

June 22, 1965

H. A. LONGDEN

3,189,956

PRODUCTION OF EFFERVESCING STEEL

Filed May 8, 1962

3 Sheets-Sheet 1

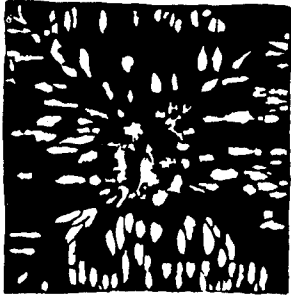


Fig. 1

Fig. 2

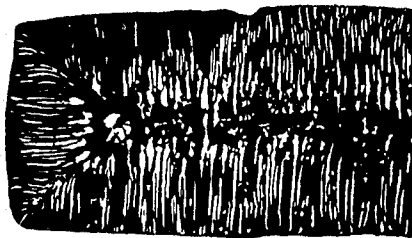


Fig. 3

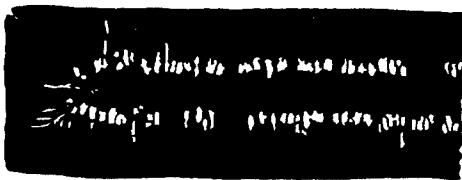


Fig. 4

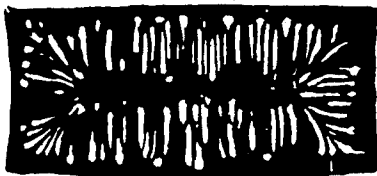


Fig. 5

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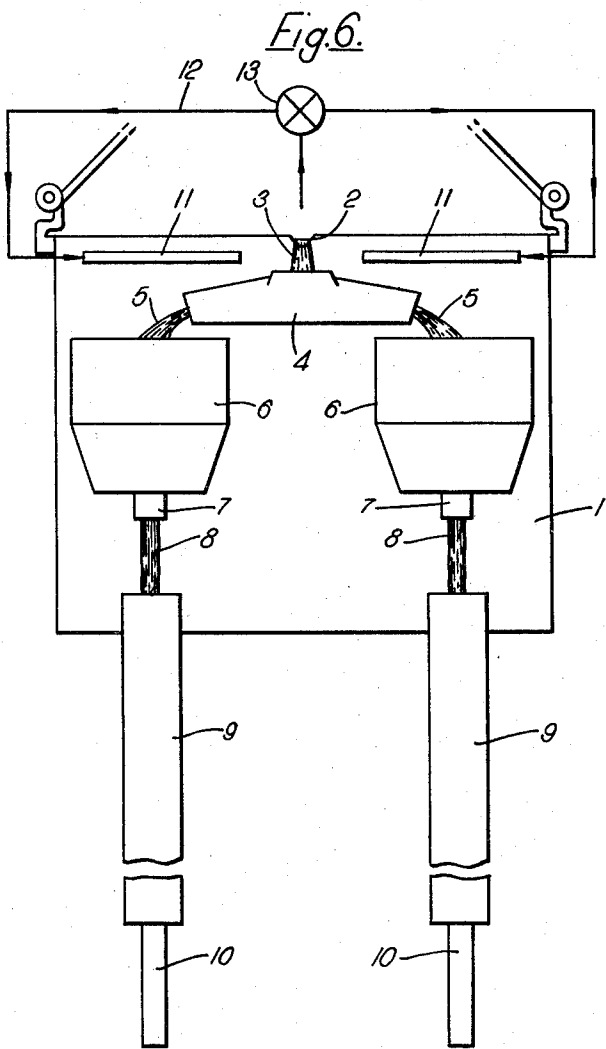
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Fig. 7.

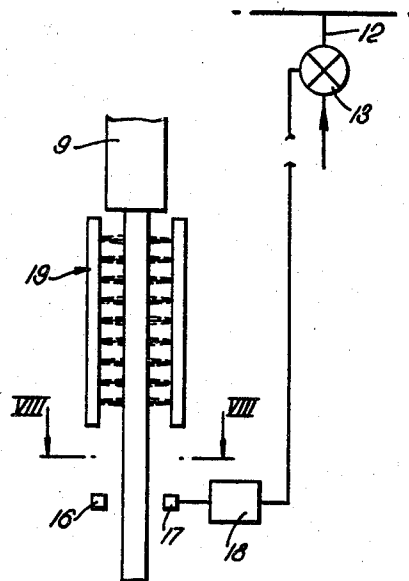


Fig. 8.



Fig. 9.



1

2

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PRODUCTION OF EFFERVESCING STEEL

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16,908/61

7 Claims. (Cl. 22-200.1)

This invention relates to the continuous casting of effervescing steel.

Effervescing steel is steel that has deliberately not been completely killed by the addition of one or more deoxidants. It is well known that the steel effervesces in the molds into which it is poured, and in consequence contains blow holes, and it is essential that these should be deep in the steel. If they are at the surface, the steel cannot be rolled satisfactorily.

I have found that the production of effervescing steel by continuous casting gives rise to special problems. In continuous casting processes the molten steel is normally poured from a ladle through a launder into a tundish, from which it flows through a nozzle as a vertical stream into the top of an open-ended mold. This mold is externally cooled so that the metal leaving it at the bottom is solidified at least to the extent that it has a solid skin. The whole operation must be so controlled that liquid metal can never break out through the skin at the bottom of the mold or overflow from the top, and the effervescence that occurs considerably increases the risk of such overflow from the top.

Now the molds used in continuous casting may be of small cross-sectional area and the casting rate for production reasons may be high. In consequence of both these factors, the free liquid surface of metal in the mold through which the gases must escape is low in relation to the volume of gases evolved and the metal becomes very turbulent and thus particularly liable to overflow.

The principal object of this invention is so to cast effervescing steel continuously as to ensure that the blow holes are buried deep in the steel.

Another object is to provide improved control of the production of continuously cast effervescing steel.

I have found that in continuously cast effervescing steel the blow holes will be formed at a suitable distance from the surface of the casting only if the product of the carbon and oxygen content ($C \times O$) is controlled so that at the time of solidification it is close to a critical value that depends on the composition of the steel and particularly on the carbon and manganese contents. It is also strongly affected by the casting conditions, such as the size of the mold and the rate of pouring. My invention broadly involves controlling this $C \times O$ product.

Types of blow holes are shown in the accompanying drawings, which also diagrammatically show apparatus in which the invention may be carried out. In these drawings:

FIGURE 1 is a section through a casting with blow holes that prevent satisfactory rolling;

FIGURE 2 is a part-section through another such casting;

FIGURE 3 is a part-section through a casting with blow holes that permit satisfactory rolling;

FIGURES 4 and 5 illustrate the change in the blow-hole formation produced in a casting by means of the invention;

FIGURE 6 shows part of one continuous casting machine;

FIGURE 7 illustrates one method of automatic control of the $C \times O$ product; and

FIGURES 8 and 9 are enlarged sections on the line VIII-VIII in FIGURE 7.

FIGURES 1 to 3 show blow holes obtained in castings of large section from three melts A, B and C intended to yield products containing 0.05% carbon and 0.30% manganese. Details of the three steels and the casting conditions (including the cross-sectional size of the mold and therefore of the casting) are given in the following table:

Table I

	A	B	C
Casting temperature, ° F.....	2,885	2,912	2,903
Casting speed in inches per minute.....	25	30	28
Size of mold.....	9 x 9"	35½ x 5"	35½ x 5"
Percent C at moment of casting.....	0.035	0.05	0.04
Percent Mn at moment of casting.....	0.38	0.24	0.38
Percent O at moment of casting.....	0.0455	0.0605	0.0475
$C \times O$	0.0016	0.0031	0.0019

In each case ferromanganese was added to the melt in the ladle before it was cast. In such low-carbon steels I have found that manganese has a pronounced effect on the oxygen content in the absence of any stronger deoxidising agent. Table I illustrates the difficulty of controlling the manganese content and therefore the oxygen content accurately.

The $C \times O$ product of Steel A was too low with the result that there were blow holes of moderate elongation at or close to the surface of the solidified steel, as shown in FIGURE 1. The $C \times O$ product of Steel B was too high with the result that there were even more blow holes remarkably elongated and extending right to the surface, as shown in FIGURE 2. As shown by FIGURE 3 the blow holes in Steel C were buried well below the surface and were not elongated. In this steel, therefore, the $C \times O$ product (0.0019) was correct for the casting conditions.

In smaller molds, e.g. 7 x 3" in cross-sectional size, the right value of $C \times O$ for steel of nominal composition 0.11% carbon and 0.35% manganese is between 0.0040 to 0.0045.

It is a simple matter of experiment to determine the critical $C \times O$ figure for any steel under any given casting conditions.

In practice it is difficult to add a deoxidant to the metal in a furnace, a launder or a ladle so as to ensure that the $C \times O$ product is always right at the moment of solidification. To avoid this difficulty there must be control at some subsequent stage. In adding a deoxidant to the steel in, say, the tundish, launder or mold there is a very grave risk that at some time in the course of continuous casting there will be slight over-addition and in consequence the level of the metal in the mold will suddenly fall to such an extent that there is not enough depth of metal left in the mold to ensure solidification. As a result, metal runs out of the bottom of the mold.

In producing a steel with a predetermined value of the $C \times O$ product according to the invention, the steel is deliberately over-deoxidized before being poured, with the result that the $C \times O$ product is reduced to less than the predetermined value and the blow holes would reach the surface of the casting, and then the $C \times O$ product is raised to the desired value at which the blow holes are formed at a suitable depth below the surface by adding an oxidant. The oxidant may be a solid, e.g., iron ore, which may be added as powder in a carrier gas blown against a stream of the molten metal or into the molten metal. I much prefer, however, to use oxygen, which may conveniently be commercial oxygen or may even be in the form of air, and to direct one or more jets of this at the metal. This may be done as the metal enters the mold, but it is preferred to direct the jet or jets at the metal leaving the ladle, so that in effect one

has in a launder or tundish a small reservoir of properly treated metal which is poured through the nozzle into the mold.

In practice an operator can watch the degree of effervescence in the mold and control the oxygen supply appropriately.

The initial slight over-deoxidation may be effected by any convenient deoxidant or deoxidants. Although the deoxidant most commonly used with effervescing steel, namely aluminum, may be used, it is undesirable as a general rule in the process of the invention because when it is used alumina tends to build up in the nozzle through which the steel is poured and may actually clog it. The preferred deoxidant used in the invention is silicon, conveniently in the form of ferro silicon.

As an example of a process according to the invention and of the way in which the structure of the metal may be controlled, steel tapped from a basic arc furnace at 3981° F. had the following composition: 0.10% carbon, 0.11% manganese and 0.0040% oxygen. The desired C x O product was about 0.0042. 12 lbs. per ton of manganese in the form of 78% manganese ferro-alloy was added to the steel in the ladle. The steel was then cast at 2912° F. into a mold 7 x 3 inches in cross-section, the average casting speed speed being 60 inches per minute. At the time of casting the carbon content was 0.11%, the manganese content 0.36% and the oxygen content 0.033%. The structure of the steel initially cast is shown in FIGURE 4, the C x O product being only 0.0036, i.e. too low. After enough steel had been cast to obtain the specimen from which FIGURE 4 was made, oxygen was blown against the stream of steel leaving the ladle, the oxygen being blown at a rate of 8 cubic feet per minute. The C x O product of the steel rose to 0.0042 and the structure of the resultant slab became that shown in FIGURE 5.

The invention may be carried out in the apparatus shown diagrammatically in FIGURE 6. In this apparatus molten steel is brought to the casting machine from a furnace in a ladle 1 having a pouring lip 2 from which a stream of metal runs as shown at 3. The casting machine comprises a cross-launder 4 from which streams 5 flow to two tundishes 6 having nozzles 7 through which the molten metal flows as streams 8 into open-ended water-cooled molds 9 to emerge as strands 10. The steel in the ladle has been deoxidized, and oxygen is blown against the stream 3. As shown, oxygen is blown in this way through two pipes 11 which branch from a single pipe 12 controlled by a valve 13. Oxygen jets may, however, be directed not at the stream 3 but at the streams 5 leaving the launder, or at the streams 8 entering the mold, or onto the molten metal in the launder 4 or the tundishes 6.

The control may be made automatic. For instance use may be made of the fact that in the solidified metal below the mold there should be a rim substantially free from blow holes. Gamma rays will be intercepted by this rim to a greater extent than by metal containing blow holes. Accordingly, as shown in FIGURES 7 to 9, I may provide a source of gamma rays 16 and a detector 17 on opposite sides of the solidified metal 10 and so obtain a signal. This signal may be transmitted to an instrument 18 connected to control the setting of the valve 13. The source and detector are placed so that if the blow holes are adequately buried as shown in FIGURE 8 the instrument 18 does not respond, but if the blow holes approach the skin as shown in FIGURE 9 the amount of the rays passing through the billet will

increase, and the resultant signal will cause increased opening of the valve 13.

In comparison with processes in which control is effected by a deoxidant, the process according to the present invention presents the advantage that if there should be any failure in the supply of oxidant the casting process will still continue safely.

The process according to the invention gives the extremely close control of C x O product which is essential to the successful continuous casting of all effervescing steels over a wide section range, and enables a satisfactory product to be obtained even in steels with a carbon content below 0.07%.

I claim:

1. A process for the continuous casting of effervescent steel to produce sound rimmed steel comprising
 - (1) over-deoxidizing molten steel and
 - (2) reoxidizing said molten steel by directing at least one jet of oxygen on said molten steel and supplying an amount of oxygen sufficient to correct the over-deoxidized condition, and then
 - (3) pouring said steel into a continuous casting mold wherein said steel effervesces and solidifies forming a sound rimmed steel.
2. The process of claim 1 wherein the amount of oxygen added is controlled by an operator to obtain the desired degree of effervescence in the mold.
3. The process of claim 2 wherein a deoxidant selected from the group consisting of silicon and ferrosilicon is added to effect said over-deoxidation.
4. A process according to claim 3 wherein the metal is poured from a ladle to a tundish and then to the open mold, and wherein the oxygen is directed at the metal as it flows from said ladle.
5. The process of claim 1 wherein the amount of oxygen supplied is controlled by an electric signal obtained from a density determining instrument comprising a source of gamma rays positioned on one side of the solidified steel product of the casting process and directed through the rim portion side of said steel, and a detector on the opposite side of said steel, whereby differences in the apparent density of said steel are detected and then correlated to provide an electric signal to control the amount of oxidant supplied.
6. The process of claim 5 wherein a deoxidant selected from the group consisting of silicon and ferrosilicon is added to effect said over-deoxidation.
7. The process of claim 1 wherein a deoxidant selected from the group consisting of silicon and ferrosilicon is added to effect said over-deoxidation.

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