EVALUATION OF THE FAILURE OF VIBRATION SCREENER SIEVE

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Abstract

Austenitic stainless steel with higher chromium and nickel contain are often used as popular material in the energetics, chemical, food processing and medical applications. That material has a suitable combination of strength and corrosion properties for a given purpose. Their processing technologies are also not above-sophisticated. For these materials are typical some of the following degradation processes. In case of corrosion some types of localized corrosion attack types, such as intergranular, corrosion cracking, etc. It is also necessary to monitor fatigue processes and influences.

This article discusses the causes of damage of the sieve of the vibratory separator of $MgCl_2 \cdot 6H_2O$. Sieve is made from Steel AISI 304. Damage manifested itself with the cracking of certain strand (wires), mostly in the area of the outer circular frame. The damage started to occur after change of the vibration (frequency) parameters. The possible influences of chemical damage by environment or corrosion attack were observed, mechanical stress, fatigue, etc.

For research the methods of optical microscopy and SEM analysis were applied. Fractographical analysis of fracture surfaces, evaluation of mechanical properties (hardness) and verification of chemical composition was carried out. The results show the majority influence of fatigue damage.

Keywords: AISI 304 steel, Fatigue, vibration separator, Corrosion environment, damage analysis

1. INTRODUCTION

The aim of the article and analysis is to determine the causes of mesh vibrating screen, which is part of a line for production of a crystalline salt of magnesium chloride ($MgCl_2 \cdot 6H_2O$) and serves to separate of the product with unsuitable grain size [1 - 9].

AISI 304 steel is the basic type of chromium-nickel austenitic stainless steel. This is the most used stainless steel. Due to low carbon content, has this steel good weldability properties. Mechanical properties are also very good. Thanks to these features, industrial use is broad-spectrum [2, 5-7, 9].

Magnesium chloride has a very high degree of aggressiveness against austenitic-structured steel. The product of the attack is pitting corrosion or corrosion transcrystalic cracking. The attack occurs in the liquid phase, which can coexist with the crystals at RH > 33 %. Corrosion cracking may occur even at temperatures of 30 - 40 °C. Production of stresses that are necessary for corrosion cracking can also result in residual stresses at a low level. The influence of the environment could be as an occasional supportive factor at the stage of initiation (possibility of initiation of short cracks or pits). Contamination of the surface during technological pause can be the cause of corrosion centers (pits) that may act as stress concentrators during further operational loading [4, 7].

2. MATERIAL AND TEST METHODS

The supplied material is the sieve of the magnesium chloride vibration screener (**Figure 1**). In the mesh of sieve occurred break of many threads. The disorder appears to be random and occurred after three weeks of operation. Normally, the screen is serviced without failure for five months. The "Magnesium line" runs in continuous operation with a capacity of 950 - 1500 kg / h, with the vibrator motors being set at 1500 rpm. According to the operator's data there is no problem with the sorter setting, the quality of the material and other commonly observed qualitative parameters. Technology of bonding sieve to frame, string material and production technology, congestion, congestion, or other operating parameters stay unchanged. The only change is that during the last assembly of the sorter was replaced by vibromotors and a screen with a new (assessed) sieve was put in another operation 3000 rpm vibrator.

Sieve parameters with 600 mm diameter:

Sieving frame, closed profile 25 x 25 mm, material AISI 304.

- Mesh 3.15 x 3.15 mm, 0.8 mm wire diameter, AISI 304 material.
- Glued joint not specified, temperature resistance reported to 120 °C.
- The screen was operated 576 hours (24 days) at 3000 rpm and 50Hz

The analysis was focused on the possibilities of corrosion and mechanical stress, as well as on the chemical composition of the screen wire. For the analysis of micro and macrostructure, classical light and stereomicroscopy, SEM analysis for fracture assessment, HV0.5 hardness measurement, and chemical composition verification by wet way decomposition were used [2 - 5].

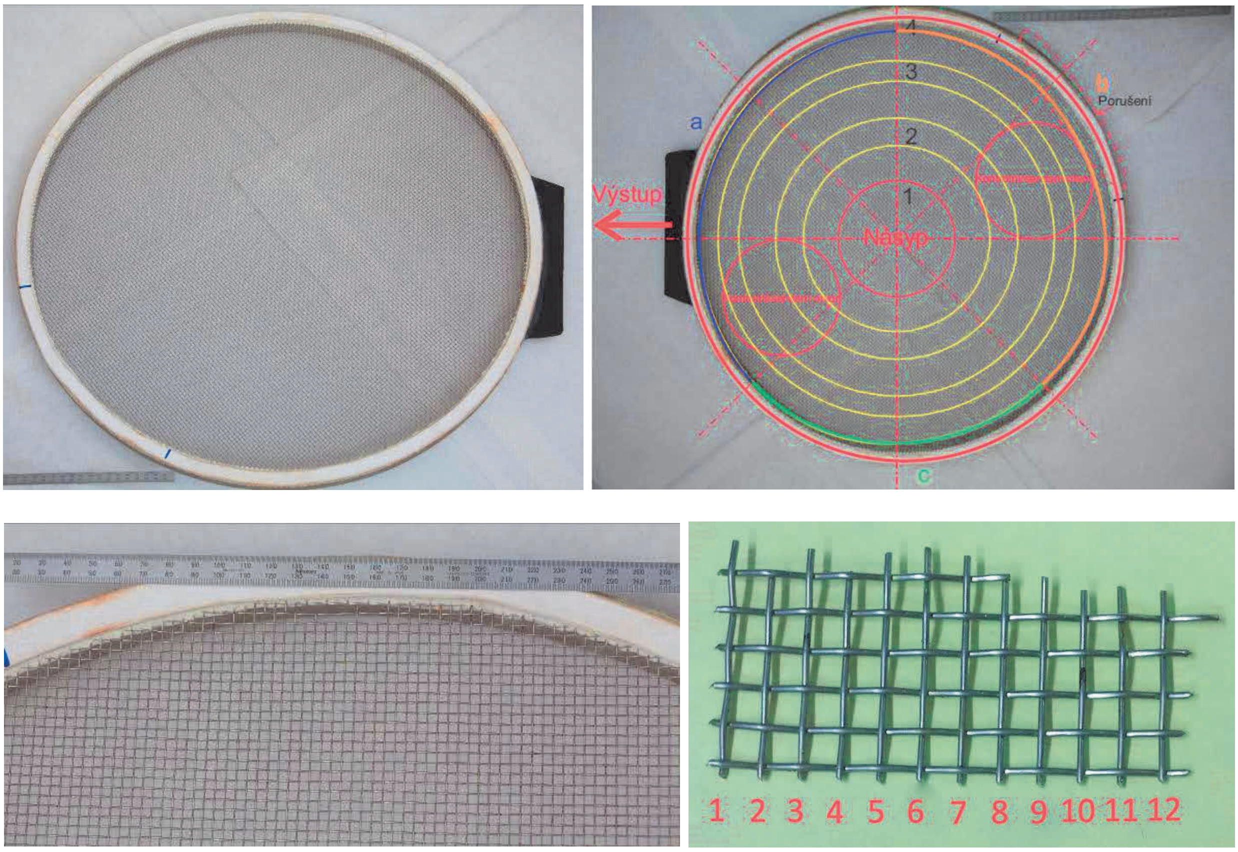

Figure 1 Sieve - the overall view; working scheme; detail of area A; wire numbering

3. RESULTS AND DISCUSSION

From the point of view of the surface, the wire mesh is not smooth, but in addition to the broken wires, no cracks have been found in other places. (**Figures 2** and **3**)

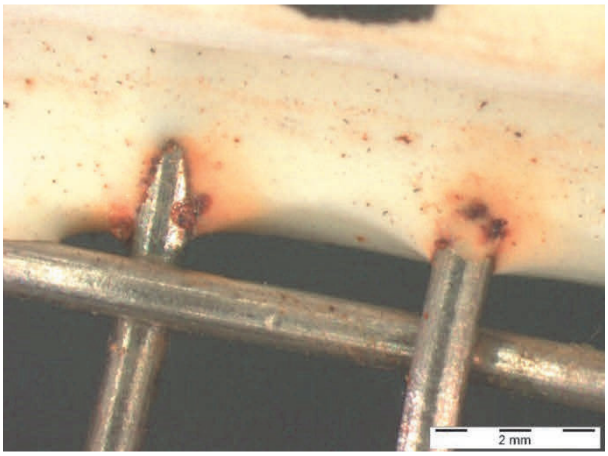

Figure 2 State of wire in area A

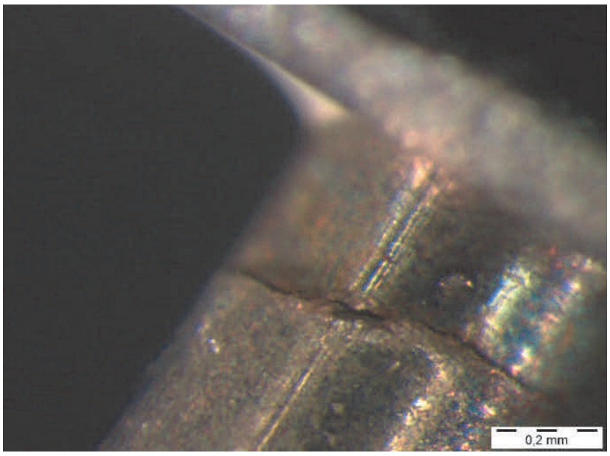

Figure 3 Fracture in area A

3.1. Metalography

For the metallographic analysis of the wire material, which forms the mesh screen, several cuttings were prepared from the area of the input and from the region of the occurrence of fractures - A. The plane of the cuts was oriented in the transverse and longitudinal direction relative to the wire axis. Cracks on the wires No. 1, 4, 6 and 11 (**Figure 1**) were observed by metallography. No cracks on the metallographic cut of fracture surfaces were found (see **Figures 4** and **5**).

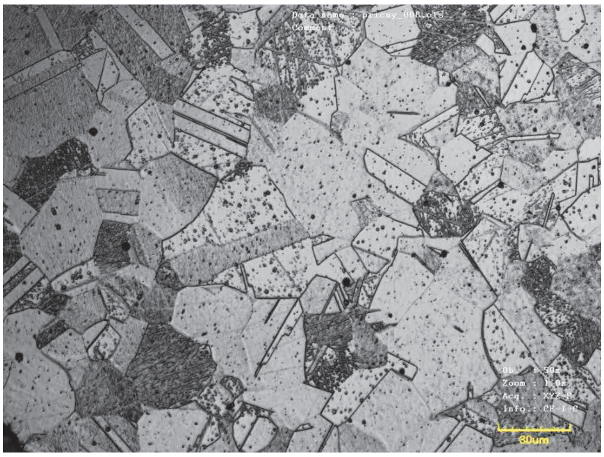

Figure 4 Longitudinal wire cut - microstructure

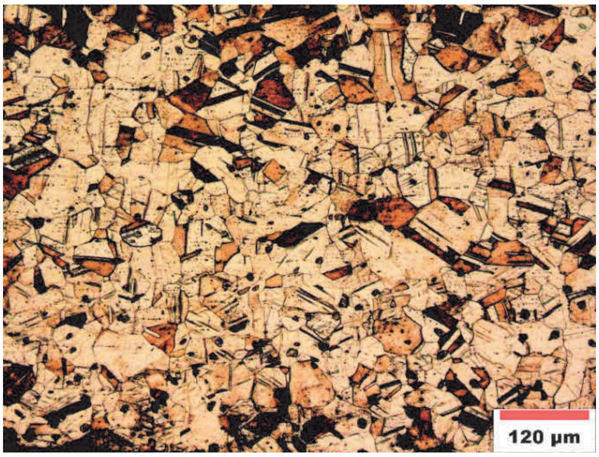

Figure 5 Transversal wire cut - microstructure

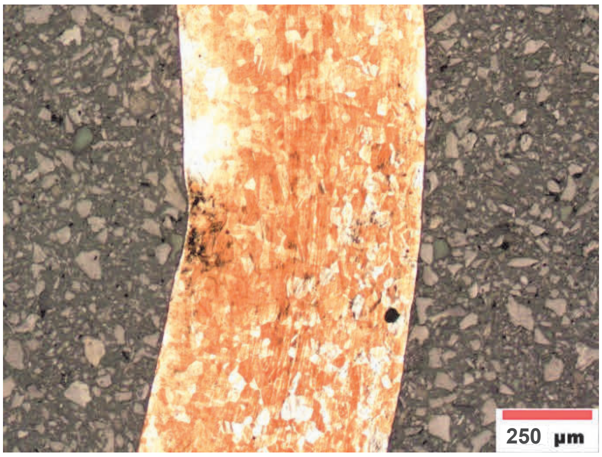

Figure 6 Beraha solution etching - area of bending

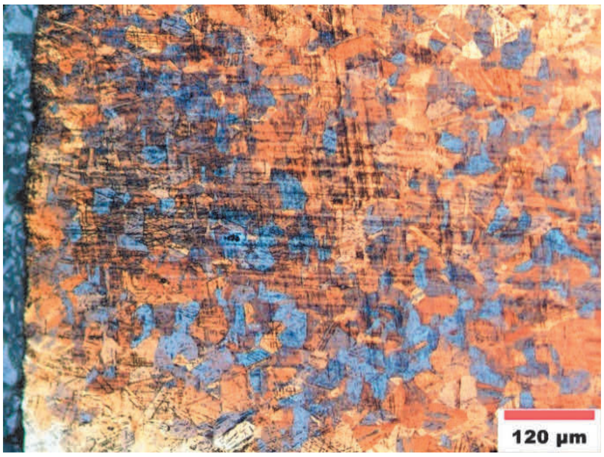

Figure 7 Beraha solution etching - area of fracture

Beraha II (HCl + water + NH4FHF) solution etching showed a microstructure in the wire bending and fracture area in the longitudinal cut [1]. In the bending region (**Figure 6**) of the screen wire, the sloping bands and the origin of the deformation-induced phase transformation were found from the upper and lower sides. This microstructural change was also found in the area of the fracture (see **Figure 7**).

3.2. Fractography

A portion of the sieve with the occurrence of fractures was separated from area A. Extremely worn fracture surfaces were excluded from further fractographic analysis and were used in metallographic analyses. Specifically, fractures No. 1, 4, 6 and 11 were numbered according to **Figure 1**. On the most preserved fracture areas - no. 5, 7, 10 and 12 have been found in the progress lines, the striations typical for fatigue failure (see **Figure 8**). The failure initiation is located on the top, hopper side of the screen. The exception is fracture No. 8, where a technological notch was found on the underside (wire perimeter of the sieved sieve outlet). At fracture 9, the fracture area is damaged by scratching, the determination of the initiation site is problematic, it is not possible to exclude the initiation and the procedure of the crack from the opposite surfaces (through the diameter of the wire) from the macroscopic view.

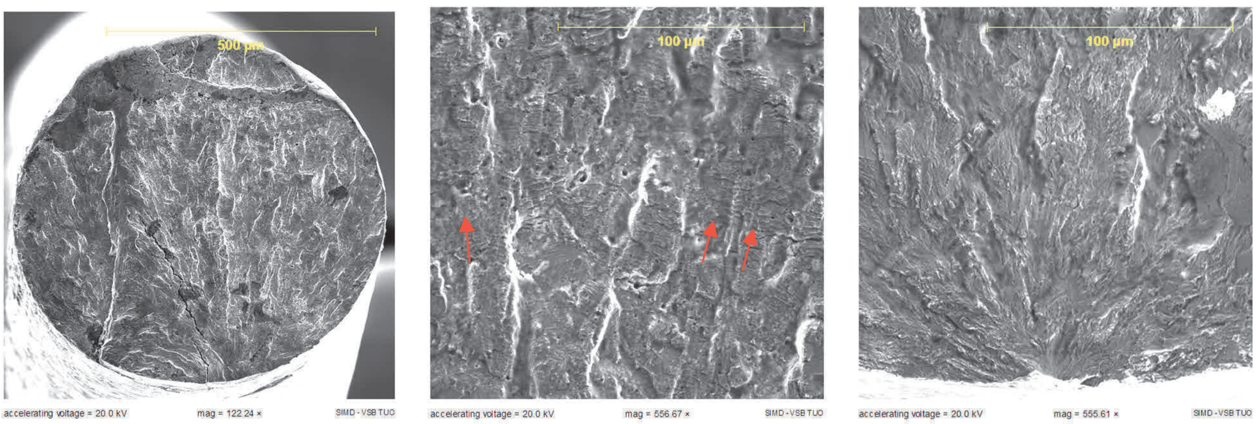

Figure 8 Fracture surface No. 7: Global view; striations; initiation

The initiation of the fractures No. 2, 5, 7, 10, 12 occurred on the upper side of the screen; Fracture No. 8 on the underside of the screen - the opposite side. The unequivocal determination of initiation at fractures 3 and 9 is problematic.

3.3. Hardness

The results of the hardness tests for HV0.5 wire are given below in **Table 1**. The hardness was measured on the metallographic cut in the polished state in both longitudinal and transverse directions.

Table 1 Results of hardness measurement

Direction of specimen	Average HV0,5	st. dev.
Transversal	296	43.2
Transversal with fractures	288	10
Longitudinal	241	37.5

The hardness results showed a slightly higher hardness value for fractured wires that indicates the austenitic steel reinforcement mechanism.

3.4. Corrosion Attack

In detail, small corrosion products were visible on the wire surface. It cannot be excluded, that this corrosion damage was partly caused by shutdown of the screen and next storing (**Figure 2**) due to residual contamination of the surface. An elevated temperature of the sift product would contribute to corrosion cracking, but only when critical relative humidity is exceeded. On some fracture areas origins of cracks with a plane perpendicular to the magistral plane were found **(Figure 8**). The influence of the environment could contribute to shortening the initiation and propagation rates, but the driving factor is the fatigue stress of the wire and the lower structural stability of the steel.

3.5. Chemical Analysis

Chemical analysis was carried out by decomposition on a wet way using 41g wire sieves. The results are shown in **Table 2**.

Table 2 Chemical composition analysis

	Element	Co	Cr	Cu	Mn	Ni	Si	P	Pb	V	Zn	Mo	Ti	C	S	N
Analysis	**wt. %**	0.082	17	0.26	1.07	7.81	0.46	0.048	<0.01	0.085	0.004	0.1	0.004	0.1	0.01	0.0687
AISI 304		-	18-20	-	max 2	8-10.5	max 1	max 0.045	-	-	-	-	-	max 0.08	max 0.03	-

From the viewpoint of the results of the chemical composition analysis, for the AISI 304 steel is unsuitable for a higher content of C, P, and a low Ni content. The steel was in the limit state of stability γ - phase (austenite), which resulted in reduced structural stability expressed by criteria M_S = 152.2 °C, M_{d30} = - 4.9 °C.

4. CONCLUSION

Due to the occurrence of progressive lines (striations) on the fracture surfaces, it can be stated that in the initiation phase there was active fatigue damage.

This fact supports the use of a 3000 rpm vibrator. Instead of 1500 rpm, which are a doubling of the stress frequency. The deformation properties of AISI 304 steel are controlled by the combined effect of deformation hardening of the austenitic phase and the formation of deformation-induced martensite. The martensitic phase transformation affects the plastic properties of AISI 304 steel. The martensitic phase increases the hardening of the material. Due to the brittleness of martensite, it reduces the fracture toughness of the steel.

The influence of the environment could contribute to shortening the initiation and propagation rates, but the driving factor is the fatigue stress of the wire and the lower structural stability of the steel. The operated screen, with the magnesium chloride support medium, is so critically stressed that local sieving of the screen wire and consequent fatigue failure occurs.

ACKNOWLEDGEMENTS

This paper was prepared with a contribution of the projects "SP2018/70 Study of relationships between the technology and processing of advanced materials, their structural characteristics and utility properties" and "SP2018/60 Specific research in the metallurgical, materials and process engineering".

This paper was created in the Project LTI17023 "Energy Research and Development Information Centre of the Czech Republic" funded by Ministry of Education, Youth and Sports of the Czech Republic, program INTER-EXCELLENCE, subprogram INTER-INFORM.

REFERENCES

[1] BRITZ, D., HEGETSCHWEILER, A., ROBERTS, M. and MÜCKLICH, F. Reproducible Surface Contrasting and Orientation Correlation of Low-Carbon Steels by Time-Resolved Beraha Color Etching. *Materials Performance and Characterization,* 2016, vol. 5, no. 5, pp. 553-563.

[2] NIKITIN, I. and JUIJERM, P. Effects of Loading Frequency on Fatigue Behavior, Residual Stress, and Microstructure of Deep-Rolled Stainless Steel AISI 304 at Elevated Temperatures. *Metall. and Mat. Trans A.*, 2018, vol. 49, no. 5, pp. 1592-1597.

[3] YAN, X. et al. Chloride-Induced Stress Corrosion Cracking of Oxide-Dispersion-Strengthened Austenitic Steels, *Corrosion,* 2018, vol. 74, no. 4, pp. 424-429.

[4] SEE, K. A., LIU Y.M., HA, Y., BARILE, CH. J. and GEWIRTH, A.A. Effect of Concentration on the Electrochemistry and Speciation of the Magnesium Aluminum Chloride Complex Electrolyte Solution. *ACS Appl. Mater. Interfaces,* 2017. vol. 9, no. 41, pp. 35729-35739.

[5] XINJUN, Y., XIANG, L. and JIANXIN, Z. Optimization of the fatigue resistance of AISI304 stainless steel by ultrasonic impact treatment. *International Journal of Fatigue,* 2014, vol. 61, no. 4, pp. 30-38.

[6] FAN, N et al. Effect of displacement amplitude on fretting wear of 304 stainless steel in air and sea water. *Lubrication science,* 2014, vol. 30, no. 3, pp. 116-125.

[7] BENSAADA, F., ANTAR, Z., ELLEUCH, K. and PONTHIAUX, P. On the tribocorrosion behavior of 304L stainless steel in olive pomace/tap water filtrate. *Wear,* 2015, vol.328-329, 15 April 2015, Pages 509-517.

[8] LANDOLT, D. *Corrosion and surface chemistry of metals*, 1st ed. Lausanne: EPFL Press, 2007. 251 p.

[9] ČÍHAL, V. *Stainless Steel and Alloys* (In Czech). 1st ed. Praha: Academia, 1999. 384 p.