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Roughness of 1.0721 steel after corrosion tests in 20% NaCl

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Abstract
Non-alloy quality case-hardening steels are used for low-load components made on automatic machining centers (automatic lines). Because of the widespread use of these steel in open constructions, they are exposed to atmospheric corrosion. The study attempted to analyze the effect of 20% aqueous NaCl solution on the roughness of the steel as a result of corrosion. The steel roughness and corrosion wear were determined according to corrosion time.

1. Introduction

Non-alloy quality case-hardening steels designed for processing on automatic machining centers have an increased sulfur and phosphorus content. The introduction of these elements affects the properties of steel. During machining, short brittle chips are formed to allow machining of steel on automatic machining centers. Unfortunately, the elevated sulfur and phosphorus content also lowers the mechanical, physical and chemical properties of steel. It does not have high strength or physical properties. Also, it is expected to lower its resistance to aggressive agents, including corrosive agents. Equally important is choosing the right quality material for your product (Kocańda D. et al. 2014, Selejdak J. et al. 2014, Ulewicz R. 2003, Ulewicz R. et al. 2014)

Due to its property, automated steel is, widely used in everyday life. It is used wherever low production prices matter, with no endurance requirements. In ordinary circumstances, constructions are not particularly protected against the effects of aggressive agents in this corrosive environment (Bohni H. 2005, Chandramouli R. et al. 2007, Dosch H. et al. 2001, El-Etre A.Y. et al. 2000, Naveen E. et al. 2017, Santana Rodriquez J.J. et al. 2006).

Corrosion mechanism of such steel is not as complex as steel with increased corrosion resistance. Its chemical composition and microstructure indicate susceptibility to surface corrosion. Corrosion, though the least dangerous of known corrosion types, causes systematic material destruction by oxidation. Material loses its volume and, therefore, strength and stiffness. Although it does not need to carry special loads, it ultimately leads to corrosive wear of the component (Alizadeh M. et al. 2013, Al-Duheisat S.A. et al. 2016, Lipiński T. 2016, Machuca L.L. et al. 2016, Scendo M. et al. 2013, Thompson N.G. et al. 2007, Uhlig H. H. et al. 1985, Zatkalíková V. et al. 2016).

Non-alloy quality case-hardening steel, due to low mechanical and physical properties, was not particularly investigated. There are also few publications presenting the results of corrosion resistance tests of this steel. In practice, the problem of changing its surface condition due to corrosion and corrosion resistance is serious, because of its wide application, and seems to be significant. It is also useful to evaluate steel according to the standard for the assessment of corrosion resistant steel (Dudek A. et al. 2014, Lipiński T. 2015, Pradityana A. et al. 2013, Szabracki P. et al. 2013, 2014).

From the foregoing considerations, it is necessary to carry out corrosion resistance testing of non-alloy quality case-hardening steels in NaCl environment.

2. Experimental

The experiment was performed on low carbon 1.0721 (10S20) steel designation according to EN 10277-3-2016, with diameter ϕ6.00 mm and 40 mm long.

Before the experiments, samples were successively polished with water paper to $R_a = 0.32$ µm, and next cleaned with water and next with 95% alcohol.

Samples with ferritic and a small perlitic microstructure were tested in accordance with standards dedicated for stainless steel PN EN ISO 3651-1 corrosive media were represented by 20% NaCl.

The corrosion rare of the 1.0721 steel measured in mm/year was calculated with the use of the below formula (1), measured in g/m^2 were calculated with the use the below formula (2):

$$r_{corm} = \frac{8760 \cdot m}{S \cdot t \cdot \rho} \tag{1}$$

$$r_{corg} = \frac{10000 \cdot m}{S \cdot t} \tag{2}$$

where:

t – time of soaking in a corrosive solution of boiling 20% NaCl [hours],
S - surface area of the sample [cm^2],
m – average mass loss in boiling solution [g],
ρ - sample density [g/cm^3].

The corrosion resistance of the 1.0721 steel in 20% NaCl was tested for time range: 48, 96, 144, 192, 240, 288, 336, 384 and 432 hours using laboratory weight loss. The mass of samples was measured by Kern ALT 3104AM digital laboratory precision scales with accuracy of measurement 0.0001 g.

Profile roughness parameters were analyzed according to the PN-EN 10049:2014-03 standard (Measurement of roughness average Ra and peak count RPc on metallic flat products) by the Diavite DH5 profilometer.

3. Results and discussion

The real chemical composition of the tested steel is presented in Table 1.

Table 1. Chemical composition of the 1.0721 (10S20): EN 10277-3-2008 steel

Mean chemical compositions [wt. %]					
C	Si	Mn	P	S	N
0.08	0.24	0.75	0.05	0.23	0.01

Mean real mechanical properties at ambient temperature of the 1.0721 steel, manufacturing according to EN 10027-1:2016-12 are presented in Table 2.

Table 2. Mechanical properties at ambient temperature of the 1.0721 steel

Mechanical properties		
R_{eH}	R_m	A
MPa	MPa	%
393	498	9

Arithmetical mean roughness value R_a of 1.0721 steel after corrosion tests in 20% NaCl is presented in Figure 1. The regression equations and its determination coefficients r^2 is presented in (3).

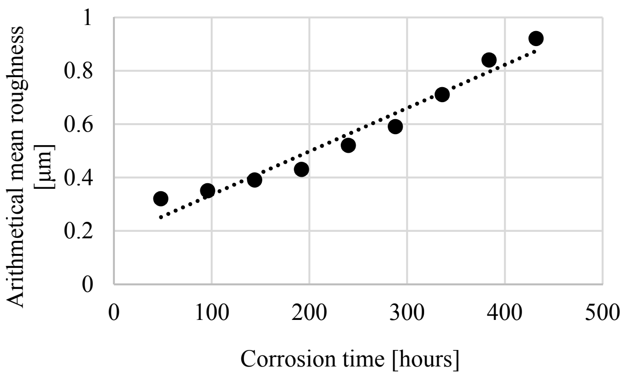

Fig. 1. Arithmetical mean roughness value the 1.0721 steel after corrosion tests in 20% NaCl water solution at ambient temperature

$$R_e = 0.0016t + 0.1742 \text{ and } r^2 = 0.9555 \tag{3}$$

Mean peak width R_q of 1.0721 steel after corrosion tests in 20% NaCl is presented in Figure 2. The regression equations and its correlation coefficients r^2 is presented in (4).

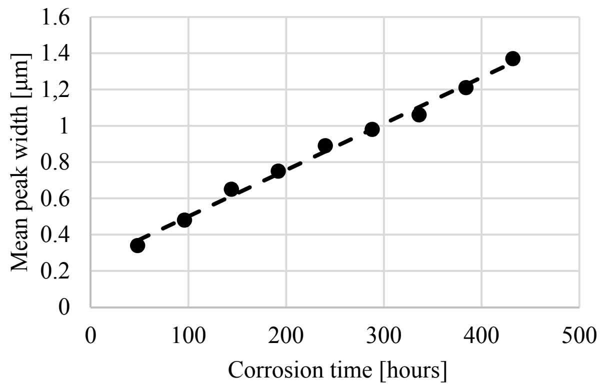

Fig. 2. Mean peak width the 1.0721 steel after corrosion tests in 20% NaCl water solution at ambient temperature

$$R_q = 0.0026t + 0.2456 \text{ and } r^2 = 0.9933 \tag{4}$$

Maximum roughness depth R_p of 1.0721 steel after corrosion tests in 20% NaCl is presented in Figure 3. The regression equations and its determination coefficients r^2 is presented in (5).

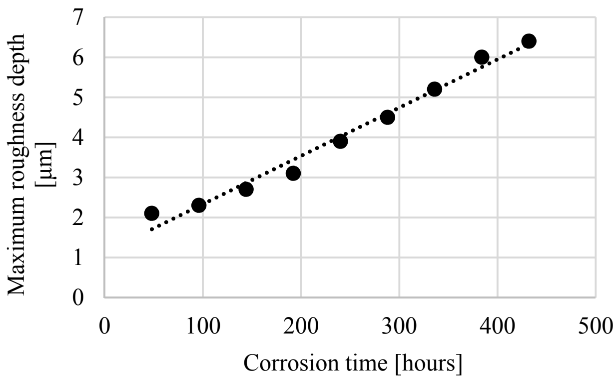

Fig. 3. Maximum roughness depth the 1.0721 steel after corrosion tests in 20% NaCl water solution at ambient temperature

$$R_p = 0.0012t + 1.1306 \text{ and } r^2 = 0.9811 \tag{5}$$

Total height of the roughness profile R_t of 1.0721 steel after corrosion tests in 20% NaCl is presented in Figure 4. The regression equations and its determination coefficients r^2 is presented in (6).

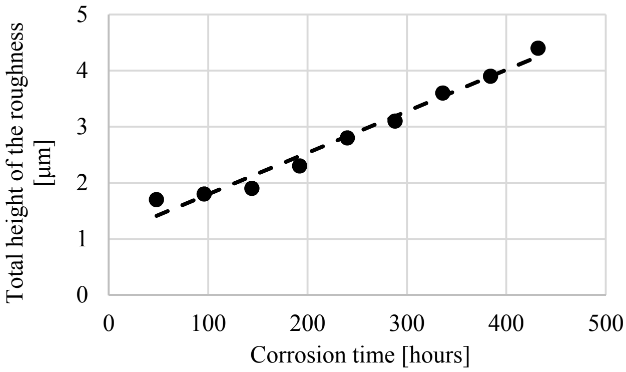

Fig. 4. Total height of the roughness profile the 1.0721 steel after corrosion tests in 20% NaCl water solution at ambient temperature

$$R_z = 0.0074t + 1.0583 \text{ and } r^2 = 0.9744 \quad (6)$$

Relative mass loss RML of 1.0721 steel after corrosion tests in 20% NaCl is presented in Figure 5. The regression equations and its determination coefficients r^2 is presented in (7).

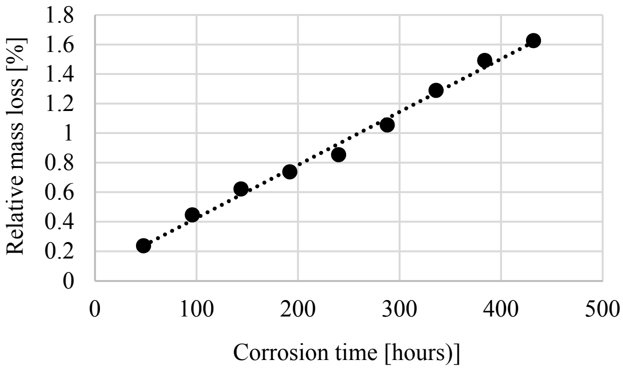

Fig. 5. Relative mass loss the 1.0721 steel after corrosion tests in 20% NaCl water solution at ambient temperature

$$RML = 0.0036t + 0.0659 \text{ and } r^2 = 0.9927 \quad (7)$$

Corrosion rate measured in mm per year of 1.0721 steel after corrosion tests in 20% NaCl is presented in Figure 6. The regression equations and its determination coefficients r^2 is presented in (8).

$$r_{corm} = 2 \cdot 10^{-6} \, t - 0.001 \, t + 0.468 \text{ and } r^2 = 0.9083 \quad (8)$$

Corrosion rate measured in gram per m^2 of 1.0721 steel after corrosion tests in 20% NaCl is presented in Figure 7. The regression equations and its determination coefficients r^2 is presented in (9).

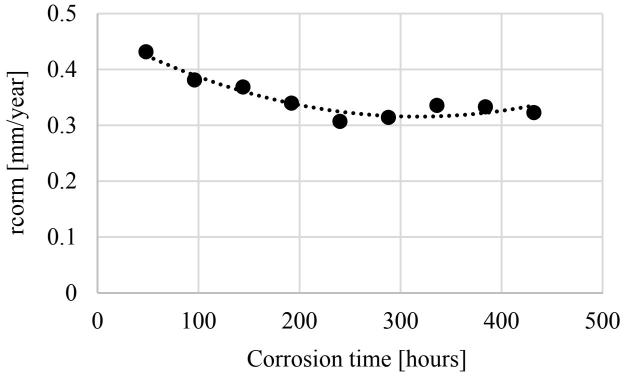

Fig. 6. Corrosion rate measured in mm per year the 1.0721 steel after corrosion tests in 20% NaCl water solution at ambient temperature

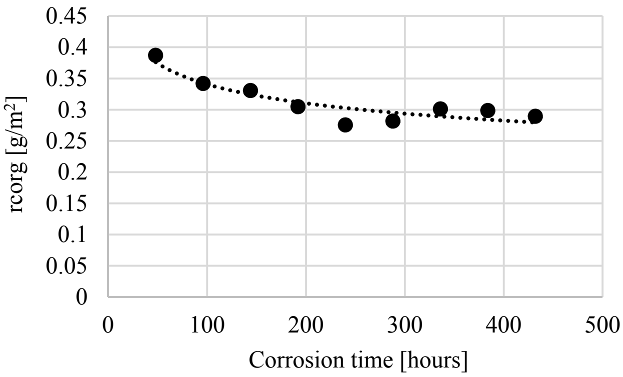

Fig. 7. Corrosion rate measured in gram per m^2 the 1.0721 steel after corrosion tests in 20% NaCl water solution at ambient temperature

$$r_{corm} = 0.6343 \, t^{-0.135} \text{ and } r^2 = 0.8056 \quad (9)$$

4. Summary and conclusion

All analyzed surface condition parameters represented by roughness can be represented with a sufficiently accurate first-order function. This fact confirms that this steel corrodes as a result of uniform corrosion. Evenly increasing roughness parameters show that during the experiment the maximum effect was not reached, after which the corrosion parameters oscillate around a constant size. Corrosion rates measured in mm/year and g/m^2 indicate an increase in the rate of corrosion in the first period. This growth is typical for any material treated with corrosive agents. Taking corrosion time to zero, the corrosion rate tends to infinity, the process starts to reach a constant value over time. In the second period, the process is stabilized and the corrosion rate oscillates around 0.32 mm/year and 0.28 g/m^2, which also confirms the uniform corrosion course.

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在20%NaCl中腐蚀试验后，1.0721钢的粗糙度

关键词
钢
腐蚀
腐蚀罕见
粗糙度
NaCl溶液

抽象

非合金质量表面硬化钢用于自动生产线（自动生产线）制造的低负荷组件。 由于这些钢在开放式结构中得到广泛应用，因此受到大气腐蚀。 该研究试图分析20%NaCl水溶液对腐蚀导致的钢的粗糙度的影响。 根据腐蚀时间确定钢的粗糙度和腐蚀磨损。