

Recenzované vědecké články

Possibilities of Controlled Reduction of Chromium from the High-chromium Slag in Production of Steels

Možnosti řízené redukce chromu z vysoce chromové strusky při výrobě ocelí

doc. Ing. Petr Jonšta, Ph.D.[1]; **Ing. Zdeněk Carbol**[1]; **prof. Ing. Jiří Bažan, CSc.**[2]; **doc. Ing. Ladislav Socha, Ph.D.**[2]; **prof. Ing. Zdeněk Adolf, CSc.**[2]; **Ing. František Chowaniec, Ph.D.**[2]; **Ing. Michal Sušovský**[1]; **Ing. Vladislav Kurka, Ph.D.**[3]; **Ing. Oldřich Salva, Ph.D.**[2]

[1] VÍTKOVICE HEAVY MACHINERY a.s., Ruská 2887/101, 706 02 Ostrava-Vítkovice, Czech Republic
[2] VŠB – Technical University of Ostrava, Faculty of Metallurgy and Materials Engineering, Department of Metallurgy and Foundry, 17. listopadu 15/2172, 708 33 Ostrava-Poruba, Czech Republic
[3] MATERIÁLOVÝ A METALURGICKÝ VÝZKUM s.r.o., Pohraniční 693/31, 703 00 Ostrava-Vítkovice, Czech Republic

This text presents possibilities of controlled reduction from high-chromium slag under operating conditions in EAF in the production of high-chromium steels. A proper proposal of the operational technology results from theoretical knowledge of reduction of chromium oxides from slag using different reduction agents, and from the method of application and modification of the melting technology in the production of high-chromium steels in EAF. The above mentioned theoretical knowledge was completed by the results of the study of Cr_2O_3 reduction from slag into steel under laboratory conditions using different reduction agents and methods of application. On the basis of theoretical knowledge and results of the laboratory experiments the technology for conditions of the EAF No. 5 of VÍTKOVICE HEAVY MACHINERY a.s. was proposed. Within the above-mentioned technology, a prototype of the slag controlled reduction device will be used that enables dosing of the reduction agent onto the slag surface in order to reach high-chromium slag controlled reduction.

***Key words**: reduction; chromium slags; alloy steels; laboratory experiments; operational experiments*

V předloženém příspěvku jsou uvedeny možnosti řízené redukce chromu z vysoce chromové strusky v provozních podmínkách na EOP při výrobě vysoce chromových ocelí. Vlastní návrh provozní technologie vychází z teoretických poznatků redukce oxidů chromu ze strusky při použití různých redukčních činidel, způsobu aplikace a úpravy technologie tavení při výrobě vysoce chromových ocelí v EOP. Z výsledků dosažených pomocí laboratorních experimentů bylo zjištěno, že jako nejúčinnější redukční činidlo se v laboratorních podmínkách jeví ferosilicium. Dále bylo prokázáno, že zvýšení teploty z 1600 na 1650 °C mělo pozitivní vliv na účinnost redukce Cr_2O_3 ze strusky. Kromě zvýšení teploty se i zvýšení teoretického množství redukčního činidla spolu s prodloužením doby redukce z 300 na 600 s pozitivně projevilo na účinnosti redukce. Při teplotě 1650 °C a použití ferosilicia bylo dosaženo účinnosti redukce Cr_2O_3 až 68,7 %. Lze také předpokládat, že se vzrůstem obsahu Cr_2O_3 se může projevit vyšší viskozita strusky spojená s tvorbou krusty, která snižuje redukční účinnost. Tento předpoklad bude ověřen následující sérií experimentů. Na základě teoretických poznatků a výsledků laboratorních experimentů byla navržena technologie pro podmínky EOP č. 5 podniku VÍTKOVICE HEAVY MACHINERY a.s. V rámci uvedené technologie bude využit prototyp zařízení pro řízenou redukci strusky umožňující dávkování redukčního činidla na hladinu strusky pro dosažení řízené redukce vysoce chromové strusky. Z výsledků dosažených pomocí provozních experimentů bylo zjištěno, že z hlediska pořízeného prototypu dmýchacího zařízení dopadl provozní experiment pozitivně. Dávkování granulovaných redukčních činidel antracitu a ferosilicia proběhlo v souladu s teoretickými požadavky. Drobné známky poškození (žáruvzdorný materiál, manipulační oko) vykazovala v důsledku působení vysoké teploty v EOP samotná dmýchací tryska. Je však potřeba přihlédnout ke skutečnosti, že se jedná o prototyp zařízení a ne trvalé řešení pro EOP. Z pohledu metalurgického je však nutno připustit, že především z důvodu málo tekuté vysoce chromové strusky došlo ke snížení obsahu Cr_2O_3 jeho redukcí na obsah 11,80 hm. %. Pro dosažení uspokojivějšího výsledku bude vhodné experiment zopakovat, avšak předpokladem je zajistit výrazně vyšší tekutost strusky. Cílem výzkumu bylo navržení a odzkoušení prototypu zařízení pro řízenou redukci strusky s vysokým obsahem oxidů chromu a nastavení druhu, množství a způsobu dávkování redukčního činidla na hladinu strusky. Tímto způsobem došlo ke snížení energetické a ekonomické náročnosti výroby vysoce chromových ocelí, zvýšení konkurenceschopnosti strojírenské společnosti na

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trhu a také posílení vědecko-výzkumné spolupráce výrobního podniku s výzkumnými pracovišti na VŠB-TU Ostrava a ve společnosti MATERIÁLOVÝ A METALURGICKÝ VÝZKUM s.r.o.

Klíčová slova*: redukce strusky; chromové strusky; legované oceli; laboratorní experimenty; provozní experimenty*

In the production of high-chromium steels in EAF, during the course of melting of a steel charge containing chromium, a loss of chromium is being occurred as a result of oxidation by its transition to slag. Primary losses have been already occurring in the course of melting of the charge in EAF, but the main part of the losses of chromium from the melt took place within the oxidation period, during which oxygen was blown with the aim of provision of basic purifying reactions and decarburization of the melt. Effective chromium oxides reduction from slag in the production of high-chromium steels depends on the selection of a suitable reduction agent and on the applied reduction technology. However, selection of a reduction agent also depends on equipment and technological possibilities of the operated EAF [1, 2].

1. Reduction of chromium oxides from slag in the production of high-chromium steels

The applied technology and a suitable reduction agent should provide a wide degree of reduction of chromium oxides from slag in the production of high-chromium steels in EAF. Among others, the following reduction agents were used: silica, carbon and calcium carbide. Several technologies were developed and applied under operating conditions, nevertheless, for efficient reduction of chromium losses in the melt, it is necessary to minimize the losses as early as during the melting period and especially during the oxidation period.

On the basis of theoretical knowledge [3 – 6], there were found out the following steps for provision of controlled reduction of chromium oxides in slag or a check of the chromium content in the melt in the production of steel in EAF. Silica reduces a degree of chromium oxidation at low temperatures, which can be used during charge melting. During the next oxidation period, reduction of chromium oxides by silica in the melt takes place. Reduction of chromium oxides by silica runs according to the following chemical reaction (1):

$$2(Cr_2O_3) + 3Si_{(s)} = 4[Cr] + 3(SiO_2) \qquad (1)$$

The result of chromium oxide reduction is represented - in the case of silica and aluminum – by oxides that reduce slag alkalinity, which leads to a necessity of addition of lime and increasing the quantity of slag in EAF.

To limit the extent of chromium oxidation, a technology of blowing carbon into slag is commonly used under plant conditions because it is economically more advantageous than reduction by means of silica or aluminum. Reduction of chromium oxides by means of carbon is realized under operating conditions with help of blowing carbon that reacts with oxides of slag together with the formation of carbon monoxide, which supports the creation of foamy slag. However, for effective reduction of chromium oxide by blowing carbon, the high temperature of slag must be ensured. For this reason, blowing carbon is realized simultaneously with blowing oxygen in the oxidation period. Reduction of chromium oxides by carbon runs according to the following reaction (2):

$$(Cr_2O_3) + 3C_{(s)} = 2[Cr] + 3CO_{(g)} \qquad (2)$$

Besides of the technology that uses silica as a reduction agent or blowing carbon, a technology of blowing calcium carbide is also used. Carbon monoxide reacts with oxides of slag, whereas products of reactions represent chromium, calcium oxide and carbon monoxide. Lime acts as flux supporting the creation of slag. Carbon monoxide improves the creation of foamy slag in comparison with blowing dusty carbon. Reduction of chromium oxides by calcium carbide runs according to the following reaction (3):

$$(Cr_2O_3) + CaC_2 = 2[Cr] + 2CO + (CaO) \qquad (3)$$

Separate reduction agents should be applied under certain conditions, which can be characterized with help of a change of Gibbs free energy depending on temperature for the reaction of chromium oxides with silica, carbon or calcium carbide, as it is shown in Fig. 1.

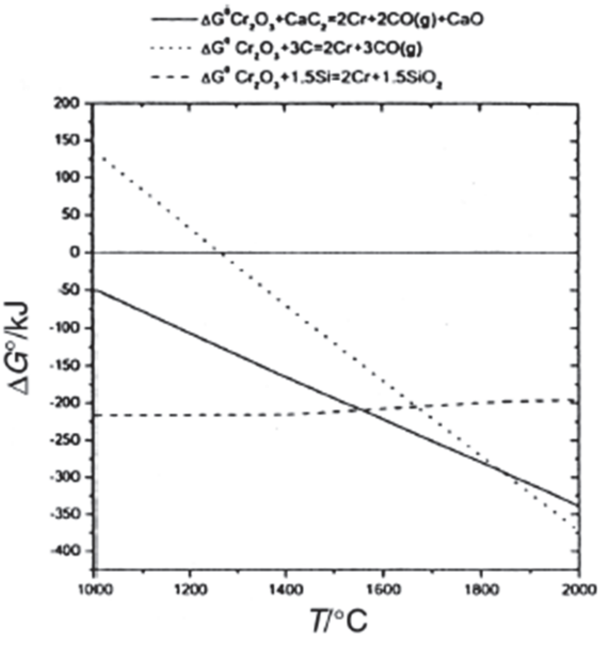

Fig. 1 Temperature dependence of Gibbs free energy for chromium oxides reduction by means of reduction agents

Obr. 1 Teplotní závislost Gibbsovy volné energie pro redukci oxidů chromu pomocí redukčních činidel

What follows from Fig. 1 is that chromium oxides reduction by carbon is more effective at high temperature. In practice, this technology is applied at blowing oxygen during the oxidation period. According to the chromium oxide reduction curve by means of silica, the reaction is not dependent on temperature and it proceeds already at low temperatures. In practice, this reduction agent should be applied already in the course of charge melting in EAF. What also results from Fig. 1 is suitability of application of calcium carbide as a reduction agent according to the achieved lower Gibbs energy values up to the range from 1550 to 1700°C.

2. Laboratory experiments

Before operational experiments, laboratory experiments were performed in order to obtain information for a proposal of technology for production of high-chromium steels under operating conditions [7, 8]. The laboratory experiments were carried out at the application of three different charges representing high-chromium steel containing approx. 9 to 18 wt. % of chromium and slag with a content of approx. 12 to 24 wt. % of Cr_2O_3. The basic chemical composition of used high-chromium steel and slag for laboratory experiments is shown in Tabs. 1 and 2.

Tab. 1 Chemical composition of A, B and C high-alloy steel used for laboratory experiments

Tab. 1 Chemické složení vysoce legované oceli A, B a C použité pro laboratorní experimenty

Type of steel	Steel chemical composition (wt. %)							
	C	**Mn**	**Si**	**P**	**S**	**Cr**	**Ni**	**Mo**
A	0.08	0.48	0.30	0.015	0.002	**8.65**	0.28	0.93
B	0.02	0.62	0.31	0.023	0.003	**12.16**	4.1	0.42
C	0.04	1.57	0.58	0.017	0.003	**17.44**	10.2	0.07

Tab. 2 Chemical composition of A, B and C slag containing Cr_2O_3 used for laboratory experiments

Tab. 2 Chemické složení strusky A, B a C obsahující Cr_2O_3 použité pro laboratorní experimenty

Type of slag	Slag chemical composition (wt. %)							
	CaO	**SiO_2**	**Al_2O_3**	**MnO**	**MgO**	**Cr_2O_3**	**FeO**	**V_2O_5**
A	6.1	21.6	9.0	6.4	×××	**23.9**	×××	0.9
B	8.2	28.6	5.0	3.8	35.7	**11.5**	4.9	0.16
C	18.19	20.42	6.18	3.09	35.2	**17.7**	5.21	×××

Two reduction agents were selected for reduction of slags containing Cr_2O_3: ferrosilicium and anthracite. The chemical composition of both reduction agents is shown in Tab. 3.

Tab. 3 Basic chemical composition of ferrosilicium and anthracite (reduction agent)

Tab. 3 Základní chemické složení ferosilicia a antracitu (redukční činidlo)

Ferrosilicium - chemical composition (wt. %)				
Si	**S**	**P**	**Mn**	**C**
73.5	0.01	0.03	0.28	0.06
Anthracite - chemical composition (wt. %)				
C	**S**	**Humidity**	**Ash**	**Fluidity**
90.08	0.97	5.82	6.80	3.12

In total, 24 relevant melts were realized under laboratory conditions. The laboratory experiments were performed in the following way: firstly, a steel charge in the amount of 200 to 300 g was added. After steel charge, melting-down and tempering to a temperature of 1650°C, a sample of steel was withdrawn. The withdrawn sample served for determination of the initial content of chromium in steel. Consequently, crushed reduced slag containing Cr_2O_3 in the amount of 10 wt. % was added to the weight of steel. 10 wt. % of CaF_2 was added to this slag in order to ensure fluidity of the reduced slag. After 60 seconds of slag addition, a selected reduction agent was added - anthracite or ferrosilicium. Additions of reduction agents were realized in two versions:

- *version I – theoretical quantity providing 100 % of Cr_2O_3 oxides reduction from slag,*
- *version II – doubled theoretical quantity providing reduction of Cr_2O_3 oxides from slag,*

The overall time of reduction agents acting was determined as 600 s. In the course of the experiments, samples of steel were withdrawn for determination of the content of chromium, and that as in the middle of the experiments after 300 s and at the end of the experiment after 600 s. After completion of the experiments, separate samples of steel were analyzed for determination of the efficiency of the reduction course under laboratory conditions.

The assessment of the Cr_2O_3 reduction course from slag to high-chromium steel under laboratory conditions was realized in several parts. First of all, assessment of the course of the increase of the chromium content in steel was performed together with an assessment of the degree of reduction with help of two reduction agents, a change of reduction agents' quantity and temperatures of 1600 and 1650°C. The processed results represent a complex assessment of the degrees of reduction, as shown in Figs. 2 – 4.

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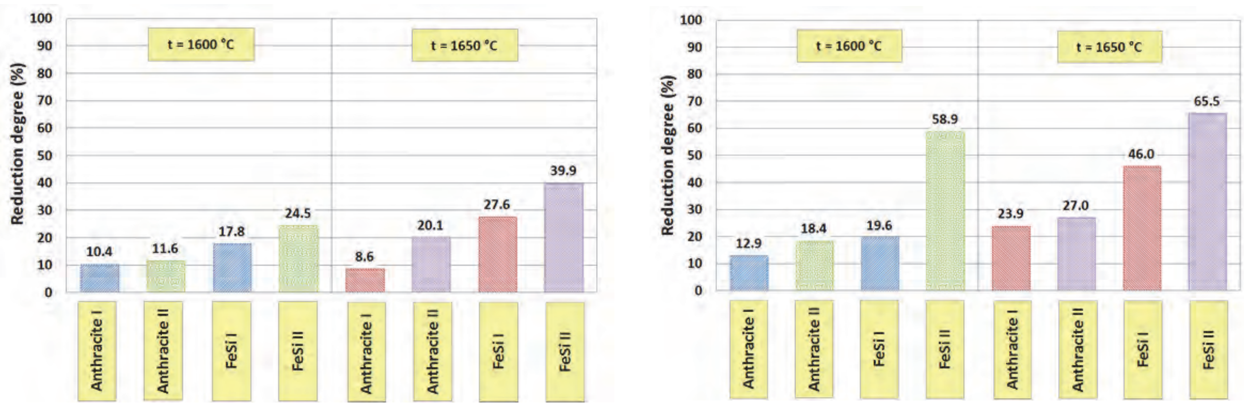
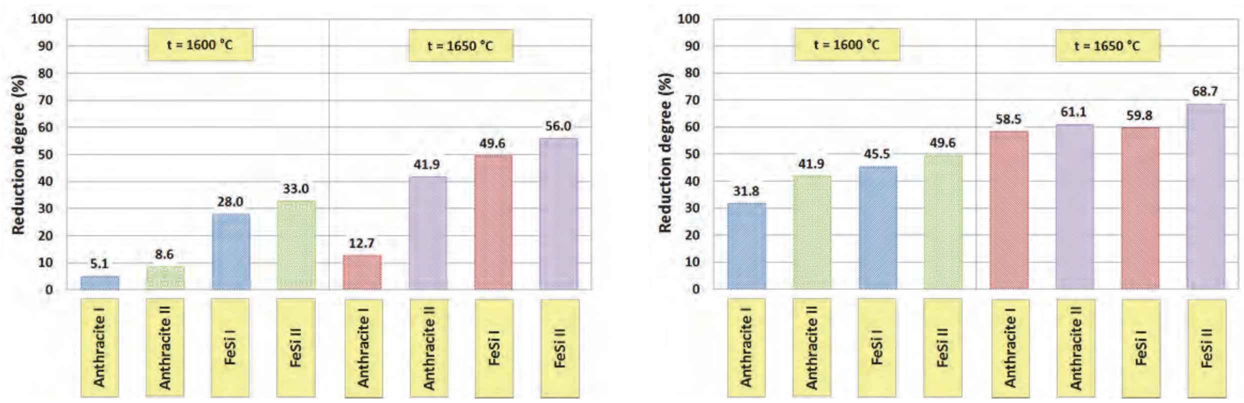


a) time of reduction 300 s *b) time of reduction 600 s*

Fig. 2 Comparison of achieved degrees of Cr_2O_3 oxides reduction while using anthracite and ferrosilicium for steel A

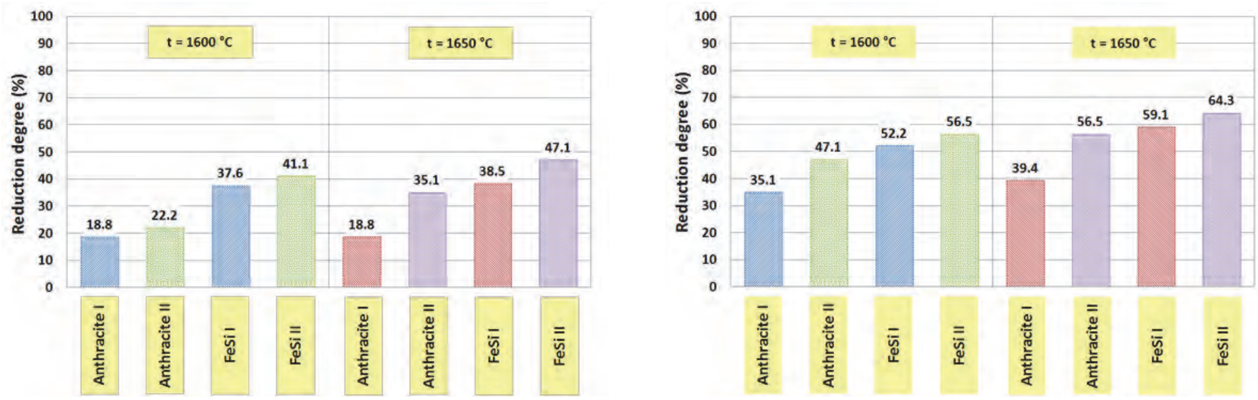
Obr. 2 Porovnání dosažených stupňů redukce oxidů Cr_2O_3 při použití antracitu a ferosilicia pro ocel A



a) time of reduction 300 s *b) time of reduction 600 s*

Fig. 3 Comparison of achieved degrees of Cr_2O_3 oxides reduction while using anthracite and ferrosilicium for steel B

Obr. 3 Porovnání dosažených stupňů redukce oxidů Cr_2O_3 při použití antracitu a ferosilicia pro ocel B



a) time of reduction 300 s *b) time of reduction 600 s*

Fig. 4 Comparison of achieved degrees of Cr_2O_3 oxides reduction while using anthracite and ferrosilicium for steel C

Obr. 4 Porovnání dosažených stupňů redukce oxidů Cr_2O_3 při použití antracitu a ferosilicia pro ocel C

Based on the results achieved by means of the laboratory experiments focused on obtaining information on the course of reduction of Cr_2O_3 from slag for high-chromium steel and increasing the content of chromium in the melt by means of reduction agents, we can state that:

- *more effective reduction agent under laboratory conditions appears to be ferrosilicium,*
- *temperature increase from 1600 to 1650°C positively affected efficiency of Cr_2O_3 reduction from slag,*
- *besides apart from increasing temperature, also increasing the theoretical quantity of reduction agent together with the prolonged time of reaction from 300 to 600 s had a positive effect on the reduction efficiency,*

- *at temperature of 1650°C and while using ferrosilicium, the Cr_2O_3 reduction efficiency up to 68.7 % was achieved.*
- *it can be also assumed that with the growth of the Cr_2O_3 content in slag, a higher slag viscosity may occur related to the creation of the incrustation that decreases the reduction efficiency. This assumption will be verified by the following series of experiments.*

3. Plant experiments

To verify a possibility of chromium reduction from slag melts of high-chromium steels were performed in the electric steelmaking plant of the company VÍTKOVICE HEAVY MACHINERY a.s. Granulated 1 – 3 mm anthracite was applied as a reduction agent for the first experimental melt. For its dosing, RCB burners were used, by which the intensified EAF No. 5 is standardly equipped. The obtained results were published in [9] and they unfortunately showed that the use of the RCB burners for bringing in the granulated reduction is limited.

That's why, for better performance of chromium reduction from slag, in the second experimental melt, a prototype of a blowing unit was used, or nozzles for bringing in the reduction agents, as evidenced by Fig. 5. Production of steel of X2CrNiMo13-4 was carried out with help of the oxidation melting technology with the use of a liquid remnant in the furnace of approx. 14 t. Approximately 37 t of alloyed waste (Cr < 16 wt. %) and approx. 10 t of alloyed cuttings were put into the melt. After scrap-iron melting-down, oxidized slag was created and after achieving temperature of 1642°C, 200 kg of aluminum skim was added to provide liquefaction of slag. Consequently, samples of slag and steel were withdrawn, in which the content of Cr_2O_3 was 21.6 wt. %, respectively 6.74 wt. %.

The proper technical test was carried out during the course of finishing the melt and consisted in verification of a possibility of chromium reduction from slag into the steel bath by blowing granulated (1 – 3 mm) reduction agents, concretely a mixture of anthracite (500 kg) and ferrosilicium of 75 wt. % (500 kg) for a melt. Filling up the pressure vessel with reduction agents is displayed in Fig. 6. Nitrogen was used as carrying medium of the reduction agents. Approximately 6.5 minutes after the agents were blown onto slag, the mixture reacted with the slag for 5 minutes and afterwards samples of slag and steel melt were withdrawn for chemical analyses to assess the effect of the above-mentioned reduction agents. Identical withdrawal was then repeated in three following five-minute intervals. Chemical composition of slag is shown in Tab. 4 and of steel in Tab. 5.

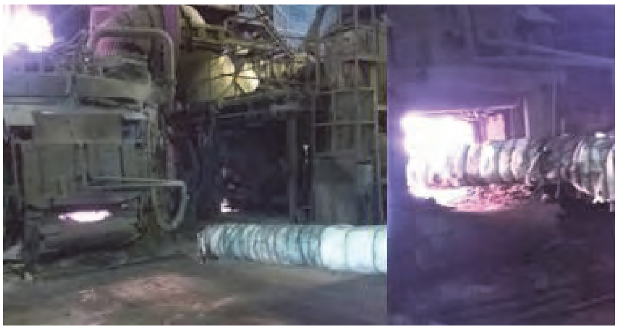


Fig. 5 The nozzle and its putting into the furnace space of EAF No. 5 during the operation test
Obr. 5 Pohled na trysku a její zavádění do pecního prostoru EOP č. 5 při provozní zkoušce

Fig. 6 Filling up the pressure vessel with reduction agents
Obr. 6 Plnění tlakové nádoby redukčními činidly

Tab. 4 Chemical composition of slag in the production of X2CrNiMo13-4 steel
Tab. 4 Chemické složení strusky při výrobě oceli X2CrNiMo13-4

Aggregate	**Sample**	**Slag chemical composition** (wt. %)									
		CaO	**Al_2O_3**	**FeO**	**MnO**	**MgO**	**SiO_2**	**Cr_2O_3**	**P_2O_5**	**S**	**TiO_2**
EAF	1	21.24	15.47	3.186	6.346	6.464	8.245	33.11	0.261	0.0298	0.3988
	2	19.07	11.60	1.7480	6.971	6.523	7.662	44.28	0.276	0.0203	0.371
	3	18.35	11.57	0.8324	7.527	6.483	7.829	47.85	0.289	0.0107	0.3702
	4	14.48	7.401	0.0019	6.837	5.771	6.159	55.35	0.296	0.0103	0.3035
	5	19.60	33.92	2.8490	3.895	6.483	6.664	11.80	0.248	0.0203	0.3737
LF	1	55.82	27.57	0.2526	0.0421	9.009	6.629	0.0972	0.011	0.4482	0.1768
	2	54.88	30.17	0.2806	0.0634	7.892	5.466	0.0915	0.011	0.4462	0.1702

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Tab. 5 Chemical composition of X2CrNiMo13-4 steel
Tab. 5 Chemické složení oceli X2CrNiMo13-4

Aggregate	**Sample**	**Steel chemical composition** (wt. %)											
		C	**Mn**	**Si**	**P**	**S**	**Cu**	**Ni**	**Cr**	**Mo**	**V**	**Ti**	**Al**
EAF	1	0.21	0.46	0.05	0.013	0.014	0.12	1.03	6.74	0.16	0.016	0.441	0.006
	2	0.20	0.46	0.04	0.013	0.014	0.12	1.13	6.60	0.16	0.016	0.405	0.005
	3	0.20	0.45	0.04	0.012	0.014	0.12	1.13	6.57	0.16	0.015	0.401	0.004
	4	0.20	0.45	0.03	0.013	0.014	0.12	1.14	6.53	0.16	0.015	0.388	0.004
LF	1	0.19	0.47	0.06	0.015	0.010	0.11	1.11	6.59	0.16	0.015	0.004	0.083
	2	0.94	0.43	0.11	0.017	0.002	0.11	3.64	11.75	0.51	0.028	0.004	0.020
	3	0.95	0.70	0.12	0.017	0.002	0.11	3.58	12.28	0.52	0.029	0.004	0.030
VOD	1	0.15	0.52	0.08	0.018	0.002	0.11	3.58	12.17	0.53	0.027	0.004	0.004
	2	0.01	0.30	0.06	0.017	0.002	0.11	3.62	11.24	0.54	0.022	0.004	0.004
	3	0.01	0.46	0.32	0.018	0.003	0.11	3.56	12.08	0.53	0.025	0.004	0.022
	4	0.01	0.55	0.33	0.018	0.002	0.11	3.56	12.37	0.53	0.027	0.004	0.022
	5	0.01	0.55	0.31	0.017	0.003	0.11	3.55	12.46	0.53	0.027	0.004	0.025
Final	×××	0.02	0.55	0.30	0.017	0.003	0.11	3.54	12.42	0.52	0.027	0.004	0.032

The main attention was focused on the change of the content of slightly reducible oxides in furnace slag, i.e. mainly Cr_2O_3. Fig. 7, shows clearly that required reduction of Cr_2O_3 occurred after blowing-in 500 kg of anthracite and 500 kg of 75 wt. % ferrosilicium. During the melt in the EAF, at first the content of Cr_2O_3 increased down to the value 55.3 wt. % took place. At the other samples (EAF No. 4 and EAF No. 5) a decrease of the content of Cr_2O_3 down to the value 11.80 wt. % took place. This fact can be explained with the period of the effect of reducing agents and also with the increase of the steel temperature. The course of X2CrNiMo13-4 steel processing temperatures is shown in Fig. 8.

The course of the content of MnO in slag in the production of steel had a similar trend as in the case of Cr_2O_3. A slight decrease of the content of MnO in furnace slag occurred as late as at the end of finishing when 100 kg of ingot aluminum was added, as evidenced by Fig. 9. The course of the content of CaO in slag in the production and secondary metallurgy steel processing in a ladle furnace is documented in Fig. 10.

The course of the content of Al_2O_3 in the slag is presented in Fig. 11. It is clear that the content of Al_2O_3 in furnace slag increased as late as before metal tapping from EAF, i.e. after addition of 200 kg aluminum skim and 100 kg of ingot aluminum. The content of SiO_2 in slag during steel production and secondary metallurgy processing in a ladle furnace mostly decreased, as it is clear from Fig. 12. Not earlier than after addition of ingot aluminum and aluminum skim at the end part of finishing, a slight growth occurred from 6.16 to 6.66 wt. %, which was connected with the fact that after slight liquefaction, FeSi blown-in via a nozzle into furnace slag started to react.

The course of the content of C, Si, S, Cr in steel during production in EAF and during the course of out-secondary metallurgy processing on LF or VOD of the steel grade X2CrNiMo13-4 is presented in Figs. 13 – 16.

According to Fig. 16, during finishing in EAF, the content of Cr in steel was first slightly decreased from the content of 6.74 to 6.53 wt. %. Right before tapping, a small increase to 6.59 wt. % occurred. The main increase of the content of Cr in steel up to 11.80 wt. % took place in the ladle furnace by addition of FeCr.

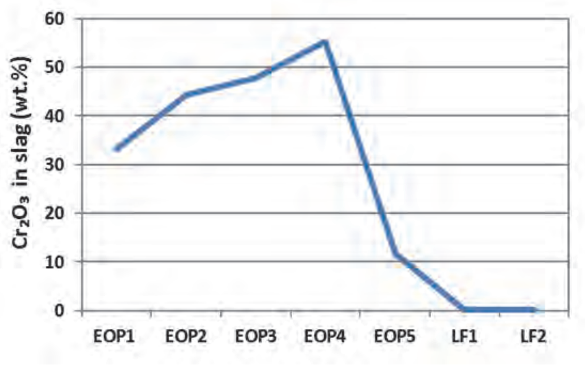

Fig. 7 The course of the content of Cr_2O_3 in slag during X2CrNiMo13-4 steel production and processing
Obr. 7 Průběh obsahu Cr_2O_3 ve strusce během výroby a zpracování oceli X2CrNiMo13-4

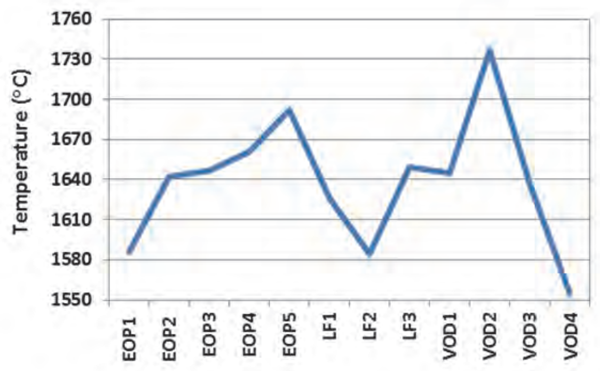

Fig. 8 The course of the temperature during X2CrNiMo13-4 steel production and processing
Obr. 8 Průběh vývoje teplot během výroby a zpracování oceli X2CrNiMo13-4

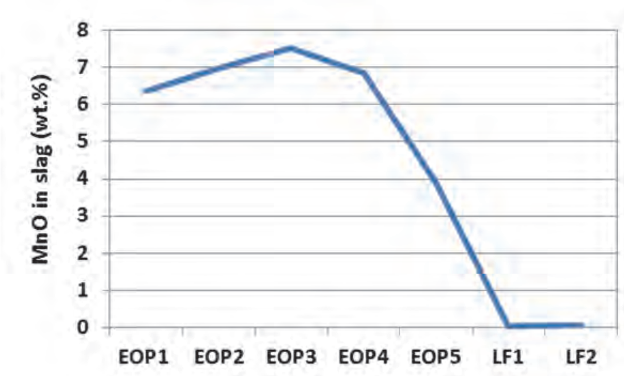

Fig. 9 The course of the content of MnO in slag during X2CrNiMo13-4 steel production and processing

Obr. 9 Průběh obsahu MnO ve strusce během výroby a zpracování oceli X2CrNiMo13-4

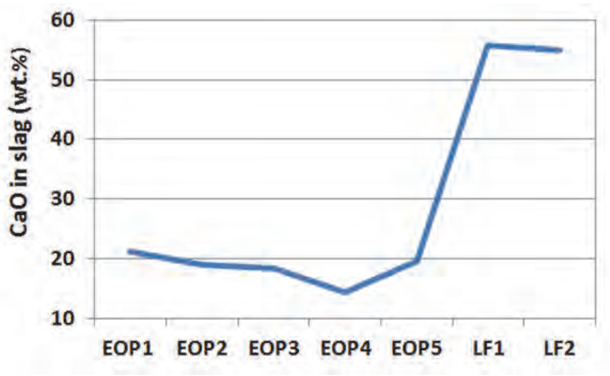

Fig. 10 The course of the content of CaO in slag during X2CrNiMo13-4 steel production and processing

Obr. 10 Průběh obsahu CaO ve strusce během výroby a zpracování oceli X2CrNiMo13-4

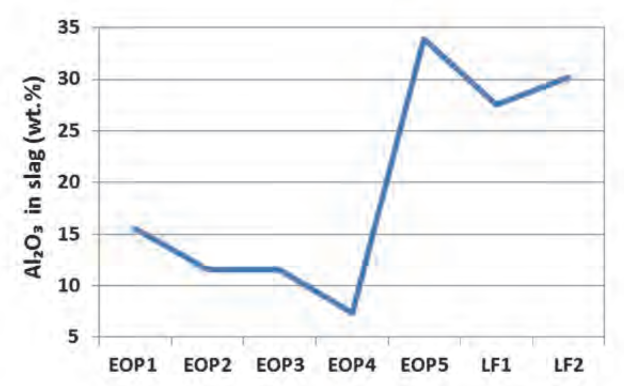

Fig. 11 The course of the content of Al_2O_3 in slag during X2CrNiMo13-4 steel production and processing

Obr. 11 Průběh obsahu Al_2O_3 ve strusce během výroby a zpracování oceli X2CrNiMo13-4

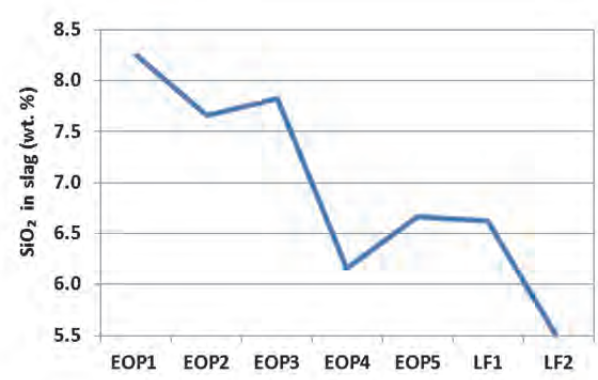

Fig. 12 The course of the content of SiO_2 in slag during X2CrNiMo13-4 steel production and processing

Obr. 12 Průběh obsahu SiO_2 ve strusce během výroby a zpracování oceli X2CrNiMo13-4

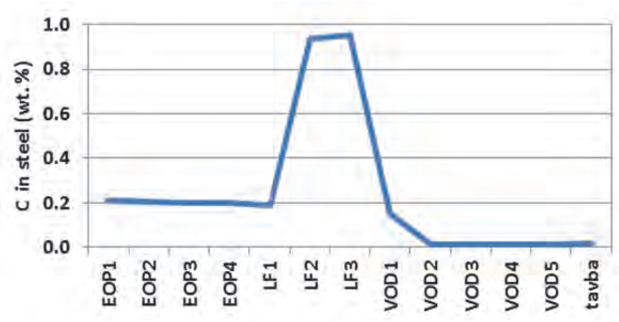

Fig. 13 The course of the content of C in steel during production in EAF and processing in LF and VOD of X2CrNiMo13-4 quality

Obr. 13 Průběh obsahu C v oceli během výroby v EOP a zpracování oceli na LF a VOD jakosti X2CrNiMo13-4

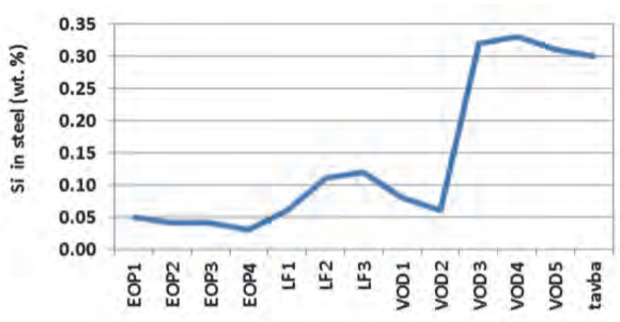

Fig. 14 The course of the content of Si in steel during production in EAF and processing in LF and VOD of X2CrNiMo13-4 quality

Obr. 14 Průběh obsahu Si v oceli během výroby v EOP a zpracování oceli na LF a VOD jakosti X2CrNiMo13-4

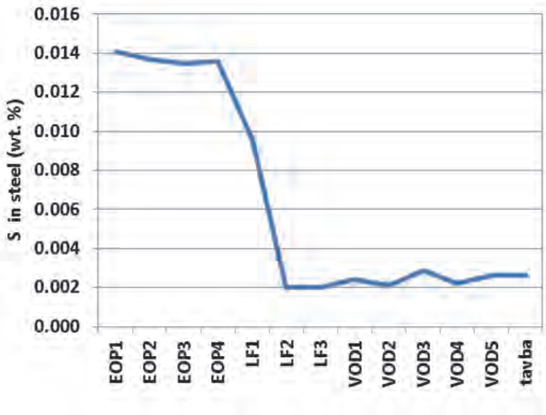

Fig. 15 The course of the content of S in steel during production in EAF and processing in LF and VOD of X2CrNiMo13-4 quality

Obr. 15 Průběh obsahu S v oceli během výroby v EOP a zpracování oceli na LF a VOD jakosti X2CrNiMo13-4

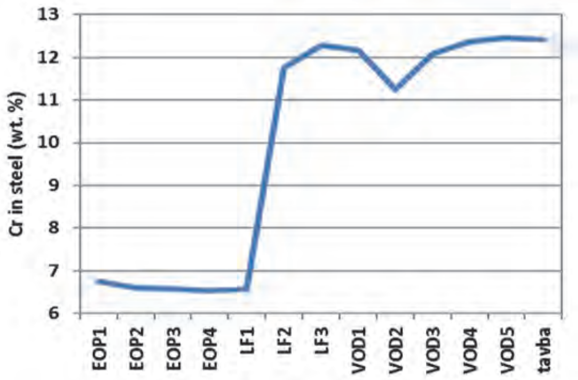

Fig. 16 The course of the content of Cr in steel during production in EAF and processing in LF and VOD of X2CrNiMo13-4 quality

Obr. 16 Průběh obsahu Cr v oceli během výroby v EOP a zpracování oceli na LF a VOD jakosti X2CrNiMo13-4

Based on the results achieved with help of realization of the operational experiments focused on verification of a possibility of chromium reduction from slag, we can state the following:

- *from the point of view of the acquired prototype of the blowing unit, the operational experiment was successful. The dosage of granulated reduction agents of anthracite and ferrosilicium was performed in accordance with the theoretical requirements.*
- *small signs of damage (refractory material, handling eye) detected in the blowing nozzle itself were caused by the impact of high temperature in EAF. Nevertheless, it is necessary to consider the fact that it is just a prototype of a device but not a permanent solution for EAF.*
- *from the metallurgical point of view, however, it must be admitted that, mainly from the reason of low-fluent high-chromium slag, decrease of Cr_2O_3 content by its reduction down to the content 11.80 wt.% took place. To achieve a more satisfactory result, the experiment should be repeated, but a pre-requisite is to provide higher fluidity of slag.*

Conclusions

On the basis of a growing demand for high-chromium steels, a project was prepared, a part of which is focused on development of steel production technology with specialization in the growth of the output of chromium from slag into the metallic melt in the production of high-chromium steels by a production unit representing the intensified EAF No. 5 in the company VÍTKOVICE HEAVY MACHINERY a.s.

In the course of solving the project, theoretical knowledge of reduction of chromium oxides from slag with the use of different reduction agents, a method of application and modification of the melting technology in the production of high-chromium steels in EAF were verified. The above-mentioned knowledge was completed by the results of the study of the course of Cr_2O_3 reduction from slag into steel under laboratory conditions for steel with the content of approx. 9 to 18 wt. % of chromium and slag with the content of approx. 12 to 24 wt. % of Cr_2O_3 and with the use of ferrosilicium and anthracite as reduction agents. The knowledge obtained during the laboratory experiments had to simulate conditions of operation of EAF No. 5 but they were also verified under operating conditions.

The aim of the research is a proposal and testing a prototype for controlled slag reduction with a high content of chromium oxides, as well as the determination of a type, quantity and a method of dosage of a reduction agent on the slag surface. It thus will decrease energetic and economic demandingness of high-chromium steel production, increase the competitiveness of the engineering company on the market, as well as enforce the scientific-research cooperation of the production enterprise with research organizations represented by the VŠB-Technical University of Ostrava and the company MATERIÁLOVÝ A METALURGICKÝ VÝZKUM s.r.o.

Acknowledgements

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27. ročník mezinárodní konference metalurgie a materiálů METAL 2018 se uskuteční ve dnech 23. - 25. května v Brně

V současné době probíhá registrace všech účastníků 27. ročníku konference metalurgie a materiálů METAL 2018, která se uskuteční ve dnech 23. - 25. května 2018 v hotelu Voroněž v Brně. V loňském roce se z celkového počtu 516 přihlášených účastníků zúčastnilo 472 osob z 25 států: 205 účastníků z České republiky, 153 z Polska, 22 z Ruska, 18 ze Slovenska, 16 z Turecka, 9 z Rumunska, 6 z Německa, 6 z Korey, a dále například ze Saudské Arábie, Indie, Rakouska nebo Slovinska. Účastníci prezentovali ve 155 přednáškách a ve 298 posterech. Mezi letošní témata konference patří:

- **Pokroková výroba železa, oceli a litiny**
  Vývoj surovinové báze pro výrobu surového železa, oceli a litiny v posledních letech. Nové prvky v řízení procesů výroby a odlévání železa, oceli a litiny. Aktuální směry vývoje technologie výroby železa a oceli. Fyzikální a numerické modelování procesů výroby železa a oceli. Nové způsoby zpracování odpadů z výroby surového železa a oceli, recyklace, bezodpadové technologie.

- **Tváření kovů**
  Teorie tváření, fyzikální podstata plasticity a metalurgická a technologická tvařitelnost kovů. Plastometrické, laboratorní a numerické modelování procesů tváření za tepla i za studena. Pokrokové metody tváření (válcování, kování, tažení a další… - vysokoredukční a vysokorychlostní procesy, termomechanické tváření, nástroje pro tváření (válce, zápustky, průvlaky), hydroforming, moderní kalibrace, tváření extrémní plastickou deformací, tváření těžko tvařitelných materiálů, tváření blízké konečnému tvaru a další). Technologické problémy a inovace ve tváření.

- **Výrobky z oceli a jejich vlastnosti**
  Fyzikální metalurgie ocelí. Vysoko pevné oceli. Vztah mezi strukturou a vlastnostmi ocelí, metody zkoušení. Oceli pro aplikace za vysokých nebo kryogenních teplot a/anebo za zvýšených tlaků.

- **Moderní trendy v povrchovém inženýrství**
  Protikorozní ochrana povrchu materiálu (vlastnosti povlaků, technologie povrchové úpravy před aplikací povlaků, teoretické otázky). PVD a CVD technologie, organické povlaky, sklovité a sklokeramické povlaky, elektrochemické procesy povlakování, žárové povlakování, iontová implantace, plazmové nástřiky aj. Vlastnosti a aplikace tenkých filmů a nanovrstev.

- **Neželezné kovy a slitiny**
  Způsoby výroby (přípravy) neželezných kovů a slitin (tavení, slévání, prášková metalurgie, rychlé ochlazování, řízená krystalizace..). Vlastnosti a užití neželezných kovů, slitin a sloučenin (Al, Mg, Cu, Ti, Ni, Nb aj.). Vysokoteplotní kovové materiály na bázi neželezných kovů (niklové slitiny a superslitiny, titanové slitiny a intermetalické sloučeniny, kobaltové slitiny, kovy platinové skupiny, wolfram a jeho slitiny). Pokrokové materiály pro biomedicínské aplikace, slitiny kovů a intermetalické sloučeniny, kompozitní materiály, materiály s řízenou pórovitostí.

- **Ekonomika a řízení metalurgické výroby**
  Metalurgická výroba, její postavení v národním hospodářství a globalizované ekonomice, technicko-ekonomická vývojová perspektiva. Řízení metalurgické výroby, metody pokročilého plánování a rozvrhování výroby, logistické řetězce v metalurgii, marketingové řízení a management kvality v oborech metalurgie a materiálového inženýrství. Ekonomické a finanční řízení metalurgického podniku, efektivnost investic a projektů technického rozvoje v metalurgii. Exaktní metody rozhodování, metody umělé inteligence a simulační techniky v projektech systémů řízení metalurgické výroby, nové informační a komunikační technologie.

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