POSSIBILITIES OF STUDY OF THE INORGANIC MELTS INTERPHASE TENSION

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Abstract
The presented paper is focused on the study possibilities of the interphase tension between liquid iron and slag. The interphase phenomena are very significant for defining and suggestion of the material properties which feature in the heterogeneous systems. They represent and important factor of effectiveness in many processes of the iron and slag production, in which there co-exist two immiscible liquid phases – oxidic and metallic. Many phases of the primary processing and refinement of the produced material include the material transfer over the interphase interface, which significantly influences the velocity of particular reactions. The interphase tension values are influential mainly during the continuous steel casting technologies, they are considerable during the products’ defects elimination. Experimental study of these phenomena is very difficult, even though there has been developed a wide range of the research methods in this field. This is the reason why there are not commonly accessible any literary data to predict the interphase effects, mainly the phenomena in the interface slag – metal.

In connection with this fact, there was elaborated an integrated conception of the inorganic melts interface study, emphasised on the experimental part. The introduction theoretically describes and solves the problem of the influence of particular elements in metal and slag melt in the interphase tension. Consequently, there follows an analysis of the original experimental research method and particular study results of the interphase tension temperature dependences of selected metallic and oxidic systems. Within the frame of expanding the original method of the interphases study, there was also developed an analysis software which was used before the particular experiments to many comparative measurements.

Keywords: method of a lying drop, surface tension, interphase tension, melt, CaO - SiO₂ - Al₂O₃ slag systems.

1. INTRODUCTION
The interphase phenomena represent an important role in defining and proposing the properties of materials in heterogeneous systems. The interphase properties leak the information needed for understanding the interphase nanostructure, respectively of the materials structures at high temperatures.

A series of primary processing steps and refinement of the produced material includes the material transfer over the interphase interface, which significantly influences the velocity of particular reactions. Thus, the interphase tensions may hasten these reactions, respectively damp down completely. This is the reason why it is necessary to know the interphase properties, which alike the other physical – chemical properties, form the properties of the final product.

The interphase tension values attain the importance mainly during the continuous steel casting technologies. Low interphase tension values increase the probability of the slag melt driftage to the slag – metal interface, which results in defects of a product. Furthermore, the interphase tension data are necessary for the study of nucleation, flotation and transfer of the oxidic inclusions from steel into slag. From the thermodynamic viewpoint, the higher interphase tension value among the slag and non – metallic inclusions, the easier is the absorption of non – metallic inclusions by the slag. On the contrary, when the interphase tension value is
extremely high, the gas bubbles appearing during the cooling of metals may accumulate on the interphase interface and this may cause the surface defects of the products. Experimental study of these phenomena is rather difficult, even though there has been developed a wide range of research methods in this field. This is the reason why there are not commonly accessible any literary data to predict the interphase effects, mainly the phenomena in the interphase slag – metal.

2. EXPERIMENT

Within the frame of introduction of new oxidic compositions in the metallurgical industry, the main interest was paid to a series of inorganic systems used as a basis of the casting powders. These systems, usually due to economical reasons, contain a wide range of admixtures which affect their utility properties. To present the obtained results a typical oxidic system was selected; it is used as a basis of the casting powders for ZPO (further mentioned system A) and metallic material which composition is shown in Table 2. The oxidic system may be considered to be a pseudoternary composition of in majority presented components of CaO – Al₂O₃ – SiO₂. The silica content is approximately 37 wt.%. Thus, it is a system assuming co-existence of polymeric silica structures with other more simple ions. Except from three mentioned components, in the system there are also significantly present these compounds: MgO, Na₂O and fluoride ions F. Determination of particular elements was realized by the AAS and ICP-AS method (Tab. 1).

Table. 1.: Chemical composition of the investigated system B

<table>
<thead>
<tr>
<th>component</th>
<th>concentration (wt.%)</th>
<th>component</th>
<th>concentration (wt.%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>37,1</td>
<td>Na₂O</td>
<td>5,1</td>
</tr>
<tr>
<td>CaO</td>
<td>29</td>
<td>K₂O</td>
<td>0,4</td>
</tr>
<tr>
<td>MgO</td>
<td>1,7</td>
<td>P₂O₅</td>
<td>0,1</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>12,5</td>
<td>F</td>
<td>4,1</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0,5</td>
<td>C_{tot}</td>
<td>7,2</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0,64</td>
<td>C_{sol}</td>
<td>6</td>
</tr>
<tr>
<td>MnO₂</td>
<td>0,1</td>
<td>CO₂</td>
<td>4,4</td>
</tr>
</tbody>
</table>

A great problem was the higher content of free carbon, which caused the fact it was not possible to guarantee the non dipping behaviour towards the graphite underlayer. This is the reason why the sample was annealed up to the temperature of 800°C, at which the carbon burnt out.

Table. 2: Chemical composition of used steel.

<table>
<thead>
<tr>
<th>element</th>
<th>wt.%</th>
<th>element</th>
<th>wt.%</th>
<th>element</th>
<th>wt.%</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0,09</td>
<td>Mn</td>
<td>0,50</td>
<td>Si</td>
<td>0,06</td>
</tr>
<tr>
<td>P</td>
<td>0,029</td>
<td>S</td>
<td>0,026</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the next phase of the experimental research a concentration range was set up. It was created by successive additions of SiO₂ by 3 percentage by weight to the basic system B in concentration range of 37,1 – 46,1 wt.% SiO₂.

For experimental research of the interphase tension the horizontal resistive graphite Tamman furnace was used; its basic construction scheme and handling is particularly described in works XX.

For calculation of the interphase tension the following relation was used:
\[
\sigma_{(o)-(G)} = \sqrt{\sigma_{(o)-(G)}^2 + \sigma_{(S)-(G)}^2 - 2\sigma_{(o)-(G)}\sigma_{(S)-(G)}\cos(\Theta)}
\]

Within the calculation of the relation (1) it was necessary to ascertain the interphase tension of the slag system molten slag – atmosphere \(\sigma_{(S)-(G)}\), then the interphase tension of the system molten steel – atmosphere \(\sigma_{(o)-(G)}\) and the dipping angle of both liquid phases \(\Theta\).

The interphase tensions steel – atmosphere and slag – atmosphere were measured by the method of a sessile drop [1-3].

For successful experimental determination of the dipping angles of both liquid systems it was necessary to solve the problem of recording the contact points of particular molten investigated phases. To this purpose the original method was used – grappling them in horizontal positions, which is described schematically in Figure 1.

![Fig 1: Schematic diagram of bedding the investigated material in Tamman furnace.](image)

During the experiment the steel disc was put into a suitably shaped cavity in corundum material. Its centre was formed by a composite thorn made of tungsten wire in corundum cover. A pellet of slag material was layed on it (Fig.2). The prepared system was placed in the working space in Tamman furnace. During the transfer of both materials (slag and oxidic slag system) to liquid phases, they remained fixed in the same position due to the composite thorn. The thorn material was very problematic because of dissimilar agressive environment of the oxidic and metallic phase at high temperatures. Its composite structure was selected because of liquefaction of most metallic materials in the molten slag, conversely the liquid oxidic system smelts most of ceramic materials.

Figure 2 (A) shows an image of the investigated molten structure. Due to specially developed software for this method, Figure 2 shows the steel surface plane (horizontal dark line), subsequently the found slag material’s borders (green curves) are spaced out by a curve line. Then, the angle \(\Theta\) is calculated on basis of these recognized shapes.
3. RESULTS

In the first phase of the experiments it was necessary to find out the surface tension of used steel (Fig. 3). A modified method of a sessile drop was selected. The choice of material determined for the underlayer was rather problematic. After a series of experiments corundum with an overlay of boronitride and yttrium oxide was selected as suitable.

From the viewpoint of application of the relation (1) for the interphase tension calculation it was necessary to attempt the experimental research of the system A surface tension (again the method of a sessile drop was used (Fig. 4).

![Fig 2: An image of a sample during the measurement in Tamman furnace (A), a prepared sample before the experiment (B), the sample after finishing the measurement and cooling (C).](image)

![Fig 3: The surface tension temperature dependence of the steel used for the interphase tension measurement.](image)

\[
y = -0.1638x + 2060\\
R^2 = 0.0219
\]
This was followed by an experiment, which result was the temperature dependence of the interphase tension in the interface molten steel – molten slag (system A, Fig. 5).

In the last phase of the research the reproducibility of the obtained outputs was proved.

In Figure 6 there are presented the temperature dependences of the interphase tensions of the dipping angles from identical molten system which was investigated twice under equivalent conditions.
4. CONCLUSION

The interphase phenomena represent the key importance in many processes of metal and steel production, where there co-exist two aliquation phases – oxidic and metallic. Within the frame of the interphase tension research, the main aim was to improve the experimental method which provided the reproducible data. Concurrently, a suitable evaluating software was developed. It was not possible to realize the comparison measurements due to lack of the literary data. When confronting the investigated systems with chemically close systems [12, 121, 130] it was found out an approximate accordance.

The reproducibility was proved by multiple measurements of identical systems (Fig. 6). The developed error did not exceed 5%. In fine it may be stated, that the prior research proceeding in this scientific area was developed. Using suitable materials and equipments, the experimental method was modernized and improved.

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REFERENCES:


