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TECHNOLOGICAL INDICATORS OF OPERATION OF THE ROTATING-HEARTH FURNACE IN CONDITIONS OF DISCONTINUED PRODUCTION

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Quality heating of the steel charge to be rolled into seamless tubes in the rotating-hearth furnace requires continuous operation of the pilger mill. Interruption of the charging schedule leads to impaired charge heating process. Prolonged heating time causes a rise in the charge temperature above the limit values, and that in turn brings to a larger quantity of scale formed on the charge surface. Final result is loss of metal and overheating of the charge accompanied by increased fuel consumption and lower furnace productivity.

Key words: rotating-hearth furnace, furnace productivity, specific fuel consumption

Tehnološki pokazetelji rada kružne peći u uvjetima diskontinuirane proizvodnje. Kvalitetno zagrijavanje čeličnog uloška u kružnoj peći zbog njegove prerade u bešavne cijevi zahtijeva kontinuirani rad pilger valjaonice. Promjene vremenskog perioda ulaganja dovodi do narušavanja tehnološkog procesa zagrijavanja uloška. Porast vremena zadržavanja uloška u peći dovodi do porasta njegove temperature iznad neke granične vrijednosti, a ovo pak dovodi do porasta količine formirane ogorine na površini uloška. Konačni rezultat je gubitak metala, pregrijavanje uloška uz povećanu potrošnju goriva i smanjenje proizvodnosti peći.

Ključne riječi: kružna peć, proizvodnost peći, specifična potrošnja goriva

INTRODUCTION

The technological process for manufacturing seamless steel tubes in the Sisak Rolling Mill includes the heating of the charge for processing in the hearth-rotating furnace. Description of the furnace and its operation can be found in literature [1]. In the process currently applied for producing the tubes with the outer diameter of 168.3–356.6 mm the temperature is between 1280 and 1300 °C [2]. The thermal regime is monitored with an optical pyrometer. Measurements are made in a hollow shell after it is manufactured, and on its surface during reheating in the furnace. After heating the shells are extended into tube blanks by means of an elongator and subsequently rolled into tubes in a pilger mill. Provided all the other parameters are stable, the heating time in the rotating-hearth furnace will depend on the quality of the workpieces and on their dimensions as well as on their arrangement on the ring-shaped hearth (in two rows, in one row, or less often, in one and a half rows). In recent years, in addition to home-manufactured charge the Rolling Mill has made use of the continuously cast charge imported from Russia, Italy and the Czech Republic. The necessary technological adaptations that have been undertaken in accordance with the type of charge available on the market have caused occasional departures from the technologically imposed limitations [3].

As a result of periodic delays in the operation of the pilger mill due to mechanical trouble the firing intensity declines and the charge is left in the furnace chamber too long. The consequences may be manifold. Among the most frequent are excessive specific fuel consumption, undue scaling [4], poor furnace productivity, and unplanned servicing. In this work we analyse the temperature regime in the rotating-hearth furnace.

HEATING REQUIREMENTS FOR THE STEEL CHARGE IN THE ROTATING-HEARTH FURNACE

The process of heating the steel charge in the rotating-hearth furnace calls for application of such technological procedures that will ensure satisfactory heating quality but also the lowest possible fuel consumption. Heating quality implies achieving the required temperature and soaking of the steel charge without allowing the charge surface to be damaged by temperature and/or gaseous atmosphere in the furnace. It is therefore wrong to suppose that quality heating can only be achieved by

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prolonging the heating time, because often the very opposite is the case. It is true that slow-rate heating will result in proper soaking of the semi-finished products, but it may also increase the steel scaling rate and induce decarburisation of carbon steels. Due to poor thermal conductivity scaling additionally prolongs the heating time. The heating time is therefore determined by temperature limitations, that is by the maximum permissible difference between the temperature of the charge cross-section and that of its surface which induces accelerated surface reactions. So, the final charge temperature is defined by the limiting temperature value required for plastic deforming.

The heating time depends on the difference between the temperature of the total surface area of the charge and the surrounding heat-irradiating elements in the furnace (luminous flame, combustion gases, and furnace walls) and that of the heat-absorbing charge surface wherefrom the heat is transfered to the inside. It follows that the temperature difference ought to be large, that is, that heating should take place at high temperatures and that the heat-absorbing surface of the steel charge should be as large as possible. However, such heating may be accompanied by the occurrence of thermal stresses in the charge, so that in establishing the temperature regime one should take into account the size and shape of the workpieces and their arrangement on the ring-shaped furnace bottom, as well as the temperature and heating rate. However, if the rotating-hearth furnace is not fired in the preheating zone (zone I), as is the case here, there is usually no risk of thermal stress. In the heating (zone II) and soaking (zone III) zones the furnace is fired according to a defined thermal framework. Consequently, furnace productivity may exhibit a wide range of variations as it is the result not only of the charge cross-section size, the distance between the charge pieces and their arrangement on the bottom (in one or in two rows), but also of the quality of the steel charge, mode of plastic processing and the thermal capacity of the furnace.

OPERATION OF THE ROTATING-HEARTH FURNACE IN CONDITIONS OF DISCONTINUED PRODUCTION

For lack of charge as well as for want of funds for its purchase on the world market the rotating-hearth furnace has not been operating in compliance with the customary standards and earlier rolling mill practice. Details of the types and sizes of the steel charges presently used for seamless tube rolling are mostly available from literature [3]. Working with the charge pieces having a square cross-section imposed major limitations to product assortment, and also created a number of technological shortcomings. Upon the introduction of the continuously cast charge the quality of seamless steel tubes improved considerably. The charge pieces with a circular section yielded expected results, and to a major extent made up for the deficiency of home-manufactured steel and reduced the number of inevitable long-lasting interruptions in production. Results of analysis of technological indicators of the rotating-hearth furnace operation conducted between 2004 and 2006 are shown in Tables 1 and 2. The figures are the mean values for that period.

Table 1 gives details of the charging regime for the rotating-hearth furnace for the steel workpieces of different type and size (having a circular section 400 mm in diameter, an eight-angled section with a 276, 294 and 320 mm opening, and a twelve-angled section with a 428 mm opening). It shows the number of rows on the bottom with the total number of individual pieces in brackets, the actual heating times, the thickness of the scale layer, and the difference in methane consumption as a consequence of the difference between the actual and the prescribed heating times (the latter are given in brackets) [5]. The estimate was made under the assumption that the thermal regime stayed unaltered regardless of the duration of the heating time, as was usually the case if there was no discontinuance of operation. A halt in furnace operation would reduce firing intensity and the charge would be left in the furnace for an unduly long time. For that reason a practice was adopted in the plant of removing the scale layer from the surface of the semi-product after it came out of the furnace. Results of measurement of the scale thickness (Table 1) show the scaling to have been unusually high. That further affected the production costs. From the standpoint of up-to-date rolling technology the above shortcomings need to be eliminated if productivity is to be increased, the production costs reduced, and the quality of the tubes and the tube surface improved [6].

Table 2 shows natural gas consumption by furnace zones, specific methane consumption and surface temperature at the end of zone III for the steel charge of different type, size, and furnace productivity. Specific fuel consumption was calculated on the basis of total natural

Table 1. **Charging and heating regimes of the rotating-hearth furnace for the production of seamless steel tubes**

Charge size / mm	Charge weight / t	Bottom rows no.	Heating time / h	Difference in fuel consumption / %	Scale thickness / mm
276	32,68	1 (76)	4,3 (3,9)	+10,26	2,1
294	55,20	1 (69)	4,9 (4,2)	+16,67	3,3
320	51,21	1 (64)	5,9 (4,6)	+28,26	3,8
400	102,12	2 (92)	7,1 (5,7)	+24,56	4,7
428	116,38	2 (95)	8,6 (6,1)	+40,98	5,5

Table 2. **Natural gas consumption and charge temperature in the rotating-hearth furnace during production of seamless steel tubes**

Charge size / mm	Furnace productivity / t/h	Fuel consumption zone I zone II zone III / m^3/h			Total fuel consumption / m^3/h	Specific fuel consumption / m^3/h	Charge surface temperature / °C
276	9,90	–	282	326	608	61,41	1290
294	11,26	–	260	330	590	52,40	1270
320	8,68	–	330	310	640	73,73	1290
400	14,38	–	255	294	549	38,18	1265
428	13,53	–	253	315	568	41,98	1270

gas consumption and the rotating-hearth furnace productivity (Table 2).

Variations in specific methane consumption do not appear to be large if they are considered in relation to the number of rows of semi-products on the circular furnace bottom, and not only as a function of furnace productivity. The average specific natural gas consumption would be appreciably lesser if the actual heating time matched the prescribed time fairly well. The reason for actual annual furnace operation being of relatively short duration lies with the lack of home-produced steel charge as well as with the generally poor state of the rolling plant equipment. For the latter reason the issue of annual natural gas consumption is also closely linked with the furnace repair work during which the furnace is «blank» fired. The natural gas consumption due to «blank» firing is included in the average specific natural gas consumption required for heating the charge of any type or size.

CONCLUSION

Without ensuring continuity of rolling production and preventing unexpected disruptions of the mill operation, minimum fuel consumption, or commercially acceptable proportion of energy cost in the price of the product, cannot be achieved. In organizing production it is therefore imperative that the Seamless Tube Rolling Mill operates in cycles, that there is enough charge for each particular cycle, that interruptions of operation are planned in advance and for an extended period of time, and that there is no «blank» firing for their duration. The necessary repair work should be carried out while the rolling mill operation is at a standstill in order to avoid any unexpected delay in operation later on. If the proportion of energy cost in the manufacturing costs is very high, the selling price of seamless steel tubes cannot be lowered to a commercially competitive level without causing a loss to the company.

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