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Moscow, USSR, 19 September - 9 October 1968

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CONTINUOUSLY CAST AND ROLLED SEMIFINISHED MATERIAL FOR LIGHT SECTION AND WIRE MILLS IN DEVELOPING COUNTRIES 1/

by

B. Tarmann

Report from the Development Department of
Messrs. Bohler and Co. Ltd., High Grade Steel
Mills, Austria

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B. Tarmann,

Austria

SUMMARY

Introduction

The manufacture of iron and steel is the prime requirement for the establishment of a heavy engineering industry, and has a decisive influence on the prosperity of a country. Recent developments in the field of metallurgy offer a series of new processes especially suited for the industrialization of developing countries. The establishment of a steel industry in developing countries depends on the availability of the basic materials from indigenous sources or on the proper siting of the plants in locations where the required basic materials are available at especially low freight rates.

From the very beginning, realistic planning will be concerned with the initial capacity of the plant and the aims of future developments. In this respect it is necessary to differentiate between large, medium and small-scale operations since

* This is a summary of a paper issued under the same title as ID/WG.14/50

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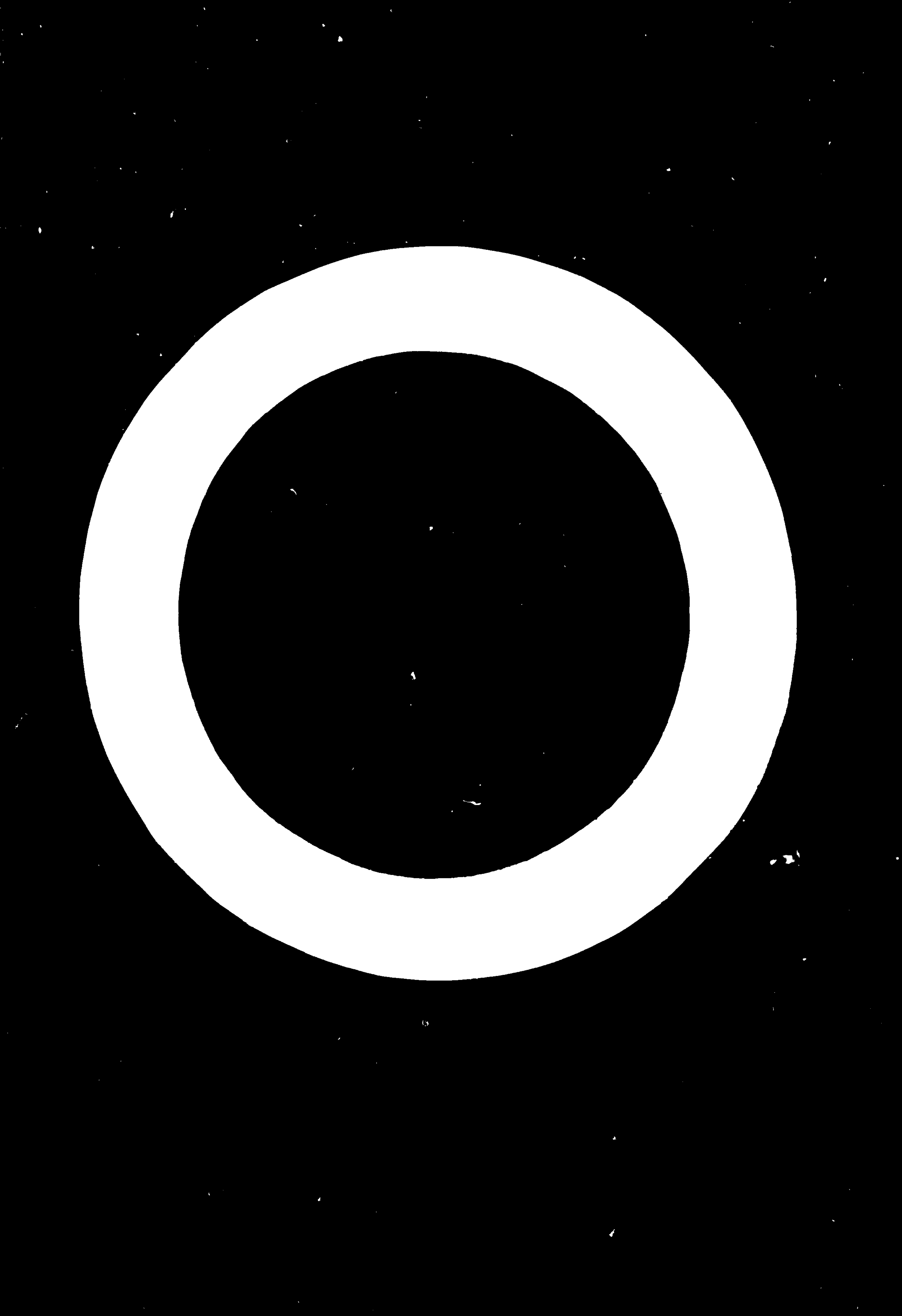

the intended type of operation will influence the choice of the processes and the required equipment. For large-scale production of ferrous metals, the following plants and equipments are available: coke ovens, coke fired blast furnaces, basic oxygen converters, blooming and slabbing mills, continuous casting machines, plate mills, cold and hot strip mills, profile (rails), bar and rod mills. For medium and small steel mills, the blooming mills, have been replaced by the continuous casting machine which is also gaining in importance in large steel mills. In medium and small steel mills, the continuous casting machine has attained a dominating position for the production of semifinished sections. This applies especially for small-scale operations which rely on scrap and the cheap freight rates of both the scrap and the finished products. In the latter case, production will be concerned mainly with the manufacture of all types of reinforcing rods and wire.

The Continuous Casting Machines

Continuous casting machines have found widespread application in the field of ferrous metallurgy. They have attained a high degree of perfection as regards their operational safety and low costs of production. Continuous casting machines can be classified into the following types:

Slab Casting Machines of all sizes. They supply excellent starting materials in the form of slabs of 1 metre width for further rolling in strip mills. The rate of production meets the demand of large-scale operations. The development aims at fully continuous casting whereby, so far, up to six heats have been cast in one continuous operation. The casting costs are reduced by the disposal of non-productive set-up times and the smaller consumption of high quality refractories per ton of steel.

Billet Casting Machines in order to attain the necessary production rate are mainly designed as multi-strand machines. On account of the smaller cross sections and reasons pertaining to the quality of the cast sections, the rate of production is considerably less than for the casting of slabs. Billet casting machines, employed for the casting of sections which can be used immediately in light section and rod mills are very sensitive to improper casting and set-up operations. By the development of integral billet casting and rolling machines, considerable progress has been made in this respect.

Integral Billet Casting and Rolling Machines permit the rolling of the cast section immediately after casting in one heat. In this manner, a medium sized cast section can be selected which increases the operational safety although the finished billet possesses a sufficiently small cross section to make it suitable for use in finishing mills. The billet obtained in this way has the additional advantage that prior to its rolling in the rolling mills it has been subjected to a hot forming operation whereby its as-cast structure is converted into an as-rolled structure. In this manner, certain limitations regarding further processing are abolished.

The BSR-Process

The process of direct rolling as developed by Messrs. Bohler & Co. Ltd. and known under the denomination BSR- (Bohler Strand Reducing) Process features three varieties.

In the first variety the normal bow-type billet casting machine is followed by the withdrawal-straightening strand, a temperature equalising zone, and a single or multi-pass rolling mill block. If the predetermined conditions regarding the temperature of the strand to be rolled, the rolling speed and the roll pass design are observed, good results are obtained.

In the second variety, the rolling mill block is designed so that it can be used for the withdrawal of the dummy bar as well. In this case the temperature equalising zone follows immediately behind the secondary cooling chamber. The rolling conditions must be determined with regard to the fact that in this case temperature equalisation is attained normally only over the surface but not over the cross section.

In the third variety, only the outer portion of the casting which is free from segregation, is being used for the finished billet. This means, the rolling process is started when the core is still more or less liquid. The process results in an additional improvement of the quality of the cast strand on account of the fact that major segregation is avoided to a large extent. For the purpose, the required casting conditions regarding surface temperature roll pass design, and reduction must be strictly maintained.

The Equipment for the BSR-Process

If multi-strand rolling mill blocks are being used for the above process, they are comparable to continuous rolling mill trains and are distinguished only by their very rigid design. The design takes account of the fact that with too long distances between the stand, cooling of the strands will become too severe. By the very compact design, the arrangement of the rolling mill stand blocks in continuous multi-strand mill trains is possible. The relatively small rolling speeds require only small drives so that the costs for the rolling mill trains can be kept low.

The dual function of the rolling mill block for the withdrawal and rolling of the strands requires a screw-down which, permits elastic guidance of the dummy bar as well as the application of a sufficiently accurate rolling pressure. For the purpose, hydraulic screw-downs have proved efficient. A further special equipment for the dual function of the rolling mill block is a speedometer which takes the casting speed directly from the strand.

The material of the rolls must be selected according to the rolling conditions which includes long contact with the cast strands. The material features a special chemical composition and careful heat treatment prior to its use.

Advantages of the BSR-Process

Integral continuous casting and rolling machines give greater operational safety at higher rates of casting, improved quality, and often lower costs for the casting of small sections, as compared to the conventional continuous casting machines. The greater operational safety is derived from the fact that the casting of larger section poses fewer difficulties. The greater rates of casting are possible on account of the larger cross sections which can be cast by this method, whereas the improved quality is derived from the direct conversion of the as-cast into an as-rolled structure. The reduction in costs is derived from the reduced number of strands as compared to conventional continuous casting machines which results in a decreased consumption of refractories, nozzles, stoppers and tundish linings.

The yield can be considered equal to that attained in conventional casting machines. It lies between 96 and 98 per cent of the liquid metal. The work required for the conditioning of the billets is less since the defects are more easily discernible on the rolled billet and, in addition, their removal is carried out with greater accuracy.

Summing up, it can be claimed that the new type of integral continuous casting and rolling machines give excellent results in the manufacture of starting materials for light section and rod mills. The simplicity of their operation and the inherent possibilities in regard to mechanization and automation of the casting and rolling process make them especially suited for the conditions prevailing in developing countries.

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Introduction

The manufacture of iron and steel is of prime importance for the establishment of a heavy engineering industry, and thus exerts a decisive influence on the prosperity of a country. Recent developments in the field of metallurgy offer a series of new processes especially suited for the industrialisation of developing countries. However, also for these countries, the establishment of a steel industry depends on the availability of the required raw materials and sources of reasonably cheap energy or depends on the possibility that the raw materials can be imported at especially low freight rates to favourably sited processing works.

From the very beginning of the industrial planning, the initial size of the works and future developments must be laid down. In this respect it is necessary to distinguish between large, medium and small scale operations. The processes to be adopted and the necessary equipment must then be selected according to the intented scale of operations. Today, the following plants and equipments are available: coke ovens, blast furnaces, basic oxygen converters, large capacity electric arc furnaces, blooming and slabbing mills, continuous casting machines, plate mills, hot and cold strip rolling mills, finishing mills for sections (rails), bars and wire. For small and medium steel mills, the blooming mills seems to be superseded by the continuous casting machine, which is gaining in importance also in large steel mills. In small and medium sized steel mills, the exclusive use of continuous casting machines should be envisaged for the manufacture of semifinished stock. This applies especially for steel mills which operate on scrap remelted in electric arc furnaces and rolled to sections, bars and wire in rolling mills.

1.1 Properties of Starting Material for Small Section and Wire Rolling Mills

The usual finishing mills used today, require billets of 50 - 100 mm sq. as starting material. In the conventional manner, these are obtained from the ingot by breaking down and rolling into billets. Bigger steel mills have a blooming mill available for the purpose. Smaller steel mills either purchase the required billets, or in case melting facilities are available, they cast small ingots of correspon-ding cross sections in multiple moulds. Both the rolling in the blooming mill and the casting of similar sections involve considerable costs. In the case of blooming mills, the costs for heating and rolling must be taken into account, while the teeming of smallest ingots is costly due to the considerable consumption of feeder-material, a fact which is supplemented by the considerable risks involved in the form of badly filled moulds, defective surfaces or cross sections of the cast ingots. In addition, excessive superheating of the liquid metal is required which raises the cost for the melting.

The requirements which must be met by the billets for the manufacture of small sections, bars and wire comprise a good surface and a homogeneous cross section. The homogeneity of the cross section is especially important in the case of modern continuous rolling mills since inhomogeneous billets tend to splitting when they enter the first pass. In this manner, the entry into the next pass may be obstacled. Surface defects on the billet, such as cold shuts, reveal their averse effects especially during rolling and drawing of the wire where they result mainly in ruptures.

1.2 The Continuous Casting

With the advent of the continuous casting machines, an equipment has been developed during the last ten years which permits the manufacture of billets of different cross sections directly from the liquid metal. These billets can be used immediately for further processing. In regard to the cross sections, however, so far certain limitations, had to be accepted. Smallest cast sections, i.e. billets of less than 100 mm sq. could be cast with difficulties only from medium sized heats, especially if higher demands were placed on their quality which did not permit high rates of casting to be used. By a combination of the continuous casting machine with an in-line rolling mill, it became possible to carry out a reduction of the cross section at the casting heat. In this manner, the limitations regarding the cross section have been overcome. By the conversion of the as-cast structure into an as-rolled structure, the properties of the billets obtained by the combined casting and rolling machine, can be made to be similar to the rolled billets which have been used so far.

The aforementioned facts should be considered as a forecast of the various advantages. However, before further pecularities of the new process will be given, a short survey should be undertaken regarding the present technical status of continuous casting and the required equipment.

2. Continuous Casting Machines - Present State of Development

Generally speaking, we distinguish today between:

Continuous Slab Casting Machines for slabs of 250 - 2000 mm width and 75 - 300 mm thickness;

Continuous Billet Casting Machines, whereby the range of cross sections extends from about 75 - 300 mm sq., the latter sections are already considered as blooms;

These machines are supplemented by a Combined Continuous Casting and Rolling Machine which, in the last year, has been developed to full operational perfection.

2.1 Slab Casting Machines

Today, slab casting machines are built almost exclusively as bow-type machines (Fig. 1)[2] and have been developed to such a perfection that they achieve full production shortly after their installation. The extent of the required maintenance work does not exceed the usual scope encountered in steel mills. The casting process proper, on account of the introduction of the casting with slag and powder shielding of the surface of the liquid metal and the guiding of the casting jet in a tube below the level of the liquid metal in the mould and through lateral outlets, has attained a high degree of operational safety. Special efforts on the part of the manufacturers of refractories have resulted in the availability of materials for stoppers and nozzles, permitting the consecutive casting of several heats. It is even expected, with good reason, that longer casting runs extending over several days may be possible shortly. In this manner considerable productivity could be attained with the continuous casting machines. In regard to their quality, sheets and strips made from continuously cast slabs do not only meet the present quality standards, but have superseded them to a marked degree whereby their manufacturing costs are considerably lower.

2.2 Continuous Billet Casting Machines

Today, continuous billet casting machines also are designed almost exclusively as bow-type machines (Fig. 2)[3] and also give satisfactory results. The required casting capacity necessitated by the present sizes of the heats can be attained for small sections only by means of casting machines of multy-strand design. As far as the cross sections are concerned, continuous casting machines are operated in the range between 75 and 150 mm sq. if the cast billets are to be finished in one heat. Billets of 300 mm sq. are cast if the cross section of the finished products is to be large or if the processing to the final cross section takes place in two heats. Occasionally bigger sections are cast, for instance, in England by Shelton Iron and Steel Co. [4], or blooms are cast which are to be rolled into beams, as is the case at Algomá Steel, Canada[5]. Such a procedure offers the advantage that big blooming mills can be avoided.

The continuous billet casting machines for small as-cast sections, despite the fact that they have attained a considerable operational safety, offer considerable difficulties since in multi-strand machines a very careful aligning of the tundish and the moulds is required in order to bringt the constricted casting jets to bear directly on to the centre of the mould. This, however, is absolutely essential for the casting speeds required for the attainment of a sufficient casting rate for small sections.

2.3 Combined Billet Casting and Rolling Machines

In the past years, a third type of continuous casting machine was developed by Messrs. Bohler Bros. & Co. at Kapfenberg which seems suitable for high rates of casting of billets. The new machine is essentially a billet casting machine supplemented by an in-line rolling mill (Fig. 3). In this manner casting and primary hotworking operation have been united within one process. The main importance lies in the fact that the continuous casting of billets with minimum cross sections from medium and large heats at economical casting rates can be carried out with good operational safety. Moreover, finishing mills or forges can be provided with billets which, not only as far as their dimensions, but also as far as their surface quality and structure is concerned, are similar to the as-rolled billets.

In the following, a more thorough treatment will be given to the combination of continuous casting with the continuous rolling of the cast strands which has been made known under the denomination BSR-Process (Bohler Strand-Reducing Process) [6] in 1966.

3. Direct Rolling of Continuously Cast Strands by Means of the BSR-Process

3.1 The Process

Essentially, the BSR-Process consists in a single or multi-pass reduction of the strand under utilization of the casting heat after the strand has passed a temperature equalizing zone which attains temperature equalization over the surface of the cast strand.

The first variation comprises a conventional continuous casting machine with mould, mould oscillating device, supporting racks and withdrawal and straightening rollers, followed by a temperature equalizing zone and a single or multiple pass rolling block. Temperature equalization can be attained not only over the surface but also over the cross section. The rolling process distinguishes itself from conventional rolling only by its low speed so that the design of the complete equipment can be carried out according to the experiences gained in normal rolling mill construction (Fig. 4).

Extensive investigations and tests have shown that it is not necessary to establish temperature equalization over the entire cross section if some definite conditions are being maintained. This led to the second variation in the process in which the rolling commences immediately after complete solidification. The machine differs from the first variation insofar as the secondary cooling zone is followed immediately by the temperature equalization zone and the rolling mill block is designed in such a manner that it can be used for the withdrawal of the dummy bar. This results in a simplification of the equipment (Fig. 4).

In variation 3 only the shell of the continuously cast section which is free from segregation is used for the manufacture of the billet. This is acieved by the interruption of the solidification by the rolling process. The reduction is started at a point of the strand where there is still some remaining liquid portion. While, in variations 1 and 2 only a reduction of the cross section ~~takes place,~~ and a conversion of the as-cast structure into an as-rolled structure takes place, variation 3 has an extrametallurgical influence since major segregation is avoided or considerably diminished. The problems which had to be solved in the development of the BSR-Process comprised the determination of the most suitable rolling temperatures and their correlation with the rate of reduction. If rolling is carried out according to variations 1 and 2, a definite minimum reduction must also be maintained in order to avoid the occurance of the dreaded bending cracks (Fig. 4).

3.2 Equipment

If the reduction is carried out according to variation 1 mentioned before, the casting equipment including the withdrawal device do not deviate from the design of the usual continuous casting machines. As has been mentioned before, the equipment required for rolling, such as temperature equalizing zone and rolling mill stands are arranged in-line with the casting machine. The design of the rolling mill stands will deviate from the normal design only insofar as, for multristrand machines, as required for the casting of medium and large size heats, the stands must be of very compact design so that the distance between the strands can be kept small. On account of the slow rate of reduction and the resulting high thermal load imposed on the material of the rolls, a sufficient and well functioning roll cooling system must be used.

For variations 2 and 3 a special design was adopted for the rolling equipment which is to meet the functional requirements (Fig. 5, 6).[7] In this case, one rolling stand of the rolling block takes over the withdrawal of the dummy bar at the beginning of the casting process. It is only after the bottom end of the cast strand has passed this stand that the screw-down is lowered to bring the full rolling pressure to bear. This double function of the first rolling stand demands that different roll pressures can be applied, for the withdrawal of the dummy bar and the rolling process. Moreover, the pair of rolls must be able to yield elastically so that small variations in the thickness of the dummy bar do not lead to excessive pressures and breakage of the rolls.

In addition, the rolls can be screwed-down only after the dummy bar has left the rolls and when the cold end of the strand is behind the rolls. This means that the rolls must be screwed-down to full pressure with the passing strand in motion. In production service, a hydraulic screw-down has proved very efficient, since, apart from its accuracy, it possesses the required elasticity during the withdrawal of the dummy bar. Short mention only should be made of the centering device which must bring the strand into its proper position before the rolls are screwed down. The roll pass design of the rolls is suited to the low speed of rolling and takes account of the high reduction as compared to rolling mill trains of the usual design.

A further pecularity of the rolling block developed for direct rolling, is the fact that it is fitted with a speedometer. In continuous casting machines the casting speed is measured by means of the speed of the withdrawal rolls. If rolling is carried out, however, the speed of the strand to be rolled is different before and after the rolls and deviates from the speed of the rolls. In order to find the actual casting speed, the latter must be taken directly from the cast strand.

In connection with the equipment, mention must be made also of the roll material, which on account of the long-time contact with the hot strand, had to be especially developed. This material, which is of special chemical composition, must be carefully heat treated. In this case, the extensive experience of Messrs. Bohler Bros. & Co. Ltd. in the manufacture of hot and cold rolls was of special benefit for the designers.

4. Advantages of Combined Continuous Casting and Rolling Machine

The advantages offered by the combined continuous casting and rolling machine over the conventional continuous billet casting machines are as follows:

- Improved Operational Safety
- High Rates of Casting
- Improved Quality of Products
- Low Costs

4.1 Improved Operational Safety

A medium sized cross section of the cast strand lends the greatest operational safety to the continuous casting process. The excessive casting speed required for the attainment of a sufficiently high rate of casting need not be applied as is the case if small sections are to be cast. The permissible tolerance regarding the impact of the casting jet on the surface of the metal in the centre of the mould is greater for larger sections. In addition, for medium sized sections the more recent casting methods employing casting tubes for the guidance of the casting jet into the moulds and the shielding of the metal surface in the mould by means of shielding powders or slags may be used.

4.2 High Rates of Casting

The rate of casting of the combined casting and rolling machine as compared to the casting of small sections in conventional machines is increased by two factors. The larger cross section of the casting automatically increases the pouring rate as compared to smaller cross sections and, moreover, the direct rolling before cutting of the strands eliminates the restrictions of the casting speed on account of the liquid core. As is well known, if the liquid core exceeds 9 - 11 metres, continuous central porosities occur over considerable lengths of the casting. On cutting the billets to multiple rolling lengths, the central porosities, but also other porosities, are accessible to the atmosphere and oxidation may take place, which, in many cases, prohibits the use of the cast billets as starting material. During the direct rolling process, the porosities are compressed prior to a possible contact with the atmosphere. The possible pouring rates per strand per hour for a range of cross sections from 140 to 200 mm sq. is to the order of 18 - 25 tons. Thus safe manufacturing conditions prevail for the casting of medium and large heats into billets 80 - 110 mm sq.

4.3 Improved Quality of Products

By the direct forming process a decisive improvement of the quality of the strands as compared to the as-cast strands takes place. As has been mentioned before, centre porosities are eliminated before they can have an averse effect (Fig. 7). Production runs have shown also that thermal cracks which may occur eventually on account of too severe or faulty secondary cooling, can be made to weld at the high temperature at which the forming takes place. The same applies also for subcutaneous pores. At the same time, the as-cast surface is transformed into an as-rolled surface whereby better conditions for the conditioning of the billets are attained if this should be necessary on account of the desired quality of the finished products. The as-cast structure is converted into an as-rolled structure. Thus, for further rolling of forging of the cast the billets, the same reheating conditions can be used as have been adopted previously for the billets rolled from ingots. This is of special importance for the more highly alloyed steels. The fact that favourable aspects regarding major segregation are attained if the rolling commences prior to complete solidification has been mentioned before.

4.4 Low Costs

In regard to the costs the following observations should be made:

A continuous casting machine with in-line rolling equipment, of course, is more expensive as far as initial costs are concerned. However, this is true only if single strand casting and casting cum rolling machines are compared. For the multi-strand machines which are required for the casting of medium and large heats, the number of strands can be kept smaller in combined casting and rolling machines since the latter permit a higher pouring rate. The operating costs can be considered to be about equal although combined casting and rolling machines require a larger crew and have a higher power consumption. However, the number of strands per machine is smaller in combined casting and rolling machines. The greater operational safety brings about a reduction of costs on account of less idle time and fewer repairs. Combined casting and rolling machines offer advantages concerning first and operation costs. The continuous casting and rolling machine at Kapfenberg has been in operation for too short a time to permit a detailed listing of the costs. However, the results which have been obtained so far seem to confirm this opinion.

For the evaluation of the operating costs, mention should be made of the yield. It is comparable to that of normal continuous casting machines. The discard for the bottom end of the strand is slightly greater than for the as-cast strand since the reduction can start only about 300 mm behind the end of the cast strand (when the cold end has passed the relevent pair of rolls). Depending on the design for multi-pass arrangements, the length of the transition part is about 300 mm. On the other hand, the discard at the top end of the strand is considerably smaller since part of the pipe is eliminated by the rolling. In a survey of the costs, the losses due to surface conditioning must be taken into account. This is especially true for quality and high grade steel mills.

According to the experience gained, the surface conditioning losses are smaller for billets 80 mm sq. than for equal cast sections. The surface conditioning of as-rolled strands can be carried out with greater reliability so that the amount of rejected finished material is considerably less than for equal as-cast strands.

5. Summary

After an introduction in which the plants which are available for metallurgical works were mentioned briefly, the requirements placed on the starting material for light section and wire mills were dealt with. The manner in which this starting material had been produced so far has been stated.

In the course of the last ten years a new process has been added, namely, the continuous casting of steel. At first, the present state of development of the process and the machines treated. Continuous slab casting machines have been introduced widely in the steel industry and are being used not only by medium sized steel mills but also by big mills. During the description of the continuous billet casting machine, the difficulties encountered in the casting of small section from large heats were described. These problems have been solved by the development of the direct rolling of strands and by proper design of such machines.

The process for the direct rolling of strands (BSR-Process) and the required equipment was explained. The process so far exists in three operational variations,

namely:

1) The rolling after complete solidification and complete temperature equalization also over the cross section.
2) The rolling immediately after complete solidification,
3) The rolling prior to complete solidification e.i. only the shell of the casting is being used for further processing.

The advantages of the new process and its suitability as a new type of metallurgical equipment were clearly defined. Its suitability is to be found especially in the fact that the process increases the operational safety of the continuous casting and enhances the pouring rate as compared to conventional machines. Morevoer, the process results in an improved quality of the products. Thus, smaller production costs are obtained for the manufacture of small billets as compared to the conventional continuous casting method.

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The photograph has been kindly put at our disposal by Messrs. Mannesmann AG., Düsseldorf

3) Billet casting machine of the Broken Hill Pty. Co. Ltd., Newcastle, Australien, according to Concast AG.
The photograph has been kindly put at our disposal by the Concast Ag., Zürich

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7) Schematic View of a Billet Reducing Machine
Billet Reducing Machine being installed
The illustrations have been kindly put at our disposal by Messrs. VÖEST Ltd., Linz

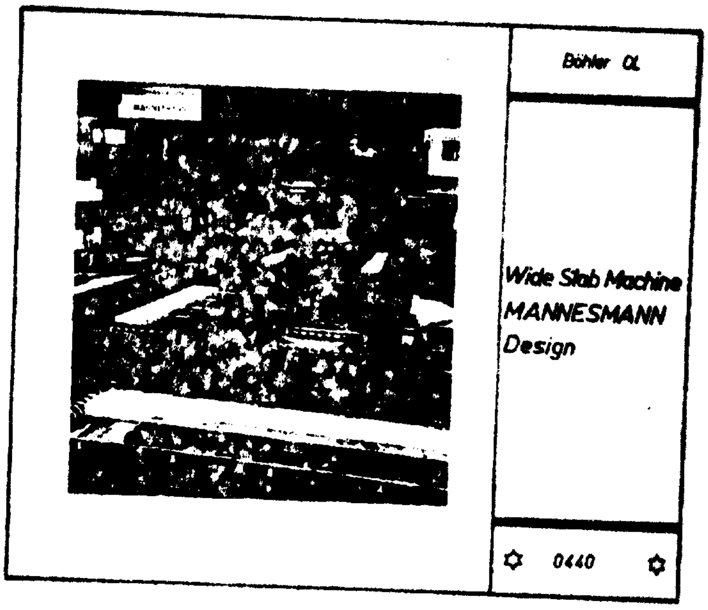

Böhler OL
Wide Slab Machine
MANNESMANN
Design
0440

Fig. 1

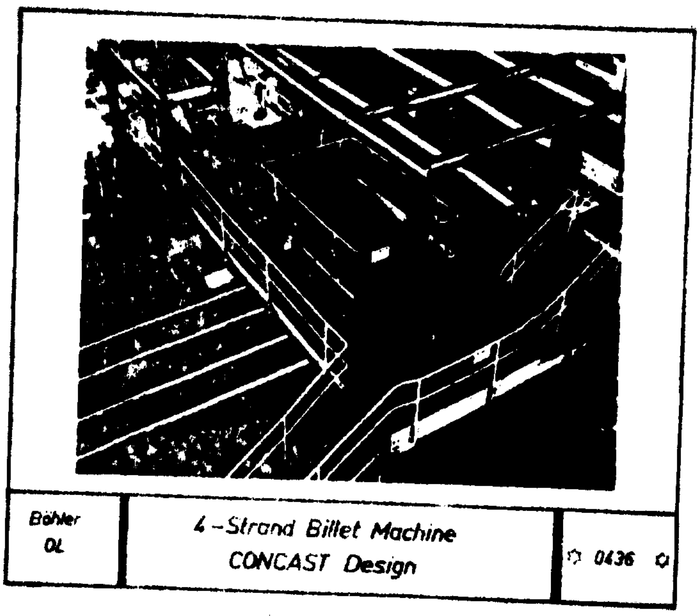

Böhler
OL
4-Strand Billet Machine
CONCAST Design
0436

Fig. 2

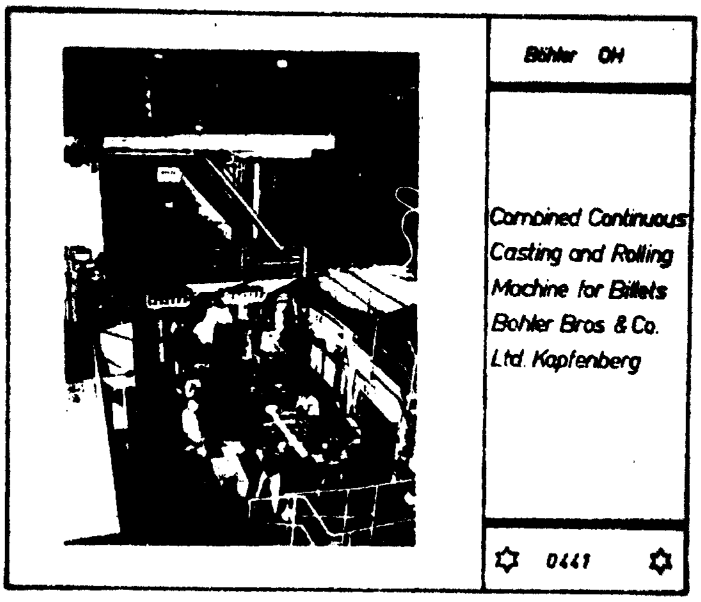

Böhler OH
Combined Continuous Casting and Rolling Machine for Billets
Bohler Bros & Co. Ltd. Kapfenberg
0441

Fig. 3

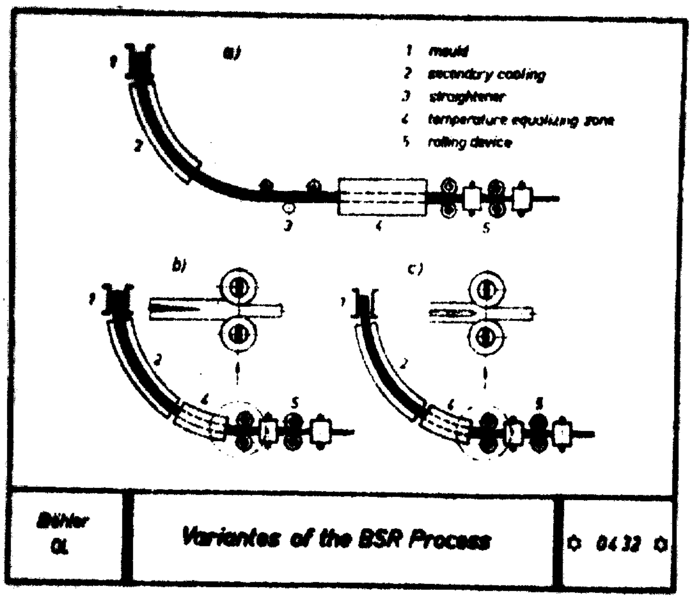

a)
1 mould
2 secondary cooling
3 straightener
4 temperature equalizing zone
5 rolling device
b)
c)
Böhler OL
Variantes of the BSR Process
0432

Fig. 4

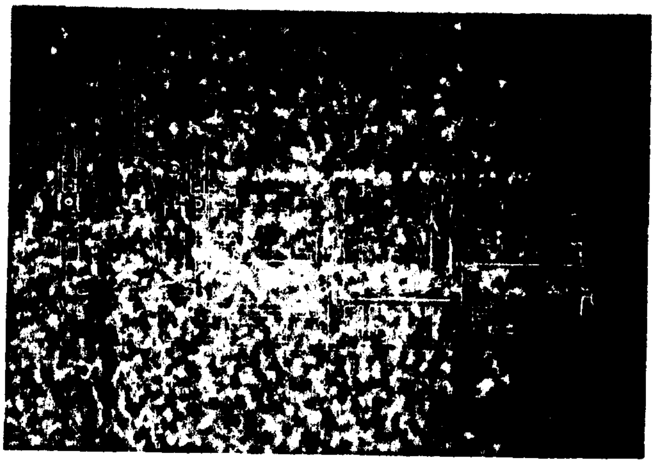
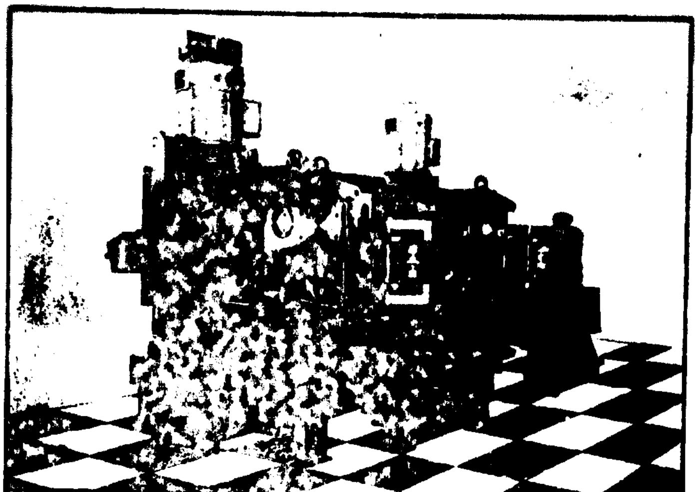


Fig. 5

Schematic View of a Billet Reducing Machine according to VÖEST



Böhler OL | Rolling Stand for Billet Reducing Machine VÖEST Design | 0439

Fig. 6

Böhler OL

Pass Sequence of Billet Reducing Machine – Etched in Hot Hydrochloric Acid

0438

Fig. 7

74.10.15