sciendo

Acta Materialia Transylvanica 6/1. (2023) 9–13.
DOI: Hungarian: https://doi.org/10.33923/amt-2023-01-02
English: https://doi.org/10.33924/amt-2023-01-02

ACTA MATERIALIA TRANSYLVANICA

Investigation of Corrosion Caused by Iron Contamination on the Surface of Stainless Steel Plates

Csaba BREZNAY,[1] Balázs VARBAI[2]

[1] *Budapest University of Technology and Economics, Faculty of Mechanical Engineering, Department of Materials Science and Engineering. Budapest, Hungary, breznay.csaba@edu.bme.hu*

[2] *Budapest University of Technology and Economics, Faculty of Mechanical Engineering, Department of Materials Science and Engineering. Budapest, Hungary, varbai.balazs@gpk.bme.hu*

Abstract

Corrosion caused by iron contamination, also known as rouging, is a possible type of corrosion of stainless steels. This type of corrosion is often confused with the corrosion of stainless steel itself. Rusty discoloration on the surface of a material considered corrosion resistant is a problem in the construction and pharmaceutical industries. Repairing rouging afterwards is usually costly, but can be prevented by good manufacturing practices and control.

In our research, we compared four commonly used stainless material grades with different surface treatments. We investigated the effect of scratches left by carbon steel on the surface of the samples and the time course of the process.

Keywords: *corrosion, rouging, stainless steel.*

1. Introduction

Stainless steel is defined as a ferrous alloy containing at least 10.5% chromium but not more than 1.2% carbon. Stainless steels can be classified into four groups according to their microstructure: ferritic, austenitic, martensitic and duplex (austenitic-ferritic) steels. They have excellent corrosion resistance due to the passive oxide layer formed by chromium. For a stainless steel to exhibit adequate corrosion resistance in a given medium, its surface must be clean and free from organic and metallic impurities. Corrosion is defined in ISO 8044:2003 (withdrawn, but last edition in Hungarian) as: „The physico-chemical interaction between a metal and its environment, resulting in a change in the properties of the metal and often in a deterioration of the functional characteristics of the metal, the environment or the technical system comprising them”[1]. Of particular importance is the corrosion caused by iron contamination (rouging), which usually occurs through contact with carbon steels. The most frequent causes are the use of inadequately cleaned auxiliary equipment and normal carbon steel tools; the cutting of raw material; production and assembly in production lines using mixed (normal carbon steel and stainless) steels. Corrosion caused by iron contamination can be simply a slight brownish (rusty) discolouration or even surface pitting corrosion [2–5]. Our experiments investigated the resistance of austenitic and duplex grades to rouging.

2. Test materials

The materials used for the experiments, their surface finishes, and the values of the pitting resistance equivalent numbers (PREN) are given in

Table 1. *Test materials, their surface finish and pitting corrosion resistance*

Grade	Surface finish	PREN
304	polished	18
316L	pickled, 2E	23
2205	brushed, 2E/2D	31
2304	pickled, 2E/2E	26

Table 1. 304 and 316L are two standard, widely used austenitic stainless steels with polished and pickled surface finishes. 2205 and 2304 are duplex stainless steels with brushed and pickled surface finishes.

The test specimens were „contaminated" with iron particles in two different ways before the test. As shown in **Figure 1,** one specimen was wire-brushed and the other was scratched with a sharpened piece of carbon steel.

In the case of the wire brush, the scratches are shallower but more numerous on the sample surface, and iron oxide from the wire brush was also deposited on the sample surface. In the case of scratching with the carbon steel piece, the scratches are deeper and fewer in number.

After scratching, the samples were stored under laboratory conditions in an atmosphere containing hydrochloric acid vapour to accelerate the corrosion process. Macro- and microscopic images of the samples were taken after two weeks and two months, respectively.

3. Results and discussion

3.1. Corrosion test results of the 304 grade specimen

The surface of the 304 grade, polished surface-finished specimen shows significant changes after only two weeks. The scratched specimen shows dense surface pitting corrosion, while the wire-brushed specimen shows rusty discolouration and scattered surface pitting corrosion (**Figure 2**).

The same sample examined after two months is shown in **Figure 3**.

A small area on the edge of the sample was masked before wire brushing, in order to have a reference for comparison with the iron contaminated material.

The masking was removed after the wire brushing was completed.

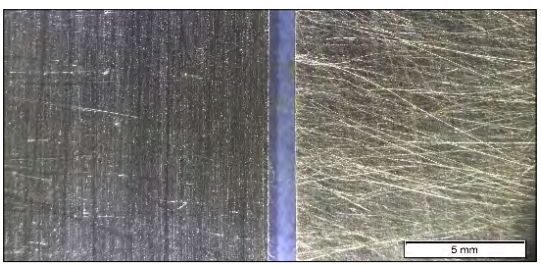

Figure 1. *Scratched (left) and wire-brushed surfaces, 2205 duplex, scale is 5 mm.*

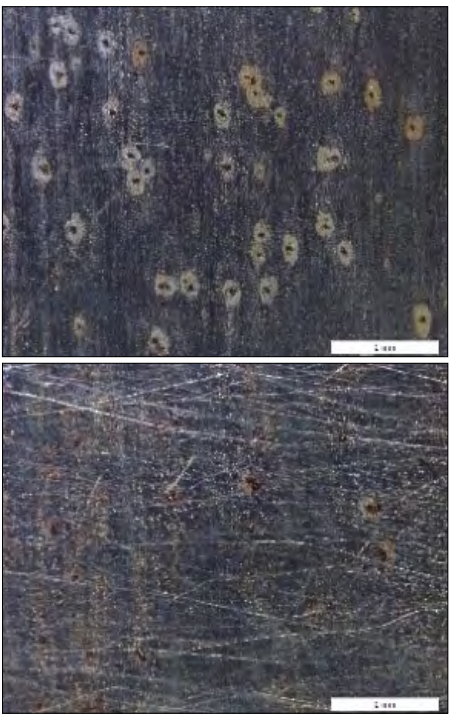

Figure 2. *Scratched (upper) and wire-brushed 304 test specimens after two weeks, scale is 2 mm.*

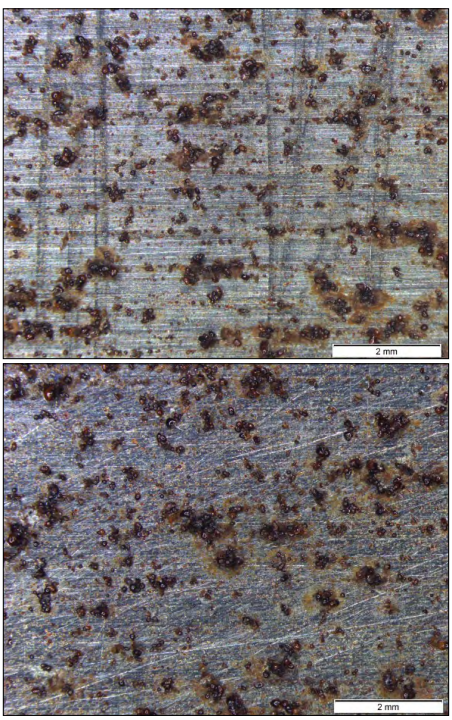

Figure 3. *Scratched (upper) and wire-brushed 304 test specimens after two months, scale is 2 mm.*

It can be clearly seen in Figures 4 and 5, that no discolouration or surface pitting has occurred on the masked surface. This phenomenon was observed in all test cases for each material grade tested.

3.2. Corrosion test results of the 316L grade specimen

On the pickled surface of the 316L sample, after two weeks, only scattered rust discolouration is visible (Figure 6).

However, after two months, large amounts of rust deposits and surface pitting were observed on the sample surface (Figure 7).

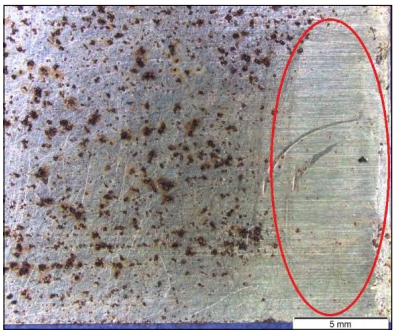

Figure 4. *The masked surface of the 304 specimen, after two months of exposure.*

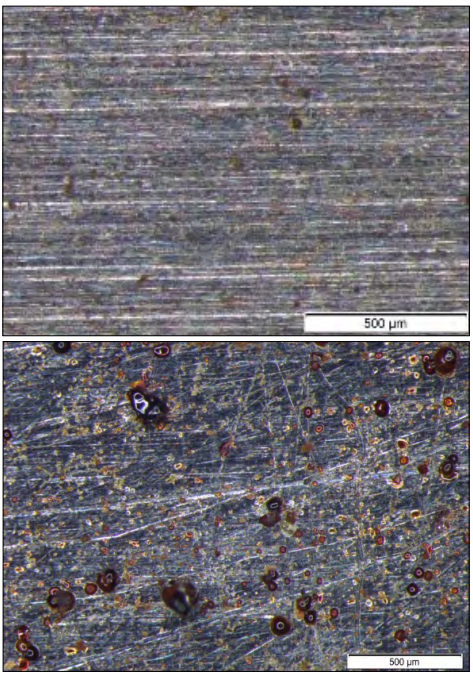

Figure 5. *The masked (upper) and iron-contaminated surface of the 304 specimen after two months, the scale is 500 µm.*

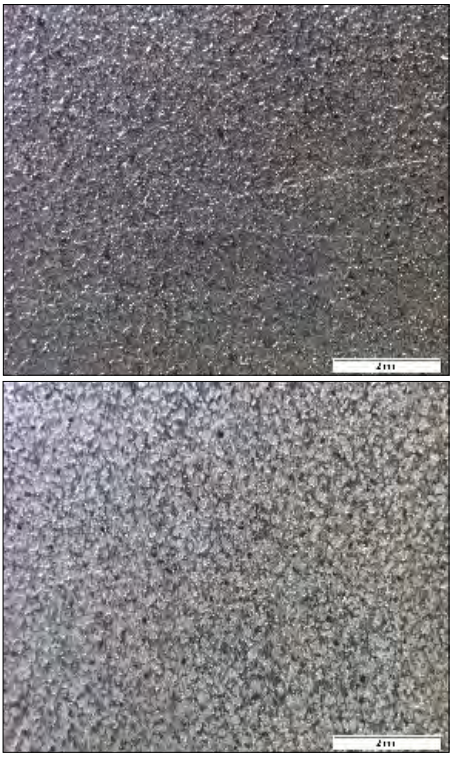

Figure 6. *Scratched (left) and wire-brushed 316L test specimens after two weeks, the scale is 2 mm.*

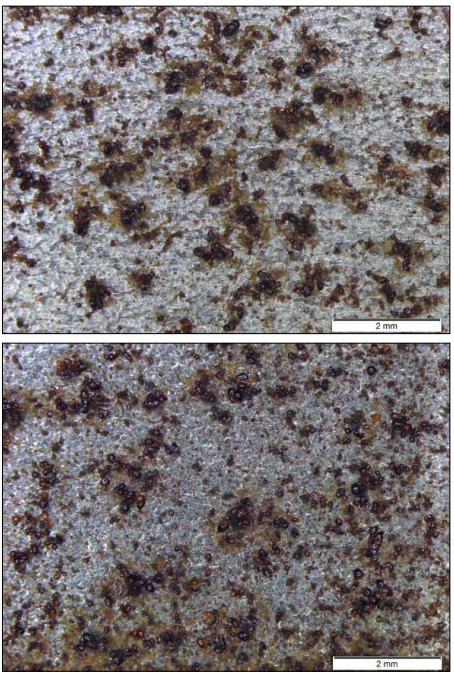

Figure 7. *Scratched (uooer) and wire-brushed 316L test specimens after two weeks, the scale is 2 mm.*

3.3. Corrosion test results of the 2205 grade specimen

he surface finish of the 2205 duplex sample is brushed. In contrast to the other samples, the surface of this material shows a rusty discolouration only in the scratches (**Figures 8–9**).

Of the four material grades tested, this material has the highest pitting resistance index (PREN), as a result, there was no surface pitting corrosion observed in the sample, even at high magnifications.

3.4. Corrosion test results of the 2304 grade specimen

On the pickled surface of the 2304 duplex specimen, a rusty discolouration is visible in patches on the scratched specimen, and a more or less uniform rusty discolouration is visible on the wire brushed specimen (**Figures 10–11. ábra**).

4. Conclusions

The rust that forms on the surface of the specimens is loose and can be easily wiped off the sur-

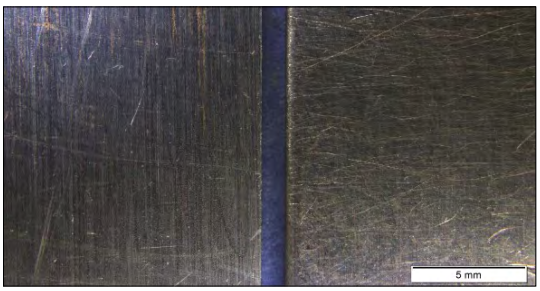

Figure 8. *Scratched (left) and wire-brushed 2205 specimens after two weeks, scale is 5 mm.*

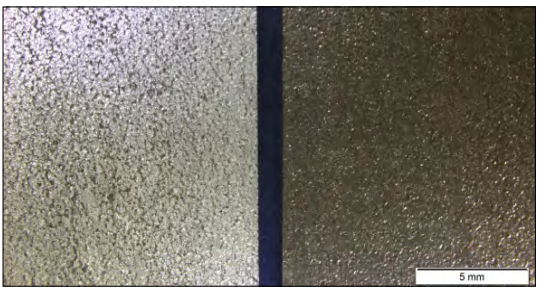

Figure 10. *Scratched (left) and wire-brushed 2304 specimens after two weeks, scale is 5 mm.*

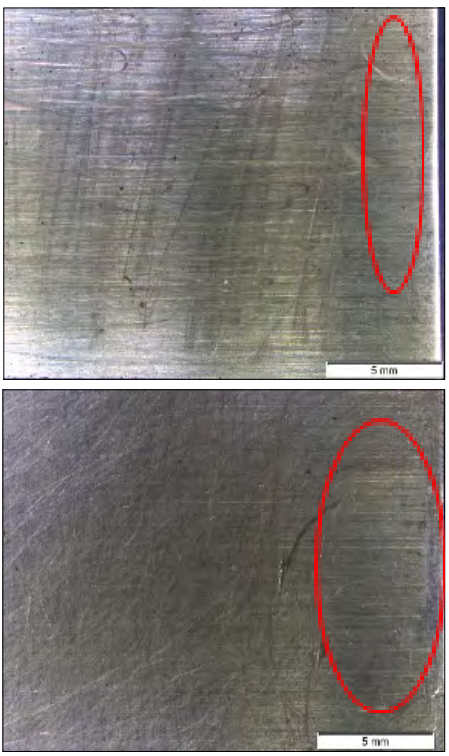

Figure 9. *Scratched (upper) and wire-brushed 2205 specimens after two months, scale is 5 mm.*

Figure 11. *Scratched (upper) and wire-brushed 2304 specimens after two months, scale is 5 mm.*

Figure 12. *The 1.4404 specimen surface after two months.*

face of the specimen, which will roll off with little force (**Figure 12**). The difficulty of repair is due to pitting corrosion of the surface.

It can be observed that the amount of rust deposited on the surface of the sample increases with time, and with it the number and depth of pits on the surface.

Acknowledgements

The publication was funded by the European Union through the ERASMUS+ Strategic Partnership Key Action 2, 2021-1-RO01-KA220-HED-000032181, ALLIES, with the support of the National Talent Programme of the Ministry of Innovation and Technology, NTP-SZKOLL-22-0080, and the National Research, Development and Innovation Office - NKFIH, (OTKA PD 138729).

References

[1] MSZ EN ISO 8044:2003 *Fémek és ötvözetek korróziója. Alapvető szakkifejezések és fogalommeghatározások (ISO 8044:1999)*. 2003.

[2] Crookes R.: *Rozsdamentes acélok pácolása és passziválása.* 2. ed., Anyagok és alkalmazások serie, vol. 4., Euro Inox, Brussels, 2010.

[3] Maller R. R.: *Passivation of stainless steel*. Trends in Food Science & Technology, 9/1. (1998).

[4] Corbett R. A.: *Rouging – A Discoloration of Stainless Steel Surfaces*. Materials Selection & Design, 2001. 64–66.

[5] Hornus E. C. et al.: *The Influence of Surface Iron Contamination on the Localized Corrosion Resistance of Austenitic and Duplex Stainless Steel, Studied with a Novel Rust Deposition Method*. Corrosion, 78/6. (2022). https://doi.org/10.5006/4067