March 17, 1959 O. SCHAABER 2,877,525

CASTING PROCESS

Filed Aug. 27, 1953 2 Sheets-Sheet 1

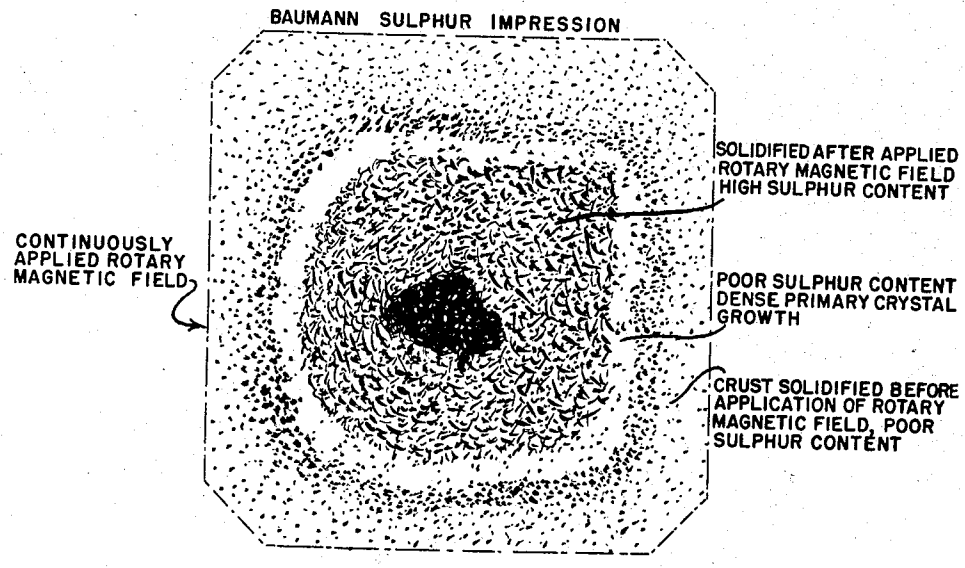


FIG. 1

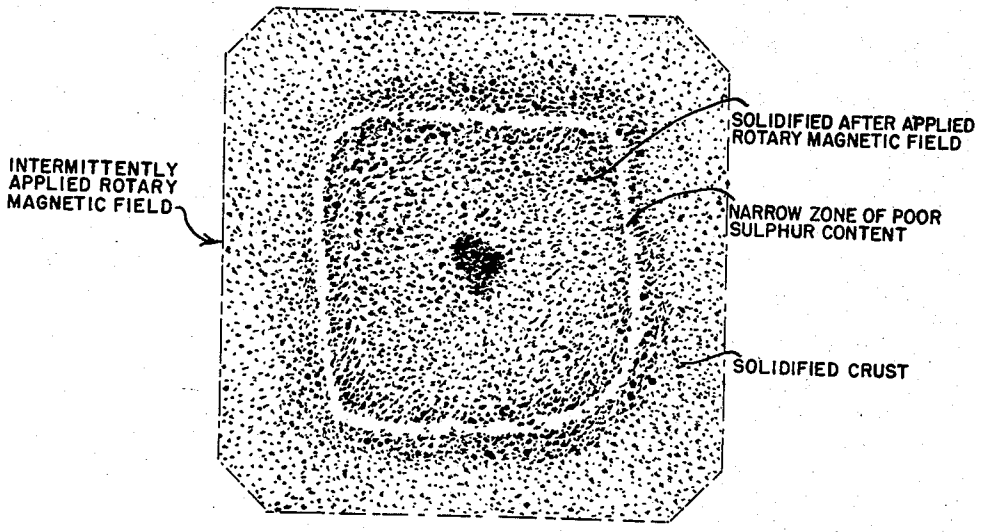


FIG. 2

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CASTING PROCESS

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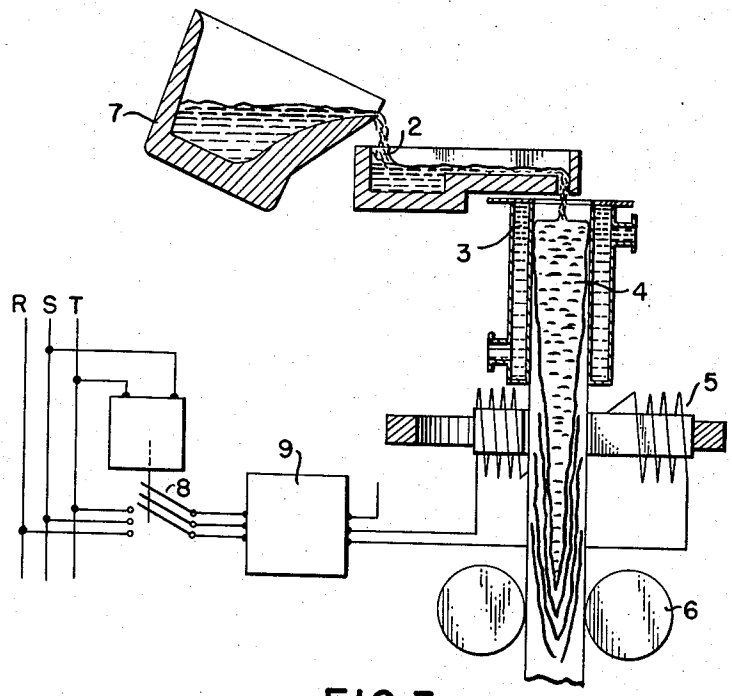


FIG. 3

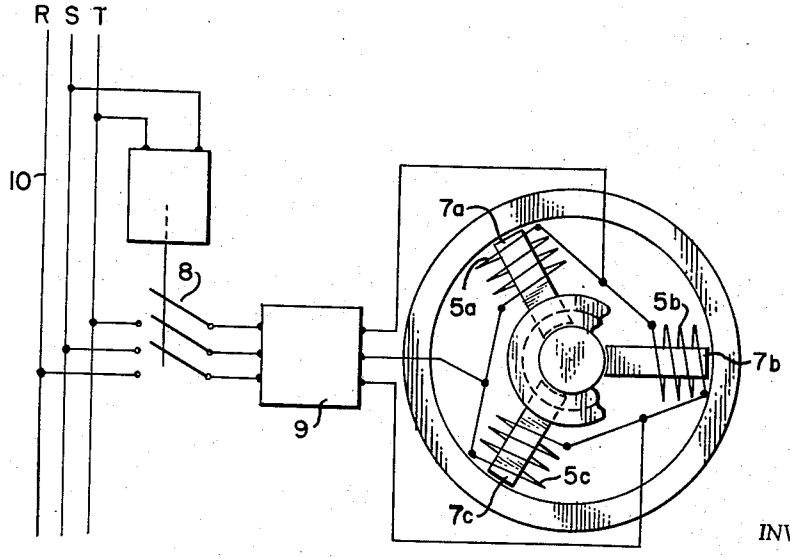


FIG. 4

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CASTING PROCESS

Otto Schaaber, Schorndorf, Wurttemberg, Germany

Application August 27, 1953, Serial No. 376,917

6 Claims. (Cl. 22—200.1)

This invention relates to a casting process of the particular kind, in which the melt as it solidifies is subjected to the action of magnetic rotary fields for influencing the structure of the solidified casting. Extensive research has shown that it is not necessary but may be even detrimental to subject the melt to the action of these fields until it has solidified completely. It is sufficient if the action is limited to a fraction of the solidifying period. A lasting effect on the structure of the finished casting could quite unexpectedly be noticed if the rotary field is also repeatedly interrupted during period of action which is already relatively short compared with the total time of solidification. The total period of action is further reduced by such a measure, from which various results and advantages of a technical nature are obtained which are hereinafter described.

The accompanying drawings serve to illustrate this description and show:

Fig. 1 a Baumann impression of the cross-section of a 100 x 100 mm. square bolt with wide annular zone poor in sulphur,

Fig. 2 a Baumann impression similar to that shown in Fig. 1 with a narrow annular zone poor in sulphur,

Fig. 3 a longitudinal section thru a continuous casting with rotary field arrangement,

Fig. 4 is a top plan view of Fig. 3.

While it was originally believed that to improve the structure of the finished casting with the aid of the rotary field this must be allowed to act continually until the state of complete solidification is reached, it was a step in the right direction to have recognized that the action of the rotary field can be limited to a fraction of the total time of solidification and preferably to less than 5% thereof. Furthermore, according to the knowledge revealed by the present invention, it is possible and advantageous to also interrupt repeatedly the magnetic rotary field during the period in which it acts and which is short as compared with the total time of solidification; whereby the duration of the intervals may be shorter than, equal to or longer than the time during which the field is switched on.

The total period during which the rotary field is acting is thus restricted as a rule to times which are considerably shorter than 5% of the total time of solidification. For example, the shrinkage depth in a round steel bolt 118 mms. in diameter amounts under certain casting conditions to roughtly 3.5 m. in the case of a casting speed of 700 mms./min. The total time of solidification can thus be reckoned as 5 minutes. In one of the above mentioned experiments with an interrupted rotary field it was discovered from the evaluation of the characteristic effect of the field, which will be referred to later, that three periods of action each of 1.8 seconds duration had sufficed to obtain the said improvement in structure. The total time of action of 5.4 seconds resulting therefrom is only 1.8% of the total period of solidification. For safety reasons, however, it is usual to allow the field to act longer.

The advantage consists in the saving of energy and, if several casting molds are to be served, in the saving of installation costs, because several rotary fields can be operated successively with a single transformer plant.

When casting steel under the action of a magnetic rotary field, the applicant noticed the curious phenomenon that those zones which during the time the rotary field is in operation, have just reached a certain range of temperature, show a slightly lower sulphur content than the neighbouring zones. The difference is not great, for example it was found that the sulphur content in the non-influenced zones on the average of five readings in each case 0.051% S, in the zone covered by the rotary field in the corresponding temperature range 0.046%, and in the core structure 0.056% S. The zone influenced by the rotary field is, however, easily recognisable from the sulphur impression according to Baumann in spite of this slight difference. For example Fig. 1 shows a Baumann impression of the cross-section of a 100 x 100 mm. square bolt with an analysis of 0.07% C, 0.1% Si, 0.28% Mn, 0.118% P, 0.035% S; the remainder being iron which was cast under the following conditions: casting temperature at the beginning was 1540° C. and 1430° C. at the end, relay field, three poles on rotary current; core 120 x 120 mms.; ten windings of flat copper stood on edge; lying directly in water; interlinked voltage; 27 v. coil current; 950 to 1000 amp. phase load; 1630 to 1730 amp.; two parallel-connected variable transformers each 45 kva.; primary side 19.8 kw. consumption. The arrangement for producing the magnetic rotary current was located below and independently of the chill.

The formation of the somewhat poor sulphur zones under the influence of the rotary field is possibly connected with the following phenomenon: The action of the rotary field on the sulphur content only occurs when the zone in question has just reached the solidification face and is just about to solidify. Crystals grow in the melt from the edge under the action of the temperature gradient. These primary crystals are themselves poorer in sulphur than the remainer of the melt, which, in the case of undisturbed crystallation solidifies somewhat later in the spaces between the primary crystals. During the time when the rotary field is operative, the primary crystals grow inwardly biased in the opposite direction to the direction of rotation. The zone with the biased growing crystals is followed by the larger inner zone, the crystallization of which under the previous action of the rotary field, takes place without biased orientation. A comparison of the lighter zones poor in sulphur on the Baumann impression, with the zone of the deflected crystal ends of the microsection surfaces shows that these two zones correspond as regards their position and are therefore identical.

The crystal points projecting into the melt are consequently not rubbed off by the action of the rotary field, as was formerly erroneously imagined, but they are bent over and then cease altogether. During the deflection in counter-direction to the direction of rotation of the field, the crystals lie more closely together. Consequently there remains very little space between them in which the remainder of the melt, which is richer in sulphur, can solidify. This layer poor in sulphur caused by the action of the rotary field, is not identical with the less stable layer also poor in sulphur which is to be observed in slow cooling ingot casting, and which there indicates the transition from the directed edge solidification to the undirected core solidification. The physical properties of the layer poor in sulphur produced by the rotary field are the same as those in the surrounding layers.

Nevertheless the presence of such zones poor in sul-

phur in the castings may, under certain circumstances, be undesirable. It is possible, even if the castings are subsequently subjected to kneading treatment, that these zones will remain and give rise to complaints. The wide zone poor in sulphur shown in Fig. 1, can be considerably improved by periodically interrupting the rotary field in accordance with the invention. Instead of the wide strip, several much narrower strips occur and, and if the intervals are of suitable length, it is even possible to allow only a single narrow strip to form, which, as can be seen from Fig. 2, is less than a millimeter in width (casting condition).

As a rule it is recommended in the case of short-time rotary field action to increase the energy of the rotary field surge as compared with that used for continual action.

Fig. 2 shows the result of a short-time rotary field action; the conditions were: Analysis 0.12% C; 0.14% Si; 0.31% Mn; 0.1% P; 0.36% S; rotary field action 2.4 secs., interval 20 secs.; rotary field strength 19.8 kw.; test arrangement as above.

The utilization of knowledge on which the application is based in continuous casting presents particular advantages, especially when casting metals with a high melting point with which the sump depth is great compared with that of low melting metals, such as light metals, that is, is at least ten percent greater. In this case it is not necessary for the rotary field to act on the entire depth of the sump, which, for example in the case of a bolt 100 x 100 mms. may be 3,000 mms.; a short zone of action will suffice, which is preferably less than 5% of the sump depth. This allows considerable freedom from a constructional point of view, because the arrangement of the rotary field can be structurally united with the cooling jacket of the casting mold or arranged entirely underneath the casting mold.

To accommodate the iron cross-section of the core for a sufficiently strong rotary field, necessitates a certain minimum height for the rotary field. As a rule the height can be taken as about 150 mms. including the coil, in the case of rotary fields for influencing cross-sections of 100 to 120 mms. When the rotary field is switched full on the effective height of the rotary field is determined by this height which must also be multiplied by a factor dependent upon the actual field strength. As, however, it is also dependent upon the temperature and the composition of the melt, the effective height can be most easily determined by experiment. The effective height of the rotary fields can be calculated from the width of the zone poor in sulphur, for example about 4 mms. in Fig. 1, if from other experiments or calculations the time is known which is required to cause the solidification of 4 mms. in the example shown in Fig. 1. From these measurements the time can be estimated at about 35 seconds. (This makes the effective height of the rotary field 350 mms. at an assumed casting speed of 600 mms./min.). The 35 seconds are, according to the knowledge obtained by the inventor, even more than is considered necessary for the period of action. For this reason a periodical interruption of the rotary field is recommended in this case.

A form of construction of a continuous casting plant with rotary field arrangement according to the invention, is illustrated in Figs. 3 and 4 of the drawings. **1** designates a casting ladle, from which the metal jet **2** drops into the cooled thru-flow chill **3**; **4** is the string which on leaving the chill **3** comes within the range of the rotary field arrangement **5** and is subsequently gripepd by the conveyor rollers **6**. The coils **5***a*, **5***b*, **5***c* of the rotary field poles **7***a*, **7***b*, **7***c* are connected to the network **10** over the interrupter **8** and the transformer **9**. The interrupter **8** switches the transformer onto the network **10** for a certain period of time with the aid of a known combination of time relays and magnetic switches, then interrupts the connection with the network for an adjustable predetermined period, in order to once more switch on the transformer. The string **4** is subjected to the action of the magnetic rotary field only for the period during which the interrupter **8** establishes the connection between the network and the transformer **9**. In the sectional illustration of the string **4** the time markings becoming visible by subsequent "development" (production of longitudinal or transverse microsection surfaces and the etching thereof) are indicated by the lines extending parallel with the solidification face.

I claim:

1. A casting process in which the molten metal is subjected to the application of magnetic rotary fields during solidification for the purpose of influencing the crystallization of the metal, comprising applying the magnetic rotating field transversely across the molten metal core constituting the major area within a solidified crust and in the order of five percent of the complete metal solidification time and before the end of the solidification period.

2. A casting process as in claim 1, comprising intermittently applying said magnetic rotating field.

3. A casting process as in claim 2, comprising reversing the direction of rotation of said magnetic field upon every intermittent application of said field.

4. A casting process as in claim 1, comprising applying said magnetic rotating field to metal being continuously cast.

5. A casting process as in claim 4, comprising applying said rotating magnetic field directly below the upper surface of the molten metal in a continuous casting mold.

6. A casting process as in claim 5, comprising said magnetic field to substantially only five percent of the height of the molten core of the ingot being cast in the mold.

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