საქართველოს მეცნიერებათა ეროვნული აკადემიის მოამბე, ტ. 4, № 2, 2010
BULLETIN OF THE GEORGIAN NATIONAL ACADEMY OF SCIENCES, vol. 4, no. 2, 2010

Metallurgy

Construction of Continuous Casting Machine Withdrawal-Roll Set for Hollow Cast Iron Billets

Irakli Zhordania*, **George Kevkhishvili****

* *Academy Member, F. Tavadze Institute of Metallurgy and Materials Science, Tbilisi*
** *F. Tavadze Institute of Metallurgy and Materials Science, Tbilisi*

ABSTRACT. A new construction and methods of estimation of the structural parameters of continuous casting billet machine according to the quantity of withdrawal force of hollow billets from the crystallizer's cavity are developed. It is connected with transition to continuous casting of hollow billets made of grey and high-duty cast iron with globular graphite. *© 2010 Bull. Georg. Natl. Acad. Sci.*

Key words: *continuous casting, cast iron pipe.*

Many-year experience of semi-continuous casting of grey iron pipes for the stable casting process show that withdrawal mechanism of casting machine in horizontal plane must have a certain level of freedom. This requirement is conditioned by the occurrence of thermal stresses in casting pipes due to their nonuniform cooling along their perimeter. It is mostly caused by the way of feeding metal into crystallizer's cavity. It is known that to distribute liquid metal uniformly along the perimeter of casting turning bowls of special construction are used [1]. Wrong speed of rotation of the bowl or the change of liquidity of the liquid metal often becomes the reason of metal runoff along the walls of crystallizer, being the cause of metal cooling in these areas. Due to nonuniform cooling radical stresses in the billet occur and in the case of rigid centering newly formed skin of casting breaks, which leads to ceasing of the casting process.

Considering this phenomenon while casting iron cast pipes, as a rule, the so-called "tables" are used to serve as withdrawal devices on semi-continuous casting machines. Extraction of pipes from crystallizer is done by means of ropes [2]. One end of the lower and upper branches of the rope are fixed on two drums having left and right screw channels for ropes. Thus, the ropes are fixed in such a way that when one of the branches is winding on the drum, the other is unwinding. Such principle of the mechanism's work excludes jumping displacement of the 'table' during the pulling of the pipe.

In the case when the length of the product is limited beforehand the application of the above construction is justified.

Following the development of the technology of continuous casting of hollow thick-walled (at respectively low diameters) cast iron billets by the Institute of Metallurgy the real need arose of transition to continuous casting from semi-continuous casting. The construction of pulling mechanism, which was good for semi-continuous casting machines, did not allow casting billets of unlimited length. Traditional schemes of mechanism of extraction used on continuous casting billet machine (CCBM) (withdrawal-roll set with one or several pairs of turning rollers) did not fit either.

The authors of the present paper proposed a simple constructive solution. The usual withdrawal-roll set, consisting of pulling rollers was placed on a hanging "table", providing freedom in horizontal plane and withdrawal of billets of unlimited length (Fig.1).

However, it should be noted that compression force while extracting hollow billets is quite limited. Though

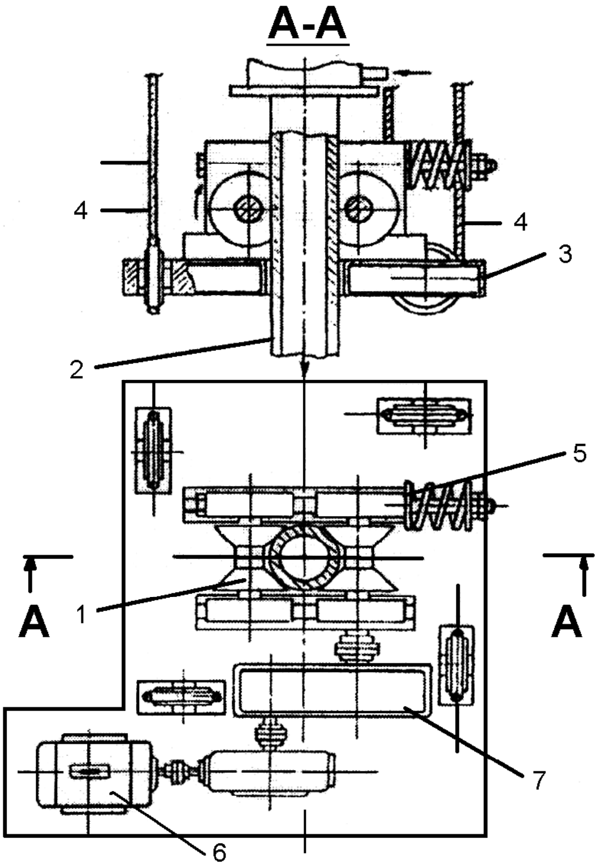

Fig. 1. Extraction mechanism of hollow billets continuous casting machine: 1 – withdrawal rollers; 2 – hollow billet; 3 – table; 4 – ropes; 5 – device for regulation of withdrawal rollers; 6 – gear; 7 – gear box.

the quantity of rollers can be increased, which is connected with the increase of equipment mass, height of the machine, also towing and slipping are not excluded.

To determine the optimal value of compressive rollers to the billet it is necessary to estimate real values of the forces of withdrawal of hollow castings and their strength limit to flattening at high (700-800° C) temperatures.

With this aim theoretical calculations and experimental investigations have been carried out. Unlike continuous casting of solid billets in slipping crystallizer, where the billet extracting force is determined on the basis of dry friction law [1] F=0.5 $\mu\ \alpha\pi DH^2$, where m is friction coefficient, α - density of filling metal; D - diameter of the billet; H - distance from meniscus of liquid metal to the lower billet end of crystallizer (Fig.2), in this case it is necessary to add more force for withdrawal of hollow billet from the inner crystallizer (mandrel), taking into account the mandrel cone angle and character of shrinking of hollow billet. On the basis of theoretical calculations [2] we obtained the formula of complete force for withdrawal of hollow billet from crystallizer:

$$F_{sum} = \frac{4\pi\mu EK_2 H_{total}^{3/2}}{5\sqrt{v}}\left[\alpha(t_0 - t_1) - \frac{2H_{con}\mathrm{tg}\beta}{d_0}\right] + 0.5\mu\alpha DL^2$$

where E is elastic modulus, μ – friction coefficient, K_2 – coefficient of crystallization from the side of inner crystallizer, H_{total} – general length of the contact zone of inner crystallizer, α – expansion coefficient, t_0 and t_1 – temperatures of solidus and casting surface, H_{con} – height of cone part of mandrel; β - mandrel cone angle, d_0 – diameter of the cylinder part of mandrel, D – diameter of outside crystallizer; L – height of contact zone of the hollow billet with outside crystallizer, V – speed of hollow billet extraction.

Inserting concrete values of the noted parameters into expression, we shall obtain the optimal withdrawal force of hollow billet total 80 kgf. Multiple experimental investigations show that for castings in diameter 150-300 mm and wall thickness 25-40 mm the withdrawal force of extraction from crystallizer at stable casting process does not exceed 80÷140 kgf (Fig.3).

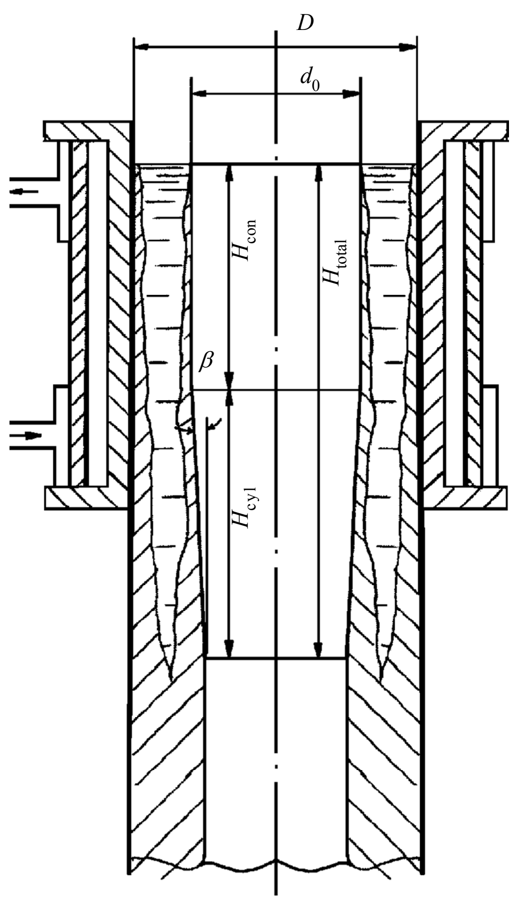

Fig. 2. Contact zones of hollow billet with crystallizer and arbor.

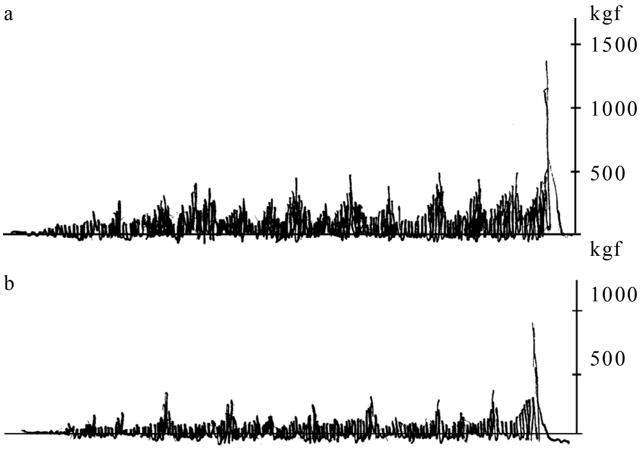

Fig.3. Withdrawal force changes at continuous casting of hollow billet (D – 150 mm, δ - 25 mm); a – grey iron; b – high-duty cast iron.

Theoretical and experimental investigations were carried out in order to determine allowable forces of rollers compression to solid billet.

Taking into account that the temperature of hollow billet changes in the range of 700-800° C at the moment of its contact with rollers of the withdrawal-roll set of CCBM, the samples of grey cast and high-duty iron castings were tested for flattening in the same range of temperatures.

The results of experimental investigation are presented in Fig.4 in the form of diagram of deformation dependence of hollow billet on compression force.

As seen from the diagram, the deformation value of the grey cast iron samples (with the aim of citation of extra reliability at calculations of withdrawal-roll set, focusing on maximal allowable force) at the compression force 500÷1100 kgf does not exceed 0.10÷0.13 mm, which does not cause cracks and residual deformations. Analogous results were received in theoretical calculations: allowable force of compression of hollow castings D = 150 mm and wall thickness δ = 25 mm in the range of 1000÷1500 kgf.

If we know the force of hollow billet extraction from crystallizer and allowable force of rollers compression to billet, we can estimate the number of pairs of rollers for the withdrawal-roll set.

It is known that $n=P/2fN$, where P is the extraction force of hollow billet, f – friction coefficient of rollers on billet, N – allowable compression force of rollers to billet.

Inserting numerical values, we receive (P=120 kgf, f=0.1, N=500 kgf) n=1.2. Thus, to make the process of continuous casting for hollow cast iron billet with diameter 150÷300 mm and wall thickness 15÷40 mm two double-rollers withdrawal-roll sets are necessary.

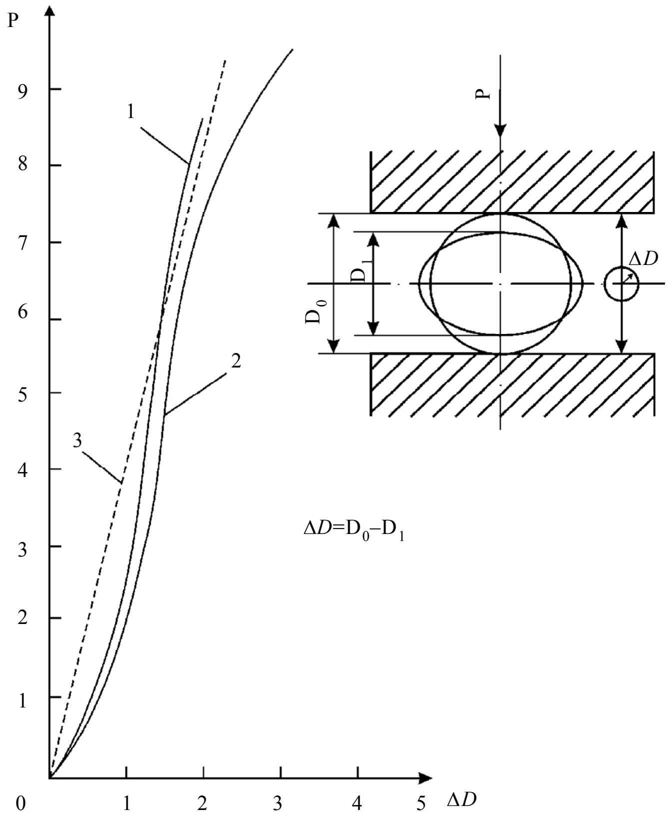

Fig. 4. Deformation dependence on hollow casting on compression force (D – 150 mm, δ – 25 mm); 1 – high-duty cast iron; 2 – grey cast iron; 3 – data of theoretical calculations.

In conclusion it should be noted that the proposed mechanism construction of extraction, beside its main requirements (the degree of freedom in horizontal plane and ability of extracting billets of unlimited length from crystallizer), solves a series of mechanical and technological problems occurring at hollow billet casting:

1. The force of the so-called breakage, which takes place only at the beginning of the process and often exceeds the extraction force by 8÷10 times, after stabilization of casting process, is done by means of suspended "table".

2. Due to combined construction of the extraction mechanism after breakage of billet, the "table" continues moving down along the technological axis of casting until its distance from liquid metal in the crystallizer ensures the passage of the billet get into withdrawal rollers at the temperature 700-800°C, depending on the diameter, wall thickness and type of the casting metal of the billet.

3. The ability of the withdrawal-roll set to move along the technological axis of casting allows to use dummy bars of minimal length, which simplifies much the process of preparing the machine for work.

მეტალურგია

ღრუტანიანი თუჯის ნამზადების უწყვეტი ჩამოსხმის მანქანის გამოწევის გალის კონსტრუქცია

ი. ჟორდანია*, გ. ქევხიშვილი**

** აკადემიკოსი, ფ. თავაძის მეტალურგიის და მასალათმცოდნეობის ინსტიტუტი, თბილისი*
*** ფ. თავაძის მეტალურგიის და მასალათმცოდნეობის ინსტიტუტი, თბილისი*

ღრუტანიანი ნამზადის უწყვეტად ჩამოსხმაზე გადასვლასთან დაკავშირებით შემუშავდა გამომწევი გალის ახალი კონსტრუქცია და დადგინდა მისი კონსტრუქციული პარამეტრების განსაზღვრის მეთოდიკა გამოწევის ძალებისა და ჩამოსასხმელი მასალის სახეობების გათვალისწინებით.

REFERENCES

1. *B.D. Khakhalin, V.I. Semko, A.N. Smolyakov et al.* (1977), Truboliteinoe proizvodstvo. M. (in Russian).
2. *G.S. Arkhipov, O.A. Baranov et al.* (1965), Polunepreryvnaya otlivka chugunnykh trub. Minsk (in Russian).

Received April, 2010