KAWASAKI STEEL TECHNICAL REPORT
No.1 (September 1980)

Slab Width Change during Continuous Casting

Hisashi Omori, Mizuo Maeda

Synopsis :
Two different techniques were developed for changing slab width during continuous casting. In one way, casting is continued without decreasing its speed. In this case, some vertical edges a rolling process are needed for correcting tapered portion of casting slab. In the other way, casting is paused, and step-like part connecting two slabs should be scrapped. These slab width changing techniques will promise: (1) Productivity gain: 30-50% (2) Refractories curtailment: 30-50% (3) Yield improvement: 0.5% (only by the farmer way) (4) Energy saving: 30-50%

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1 Introduction

The process of continuously casting molten steel into semifinished steels offers great economies in increased yield and savings on energy, resources and manpower—those benefits derived principally from the bypassing of several intermediate steps required for the conventional ingot-slab process. This, together with the recent advance in the continuous casting technology, has brought about a sharp rise in the percentage of raw steel output turned into semi-finished forms by the continuous casting process.

Fig. 1 shows how steeply the continuous casting ratio has climbed at Kawasaki Steel Corporation's Mizushima Works over the past few years. In fact, the rise in this ratio at this plant has been so dramatic that, in Japan, Mizushima Works leads the way in continuous casting.

To present more concrete data, this ratio at Mizushima Works, which stood at 65% in fiscal 1978, and over 80% in fiscal 1979, and plans are currently underway to further boost this figure to over 90% several years hence.

Briefly stated, such was the backdrop against which a new continuous casting technique for slab width change without machine stop—the subject which is explained in detail in the following paragraphs—was developed and put to commercial use. The pupose was to enhance the productivity and operating economies of the continuous casting machine by small capital investment, and thereby attain a further increase in the continuous casting ratio. Evolved out of such a motivation, this technique is designed to find wide applications in the continuous casting of slab.

It may be worth noting that by the use of this technique alone, Mizushima Works' continuous caster rated at some 80 000 metric tons monthly earned profits totaling some ¥1 000 million ($5 million) in the latest fiscal year for which statistics are available.

2 Current Status of Continuous Casting

2.1 Continuous Caster

Photo. 1 shows No. 5 Continuous caster at Mizushima Works, and **Table 1** it's main specification.

Molten steel is discharged from the ladle into the tundish which in turn feeds it to the mold. Solidification of the cast steel starts inside the mold, and is completed as it moves down through the roller apron at a strand regulated speed. After the curved shape of cast slab was straightened flat, it is cut to the desired length by the torch cutter.

2.2 Needs for Slab Width Change During Casting

Because of the operating economies the CC process offers over the primary mill process, there have been developed various new techniques that meet the requirements for higher productivity of the CC

* Originally made public at 37th Electric Furnace Conference held by The Iron & Steel Society by the title of "TECHNIQUE FOR CONTINUOUSLY CASTING SLABS OF VERYING WIDTHS WITHOUT DECREASING SPEED"

** Mizushima Works

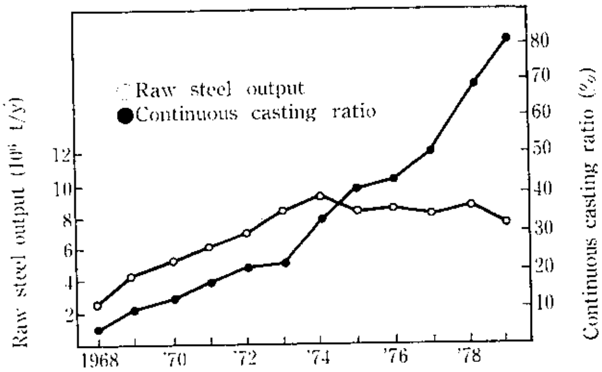


Fig. 1 Annual raw steel output and continuous casting ratio at Mizushima Works

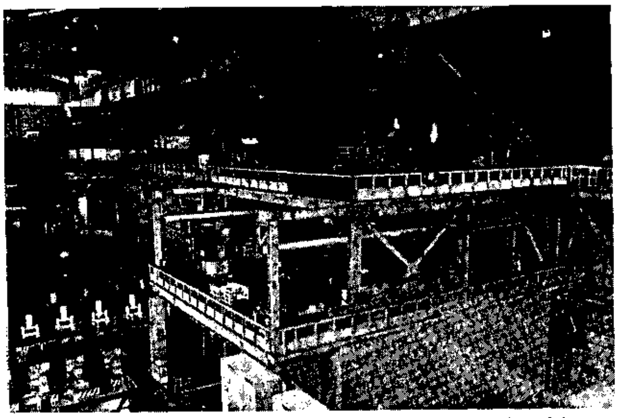


Photo. 1 No.5 Continuous slab caster at Mizushima Works

machine. All these new techniques are related to any one of the following five technically conceivable means of boosting the CC unit's productivity:

(1) Continuous-continuous casting of ordered (specified) slabs different in width,
(2) Continuous-continuous casting of slabs of different chemical composition,
(3) Reduced downtime for machine repairs or restart,
(4) High-speed casting, and
(5) Casting of slabs larger in cross-sectional size.

Fig. 2 shows the law of causation among the five technically conceivable means.

The technique, discussed herein, is purported to effect the continuous-continuous casting of slabs of different widths.

3 Brief Description of Slab Width Change

3.1 General Aspects

Kawasaki's continuous casting technique for slab width change started to develop around the end of 1974, and after stages of development such as laboratory tests and experimental application, it has been in

Table 1 Main specification of No.5 CCM at Mizushima Works

	Specification
Ladle capacity	275 t (270 t LD×2/3)
Type of CCM	2 strands curved type slab machine
Steel grades	C-steels and low alloy steels
Slab Size & casting speed	190 × (1 400～1 900) × (1.6～1.8) m/min 220 × (850～1 550) × (1.6～1.8) m/min 260 × (850～1 550) × max 1.6 m/min
Supporting length	33.99 m from meniscus to the end of P.R.)
Casting radius	12.0 m, 19.22 m
Distance of strands	6 000 mm
Un-bending	2-point unbending

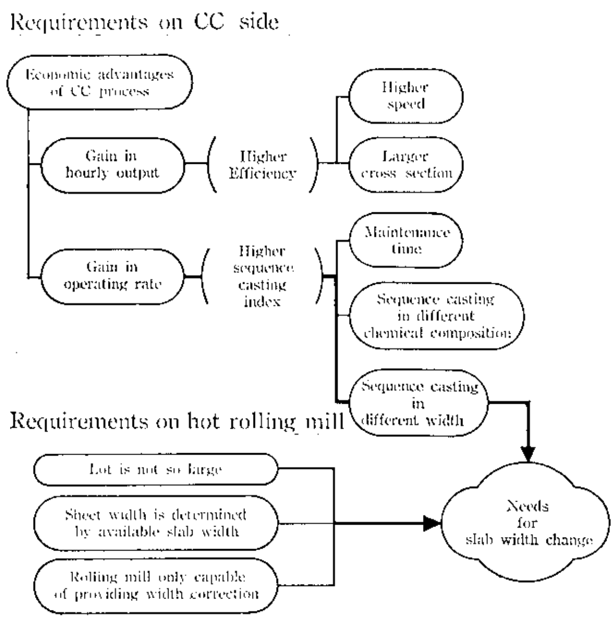


Fig. 2 Law of causation among five conceivable means

commercial use with successful operation since the beginning of 1978.

Kawasaki's technique has the following three magnificent advantages in comparison with other techniques:

(1) It can be accommodated not only to widen but also to narrow the slab width.
(2) Slab width change can be performed in approximately normal casting speed.

(3) Slab width change can be performed without yield loss.

3.2 Method

In the past it was commonly held among CC engineers that any attempt to move narrow faces of the mold during the casting operation would exert forces resulting in a rupture of the skin before the solidification of the cast is completed, thereby causing a breakout that leads to the flow-out of molton steel.

The new technique was established by defying such a common sense knowledge. **Fig. 3** shows what happens inside the mold when this technique is applied. In other words, the new technique was accomplished by moving a pair of narrow faces either inward or outward during the casting operation. What is most important is that the casting's width can be changed without interrupting the casting operation.

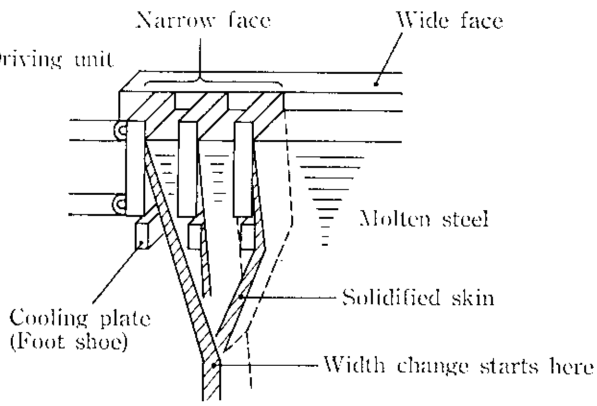


Fig. 3 Schematic diagram depicting how the strand's width is changed

3.3 Narrowing Slab Width

Theoretical analysis was made at first, in order to avoid some problems caused by the compression of solidified skin in the process of narrowing the strand's width.

In this analysis, for instance, the force F caused by the compression of solidified skin can be expressed as the following equation.

$$F = K\sqrt{\frac{V}{V_C}}$$

Where the proportional constant K is determined by creap conditions, solidifying coefficient and mould width, V is narrowing speed and V_C casting speed.

Thus, the force F is in proportion to the square root of the ratio of V to V_C. This leads to conclude that:

(1) If the ratio of narrowing speed to casting speed remains constant, there is little change in the force;

(2) Narrowing slab width in high speed casting gives no problems to operation. Not only that, it tends to reduce the force; and

(3) It is not necessary to slow the casting speed for the purpose of narrowing slab width.

As a result, the possibility of narrowing the strand

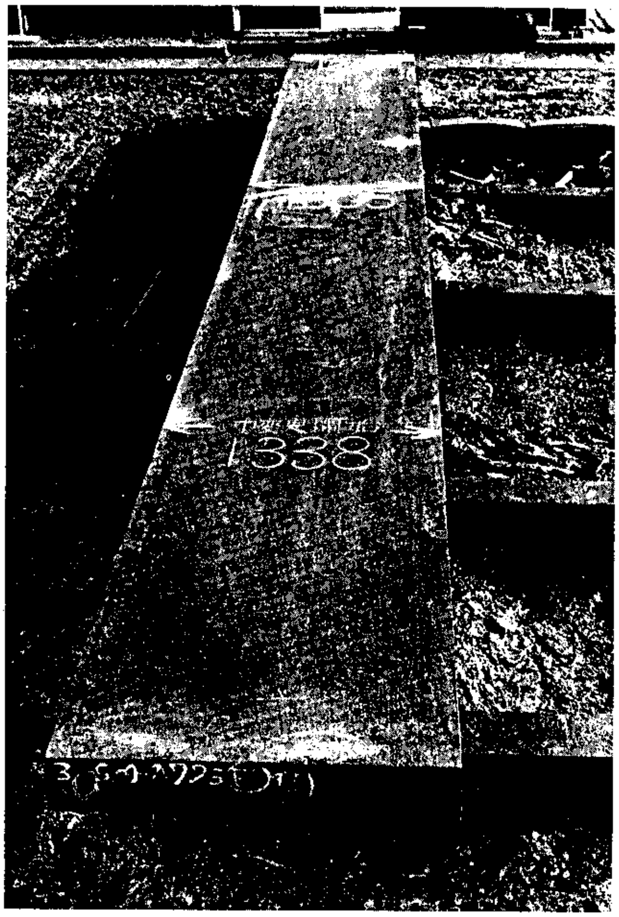


Photo. 2 A piece of slab changed in width

Table 2 Operational conditions

Casting speed	1.0 m/min
Width narrowing speed	4.5 mm/min for one narrow face (9.0 mm/min for both narrow faces)
Amount of narrowed width	37 mm for one narrow face (74 mm for both narrow faces)
Change in slab size	Prior to change ; 220 mm × 1 338 mm After change ; 220 mm × 1 264 mm
Time spent for width change	8 min

width became clear.

Shown in **Photo. 2** is a piece of cast slab to which the new technique was applied. **Table 2** lists operational conditions under which that slab's width was changed.

As shown in **Photo. 2**, the technique is efficient not only in changing the slab width but also in controlling side bulging of the slab and any internal cracks.

3.4 Widening Slab Width

Meanwhile, in the case of widening slab width, the following problems should be considered. That is, there is a phenomenon that a cleavage forms in the solidified skin, releasing molten steel at a too high widening speed. In addition, side bulging of the slab occurs along the narrow face at the same time, sometimes gorwing to more than several millimeters. In such a case where the narrow face moves outward with normal mold taper, a cleavage appears in the narrow face of the strand at the lower part of the mold. **Fig. 4** shows how the side bulging occurs at a high widening speed.

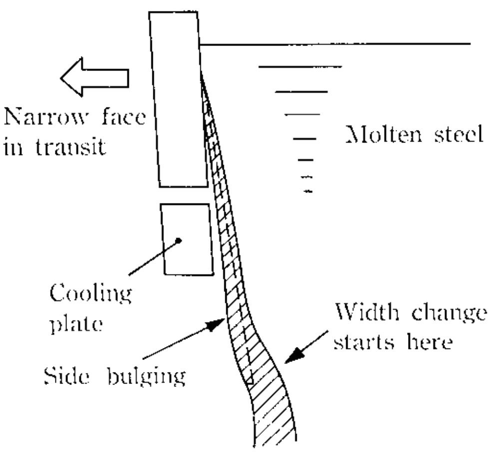


Fig. 4 Schematic diagram showing how the bulging occurs at the high widening speed

Consequently, it will be necessary that the narrow face should move outward with steeper mold taper in order to avoid such cleavage by compressing solidified skin at the lower part of the mold.

So, what is most important for Kawasaki's method is to make the mold taper larger and to keep the compression of solidified skin at the lower part of the mold. And under this consideration, the side builging is avoided at only a slight decrease of the casting speed. But, theoretically it is better to set the widening speed lower compared with the narrowing speed.

4 Major Equipment and How to Use Them

Original equipment for slab width change is composed of support system for the narrow face, driving mechanism, opening units for wide face and electrical control units. Also, major equipment used in this technique include the following:

(1) Special support system for the narrow face which avoids the uncontrollable movement according to gap included in the connection of mechanism during casting,

(2) Driving unit for the narrow face which have enough capacity for making the movement not only in a steady manner but also at a controlled speed.

Of course, these required facilities and mechanical capacity were endorsed by experimental equipment which had some measuring units such as load cells.

Commercial application of new slab width changing technique was performed in No. 5 continuous caster at Mizushima Works.

Photo. 3 shows the mold for slab width change which has special mechanisms in supporting system in order to avoid uncontrollable movement. **Fig. 5** shows the sequence of steps that should be taken to change the strand width.

Fig. 6(a) ~ (d) show some examples of slab width changing equipment.

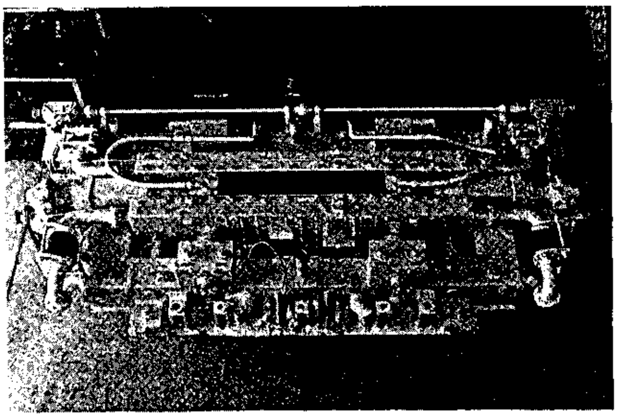


Photo. 3 Mold for slab width change

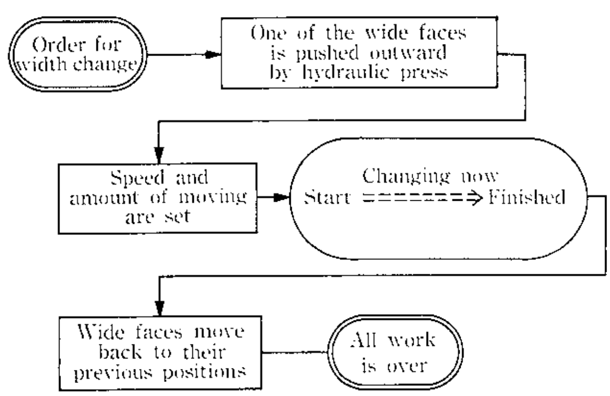
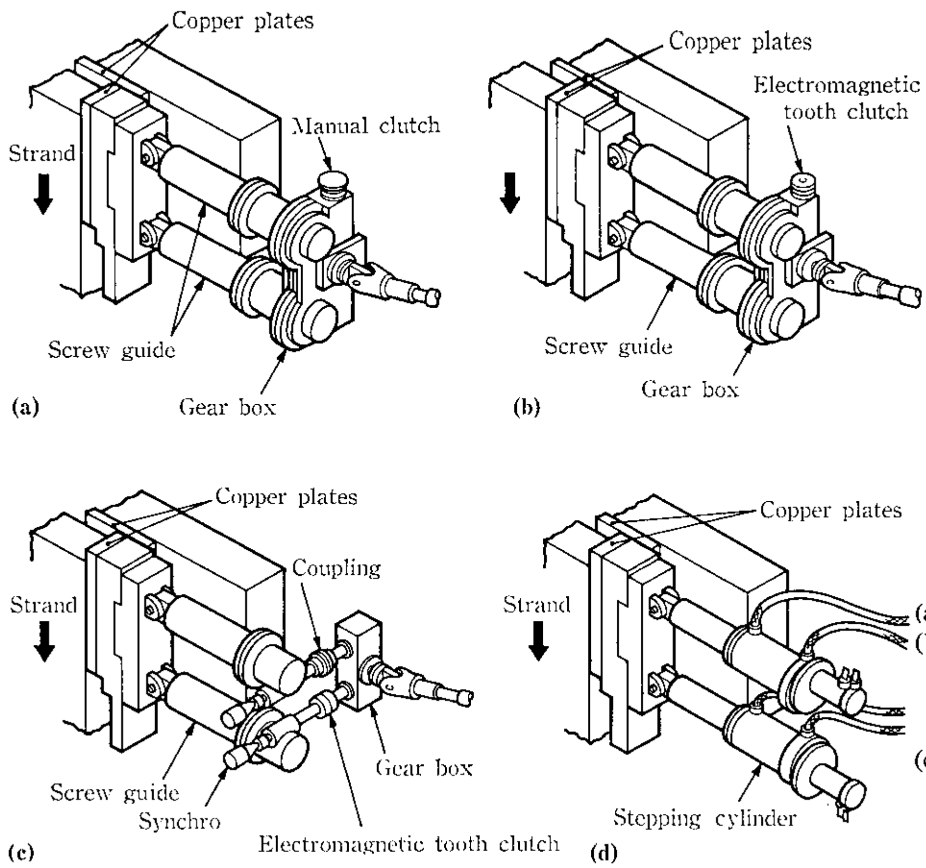


Fig. 5 Sequence of steps



(a): Most stabilized mechanism
(b) and (c): In addition to the type shown in (a), mold taper of narrow face can be changed freely.
(d): Mold taper of narrow face can be changed freely, and the response is very rapid.

Fig. 6 Schema of some mechanisms for slab width change

Table 3 Results of new technique applied to actual CC operation

Item	After appli-cation (A)	Before appli-cation (B)	Difference (A)−(B)
Sequence casting index*(heats/chance)	6.5	1.8	4.7
Specific consumption of refractories**(kg/t)	1.6	5.6	−4.0
Specific consumption of energy**(kcal/t)	3.3	11.4	−8.1
Crop loss (kg/t)	2.2	7.9	−5.7
Output (t/month)	127 000	80 000	47 000
Frequency of width changes(times/month)	212	0	212

* Sequence Casting Index: The number of BOF heats per casting chance.
** Specific consumption of refractories and energy: The number of tundish used per casting chance is normally one. Therefore, unit consumption means how much refractories were expended, and how much energy was required to preheat that tundish.

5 Benefits

Table 3 lists benefits arising from the application of this new technique in No. 5 continuous caster Mizushima Works. **Fig. 7** shows the chronological progress of the development work, the number of times slab width was changed monthly, and the monthly output of continuously cast slabs.

As shown in **Table 3**, this new technique, when

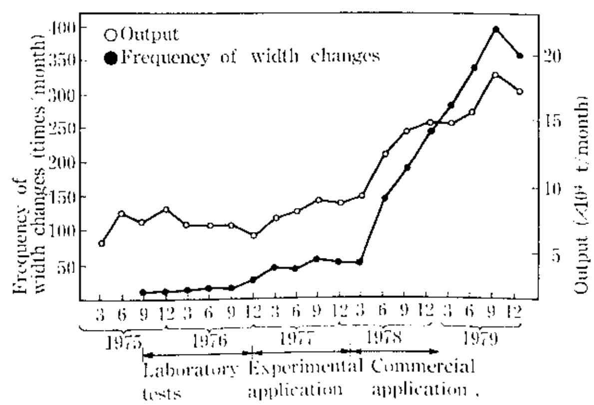


Fig. 7 Chronological progress in frequency of width changes and Mizushima No.5 CC machine's output

applied to the continuous caster rated at some 80 000 metric tons monthly, resulted in annual cost savings or profits totaling approximately ¥1 000 million, with a 50% gain in productivity.

In addition, it is useful in other applications, such as:

(1) Continuous-continuous casting of slabs of different widths and different chemical compositions,
(2) Casting of slabs to any arbitrary combination of ordered width specifications from the same heat, and
(3) Slab width control to be constant in any different casting conditions.

6 Summary

(1) Kawasaki's slab width changing technique was successfully developed and has many excellent features such as follows:
   ① It can be used not only to widen but also to narrow the slab width.
   ② It can be performed in approximately normal casting speed.
   ③ It can be performed without yield loss.
(2) Kawasaki's slab width changing technique assure:
   ① Productivity gain: 30 ~ 50%
   ② Refractories curtailment: 30 ~ 50%
   ③ Yield improvement: 0.5%
   ④ Energy savings: 30 ~ 50%
   In addition, these benefits will further increase by combining the technique with sequence casting of heats with different chemical composition.
(3) The validity of this technique is supported by several technical reports and many patents, as one of the most creative ones in the development of continuous casting techniques.