with the aim to promote hygiene during the processing and packing of food products (15). It provides practical direction on hygienic design. The EHEDG may also authorise the use of the certification logo on equipment that complies with the relevant hygiene criteria (16, 17).

In the USA, the 3-A Sanitary Standards Inc. publishes uniform standards for the hygienic design of equipment, with the first 3-A sanitary standards being developed in the late 1920s. The 3-A Sanitary Standards serve as important references for many state and federal regulatory authorities (18).

In 1993, the EHEDG and the 3-A organisation concluded that it would be beneficial if US and European Standards were similar. Co-operation between the two organisations has been established with the aim of investigating how to produce standards for food processing equipment that would be acceptable in both Europe and the USA (13).

The EHEDG recommends surface roughness of less 0.8μm and all 3-A sanitary criteria now also always include surface finish requirements which are equivalent to smoother than a 0.8 μm (32 $\mu in.$) Ra (9, 19, 20). The American Meat Institute Equipment Design Task Force also recommends that surfaces should also not exceed 0.8 μm (21).

Adhesion

The amount of residual soil after cleaning has been shown to be influenced by the initial contamination on a surface (22, 23). In the assessment of surface finish on cleanability it may be useful to consider the effect of roughness on bacterial and soil adhesion.

In the dental industry, a surface with Ra value of less than 0.2 μm is deemed to accumulate plaque less well (24). A study of four bacterial species appeared to support this view with bacterial adhesion being lowest on a stainless steel surface with a Ra of 0.16 μm with rougher and smoother surfaces having greater adhesion (25). A later study of *Staphylococcus aureus* would also appear to give additional support to this view (26) and small changes in surface topography of 0.1μm have been found to influence bacterial adhesion (27).

In a study of rougher surfaces (Ra 0.029 – 3.2 μm) the minimum adhesion was found at Ra 0.8 μm with both smoother and rougher surfaces having greater adhesion (28), but this is contradicted by a study of the adhesion of *Streptococci*, which found that surface roughness did not greatly impact on adhesion with "entrapment" being greatest at Ra 0.9 μm (29).

Many other studies have found no correlation between surface roughness and bacterial adhesion for stainless steel with a variety of finishes with Ra of up to 1.37 μm (30-35).

One study found no correlation between surface finish and adhesion, but a re-examination of the result suggested a significant correlation (6, 36).

Studies of welds (up to Ra 1.19 μm) found that there was no difference in the adhesion to the weld and the smoother base stainless steel (37, 38).

A study of the transfer of bacteria from a contaminated meat product to stainless also found no significant difference between various finishes (Ra 0.25-0.75 μm) (39).

The adhesion distribution and the effect of surface roughness have been shown to be different for bacteria of different surface energies and for rod and cocci bacteria (40, 41). These differences between different bacteria together with the type of soil, enumeration method and the range of roughness may help to explain the apparent contradictions in the results (42).

Drainage

The first step in cleaning is the drainage of residual product from the system. In the drainage of sucrose solution, although surface roughness was found to be significant, there was no correlation between Ra 0.025-0.45 μm and it was concluded that heavy investment in highly polished surface is probably unwarranted (5). In study of the drainage of edible oils and food emulsions it was concluded that stainless steel surface roughness encountered in the food industry is not a major factor in newtonian food liquid drainage (43).

Cleaning

In a modelling study it has been suggested that surface topography only has a negative effect on cleanability if crevices are "large and deep" (44). Roughened stainless steel (Ra 5.38 μm) has been shown to be unacceptable (45) and abraded stainless steel has also been found to be more difficult to clean than un-abraded, but resistance of stainless steel to abrasion makes it more likely to retain its hygienic properties than many other materials (46-48). Rough surfaces caused by welding (Ra 1.97 to 4.56 μm) have also been shown to be less cleanable than bright annealed stainless steel (49), but others have found no difference in cleanability of well executed welds and the surrounding material (50).

"Highly adhesive milk soil" was found to be more difficult to remove with increasing surface roughness (Ra 0.11-0.3 μm) (51) and *E. coli* was also found to be more difficult to rinse from rougher surfaces (Ra 0.04-1.37 μm), although no difference in initial bacterial adhesion was found (35).

Some studies have found an influence of surface finish on cleanability, but without a correlation with surface roughness as indicated by Ra (52-55), indicating that it may be nature of the surface rather than the magnitude of roughness of the surface that is important.

The majority of studies have found little or no significant difference in the effect of surface roughness on cleanability or rinse-ability (56-62). In a study mimicking intensive cleaning found in the brewery industry, there was little difference in the cleanability of 4 common surface finishes (2) and no difference in cleanability was found between 3 different commercial finishes in a study of milk plate heat-exchangers (63).

A study of spray cleaning of 9 different finishes found no evidence that a surface finish less than 1 μm Ra has any effect on cleanability (64) and another study of 4 commercially available finishes found that for Ra values below 0.8 μm surface topography did not affect cleanablity (65).

Conclusion

This updated brief review would appear to confirm, the conclusion of my previous review (1) and a recent review for the pharmaceutical industry (66), that if surface finish of commonly used commercial stainless steel does have an effect, it is probably small in relation to other factors in cleaning and design. The weight of evidence would not normally justify the food industry investing in mechanically highly polished surfaces. The suggested maximum surface roughness of less Ra 0.8 μm for stainless steel for the food industry would appear to be reasonable and appropriate.

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