УДК 621.746.5.047 - 412:621.771.237.016.2

Prospects of Medium Thickness Slabs Application in Technological Complex "Continuous Slab Casting – Hot Rolling Mill"

Alexander G. Solovyev, Michael V. Shitov* and Dmitry O. Drobny Magnitogorsk State Technical University named after G.I. Nosov 38 Avenue Lenin, Magnitogorsk, 455000, Russia

Received 14.11.2013, received in revised form 05.02.2014, accepted 10.03.2014

The consideration was given to a transition to medium thickness slabs for complexes CCM-Plate Mill and CCM-Hot Rolling Mill. We used two examples, considering their technical characteristics, to show possible advantages and disadvantages. From the point of view of energy efficiency, we proposed a number of measures for a perspective application of this transition.

Keywords: continuous casting machine, wide-strip hot rolling mill, plate mill, thick slabs, medium thickness slabs, efficiency, energy resources, technological complex, product mix, production cycle of finished products.

The processes of slab continuous casting and subsequent hot rolling of plates and strips are among the most energy-intensive in the steel industry. These processes, technical and technological solutions implementing them, first of all affect the consumer properties of finished products and at the same time, to a large extent, determine the technical and economic performances of a steel plant operation as a whole. All of this determines the relevance and importance of issues aimed at improving the efficiency of technological complex "continuous casting – hot plate rolling". The problem of efficiency includes a number of important objectives: saving of energy, metals and auxiliary materials, performance increase of individual machines, sites, links, streams, improving the quality of strips from the point of view of physical and mechanical properties, surface condition, shape and profile, automation and process control. The acute problem of efficiency mostly has to do with conventional technological complexes with thick slabs CCM and wide-strip hot rolling mill or plate mill. Further discussion of the efficiency issue will be developed in the context of these complexes.

The introduction and development of continuous casting technology and thin slabs rolling at the turn of XX and XXI centuries significantly reduced the energy consumption for the production of one tone of finished product (Fig. 1.). Cost reduction is provided primarily by minimizing the number of

[©] Siberian Federal University. All rights reserved

^{*} Corresponding author E-mail address: mihailschitov@mail.ru



Fig. 1. Yield energy consumption on different lines: 1 - fuel gas; 2 - electric power

process steps. The leading machinery works rapidly develop and introduce new technologies. However, the major production of flat products is still provided by plate mills and hot rolling mills. Besides, one cannot say of replacing the abovementioned machines with Compact Strip Production in the coming years.

Obviously, there is always a question of production efficiency. But the most critical question is the question of "borderline product mix" production. Meaning the finished product mix which can be produced on different lines: hot rolling mills, plate mills, Steckel mills, thin slab compact strip mills [1]. For plate rolling these are plates of thickness 6-25, width up to 2500 mm and thickness 20-50 mm., width up to 2000 mm. For coils these are strips of thickness up to 12.5 mm and width up to 1850 mm.

A significant amount of production of the above mentioned products in the post-Soviet space is concentrated in old plants with old plate mills. For example, OJSC "AMZ" mill 2850, OJSC «Ural Steel» mill 2800, OJSC «MMK» mill 2350, «Red October» mill 2000 and others. After the commissioning of cut-to-length line 6-25 x 1000-2350 at OJSC «MMK» with the capacity of 1.0 million tons per year and two mills 5000 the general situation in the market for such plate mills deteriorated.

In this situation the experience of «Asha Metallurgical Plant" is interesting. In consequence of the comprehensive modernization of steelmaking facility, the liquid steel is produced in the up-todated 100 ton electric arc furnace with scrap preheating, and slabs are casted in one strand caster. The machine design provides a slab with thickness of 180 and 240 mm, width up to 1600 mm. The modern equipment of the new EAF shop: electric arc furnace (EAF), ladle furnace, the caster provides production up to 1 million tons per year of continuously casted thick slabs. However, the production of rolled products is still provided by the old mill 2850. Furthermore, as a result of modernization of steelmaking facility only, the quantity of faulty production decreased, consumption index decreased, the quality of finished products increased. For further improvement of technical-economic indicators the decision of complex revamping of mill 2850 was adopted.

The combination of cost cutting for all kinds of energy with the reduction of production cycle and shipment of finished products are virtually the only way to further improvement of operation efficiency of technological complex Caster – Plate mill.

The company analyzed the existing and prospective order portfolio, the technological capabilities of the existing equipment and rolling modes being applied. To minimize the inventory, increase the share and temperature of hot charging, reduce orders execution time the company developed and implemented a technology of total product mix production from slabs of single cross-section 240 x 1600 mm. The new technology made it possible to get sheets of any required size mix from one heat. Practically, the plant started to operate as a scrap metal company or steel service center.

From the viewpoint of slabs continuous casting, currently for the production of plates in the thickness range up to 50 mm, thick 200-400 mm and medium 130-200 mm slabs are used. In the past two decades the technology and equipment for continuous casting of thin and medium slabs have been intensively developed. At present, medium and thin slab casters can cast virtually any grades of steel. Besides, the slabs after thin slab casters meet the requirements claimed to rolled plate products from the point of view of all parameters [2]. Further production of plates with thickness up to 50 mm from medium slabs is successfully implemented in a number of metallurgical enterprises [3].

The bulk production is sheets 12-25 mm thickness. The company analyzed the capabilities of plate production from medium and thick slabs under the technology of one cross-section casting for the entire finished product mix. The results can be summarized as follows:

- instead of thick slab 240 x 1600 mm it makes sense to use a medium slab 180 x 2000 mm. For transition to a new section of slab it is necessary to revamp the caster. According to the analysis of the machine design, such width increase can be realized with little or no reconstruction of the foundations.
- the application of medium thickness 150 x 2800 mm slabs ensures the production of rolls not more than 25 m long under the technology of one width slab casting. In the case of application of slabs in several sizes, it is possible to reduce the consumption index due to production of rolls up to 48 m long.
- the reduction of slab thickness will have a positive impact on the mill's productivity and electrical power and gas flow rate for rolling.

The main production of coils with thickness up to 12.5 mm in the Russian Federation is provided by three rolling mills 2000 and one rolling mill 2500. In addition, OJSC "Amur metal" produce the coiled stock on combination mills 2800/1700, 2300/1700, Steckel mill, and OJSC "VMZ" produce it on Compact Strip Production machine. All the companies, except for OJSC "VMZ", use slabs with thickness 200-250 mm. It should be noted that, historically, the first hot rolling mills used medium thickness slabs coming from slabbing mills as semifinished rolled stock. In practice of modern hot rolling mills operation the continuously casted medium slabs are widely coming into use [3].

In the technological complex CCM – hot rolling mill slabs take place on three areas: 1 - continuous casting area; storage and transfer to the reheating furnaces; 2 reheating furnaces area; 3 - roughing mill. CCM and hot rolling mill are one the most expensive metallurgical units. Each of the units is



Fig. 2. The influence of slab thicknes on productivity of CCM, furnace and yield fuel flow rate for heating

operated for decades and each of them is subject to numerous upgrades and revampings for their lifecycle. Construction of new facilities takes place in exceptional cases. There was a consideration of an option to use medium thickness slabs applying to the technological system of slab continuous casting in oxygen converter shop – hot rolling mill 2000 OJSC "MMK".

The transition to medium thickness slabs uniquely affects each production area. For example, when casting thinner slabs, the caster's performance decreases. The analysis of continuous casting area was made in accordance with the procedure presented in study [4]. The summarized results are shown in Fig. 2. The following results were achieved for the most popular slab with width of 1300 mm in the thickness range of 150 - 350 mm with two-strand casting process. With the transition from slab 250 mm to slab 200 mm the losses are 3.2 %, to slab 150 mm - 6.4 %, considering the working time fund of 300 days, the losses can be 30 - 60 and 70 - 130 th. tones for the relevant slab thickness. There are five CCM operating in oxygen convertor shop. Two four strands machines with capacity of 3 million tons per year, two combined two or four strands machines depending on the width of casted slabs with capacity of 2 million tons per year and one single strand machine with capacity of 1.8 million tons per year. To meet the needs of mill 2000 for medium width slabs production, it is necessary to reconstruct two or three machines. Each of the machines has a working time fund surplus which is sufficient to cover the loss of productivity in the case of medium thickness slabs casting. A positive factor is the reduction of scrap, which can reach 13 - 18 % for a slab of 200 mm and 24 - 38 % for a slab of 150 mm.

The next link, which is influenced by slab thickness, is furnaces. The transition to thinner slabs is beneficial to both fuel consumption and capacity of the unit (Fig. 2). If we evaluate the heating time ratio, which affects the productivity of a furnace, for slab 250 to slab 200 and 150, as the ratio of squares of their thicknesses [5], it turns out that productivity increases in a parabolic relationship with decreasing of slab thickness. Yield fuel consumption was calculated by drawing the heat balance for slabs of different thickness [6], taking into account the technical characteristics of the existing furnace of hot rolling mill 2000. Yield consumption for slabs 200 and 150 mm differs from slab 250 mm by 0.6 % and 1.9 % respectively. The metal losses in scale, despite the increasing surface area,

can be evaluated, according to operation [5], as equal or even lower. The negative factor is that during transition to thinner slabs, to ensure a preset weight of coils some part of slabs, according to the technical characteristics, cannot be charged into a furnace due to the extension of maximum allowable length. The production program of mill 2000 is provided by four reheating furnaces. Three of them have been operated since the commissioning of the mill. In case of transition to thinner slabs, it will be necessary to reconstruct the furnaces to increase their width, to keep the previous product mix. According to the preliminary research, the civil constructions of the shop building make it possible to install new furnaces at the position of the old ones to reheat slabs of maximum length up to 14-15 m.

The last link – roughing mill – reduces a slab to the preset dimensions in both horizontal and vertical direction. To analyze the influence of slab thickness change, we used "The program of indicators calculation for the analysis of structural and layout solutions of hot rolling mills" (Certificate of state registration for a computer # 2010615121 dd. 10.08.2010). The thicker a slab, the greater specific energy consumption, but at the same time, the performance of roughing mill increases (Fig. 3, a). Energy saving for slabs 200 and 150 compared with slab 250 is 18 and 38 %. Roughing mill is not a bottleneck, if a roughing mill and finishing mill are charged in a rational way, therefore the transition to thinner slabs will not affect the mill performance as a whole.

On the other hand the roughing mill reduces a slab across the width, which plays an important role in the formation of rolling campaigns. And when the productivity of continuous casting is not sufficient, that reducing enables to unload CCM or at least find a compromising solution for complex CCM – hot rolling mill working with a preset product mix. The transition to thinner slabs may prevent an effective change in width. A significant change in the width takes place during the first 2-3 vertical passages, especially when the first vertical stand is equipped with grooved rolls, further reduction across the width only removes a natural broadening, subsequent passages are limited with transverse stability. For slabs 150 - 199 mm 4 stands or 4 reverse passages are used, for slabs $200 \div 249 - 5$, $250 \div 299 - 6$, $300 \div 350 - 7$. However, if the transition from the slab 250 to 200 affects the reducing ability slightly 5 - 15 mm, the losses for slab 150 are 45 - 55 mm (Fig. 3 b). To maintain the reducing ability, it is necessary to change the rolling technology, i.e. reduce more across the width with planishing



Fig. 3 – The dependence of total specific energy consumption and roughing mill performance on slab thickness (a) and effective change of slab width and sustainable reduction of the strip on slab thickness (b) from slab $1500 \times 150 \times 350 \times 7000$ mm in strip plate $1365 - 1420 \times 32$ mm for steel grade CT. 3 cfl.

passages, which are blank passages for horizontal stands. The design of roughing mill of mill 2000 OJSC "MMK" ensures the implementation of such technology.

Hence, proceeding from features of complexes, it is possible to draw conclusions.

The application of medium thickness slabs in complex CCM – Plate mill generally improves the competitiveness of the products. Especially it is promising to use medium slabs on old plate mills, by reducing the consumption index and gas flow rate for heating.

The transition to thinner slabs in complex CCM – Plate mill, from a technological point of view, requires to take into account a certain number of factors that contradictorily influence both the productivity and the economic indicators of the complex. In study [7], economicwise, the optimum slab thickness is 307 mm, in spite of the fact that in study [5], basing on the same mill, they say that it is more effective to use thinner slabs. Consequently, the transition to slabs of one or another thickness should be analyzed from different points of view and the decision should consider all the pros and cons, including a possible reconstruction.

References

[1] *Solovyev A.G, Shytov M.V, Drobny D.O.* Prospects for development of the technological system "continuous slab casting – hot rolling mill" from the point of view of energy efficiency / simulation of metal forming processes: scientific work under the editorship of Salganik V.M. Magnitogorsk: Magnitogorsk State University, 2011. P. 31-36.

[2] *Konovalov Y.V.* Millman's desk book. Reference edition in 2 books. Book 1. Production of hot-rolled sheets and strip. M.: Teplotechnik, 2008. 640 s.

[3] Best of both worlds. Medium-thick-slab casting and rolling offers a host of benefits for producers. Metals & Mining. 2009. № 2. P. 48-49.

[4] *Niskovskih V.M., Karlinsky S.E., Baranov A.D.* Continuous casting machines. M.: Metallurgy, 1991. 272 p.

[5] *Hloponin V.N.* Possible energy-efficient and metal saving operation of complex CCM – Plate Mill // Metallurgist. 2010. № 12. P. 47-53.

[6] Calculation of reheating and heat treatment furnaces. / ref. ed. S.B. Vasilkov, M.M Genkina, V.L Gusovsky and other. M: Metallurgy, 1983. 480 p.

[7] Zaitsev V.S Optimization of continuously casted slab thickness under the criterion of minimum total cost in the steelmaking – rolling complex // Production of rolled products. 2011. N_{2} 6. P. 2-9.

Перспективы использования слябов средней толщины в технологическом комплексе «непрерывная разливка слябов – стан горячей прокатки»

А.Г. Соловьев, М.В. Шитов, Д.О. Дробный Магнитогорский государственный технический университет им. Г.И. Носова

Россия, 455000, Магнитогорск, пр. Ленина, 38

Рассмотрен переход на слябы средней толщины для комплексов МНЛЗ-ТЛС и МНЛЗ-ШСГП. На двух примерах с учётом их технических характеристик показаны возможные преимущества и недостатки. С точки зрения энергоэффективности предложен ряд мероприятий для перспективного использования данного направления.

Ключевые слова: машина непрерывной разливки заготовок, широкополосный стан горячей прокатки, толстолистовой стан, толстые слябы, слябы средней толщины, эффективность, энергоресурсы, технологический комплекс, сортамент, цикл производства готовой продукции.