CONTINUOUS CASTING DEVELOPMENT FOR STEEL(*)

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Continuous casting processes for steel have all had their origin in some form of pilot plant development and experience, the importance of gaining "know-how" being a predominant feature.

The first pilot plant to cast metal continuously was built by Henry Bessemer just over one hundred years ago. Whilst machines were developed for non-ferrous metals, progress with liquid steel was more difficult, mainly due to the high handling temperatures and to its low thermal conductivity when solidified.

FEATURES OF THE PROCESS:

Continuous casting aims to replace ingot production by the direct casting of billets, blooms and slab sections in long continuous lengths. Vertical water-cooled moulds, usually of copper, are used to solidify the section walls to required shape and, below the mould, water sprays complete the solidification of the liquid centre. Withdrawal rolls are used to control the descent of a cast length, which is finally cut to required lengths and discharged.

Section sizes cast to-date range from the 2 in. sq. billets regularly cast at Barrow to the 36 in. x 5½ in. slabs, also cast at barrow on a more recently installed experimental machine. Trends exist towards the casting of still larger slab sections and towards constructing plants with larger ladle capacities, 50 ton ladles being at present in use in Russia and Canada. Likewise, production rates will continue to increase.

Stainless and special high alloy steels are cast, notably at Atlas, Schoeller-Bleckmann and Krasny Oktybr, but much the greater tonnages are cast in plain carbon and low alloy steels. Mainly killed steels are cast, usually deoxidised with ferro-silicon but also with aluminium. The casting of unkilled or rimming steel has been developed mainly at Atlas, Charleroi and Krasnoye Sormove, using controlled additions of aluminium to the mould. Recently at Barrow, 9 in.sq.blooms and 36 in. x 5½ in. slabs have been cast in low carbon rimming steels by a novel method in which no aluminium is fed to the mould.

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Continuous cast steel sections have a cast structure and require to be hot worked by rolling or forging before being used for engineering purposes. The physical properties of the rolled or forged material have been found to be entirely satisfactory and not distinguishable from those of good quality products derived from orthodox ingots.

ADVANTAGES OF THE PROCESS:

The principal process advantages are: high levels of yield, reduced rolling operations, reduced surface dressing prior to re-rolling, low capital cost installations, and attractive operating costs.

DEVELOPMENT TRENDS:

The most important and fundamental trend is towards higher casting speeds and therefore increased production rates in tons/hr./mould.

(i) Multi-Stranding

Multi-strand machines may be adopted to dispose of the contents of larger ladles and furnaces and may well be justified in certain circumstances. Twin-stranding itself is of special advantage when casting small billets at high speeds since it ensures a high level of yield. Plants capable of higher casting speeds will, however, meet steelmakers requirements more easily. If, for a given furnace, the use of an extra strand can be eliminated, savings can be made on the initial capital cost, on metal discard and other operating costs.

(ii) Metal Pouring Time:

Two main methods of supplying liquid steel to casting machines exist. "Tea-Pot" or "semi-teapot" type lip-pour ladles give a full range of metal flow control, can easily be preheated, and allow pouring to continue for periods up to about $1\frac{1}{4}$ hrs. With longer periods chemical changes in the steel become appreciable.

Nozzle-pour ladles present difficulties in flow control, and in preheating and pouring for periods longer than about $\frac{1}{4}$ hr. due to the risk of losing the stopper if the stopper rod becomes overheated. Whilst these ladles will come into fairly common use with high production rate machines, there will always be a risk of a 'running stopper' and the greater limitation on pouring period will involve using extra strands. In many cases, therefore, lip-pour ladles will be preferred.

(iii) Section Solidification Features:

Correct mould design and mould operation are required to ensure continual solidification of the section walls, even at moderate speeds. Internal solidification depends on the design and dimensions of the spray cooling system below the mould, whilst with large sections roller aprons are necessary to prevent bulging of the section walls, for example the broad faces of a large slab.

The central liquid metal crater increases in depth with increase in casting speed and must be contained within the spray zone. For higher casting speeds, however, a spray system of greater intensity (there are limitations here), or of greater height may be used. Considerations of spray cooling and product quality do not therefore present a limit to higher production rates.

(iv) Typical Mould Designs:

Whilst differing in constructional detail, three main types of mould are used.

Thin-walled, tubular moulds, normally of pure copper, (perhaps of copper alloy and even of thin stainless steel), are externally cooled by high velocity water passed up an annulus formed by sheet metal casings. These tubes tend, however, to distort under operating conditions, particularly the larger sizes, causing ruptures of the cast section walls which result in liquid steel breakouts from the molten centre. Nevertheless, such moulds are preferred for the production of small sections at high speeds.

For medium and large sections heavy cast or forged pure copper block moulds are used, with the mould cavity machined vertically though the centre and vertical water-cooling passages drilled around the perimeter within the thick walls. These moulds can be suitably tapered - smaller at the lower end by, say, 1 per cent - to enhance contact between mould face and cast section surface, and uniformity of cooling makes them particularly suitable for large sections.

Plate-moulds are constructed from copper plates bolted to steel backing plates, with vertical grooves cut between to act as cooling water passages. Individual mould faces, prepared separately, are bolted together to form the mould cavity. The design is suitable for small, medium and large sections, since it can be assembled with taper and is relatively free of distortion in service.

The heat transfer capabilities of the three types of mould are more than adequate. Observations at Barrow indicate that tubular moulds can cast 2 in. billets at 450 ins./min., a large, cast-copper slab mould probably can run up to 65 ins./min. and 9 in.sq. plate moulds probably at 75 ins./min. - speeds much higher than envisaged in the near future elsewhere. Mould heat transfer is not therefore a limiting factor to higher production rates.

Normally, moulds are internally chrome-plated to increase abrasion resistance and provide a smooth surface finish. When casting a lubricant such as rape seed oil is supplied to the mould faces to reduce frictional drag and the tendency of newly solidified metal to adhere. Some drag, however, may remain and become critical, so that portions of newly solidified metal may stick to the mould faces and result in a breakout of metal. This type of interruption is prone at higher casting speeds and its prevention is to be found in the method of mould operation, upon which ultimately therefore the attainment of higher production rates depends.

DIFFERENT MOULD OPERATIONS:

The earliest procedures were based on using rigidly mounted moulds. With uniform pouring and withdrawal rates, a steady metal meniscus level is obtainable, but only slow casting speeds are possible. The Bohler plant at Kapfenberg is a notable example, efficient mould lubrication mainly preventing surface ruptures.

Chiefly used today, however, is the method developed by Junghans in which the mould is vertically reciprocated with strokes of about 1 inch. Whilst meniscus height remains steady, the mould is moved down for about three-quarters of each cycle at the same speed as the section being cast, and raised about three times faster in each remaining quarter cycle. The down strokes ensure static conditions for initial skin solidification whilst the enforced stripping action of each upstroke prevents serious sticking on the mould faces. The method thus allows casting at higher speeds.

To improve the performance of fixed moulds the pause/pull method of operation was developed. During pauses in withdrawal, metal level is allowed to rise to obtain static conditions of solidification. During the pull periods the section is extracted at higher than average rates and metal level falls. This method - largely the reverse of the Junghans process - requires the withdrawal machinery to be continually accelerating and decelerating so that it is not so convenient for casting at higher speeds or when casting heavy sections.

In the Vergniaud and BISRA processes the mould is mounted on springs. Should newly solidified skin stick to the mould, it is able to move down with the section, thus allowing time for further solidification and increase in strength of the skin. The spring resisting force also increases until the section wall is forcibly separated from the mould. At medium casting speeds, sticking can occur repeatedly at short intervals. The corrective action of the springs can scarcely take effect and mould drag tends to increase so that a limit is placed thereby on higher casting speeds.

The use of reciprocated moulds to cast at appreciably higher speeds was developed at Barrow. The mould is always moved downwards slightly faster than the cast section. Known as reciprocating with Negative strip, the newly solidified skin is made to keep contact with the descending section wall solidified in the previous mould cycle. Skin shrinkage is compensated for by compacting the surface crystallisation in a downwards direction. Surface ruptures are prevented and, should any metal stick to the mould, it is released by compressive forces as the mould downstrokes overtake the descent of the section. Mould drag may thus be reduced to zero or a negative value. This Barrow procedure would appear to remove restrictions to higher production rates as far as mould operation is concerned.

Current work by BISRA aims to introduce the Barrow idea of negative strip into the operation of the spring-mounted mould, means being attached to drive the mould downwards more rapidly when the cast section adheres to the mould face. Release is thus obtained by compressive forces so that higher speeds than with the simple spring-mounting are possible. The additional mechanism can only operate, however, after sticking occurs so that some mould drag will always remain, thus setting some limit on higher casting speeds.

BRIEF DESCRIPTION OF BARROW PRACTICE:

The Barrow process for producing small billets and slabs has already been described in the cine film and therefore needs no further reference.

Operations on the 36 in. x 5½ in. slab machine installed by The United Steel Companies Ltd. at Barrow in January, 1959, need also only briefly be mentioned since similar principles of operation are adopted.

The practice developed is characterised by relatively high production rates. Metal from either lip-pour or bottom-pour ladles is teemed through a preheated tundish which is fitted with four nozzles discharging along the broad centreline of the slab mould. This is of the cast copper block design, reciprocated by a separate drive to that used to power a double pair of withdrawal rolls. Suitable water sprays and a roller apron complete solidification whilst maintaining the slab section shape by preventing bulging. The dummy bar sections and cast slab portions are removed below the cut-off torch by a tilting discharge basket. This basket receives the cast section in a vertical position, descends, and tilts to discharge it onto a horizontal roller track below ground level.

The slab machine may be converted to the casting of blooms by mounting two moulds of the four-plate type and supplying these through a transverse tilting launder and two nozzle-pouring tundishes. Separate dummy bars are used for each mould but the slab withdrawal rolls are common to both strands. Metal level in each mould has therefore to be balanced by adjusting the tilting launder.

FUTURE OUTLOOK:

The demand for continuous casting installations with greater production rates will, in general, always remain, and therefore the trend towards higher casting speeds.

Enough has been said to show that the essential process differences lie in the method of mould operation adopted. The process with the highest casting speed potential (or, inversely, minimum mould drag), should develop to meet the higher tonnage rates required; thus, the method developed at Barrow is likely to survive.

Continuous casting has more or less developed out of the pilot plant stage into that of a production method. Each new production plant installation will bring fresh design and new experience and, in its own way, pioneer further along the path of development and highlight anew the vital role of the early pilot scale machines in the development of the process. One may visualise casting machines leapfrogging in performance towards the exciting possibilities of ultimate perfection.

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