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Impact of metallurgical factors on the resistance of working ladle lining

This article examines the impact of main metallurgical factors on the stability of the working lining of steel ladles for plant that smelts low-alloy, carbon and low silicate assortment with turnover of more than 4,5 ladle heats/day, shares of heats processed on the ladle furnace – 100% and casting on continuous casting machine by open stream. By results of work the determinants factors and their share of influence on the stability of steel ladle have been estimated.

Ключевые слова: *lining, steel ladle, treatment in ladle, refractories, steel ladle resistance, wear.*

The effect of the metallurgical factors on ladle working lining stability is considered by each enterprise on an individual basis. The following key parameters, which have the major impact, may be marked out without dispute. They may include the duration of argon metal processing in a ladle-furnace (LF), duration of metal stay in a ladle, duration of metal heating in the LF, vacuuming duration, ladle turnover, metal temperature at the heat discharge from a melting unit, metal temperature in the ladle before and after secondary processing, as well as a number of process parameters (quantity of slag-forming constituents, flux cored wire, deoxidizing agents and other agents delivered for melting). Some dependences are discussed in numerous publications [1, 2]. This paper describes a balanced-war differentiated lining [3] of the ladle working lining operated in a converter plant, which melts low-alloyed, carbon and low-silicon steel grades, with a sufficient ladle turnover making 4,5 heats per day. It should be noted that the share of heats processed in the LF is 100%; casting is open jet in a continuous casting machine. Periclase-carbonaceous refractory materials are used for wall and slag belt lining.

The data was analysed using the production files for the period from 2012 to the first quarter of 2016 (each point on diagrams 1, 2, 5 and 7 corresponds to the inspected data file for 9,2 to 9,5 thousand heats).

The analysis showed that the lining stability reduction is accompanied by the exaggeration of operating conditions for ladles in terms of the following factors:

– duration of argon metal processing in the LF;

– duration of metal stay in the ladle;

– metal temperature at the heat discharge from the converter plant;

– duration of metal heating in the LF.

One of the factors, which has the most adverse impact on the lining stability, is time of metal processing in the ladle-furnace. The time of metal processing (purging) combined with high consumption rate of inert gas is accompanied by a higher-than-anticipated wear of the slag belt mainly where purge units are located. This is because the gas-liquid upward flow forms a zone of increased metal circulation next to the upper rows of the wall lining when it reaches the ladle top. This mechanism is followed by erosion (mechanical) wear of the ladle slag belt lining. Fig. 1 shows the dependence of the lining stability on the time of metal processing in the LF.

In accordance with the diagram, the ladle stability is inversely proportional to the time of metal processing in the LF and is of multinominal nature, with a high degree of authenticity. This confirms the high negative impact of this parameter on the lining stability. The increase in the stability of the ladle working lining and the achievement of the ladle stability indicator without hot repairs at a level

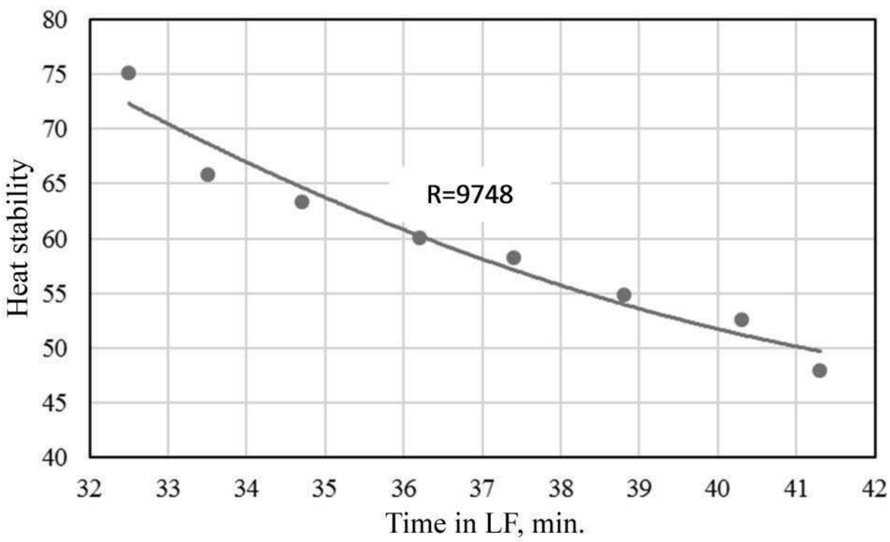

Fig. 1. Change of the ladle lining stability depending on the time of metal processing in the LF

of 65 heats are possible provided that the duration of the heat processing in the LF is 33-35 minutes.

The change in basic process unit operation causes the change in the total time of metal stay in the ladle. Fig. 2 shows the dependence of the ladle lining stability on the average time of metal stay in it.

As it follows from Fig. 2, the increase in the time of metal stay in the ladle by 19,5 minutes on an average is accompanied the synchronous reduction in the lining stability. This parameter increase is observed not only in terms of the average indicators, but also individual heats. The time of metal stay for individual heats may reach 550-600 minutes.

In case of prolonged metal stay in the ladle, the aggressive slag impact on the slag belt lining increases. While studying the problems of the slag belt wear, it was established that the advanced wear of the slag belt may be caused for a single heat by chemical corrosion (Fig. 3).

The increase in the time of metal stay in the ladle is conditioned by the necessity of metal accumulation upstream of the CC machine. The data on the average daily quantity of heats (without regard to the period of finished product output volume reduction, which is conditioned by non-production factors) is given in Fig. 4.

To reduce the negative impact of the aggressive environment on the ladle slag belt lining, it is recommended to inject magnesium-containing additives (dolomitized lime and/or flux) into the ladle upstream of the CC machine or LF.

To find out the factors, which have an impact on the change of the ladle lining stability, the dynamics of the metal temperature change at the heat discharge from a converter plant was analyzed (see Fig. 5).

The increase in the average metal temperature at the heat discharge from the converter plant by 13 °C on an average is conditioned by the electric power consumption decrease in the period of the heat processing in the LF. The dependence of the lining stability on the average temperature of discharged metal is non-linear; however, this factor shall be considered in combination with the ladle lining temperature when it

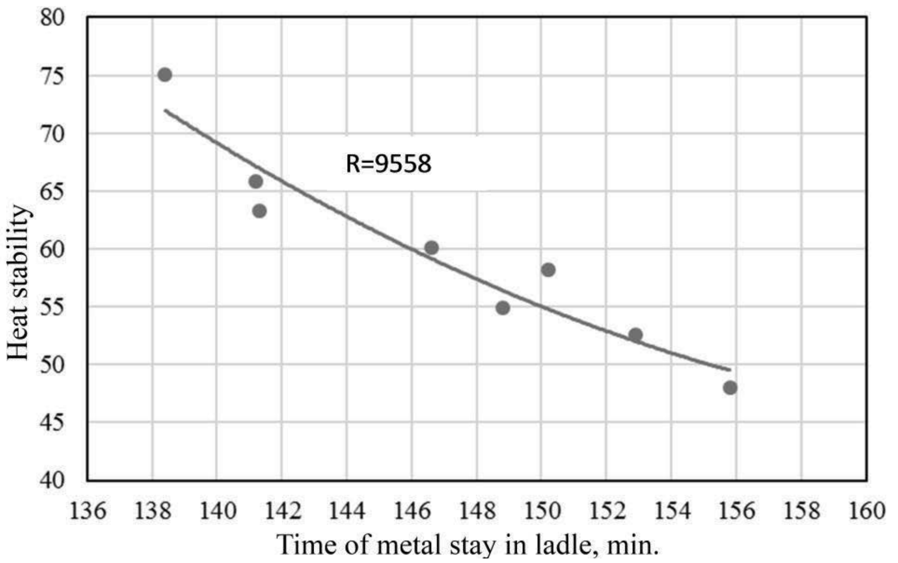

Fig. 2. Change of the ladle lining stability depending on the time of metal stay in the ladle

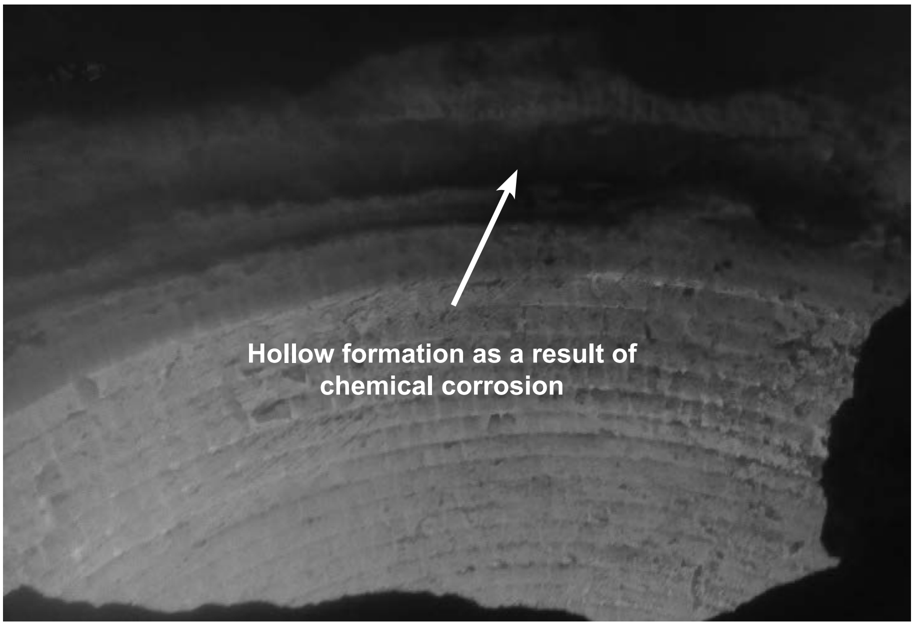

Fig. 3. Advanced wear of the slag belt with a hollow formation as a result of chemical corrosion

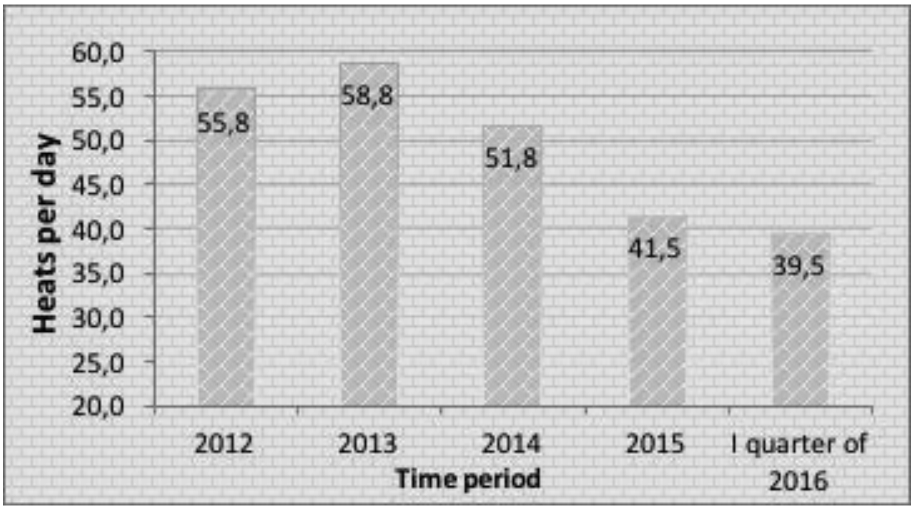

Fig. 4. Average daily quantity of heats

is placed for metal reception from the converter plant both after heating in ladle heating units and in the "from heat to heat" cycle.

In the course of the ladle preparation between heats (maintenance of steel discharge channels and purge units), the ladle lining is cooled down to 850-950 °C (in certain cases, the temperature may decrease to 700 °C). At further metal reception, sharp heating («thermal shock») of the lining (the temperature "jump" may be 500 °C to 800 °C) may take place. The lining operation in the sharp inversion mode (sign change) of the thermal flow (heating – cooling – heating) causes cyclic loads and thermal stress development in the lining pattern. This results in the formation of fatigue cracks in the working lining of the ladle walls and bottom [4]. Therefore, the increased metal temperature at the heat discharge from the converter plant and decrease of the thermal support to the ladle may, when combined, have a considerable impact on the lining stability (on the ladle bottom to a greater degree). The advanced wear of the lining, which is caused by the above mechanism, will only increase (Fig. 6). It is recommended to prohibit any decrease of the ladle lining temperature below 1,000-1,100 °C before its delivery for melting.

As far as the heat supply for melting in the LF is performed by arc heating of slag (slag to metal heat transfer), maximum loads occur in the zone of slag melting contact with the lining (slag belt zone) and they cause advanced wear of the slag belt in future. The impact of the metal heating time on the change in the ladle lining stability is shown in Fig. 7.

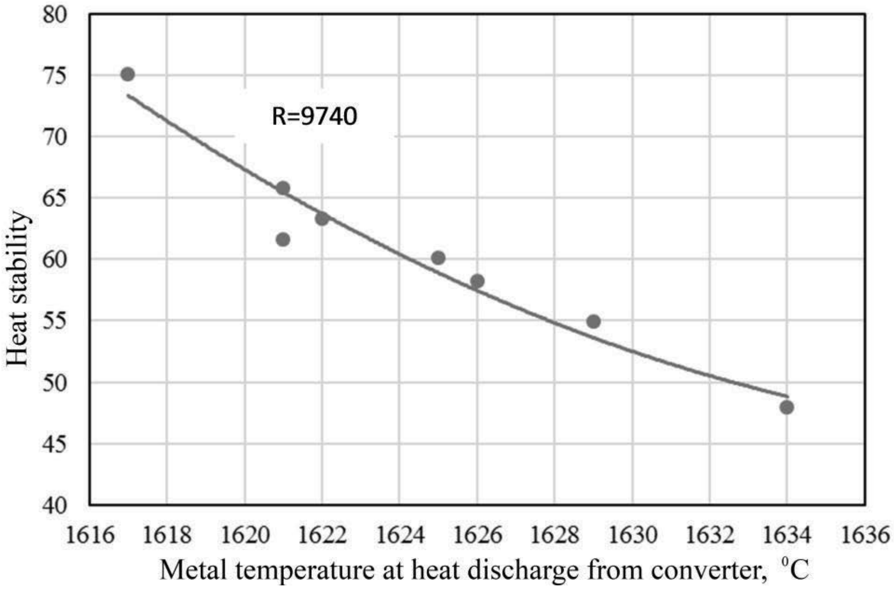

Fig. 5. Change of the ladle lining stability depending on the metal temperature at the heat discharge from the converter plant

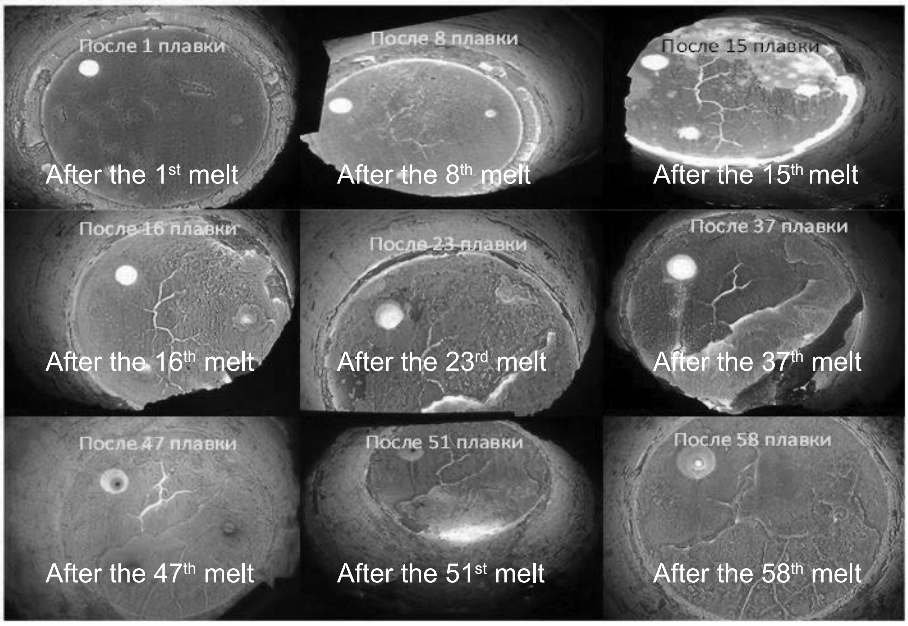

Fig. 6. Dynamics in the development of concrete cracking in the working layer of the ladle bottom in the course of its operation

Based on the provided data, it follows that the increase in the time of metal arc heating in the ladle by 6,5 minutes (36,7%) reduces the ladle working lining stability by 27,1 heats. The analysis of the data array shows the following:

– time of metal heating less than 18 minutes allows achieving the maximum stability value;

– when the heating duration increases to 18,9-19 minutes, the lining stability decreases to 63,3–65,8 heats;

– when the duration of the metal heating in the LF exceeds 24 minutes, the sharp reduction of the ladle lining stability to 48,1-54,9 heats is observed.

Therefore, the increase in the duration of processing in the LF causes the ladle stability reduction.

To this end, to achieve the optimal indicator of the ladle stability (exclusion of hot repairs), it is recommended to decrease the duration of metal arc heating to 19-19,5 minutes.

In accordance with the work performed, it is not possible to identify the determinant and its impact on the ladle lining stability. All the analyzed factors act together; however, the proposed recommendations allow reaching the optimal stability within the set production. To this end, the following conclusions can be made for steel-making with a sufficient ladle turnover, which exceeds 4,5 heats/day, 100% heats processed in the LF and open jet casting to the CC machine:

1. The ladle stability is inversely proportional to the time of metal processing in the LF and is of multinominal nature, with a high degree of authenticity. This confirms the high negative impact of this parameter on the lining stability. The increase in the ladle working lining stability and the achievement of the ladle stability indicator without hot repairs at a level of 65 heats are possible

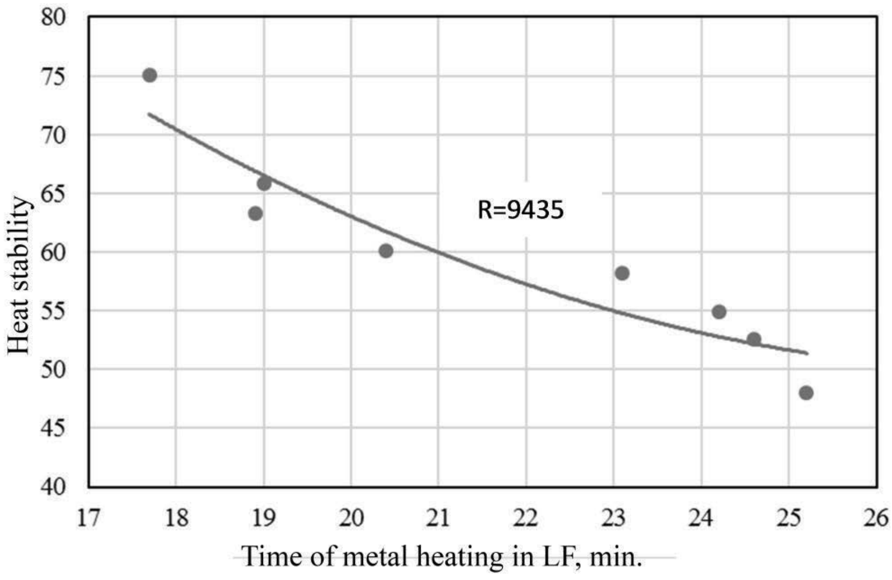

Fig. 7. in the ladle lining stability depending on the time of metal heating in the LF

32-36%. For this purpose, to reduce the negative impact of the aggressive environment on the lining of the ladle slag belt, it is recommended to inject magnesium-containing additives (dolomitized lime and/or flux) to the ladle under the steel-making unit or to the LF.

3. The dependence of the lining stability on the average temperature of discharge metal is non-linear; however, this factor shall be considered together with the ladle lining temperature when the ladle is set for metal reception from the converter both after heating in the ladle heating units and in the "from heat to heat" cycle. It is recommended to prohibit the decrease the ladle lining temperature below 1,000-1,100 °C before its delivery for melting.

provided that the duration of the heat processing in the LF is 33-35 minutes.

2. The increase of the time of metal stay in the ladle from 130 to 156 minutes on an average is accompanied by the synchronous reduction in the lining stability by

4. If the time of metal arc heating in the ladle is increased by 6,5 minutes (36,7%), the stability of the ladle working lining reduces by 27,1 heats. The optimal indicator of the ladle stability (except hot repairs) may be achieved only when the duration of metal arc heating is decreased to 19-19,5 minutes.

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Аннотация

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Влияние металлургических факторов на стойкость рабочей футеровки

В статье рассмотрено влияние основных металлургических факторов на стойкость рабочей футеровки сталеразливочных ковшей для завода, выплавляющего низколегированный, углеродистый и низкокремнистый сортамент с оборачиваемостью стальковша более 4,5 плавок/сутки, долей плавок обрабатываемых на установке «ковш-печь» (УКП) – 100% и разливкой на машине непрерывного литья заготовок (МНЛЗ) открытой струей. По результатам работы оценены определяющие факторы и их доля влияния на стойкость стальковша.

Ключевые слова

Футеровка, сталеразливочный ковш, внепечная обработка, огнеупоры, стойкость стальковша, износ.

Анотація

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Вплив металургійних факторів на стійкість робочої футерівки

У статті розглянуто вплив основних металургійних факторів на стійкість робочої футерівки сталерозливних ковшів для заводу, який виплавляє низьколегований, вуглецевий і низькокремнистий сортамент з оборотністю стальківша понад 4,5 плавок/добу, часткою плавок, що обробляються на установці «ківш-піч» (УКП) – 100% і розливанням на машині неперервного лиття заготовок (МБЛЗ) відкритим струменем. За результатами роботи оцінено визначальні чинники і їх частку впливу на стійкість стальківша.

Ключові слова

Футерівка, сталерозливний ківш, внепічна обробка, вогнетриви, стійкість стальківша, зношення.

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