MATERIAL SECURITY OF LOW CARBON WIRE SUPPLY CHAINS IN THE CZECH REPUBLIC IN SELECTED FIELDS OF METALLURGICAL PRODUCTION

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Abstract

The article deals with the issue of technological thinking in the process of material security of supply chains of a selected group of products in the field of metallurgical secondary production. The commercial potential of this distribution, redistribution of low-carbon wire products and low-carbon materials from metallurgical secondary production, which is redistributed over long distances from the place of production to the place of consumption with the necessary requirements to control incoming materials into production and subsequent final processing. The research performed on the material of the thus redistributed selected sample showed partial differences in the deviations of the given declared values and thus an inaccurate interpretation of the accompanying data to the materials. The authors prove the fact on the given example of analysis of delivered redistribution samples.

Keywords: Low-carbon wire, material safety, input material properties, steel, economic thinking

1. INTRODUCTION

Material safety in the supply chains of low-carbon wire in the Czech Republic across selected operations in secondary metallurgical production has certain drawbacks which are in need of attention. The distribution and redistribution of products using low-carbon wire and low carbon materials in metallurgical secondary production and additional redistribution over long distances from the place of production to the place of consumption results in certain commercial conditions. These conditions include checking the materials before entry into production and during final processing at processing operations and assessing the risks of material safety.

The aim of the paper is to raise attention to the research findings on material safety in low-carbon wire and low-carbon material supply chains in selected operations of secondary metallurgical production in the Czech Republic.

2. LOW-CARBON WIRE MATERIAL SAFETY ISSUES

The material safety issues of low-carbon wire in the Czech Republic highlight important requirements in checking materials entering production and during final processing at processing operations. These issues are a result of the disconnection between unified technological processes governing the long-distance transportation of materials. Research compiled on selected samples of redistributed materials reveals partial differences in declared values, and hence, inconsistent interpretation of the accompanying data on the supplied materials. If these materials are used, material safety could be compromised. An example analysis was conducted on supplied redistribution samples.

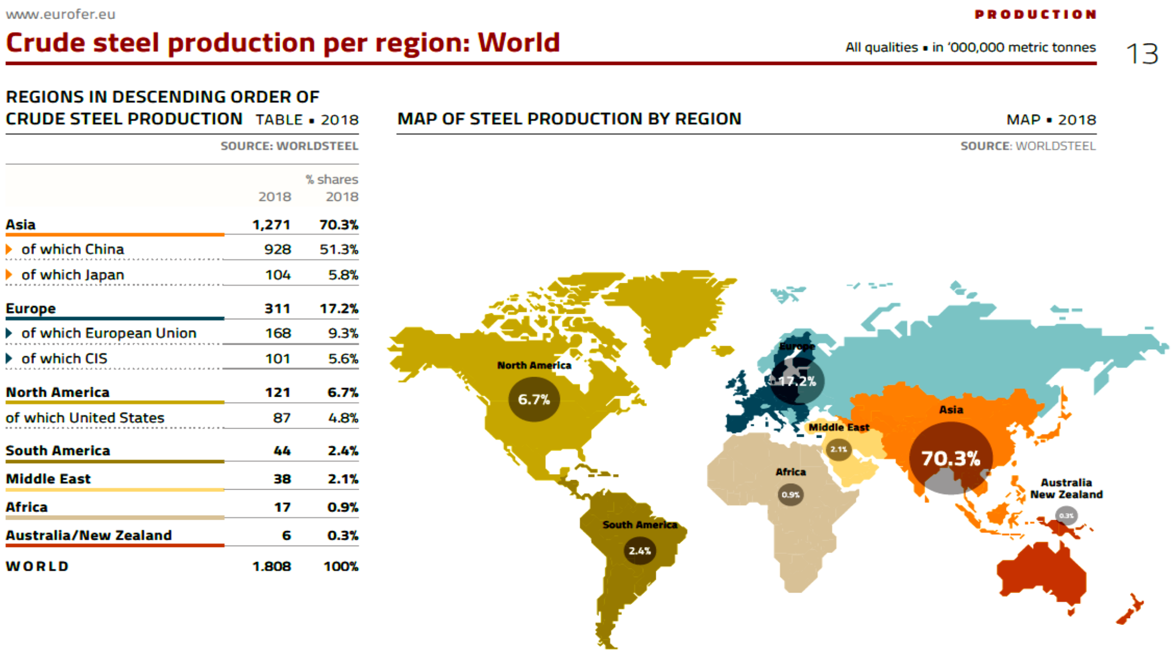
Low-carbon wire and low-carbon materials are used in many operations, such as food production, medicine, defence, and other industries. Many machine parts are constructed from foreign products that use low-carbon steel, and as a result of low quality, the given products are prone to breakdown. In normal operation, these products may cause production downtime that extends to days due to the complexity in servicing and supplying the part or material.

Low-carbon steel with micro-additions of boron has good ductility and deformability and can be used in place of low-carbon rimming steels [1,2]. A few information is available regarding the structure and properties of moderate-carbon steel wire, such as steel 50 wire, after such deformation [3].

2.1. Global steel production

The Czech steel industry is currently facing protectionism issues and attacks on free trade, US tariffs on steel produced in the EU and other countries, and millions of tonnes of steel being diverted from third world countries to the open European market. According to the pages of the STEEL UNION, 1.7 mil. tonnes of crude steel were produced in 2018 in the Czech Republic by April, and exports in the first quarter of 2018 totalled 2 mil. tonnes, the highest in the country's history. Imports from third world countries also reached their highest levels, totalling 40 mil. tonnes across the EU [4-7]. This makes the EU the world's largest importer of steel [8]. European steel in the figures from the STEEL UNION [9] website shows a clear threat from growing imports, which increased by 12 % over 2018 (see **Figures 1 and 2**).

A significant issue concerns rolled and drawn wire. Wire production is a rising trend, but as a result of a disconnected technology supply chain, orders are being placed with third countries. South Africa has the highest intensity of impact in iron mining on unit GDP (4.35E-4 TNI / US $) and Canada has the highest intensity in steel production (5.81E-3 TNI / US $) [10].



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PRODUCTION

Crude steel production per region: World

All qualities • in '000,000 metric tonnes

13

REGIONS IN DESCENDING ORDER OF CRUDE STEEL PRODUCTION TABLE • 2018

SOURCE: WORLDSTEEL

	2018	% shares 2018
Asia	1,271	70.3%
of which China	928	51.3%
of which Japan	104	5.8%
Europe	311	17.2%
of which European Union	168	9.3%
of which CIS	101	5.6%
North America	121	6.7%
of which United States	87	4.8%
South America	44	2.4%
Middle East	38	2.1%
Africa	17	0.9%
Australia/New Zealand	6	0.3%
WORLD	1.808	100%

MAP OF STEEL PRODUCTION BY REGION

MAP • 2018

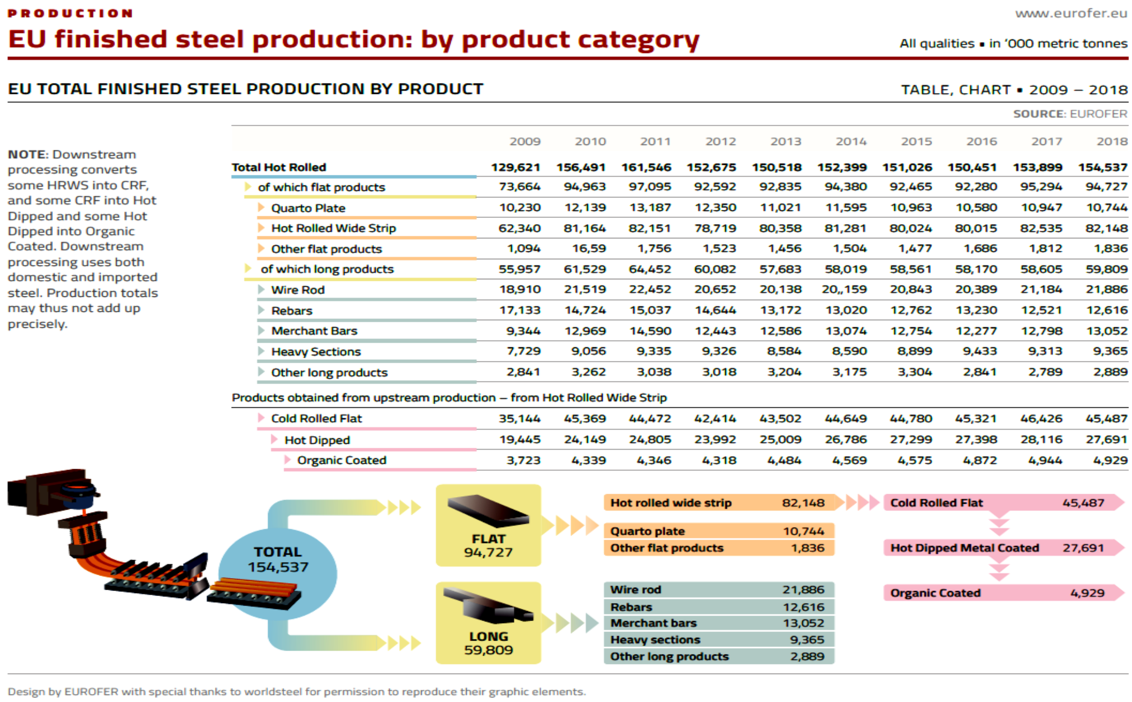
SOURCE: WORLDSTEEL

Figure 1 Statistics from EUROFER and the Steel Union [1,4]

2.2. Findings

Consequences of low-carbon steel production trends in connection with distribution:

- Disconnection of the production and supply chain of low-carbon steel depends on the ordering system and amount of production required.
- Economic motivation for production and demand.
- Coverage and interconnection of IT processes between demand, production and economic spheres.



PRODUCTION

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EU finished steel production: by product category

All qualities ▪ in '000 metric tonnes

EU TOTAL FINISHED STEEL PRODUCTION BY PRODUCT

TABLE, CHART ▪ 2009 – 2018

SOURCE: EUROFER

NOTE: Downstream processing converts some HRWS into CRF, and some CRF into Hot Dipped and some Hot Dipped into Organic Coated. Downstream processing uses both domestic and imported steel. Production totals may thus not add up precisely.

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Total Hot Rolled	**129,621**	**156,491**	**161,546**	**152,675**	**150,518**	**152,399**	**151,026**	**150,451**	**153,899**	**154,537**
of which flat products	73,664	94,963	97,095	92,592	92,835	94,380	92,465	92,280	95,294	94,727
Quarto Plate	10,230	12,139	13,187	12,350	11,021	11,595	10,963	10,580	10,947	10,744
Hot Rolled Wide Strip	62,340	81,164	82,151	78,719	80,358	81,281	80,024	80,015	82,535	82,148
Other flat products	1,094	16,59	1,756	1,523	1,456	1,504	1,477	1,686	1,812	1,836
of which long products	55,957	61,529	64,452	60,082	57,683	58,019	58,561	58,170	58,605	59,809
Wire Rod	18,910	21,519	22,452	20,652	20,138	20,,159	20,843	20,389	21,184	21,886
Rebars	17,133	14,724	15,037	14,644	13,172	13,020	12,762	13,230	12,521	12,616
Merchant Bars	9,344	12,969	14,590	12,443	12,586	13,074	12,754	12,277	12,798	13,052
Heavy Sections	7,729	9,056	9,335	9,326	8,584	8,590	8,899	9,433	9,313	9,365
Other long products	2,841	3,262	3,038	3,018	3,204	3,175	3,304	2,841	2,789	2,889
Products obtained from upstream production – from Hot Rolled Wide Strip										
Cold Rolled Flat	35,144	45,369	44,472	42,414	43,502	44,649	44,780	45,321	46,426	45,487
Hot Dipped	19,445	24,149	24,805	23,992	25,009	26,786	27,299	27,398	28,116	27,691
Organic Coated	3,723	4,339	4,346	4,318	4,484	4,569	4,575	4,872	4,944	4,929

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Figure 2 Statistics from EUROFER and the Steel Union [1,4]

3. DIAGNOSTICS OF LOW-CARBON STEEL SAMPLE MATERIALS

Research diagnostics were performed on two sheet metal items (15260 steel) subjected to burst tests. Already then, it became evident that a small series order of materials is a time-consuming process for suppliers to deliver. The nominal composition of the steel is shown in **Table 1.**

Many different metals and alloys can be used to produce different types of equipment that are part of a chemical process [11].

Table 1 Nominal chemical composition of 15260 steel (wt%) [3]

Steel	C	Mn	Si	Cr	V	Ni	P	S
15260	0.47–.55	0.70–1.00	0.15–0.40	0.90–1.20	0.10–0.20	max. 0.3	max. 0.035	max. 0.035

Six SEM analyses of the fracture surface area were performed on six samples after a tensile test to determine the differences between the three series of samples and the chemical analysis of the OES (**Tables 2 and 3**). The chemical representation of the items corresponds to the standard ČSN 41 5260 for the material 15260 Mn-Cr-V Steel (**Table 2**).

Table 2 Results of the optical emission spectrometry (OES) analysis of samples (wt%)

Sample	C	Si	Mn	P	S	Cr	Ni	Mo	Al	Cu	Co	Ti	Nb
Sheet	0.54	0.218	0.79	0.015	0.0071	1.01	0.053	0.0097	0.027	0.013	0.018	0.0036	<0.004
C2	0.54	0.231	0.82	0.017	0.0072	1.02	0.057	0.011	0.032	0.014	0.020	0.0046	<0.004

Sample	V	W	Pb	Mg	B	Sn	Zn	As	Bi	Ca	Zr	Fe
Sheet	0.108	<0.001	<0.003	0.002	0.0009	0.0052	<0.002	0.006	0.0077	0.0024	<0.003	97.2
C2	0.109	<0.001	<0.003	0.0019	0.0012	0.0052	<0.002	0.0076	0.0094	0.0027	0.0035	97.1

Table 3 Tensile test results and 15260 steel sheet hardness

Sample	$R_{p\,0.2}$ (MPa)	R_m (MPa)	Hardness HRC
A1	1807	1908	49.2
A2	1810	1941	49.6
A3	1806	1901	49.8
B1	1577	1643	44.0
B2	1552	1599	45.3
B3	1568	1619	44.4
C1	1536	1638	44.9
C2	1566	1657	45.4
C3	1557	1624	45.4

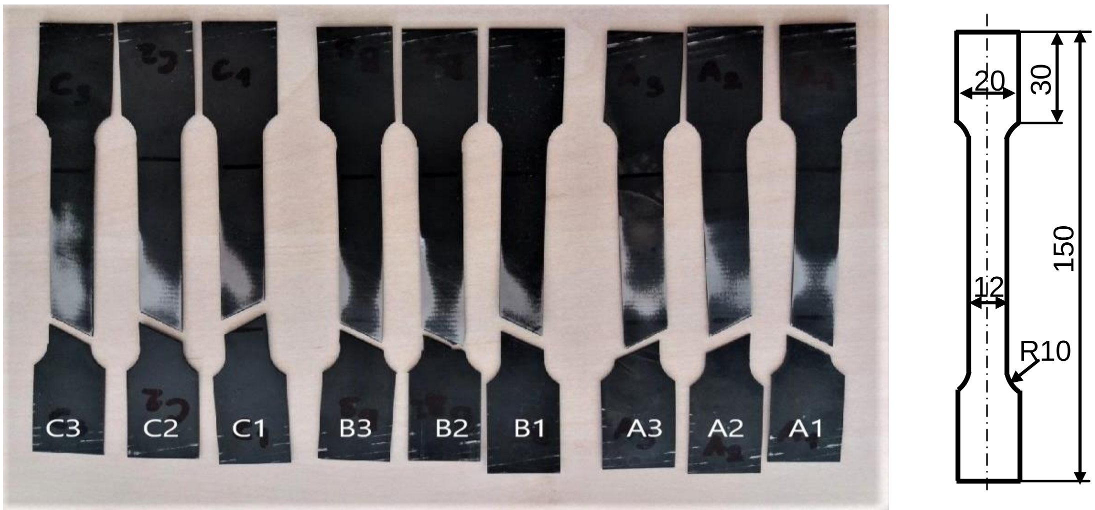
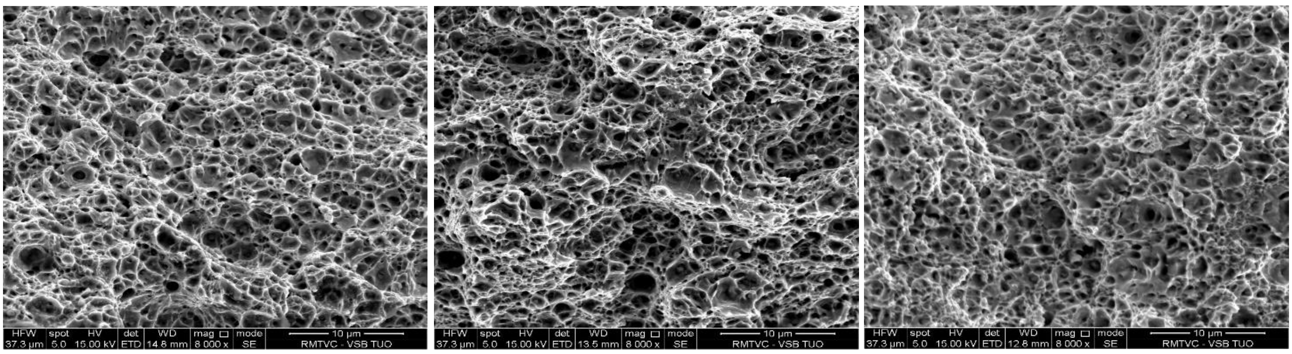


Figure 3 Burst test control samples

Samples A, B and C in **Figure 3** show the same black finish, with the following differences:

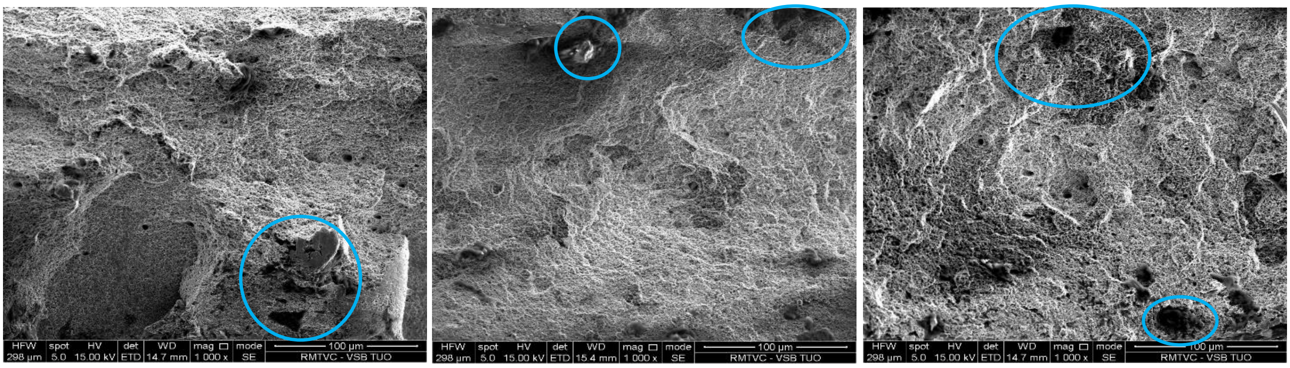
- Sample A was hardened to 54 ± 2 HRC.
- Samples B and C were hardened to 49 ± 2 HRC.
- Sample C had also been blasted; the shift in yield strength was not verified.



a) Sample A3 b) Sample B3 c) Sample C3

Figure 4 SEM images of the fracture surface areas after tensile tests

The images of SEM analysis of the fracture surface areas after tensile tests shown in **Figure 4** indicate the following: the fracture surfaces of all documented samples correspond to transcrystalline ductile fractures with dimple morphology. The size of the dimples appears to be essentially the same in all samples. No morphology differences were observed between the type A samples with a higher HRC hardness and the type B and C samples. To a small extent, some samples also had larger dimples where coarser non-metallic inclusions were observed (**Figure 5**). At low magnification, relatively coarse non-metallic inclusions were observed on the fracture surfaces of the samples. These inclusions can lead to premature failure of the material during tensile tests.



a) Sample A3 b) Sample C2 c) Sample C3

Figure 5 SEM images of the fracture surface areas with non-metallic inclusions

The quarry was non-standard. There was a failure of the material outside the middle part without plastic deformation, which indicates that the material is quite hard and premature fracture can be affected by the inclusions present, as demonstrated by detailed SEM analysis. The fact that in practically all cases the line of destruction is oblique may be related to the rolling direction of the supplied sheet.

3.1. Results

Researching and inspecting the materials produced by third parties and subsequently supplied by Czech subcontractors due to demand for small quantities of small parts and component production leads to an increase in input checks. Consequential factors affecting purchasing from third countries:

1) Pressure from the manufacturer on the price of the final product.
2) Pressure on the delivered quantity depending on reductions in production.
3) Disconnection in the production and supply chain over long distances from the place of production to the place of consumption.
4) Resultant and necessary diagnostics in inter-operational inspections to guarantee the final product quality.
5) Higher service costs for warranties and repairs.
6) More time needed for servicing during warranty repairs.
7) More time needed for delivery.
8) Essential document interpretation checks.

The findings on material safety in low-carbon materials and wire supply chains in selected secondary metallurgical production in the Czech Republic highlight the draw backs for competitiveness and require increased attention in companies across the country and the EU. Low-carbon materials introduce a diagnostic point in the process beginning with purchasing up to finalizing production and end use.

4. CONCLUSION

The issue of material safety in low-carbon wire therefore demands attention regarding the technological process of disconnection and long-distance transportation from third countries. A large number of logistical steps and associated handling operations have been created, which have moved analysis of operation control into the area of simulation and virtual reality control and spreadsheet processes.

Currently, this production chain has been interrupted, and Czech subcontractors purchasing from third party producers in China, India, etc, have been supplying customers with low quantities in unknown and inconsistent quality. However, the Czech Republic has its own capability to produce low-carbon quality wire, low-carbon steel according to customer requirements, but due to the effects illustrated in the above-mentioned findings, Czech manufacturers are seeing lower demand.

In the 15260 steel sample, the chemical composition was in accordance with the ČSN 41 5260 standard. The character of the fractures after tensile tests was standard for the material given its previous hardening heat treatment. In all probability, the failure of material during the tensile test was caused by internal inclusions of non-metallic origin.

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REFERENCES

[1] YALAMANCHILI, B., NELSON, J., POWER, P., LANHAM, D. North Star Steel Texas' experience with boron additions to low-carbon steel. *Wire Journal International.* 2001, no. 11, pp. 90-94.

[2] FRANK, A. R., KIRKCALDY, A. The effect of boron on the properties of electric-arc-sourced plain carbon wire – drawing qualities. *Wire Journal International.* 1998, no. 5, pp. 100-103.

[3] POLYAKOVA, M., CALLIARI, I., GULIN, A. Effect of microstructure and mechanical properties formation of medium carbon steel wire through continuous combined deformation. *Key Engineering Materials*. 2020, vol. 716, pp. 201-207.

[4] STEEL UNION. *Statistics, Referencing Guide* [online]. [viewed. 2020-05-13]. Available from: https://www.ocelarskaunie.cz/ocelarstvi/statistiky/.

[5] STEEL UNION. *Steel products of our members. Referencing Guide* [online]. [viewed. 2020-05-13]. Available from: https://www.ocelarskaunie.cz/ocelove-vyrobky-nasich-clenu/.

[6] CZECH STANDARDIZATION AGENCY. *Online for individuals*. *Referencing Guide* [online]. [viewed. 2020-05-13]. Available from: https://csnonline.agentura-cas.cz/Vysledky.aspx.

[7] EUROFER. *Annual Report 2019*. *Referencing Guide* [online]. [viewed. 2020-05-13]. Available from: http://www.eurofer.org/News%26Events/PublicationsLinksList/201907-AnnualReport.pdf.

[8] STEEL UNION. *Import of steel to the Czech Republic and Europeatanall-timehigh. Referencing Guide* [online]. [viewed. 2020-05-13]. Available from: https://www.ocelarskaunie.cz/dovoz-oceli-do-cr-a-evropy-na-historickem-maximu/.

[9] STEEL UNION. *European steel in numbers 2019. Referencing Guide* [online]. [viewed. 2020-05-13]. Available from: https://www.ocelarskaunie.cz/evropska-ocel-v-cislech-2019/.

[10] TAIT, W.S. Corrosion prevention and control of chemical processing equipment. In *Handbook of Environmental Degradation of Materials*. William Andrew Publishing, 2005, pp. 565-581.

[11] LIU, Y., LI, H., HUANG, S., AN, H., SANTAGATA, R., ULGIATI, S. Environmental and economic-related impact assessment of iron and steel production. A call for shared responsibility in global trade. *Journal of Cleaner Production.* 2020, vol. 269, paper no. 122239.