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DYNAMIC VISCOSITY OF BLAST FURNACE PRIMARY AND FINAL SLAG WITH TITANIUM AND ALKALI ADMIXTURES

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For the sake of difficulties with changes of the slags absolute viscosity in blast furnace raised of contents of titanium compounds, examinations of this physical quantity were undertaken studies. The main objective of works was the determine of titanium and alkalis compounds on the dynamic viscosity of synthetic blast furnace primary and final slags in the multicomponent systems. Practical studies have been realize on concentric cylinders rotation viscometer methods. Range of temperatures for primary slags: 1200-1300°C, for final slags: 1400-1500°C. The following slags systems were being studies: $\text{CaO-SiO}_2\text{-Al}_2\text{O}_3\text{-MgO-FeO-TiO}_2\text{-(K}_2\text{O+Na}_2\text{O)}$ and $\text{CaO-SiO}_2\text{-Al}_2\text{O}_3\text{-MgO-TiO}_2\text{-(K}_2\text{O+Na}_2\text{O)}$.

Ze względu na trudności związane ze zmianami lepkości dynamicznej żużli w wielkim piecu zawierających podwyższone zawartości związków tytanu, podjęto badania tej wielkości fizycznej. Celem pracy było określenie wpływu związków tytanu i alkaliów na współczynnik lepkości dynamicznej syntetycznych żużli wielkopieczowych w układach wieloskładnikowych dla żużli pierwotnych oraz końcowych. Badania przeprowadzono na wiskozymetrze opartym o metody koncentrycznych cylindrów. Zakres temperatur dla żużli pierwotnych: 1200-1300°C, dla żużli końcowych: 1400-1500°C. Badano następujące układy żużlowe: $\text{CaO-SiO}_2\text{-Al}_2\text{O}_3\text{-MgO-FeO-TiO}_2\text{-(K}_2\text{O+Na}_2\text{O)}$ oraz $\text{CaO-SiO}_2\text{-Al}_2\text{O}_3\text{-MgO-TiO}_2\text{-(K}_2\text{O+Na}_2\text{O)}$.

1. Introduction

With the knowledge of, among others, the dynamic viscosity for blast furnace slag (primary and secondary), it is possible to describe and optimise conditions in the dripping zone (sub-cohesion) and in the hearth zone. In the blast furnace conditions, it is vitally important to determine, for a given charge, such chemical composition of slag that, among others, its viscosity does not interfere with proper performance of the furnace. Ranging from primary slag to discharge slag, liquid phases present during the raw iron melting exhibit considerable differences in the chemistry and physical properties.

Currently, while employing the coal dust blowing technology and introducing titanium compounds with the charge and reducing the unit amount of slag, it becomes important to be aware of the dynamic viscosity of slag and metallic liquid phases. This property is crucial for, among others, the phenomena occurring in the dripping and hearth zones in a blast furnace. It critically affects the progress of chemical reactions such as: reduction of iron oxides in liquid phase, reduction of MnO, SiO₂, and

metal desulphurisation. It is an extremely important factor for proper mechanics of motion of charge materials in a blast furnace and for proper flow of reduction gases through the charge column.

2. Titanium and alkali compounds in blast furnace

In a complete steel production cycle, the blast furnace stage is one of the most energy-consuming. It also generates huge amounts of substances which are detrimental to human environment. Constantly growing prices of energy and charges for CO₂ emission make the blast furnace specialists worldwide seek ways to optimise iron production processes.

A deciding component of the process is, among others, the deterioration of refractory lining within the hearth area of a blast furnace. Prolongation of the performance of a blast furnace and maintaining its productivity reduces the cost of major overhauls, and consequently the cost of pig iron production. This is the reason for the interest in the behaviour of titanium and its com-

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pounds in blast furnaces. Alkalies introduced to a blast furnace cause numerous problems in pig iron melting process and have negative effects on the refractory lining. Most alkali substances are removed from the blast furnace as dissolved in the final slag. While pursuing the improvement in the methods of pig iron production, it is important to know how such substances behave: alkalies and titanium compounds during the pig iron melting process and, among others, how they influence the dynamic viscosity coefficient of dripping slag being formed.

The authors [1] studied the dynamic viscosity for synthetic blast furnace slag containing titanium compounds. Tests were performed in temperature ranges 1400-1600°C and for the following composition of slag: %MgO - 5, 7, 9, 12, %TiO₂ - 0.5, 1.5, 2.5, 10, 15; slag basicity: (CaO/SiO₂) within the limits 1.1–1.15.

While studying the results obtained, the authors concluded the following:

- the value of dynamic viscosity of synthetic and industrial slag of similar composition, exhibits minor differences within limits which are negligible for the blast furnace process,
- no excessive increase in the viscosity of blast furnace

slag containing titanium was found, which would exclude it from the blast furnace process; in temperature close to slag temperature in the hearth, i.e. 1500 - 1550°C;

- the effect of MgO contents on the change of the dynamic viscosity is visible,

- maximum dynamic viscosity was achieved for slag containing 9% MgO and CaO/SiO₂ = 1.1-1.15 at 0.5-1.5% TiO₂, and at 10% TiO₂;

- in case of slag containing 12% MgO, the viscosity minimum appears at 1.7-2.5% TiO₂ for the slag and the maximum at 0.5 and 4.5% TiO₂.

In the blast furnace technology, the range of around 0.5% content of TiO₂ in the slag should therefore be avoided, and the content of MgO should not exceed 7%; also, TiO₂ range of 2.5-5% should be avoided for MgO present usually in the blast furnace slag, i.e. 5-7% [1].

In Chinese mills, iron ores of increased titanium contents of around 10.6 %TiO₂ are used, and therefore, authors [2] studied the behaviour of slag with increased contents of TiO₂ of some 22-25%, subjected to oxidation process. Oxidation controls the kind and content of titanium oxides in slag. Changes of dynamic viscosity are presented in figure 1.

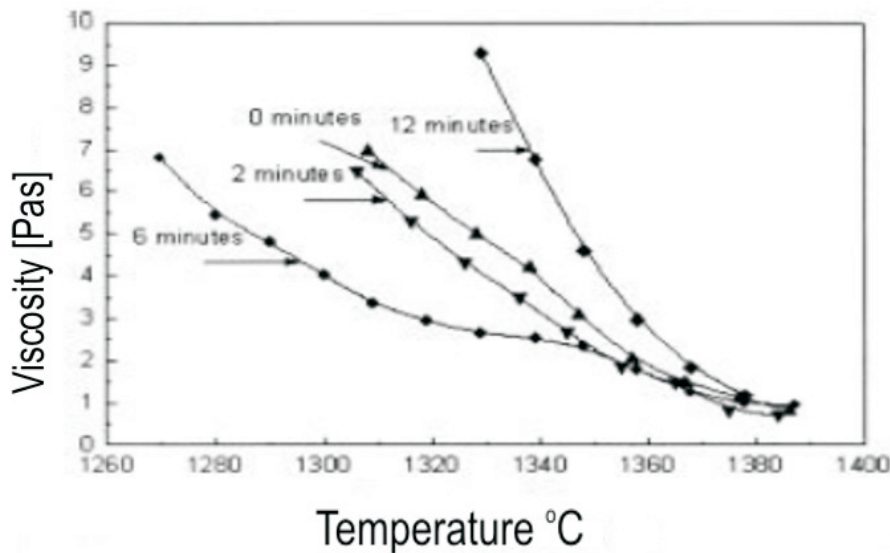


Fig. 1. Changes of dynamic viscosity of raw and oxidized slag, depending on the temperature and oxidisation time [2]

Figure 1 shows that slag viscosity reduces with the increase of oxidising time, but increases rapidly after long oxidising, 12 minutes in this case. Slag viscosity as well as softening point depend on the content of (FeO_x), TiC, temperature, formation of crystal phase. Together with the increase of temperature, the dynamic viscosity of homogeneous and heterogeneous slag is reduced;

differences of the temperature effects result from the formation of crystal phases, The viscosity of heterogeneous slag will increase along with the increase of the softening point temperature [2].

The TiC admixture intensifies the wetting between the slag and metallic Fe droplets. For that reason, transport and separation of metallic Fe droplets from slag

is difficult. After air inflow into the slag, the TiC contents disappears, slag viscosity decreases, and the slag temperature increases.

Based on numerous studies, Authors [2] conclude that TiC causes a rapid increase in viscosity, non-deoxidised slag has greater viscosity. Titanium carbides considerably affect the slag viscosity; TiC admixture leads to an increase of softening temperature and great increase of viscosity [2].

Research was also made [3] on physical properties (viscosity) of slag containing TiO_2 in strongly reducing environment. Reduction of TiO_2 to Ti_2O_3 led to slight decrease of slag viscosity, but only when little amount of TiC (some 1~3%) was formed during the reaction. Solid compounds of slag did not appear to be the reason

for the increase of melting temperature of the slag being reduced, which – in most cases – was $1420^\circ C$. Fluidity of slag depended on solid compounds in the heterogeneous slag structure.

Reduction of TiO_2 to Ti_2O_3 was initially rapid, and then slowed down. It is important to add that especially fast increase in viscosity depends not only on the TiC contents, but also on TiO. TiO_2 reduction degree depends on the basicity. During the reduction of TiO_2 in acid slag, Ti_2O_3 is the prevailing product, whereas TiO and TiC are formed in the basic slag. It is worth mentioning that TiC being formed is accompanied by a small amount of TiO, which leads to the increase in viscosity. [3].

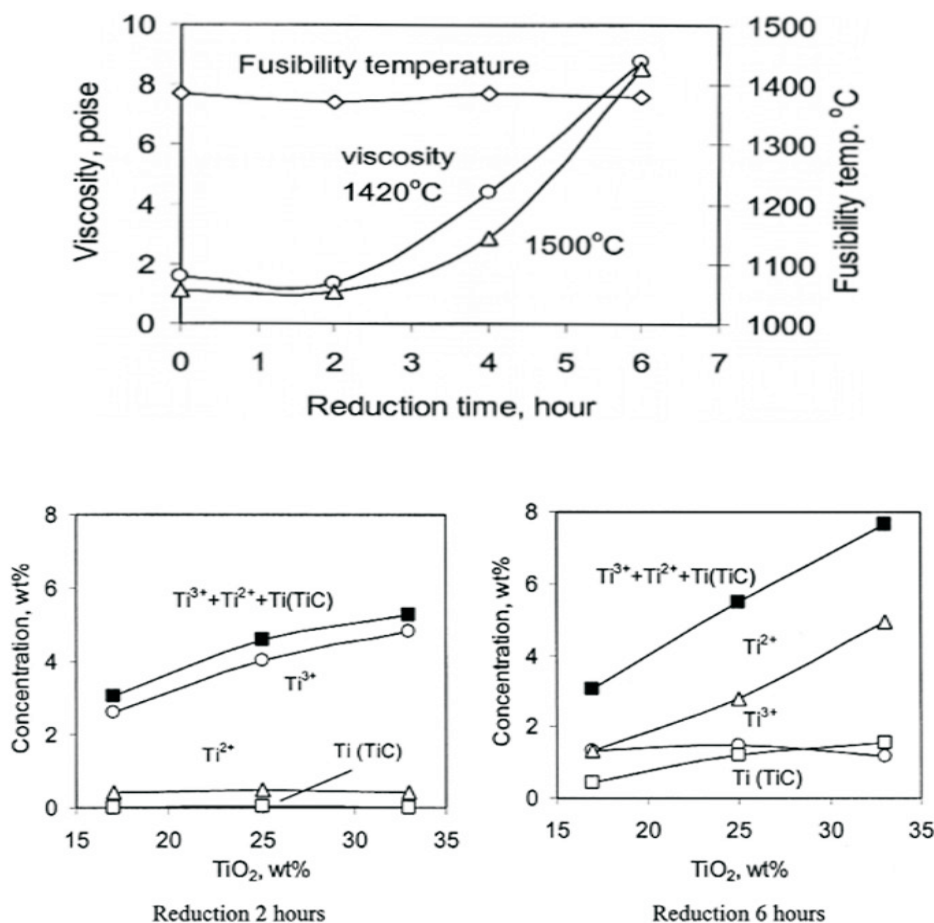


Fig. 2. Changes of viscosity for various reduction times and concentrations of TiO_2 in slag [3]

Changes of viscosity for varying reduction times are presented in figure 2. The increase of dynamic viscosity is visible at increasing amount of TiC and TiO, regardless of the reduction duration. According to the research

[3], TiO is the cause of densification of heterogeneous slag, as TiO is probably bonded with solid TiC, which results in negative effects on the viscosity. Authors [3] conclude that contents of 3~7 mass% TiO and 1~3 mass%

TiC, are of key importance for the densification of slag, by forming solid particles containing, among others, titanium carbides.

3. Own studies

The present paper aims to determine the effect of alkali and titanium on the dynamic viscosity in synthetic slag of the initial and final types. Two multi-component slag types were analysed: **I**) CaO-SiO₂-Al₂O₃-MgO-TiO₂-(K₂O+Na₂O), considered as final slag (hearth) and **II**) CaO-SiO₂-Al₂O₃-FeO-MgO-(K₂O+Na₂O) and **III**) CaO-SiO₂-Al₂O₃-FeO-MgO-TiO₂-(K₂O+Na₂O), considered as primary slag types. All initial slag types were properly treated with admixtures in order to achieve expected chemical compositions.

Tests were carried out in stages. The first stage involved formation of slag samples of assumed chemical composition. Multi-component slag samples were produced in liquid state synthesis of pure components: CaO – calcined powder p.a. grade., SiO₂ – quartz p.a. grade., Al₂O₃ – for chromatography, MgO – calcined powder p.a. grade. (all from E. Merck), FeO – rolling mill scale, K₂CO₃ – calcined powder p.a. grade. (from MTM Research Chemicals LOBA Feinchemie GmbH), Na₂CO₃ - anhydrous powder p.a. grade. (from ODCZYNNIKI Sp. z o.o.). While preparing slag samples, special attention was paid to careful weighing of individual components and their mixing. After melting, the crucible with slag was broken and subjected to analysis.

For slag system no.1 (primary slag) two types of slag were composed:

A) CaO – 41.13%, SiO₂ – 40.03%, Al₂O₃ – 9.52%, MgO – 6.48% basicity – 1.0.

B) CaO – 46.10%, SiO₂ – 39.98%, Al₂O₃ – 8.51% i MgO – 5.37% basicity – 1.15.

The following assumptions were made as regards the composition of final slag (hearth slag):

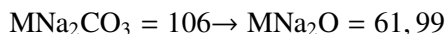
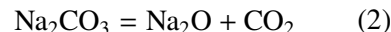
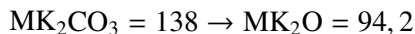
- TiO₂: 1%, 5%, 10%, 15%
- Alkalies: 0.5%, 1%, 1.5%
- Basicity: 1.0; 1.15

Wide range of TiO₂ contents from 1 to 15% was selected in order to allow for determination of the influence of titanium on the properties of liquid slag phases and possible formation of carbides during the experiments, and their effects on the change of viscosity.

The selected values of basicity correspond to the conditions in the furnace, where slag changes its character from acidic, for initial slag, to basic for the final slag.

The level of alkali compounds added to the slag resulted from the analysis of the literature data on their

accumulation and circulation within the furnace. It is comparable to values which may potentially occur in a blast furnace, in the dripping and hearth zone. Slag components: Na₂O and K₂O were obtained as a result of dissociation of carbonates. The amounts of used carbonates were calculated according to reactions 1 and 2.



Examined slags: **II**) CaO-SiO₂-Al₂O₃-FeO-MgO-(K₂O+Na₂O). Initial slag has the following composition: **C**) CaO - 39.82%; SiO₂ - 43.09%; MgO - 6.76%; Al₂O₃ - 9.71%. The following assumptions were made as regards the composition of initial slag:

- FeO: 10%, 15%, 25%
- Alkali compounds: 4%, 6%, 9%
- Basicity: 0.92;
- Temperature: 1200°C, 1250°C, 1300°C

Examined slags: **III**) CaO-SiO₂-Al₂O₃-FeO-MgO-TiO₂-(K₂O+Na₂O)

D) CaO - 35.58%; SiO₂ - 49.71%; Al₂O₃ - 7.25%; MgO - 6.33%

E) CaO - 29.74% ; SiO₂ - 57.96%; Al₂O₃ - 6.06%; MgO - 5.29%

The following assumptions were made as regards the composition of initial slag:

- FeO: 25%
- Alkalies: 8%; 10%
- Basicity: 0.5; 0.7
- TiO₂: 5%; 10%; 15%
- Temperature: 1200°C; 1250°C; 1275°C; 1300°C

Slag used for the tests contained a high level of FeO, which is typical for slag forming under the cohesion zone.

For testing dynamic viscosity of slag, a viscometer, constructed at the Faculty of Metal Engineering and Industrial Computer Science, Department of Metallurgy of Iron Alloys was used. Measurement of viscosity with that apparatus is based on the method of concentric cylinders with a rotary inner cylinder. The equipment is schematically shown in figure 3.

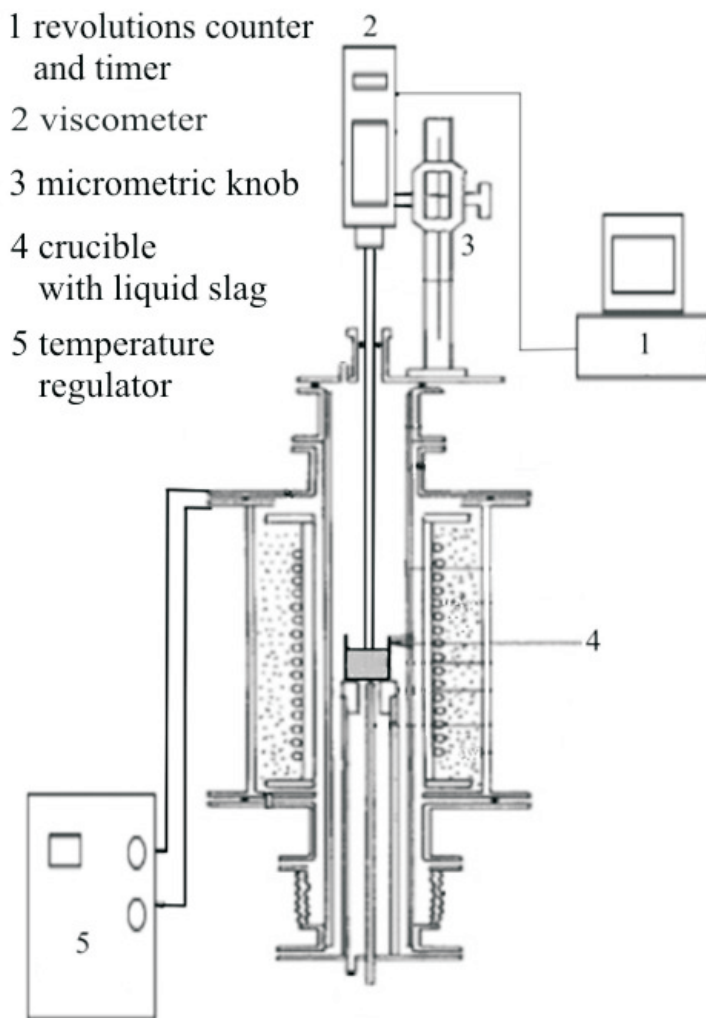


Fig. 3. Facility for the measurement of dynamic viscosity

The temperature was measured with Pt-PtRh thermocouple. Measuring accuracy within the viscosity range from 5 to 10[Pas] and temperature 1600°C is $\pm 5\%$, whereas the error may be due to the inaccuracy of temperature measurement. For viscosity below 5[Pas] this error is higher, of some $\pm 10\%$ at 1[Pas].

The method utilized in the present work has the following advantages:

1. dynamic viscosity is described as a simple dependency of time, which – while using precise chronometers – allows to measure the dynamic viscosity quite accurately,
2. very simple calibration of the apparatus with liquid of known viscosity,
3. stirring of the sample studied at the time of measurement, due to the rotation of a cylinder inside the slag,

4. possibility to measure temperature at the time of testing with thermocouples, owing to the stationary external crucible,
5. bottom part of the furnace can be tightly enclosed which allows the use of a graphite heater in protective atmosphere.

For the primary (ferrous) slag the following measurement system was utilised: inner cylinder made of molybdenum, external cylinder – alundum crucible. For the final (hearth) slag, the system used was as follows: inner cylinder – graphite, external cylinder – graphite (graphite crucible).

Once the time of the inner cylinder rotation was measured, the dynamic viscosity was calculated using the dependency:

$$\eta = A * (t - t_0) - B \quad (3)$$

where:

t_0 – idle run time [s],

t – average measurement time [s].

The constants A and B in formula (3) were obtained while calibrating the viscometer with oil of known dynamic viscosity in the function of temperature from 20 - 65 °C. Both molybdenum-alundum and

graphite-graphite cylinders system were taken into account.

The results of the studies of dynamic viscosity of initial slag are given in tables 1 and 2. Table 1. Results of measurements of the dynamic viscosity for II C slag system.

TABLE 1

Results of measurements of the dynamic viscosity for II C slag system

N ^o	Viscosity [Pas]	FeO content in slag [%]	Alkalies content in slag [%]	Temperature [°C]
1	1,2690	10,0	4	1200
2	0,5375	10,0	4	1250
3	0,4441	10,0	4	1300
4	0,9308	10,0	6	1200
5	0,3373	10,0	6	1250
6	0,1248	10,0	6	1300
7	0,5364	10,0	9	1200
8	0,1220	10,0	9	1250
9	0,0683	10,0	9	1300
10	0,8099	15,0	4	1200
11	0,9646	15,0	4	1250
12	0,8508	15,0	4	1300
13	0,9845	15,0	6	1200
14	0,4563	15,0	6	1250
15	0,4085	15,0	6	1300
16	1,1111	15,0	9	1200
17	0,7159	15,0	9	1250
18	0,3731	15,0	9	1300
19	1,0861	25,0	4	1200
20	0,6308	25,0	4	1250
21	0,5707	25,0	4	1300
22	2,5612	25,0	6	1200
23	1,9654	25,0	6	1250
24	1,1797	25,0	6	1300
25	0,9856	25,0	9	1200
26	0,5688	25,0	9	1250
27	0,4217	25,0	9	1300

Graphical presentation of dynamic viscosity for the synthetic slags of variable alkalies and FeO contents, are presented in figure 4.

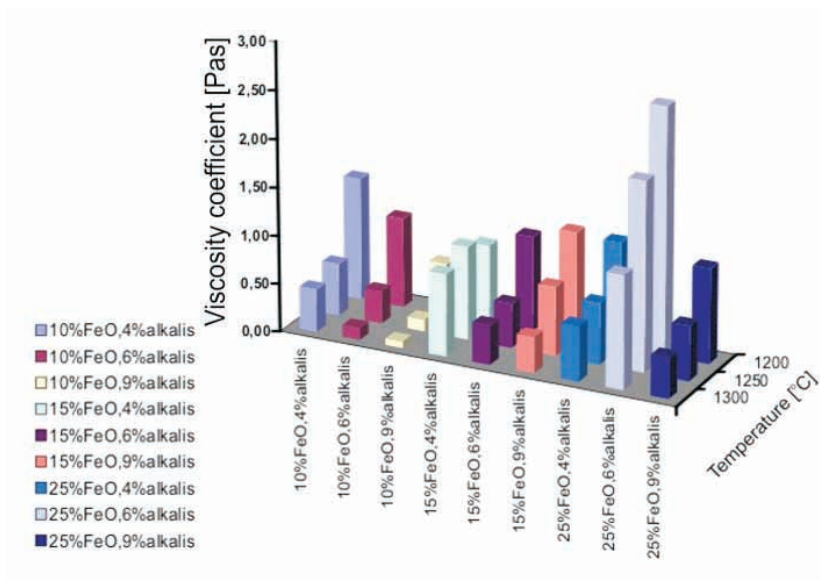


Fig. 4. Viscosity of primary slag with alkaline admixtures

TABLE 2

Results of the dynamic viscosity for III D and E slag systems

Nº	B1 – 0,7	B1 – 0,5	Alkalies content in slag [%]	TiO ₂ content in slag [%]	Temperature [°C]
	Viscosity [Pas]	Viscosity [Pas]			
1	0,9478	1,0398	8	5	1200
2	0,3428	0,5282	8	5	1250
3	0,2855	0,2916	8	5	1275
4	0,1816	0,1637	8	5	1300
5	0,9925	0,6024	10	5	1200
6	0,3466	0,3505	10	5	1250
7	0,2764	0,2072	10	5	1275
8	0,2290	0,1266	10	5	1300
9	1,2867	0,5717	8	10	1200
10	0,3313	0,2801	8	10	1250
11	0,2290	0,1791	8	10	1275
12	0,1663	0,1292	8	10	1300
13	0,8096	0,2290	10	10	1200
14	0,1855	0,1113	10	10	1250
15	0,1164	0,0179	10	10	1275
16	0,0256	0,0154	10	10	1300
17	1,7625	0,6715	8	15	1200
18	0,2430	0,2865	8	15	1250
19	0,1485	0,1663	8	15	1275
20	0,1011	0,1190	8	15	1300
21	2,4224	0,6242	10	15	1200
22	0,1624	0,1637	10	15	1250
23	0,0056	0,0448	10	15	1275
24	0,0077	0,0013	10	15	1300

A considerable influence of alkaline substances on the reduction of viscosity is apparent. For an addition of 9% alkali, the lowest viscosity values were obtained at the level of 10 and 25% FeO. The influence of temperature on viscosity is apparent – the higher the temperature, the lower the viscosity. The influence of FeO content in the primary slag containing alkali compounds on its viscosity is not explicitly visible. It can be concluded that the differences in viscosity coefficient for slag at

1200°C are higher than these at 1300°C. Such differences decrease along with the increase of temperature.

The results of testing the dynamic viscosity of primary slag with addition of alkalis and TiO₂ with constant contents of FeO at some 25 %, are given in table 2.

Figure 5 graphically presents the dependency of dynamic viscosity on temperature for constant contents of alkalis and titanium compounds for slag basicity 0.7.

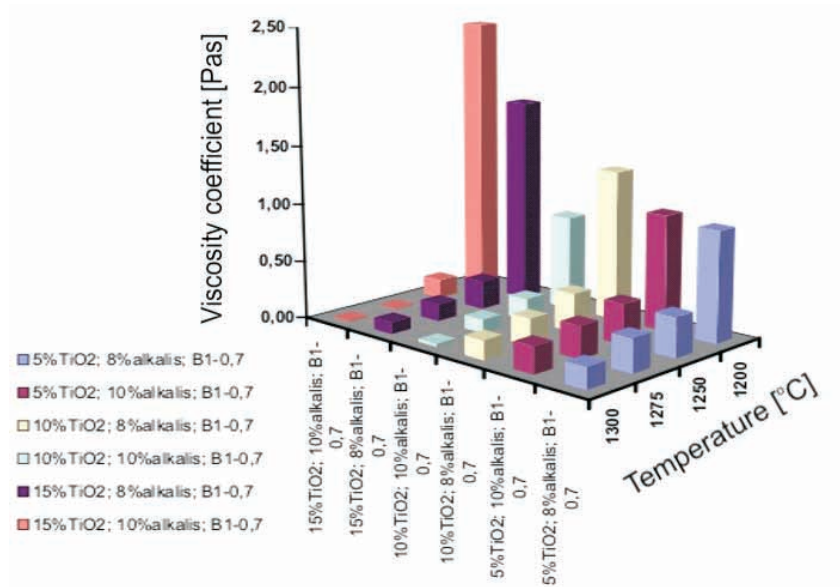


Fig. 5. Viscosity of ferrous primary slag types containing alkalis and TiO₂ for the system of B1-0.7

Figure 6 graphically presents the dependency of viscosity on temperature for constant contents of alkalis and titanium compounds for slag basicity 0.5.

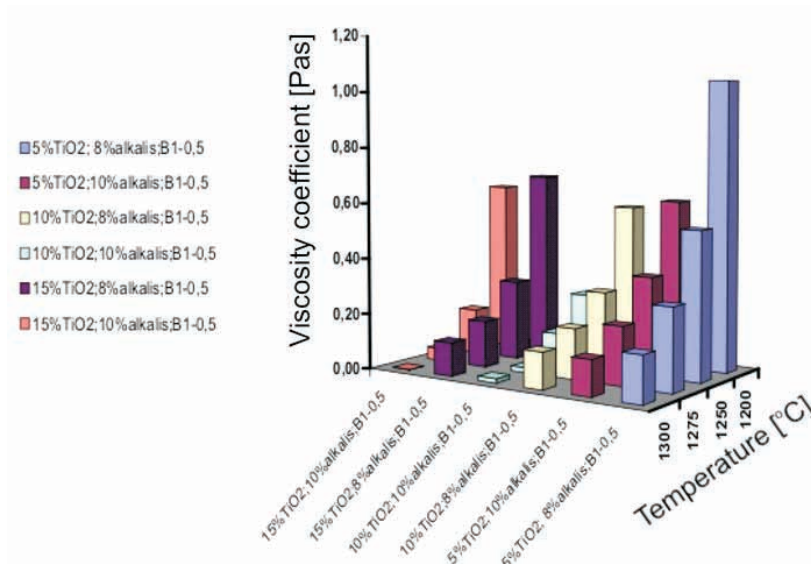


Fig. 6. Viscosity of FeO-rich primary slag types containing alkalis and TiO₂ for the system of B1-0.5

An increase of temperature causes the slag viscosity reduction, regardless of the contents of TiO_2 and alkalis in the slag. For slag basicity = 0.7 (B1) for lower temperatures (1200-1250°C) such trend is more apparent than for the system of B1 = 0.5. Contents of 15% TiO_2 in slag of B1=0.7; causes the coefficient value to increase in lower temperatures. For slag of B1-0.5 no such trend is observed. In the temperature range 1250-1300°C this tendency is reversed – this happens irrespective of the contents of alkaline substances. This may prove the change (increase) of solubility of TiO_2 in slag in higher temperatures, which is clearly visible for the slag system of basicity 0.7. It has to be stated that alkalis have a

thinning action on the slag causing the viscosity values to decrease. Their influence is much stronger for more acid slag, i.e. B1 = 0.5, which might result from the fact that alkalis are strongly absorbed in acid slag. Viscosity for slag containing 10 % alkalis is much lower than that for slag containing 8 % alkalis. The effect of alkalis on the reduction of viscosity is apparent at increased TiO_2 contents by some 15%. The effect of alkalis on the reduction of viscosity is also stronger for lower temperatures. The question still exists how the change of composition due to alkalis evaporation influences the slag viscosity.

TABLE 3

Results of the dynamic viscosity for I A and E slag systems

N°	B1 – 1,0	B1 – 1,15	TiO_2 content in slag [%]	Alkalis content in slag [%]	Temperature [°C]
	Viscosity [Pas]	Viscosity [Pas]			
1	0,7410	0,6587	1	0,5	1400
2	0,5940	0,6255	1	0,5	1450
3	0,5910	0,6078	1	0,5	1500
4	0,6340	0,6502	5	0,5	1400
5	0,5970	0,6086	5	0,5	1450
6	0,5140	0,6021	5	0,5	1500
7	0,6600	0,6116	10	0,5	1400
8	0,6230	0,6055	10	0,5	1450
9	0,5160	0,5995	10	0,5	1500
10	0,5218	0,6359	15	0,5	1400
11	0,5270	0,6131	15	0,5	1450
12	0,5945	0,6040	15	0,5	1500
13	0,6550	0,7011	1	1	1400
14	0,6110	0,5888	1	1	1450
15	0,5940	0,5979	1	1	1500
16	0,6350	0,6298	5	1	1400
17	0,4986	0,6161	5	1	1450
18	0,4532	0,6086	5	1	1500
19	0,6520	0,6547	10	1	1400
20	0,6250	0,5979	10	1	1450
21	0,5690	0,5964	10	1	1500
22	0,6472	0,6465	15	1	1400
23	0,6024	0,6116	15	1	1450
24	0,5812	0,6040	15	1	1500
25	0,6440	0,6732	1	1,5	1400
26	0,6160	0,6177	1	1,5	1450
27	0,4560	0,6010	1	1,5	1500
28	0,6240	0,6252	5	1,5	1400
29	0,5214	0,5979	5	1,5	1450
30	0,5090	0,5949	5	1,5	1500
31	0,6280	0,6650	10	1,5	1400
32	0,5473	0,6161	10	1,5	1450
33	0,4570	0,6086	10	1,5	1500
34	0,5942	0,6017	15	1,5	1400
35	0,5423	0,5995	15	1,5	1450
36	0,4018	0,5979	15	1,5	1500

The results of testing the dynamic viscosity of final slag with addition of alkalis and TiO_2 for basicity $\frac{\text{CaO}}{\text{SiO}_2} = 1.0$ and 1.15 are given in table 3.

Figures 7 and 8 graphically present the dependency

of viscosity on temperature for constant contents of alkalis and titanium compounds for slag basicity 1.0 and 1.15.

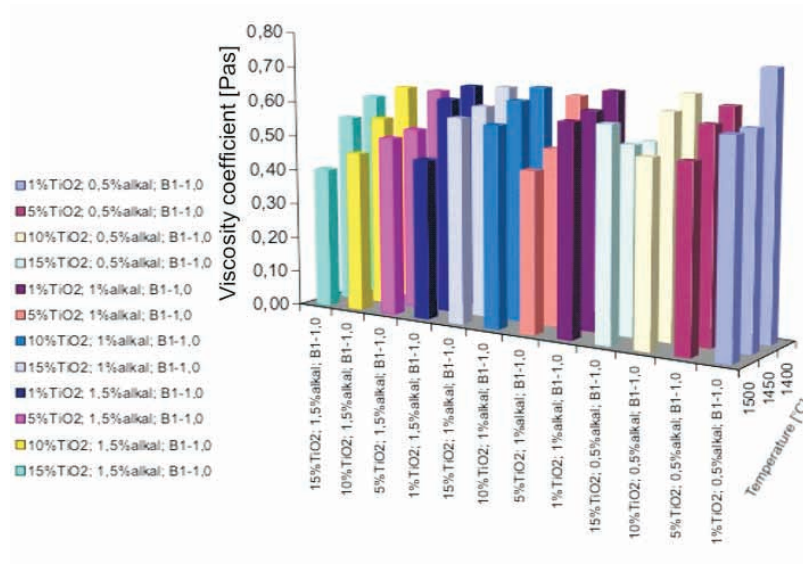


Fig. 7. Viscosity of synthetic blast furnace slag of final type containing alkalis and TiO_2 of B1-1.0

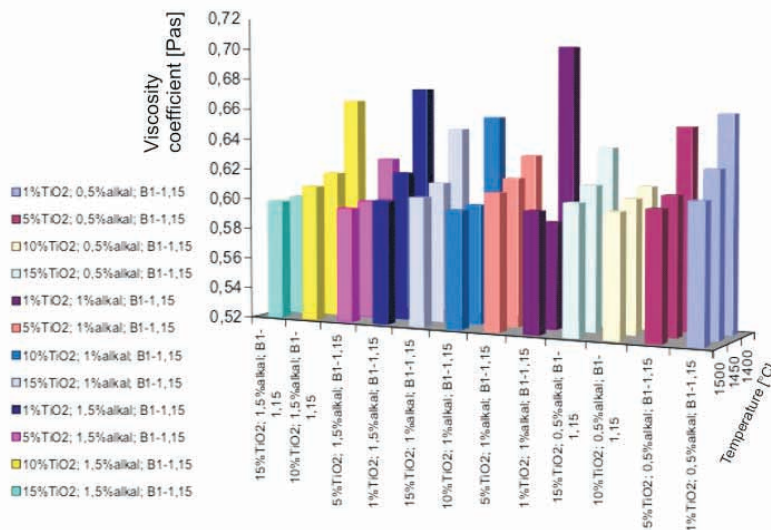


Fig. 8. Viscosity of synthetic blast furnace slag of final type containing alkalis and TiO_2 of B1-1.15

Slight amounts of alkali 0.5 - 1.5 % (in final slag, as compared to primary slag) have a liquefying action on the slag. In higher temperatures (1450 $^{\circ}\text{C}$ and 1500 $^{\circ}\text{C}$), the slag has apparently lower viscosity. In lower temperature (1400 $^{\circ}\text{C}$) the slags exhibit differences in viscosity regardless of the contents of TiO_2 in the system. It

was observed that alkali compounds, while evaporating, cause graphite crucible erosion. That process was best visible at higher temperatures. For slag of basicity of 1.15, greater variability of the viscosity is visible than for the 1.0 slag. Great variability of viscosity is visible for more basic slag (1.15), which can be the result of

more intense evaporation of alkali substances from the slag and changing viscosity at the same time.

Figure 6 presents the influence of increased titanium contents (10-15%) on dynamic viscosity of final slag in elevated temperatures (1500°C). The dynamic viscosity is decreased.

Change of slag viscosity by alkalies depends also on the change of contents of other slag components, e.g. TiO₂ and temperature. TiO₂ contents in the slag affects the reduction of viscosity in case of slag of B1-1.0, regardless of the contents of alkalies. The most critical factor for the reduction of viscosity is the temperature increase. The temperature increase not only liquefies the slag to a greater degree, but also accelerates evaporation of alkali compounds.

4. Conclusions

As a result of laboratory examination, the following conclusions can be drawn:

- The effect of temperature on the viscosity was proven, also for synthetic blast furnace slag types studied in the present paper;
- Differences in dynamic viscosity for slags at the temperature of 1200°C – is higher than for the temperature of 1300°C. Such differences reduce along with the increase of temperature;
- For both, the primary and final slag, alkalies cause the dynamic viscosity decrease. For the primary slag, the greater the FeO content is, the weaker is the effect of alkalies, and – for final slag – the greater the basicity, the weaker is the effect of alkalies on the viscosity. Addition of 5 – 15 % titanium reduces the viscosity of primary slag;
- Alkaline additives have greater influence on viscosity, than titanium oxides in the primary slag. Alkalies are more thinning to the slag as TiO₂;
- For final slag of higher basicity B1-1.15, greater differences of the viscosity were found than for slag of lower basicity, of B1-1.0 – this may result from the phenomenon of evaporation in high temperatures in more alkali systems;

- The results obtained prove the principle that alkalies reduce slag viscosity, in general, the more alkali, the lower the viscosity of ferrous slag.

Based on the studies carried out and analysis of the results obtained, it can be concluded that temperature most considerably affects the viscosity in the studied slag system, then the alkali and TiO₂ amount. Primary blast furnace slag is still the subject of research. It is extremely difficult to analyse such systems practically. It has to be stated that detailed research on the effects of chemical composition on the viscosity of primary slag should be continued for other ranges of FeO contents. It is apparently necessary to continue the research on the changes of dynamic viscosity for slag systems containing solid phases, e.g. TiC, 2CaO-SiO₂ and a great contents of TiO₂ – above 25% – in high and low temperatures. The latter statement applies more to the research problems related to the initial slag, rather than to the issues discussed in this project.

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