(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 076 541**
A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 82201205.0

(22) Date of filing: 28.09.82

(51) Int. Cl.³: B 22 D 27/06
C 22 C 37/00

(30) Priority: 05.10.81 NL 8104509

(43) Date of publication of application:
13.04.83 Bulletin 83/15

(84) Designated Contracting States:
BE DE FR LU

(71) Applicant: HOOGOVENS GROEP B.V.
P.O. Box 10.000
NL-1970 CA IJmuiden(NL)

(72) Inventor: Vermande, Cornelis, Dr. Ir.
Olga v. Gotschlaan 3
NL-2082 HV Santpoort Zuid(NL)

(74) Representative: Zuidema, Bert, Ir. et al,
p/a HOOGOVENS GROEP B.V. P.O. Box 10.000
NL-1970 CA IJmuiden(NL)

(54) Cast-iron ingot mould for use in the production of steel ingots and method of manufacturing the mould.

(57) Cast-iron ingot moulds for use in the production of steel ingots suffer from the risk of broken feet, which reduces their average useful life. This is counteracted by increasing the P-content of the cast-iron and in particular by casting the ingot mould from a cast iron having the composition (by weight):

C	3.8 - 4.7 %
Si	0.55 - 1.15 %
Mn	0.74 - 1.3 %
S	0.01 - 0.035%
P	0.14 - 0.195%

rest Fe and usual impurities

wherein the Si-content is smaller than the Mn-content.

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"Cast-iron ingot mould for use in the production of steel ingots and method of manufacturing the mould"

This invention relates to a cast-iron ingot mould for use in the production of steel ingots in the steel industry, and to a method of manufacturing such an ingot mould.

In the manufacture of rolled steel products, the starting material is often steel ingots which have been obtained by casting liquid steel into a cast-iron ingot mould and allowing the steel to solidify at least partly in the ingot mould. Such an ingot mould is a thick-walled hollow cast-iron body open at both ends and with a slightly tapering shape so that the ingot mould can be stripped from the cast steel ingot. During casting of the steel ingot, the ingot mould is located on a heavy metal ingot plate, which defines the bottom of the ingot. The foot of the ingot mould contacts the plate.

During solidification of the steel a substantial part of the heat present in the steel is transmitted to the ingot mould and to the ingot plate, both of which are thus subjected to high thermal stresses. During the subsequent stripping of the mould from the solidified steel ingot, the ingot mould is further subjected to severe mechanical stresses, which in turn are followed by a thermal load as the ingot mould cools down after stripping. All this results in that ingot moulds are subject to damage and wear, which limit their useful life. This life-span is an important cost-determining factor for the final steel product.

With ingot moulds of good quality, 100 castings per ingot mould are considered normal for a life-span. Nevertheless it is found that with ingot moulds of otherwise very good quality there now and then occurs the phenomenon of broken feet. This consists in the breakage away of pieces of material from the mould on the inside of the mould foot during stripping. Unlike other forms of damage which can limit, the life-span of the ingot mould, it appears that broken feet often occur during the first castings made in the ingot mould. If they do not occur then, there is a significantly lower chance that they will occur again during further use of the ingot mould. It further appears that the probability of broken feet occurring is greater at a higher temperature of the ingot mould foot. This for instance may be the case if during casting use is made of ingot plates which have not been completely cooled down.

It is supposed that the phenomenon of broken feet is influenced by the susceptibility of the ingot mould material to welding to the solidifying steel, and is also influenced by the strength and brittleness of the ingot mould material in the foot region. Therefore there has been a general aim to select the composition of the ingot mould so that a stronger and less brittle material is obtained.

It is generally known that the presence of phosphorus in cast-iron has a weakening effect on the metal and in particular increases the brittleness. Therefore there is a general tendency to keep down the percentage of phosphorus in the cast-iron used for ingot moulds. Phosphorus percentages of less than 0.1% by weight are sought. Nevertheless it has not been found possible to counteract successfully the phenomenon of broken feet by further reduction of the phosphorus content.

German Offenlegungsschrift 1 758 706 describes a liquid cast-iron composition for the production of ingot mould, which contains:

C	about	3.5	-	4.40	%
Si	about	0.3	-	1.2	%
Mn	about	0.7	-	2.0	%
P max		0.35			%
S max		0.06			%

Before casting, this liquid cast iron is enriched with substantial quantities of silicon, either in a metallic form or as a metal alloy of silicon, in order to achieve a silicon content in the cast ingot mould which is between 0.4 and 0.5% higher than the Mn content. This means that in general the Si content in the ingot mould should be between 1.2 and 2.4%.

It is known that alloying cast-iron with silicon is expensive and requires a careful control in order to prevent the formation of graphite.

The present invention has the object of improving the quality of cast-iron ingot moulds, in particular ingot moulds which are to be used for the production of heavy ingots in the weight range of 24 tons and above, and is especially concerned at minimizing the problem of broken feet, especially by the use of a process which is of low cost and is easily carried out.

It has now been found that, to improve the quality of ingot moulds and to increase their life-span, especially with regard to the ingot mould feet, the analysis of the cast-iron is of great importance. More particularly it has been found that good results can only be achieved with an analysis in which the margins for the varying alloying elements and for carbon are narrower and more specific than previously disclosed, for example in the German specification mentioned above. It has been found, surprisingly, that the phenomenon of broken feet in an ingot mould can be counteracted very effectively by raising the percentage of phosphorus instead of by lowering it.

The invention therefore consists in a cast-iron ingot mould with an analysis (by weight) of the cast-iron of:

C	about	3.8	-	4.7	%
Si	about	0.55	-	1.15	%
Mn	about	0.74	-	1.3	%
S	about	0.01	-	0.035	%
P	about	0.14	-	0.195	%

rest Fe and usual impurities,

wherein the Si-content is smaller than the Mn-content.

Preferably the sulphur content is between 0.015 and 0.25%.

It should be regarded as a special advantage of these ingot moulds of the invention that the Si-content need not be increased, and is in fact kept smaller than the Mn-content.

Especially good results are obtained if the Si-content is between 0.55 and 0.75% and the Mn content 0.74 and 0.95% but alternatively the Si-content may be between 1.0 and 1.15% and the Mn-content between 1.1 and 1.3%.

A phosphorus content between 0.14 and 0.195% is unusually high for a cast-iron analysis. Nevertheless it has been found that this high phosphorus percentage definitely improves the life-span of ingot moulds of the above new composition, particularly by effectively counteracting the phenomenon of broken feet.

Best results have been obtained if the P content is between the narrow limits of 0.16 and 0.18%.

As explained already the main effect of the increased P-content is to lower the risk of broken feet. Since this phenomenon of broken feet is restricted to the inside of the mould foot, where it can occur with moulds of otherwise outstanding quality and long useful life, it is in many cases not necessary to increase the phosphorus content throughout the entire mould. Where this is possible in production conditions, and where it is desirable for other technical reasons, it is recommended that outside the region at the mould foot the P-content is about 0.06% lower than in the mould foot itself.

The invention relates to not only the ingot mould, but also to a method for the manufacture of the ingot moulds according to the present invention as described above. According to this method, before casting of the ingot mould a cast-iron composition of the analysis (by weight):

C	about	3.8	-	4.7	%
Si	about	0.55	-	1.15	%
Mn	about	0.74	-	1.3	%
S	about	0.01	-	0.035	%
P	about	0.08	-	0.13	%

is enriched with P by the addition of suitable amounts of an iron-phosphorus alloy. Compared with a method where a pig iron with high phosphorus content is produced in a blast furnace, this new method has clear advantages. These consist in that firstly no abnormal production scheme has to be used in operating the blast furnace, and secondly the addition of a phosphorus alloy to the cast-iron makes possible a much more accurate adjustment of the phosphorus content within the desired limits.

It has been found that use of ingot moulds according to the invention can reduce the percentage of broken feet to only a fraction of the previously usual percentage. This effects a substantial reduction in the costs of the use of ingot moulds and of repair of ingot moulds with broken feet, which in turn results into a substantial lowering of the cost of the cast steel ingots. In addition the cast steel ingots manufactured with the ingot moulds of the invention can have a smoother surface near the ingot mould foot, which provides advantages in the further conversion of the steel ingots into rolled products.

During tests in the applicant's works two series each of 100 ingot moulds were compared under similar conditions. One series had been manufactured to have a composition throughout as described above according to the invention. In the other series the phosphorus percentage was selected at the conventional level, i.e. about 0.06 % lower.

The same criteria were used for judging (i) the general condition of these ingot moulds, (ii) their life-span until they were no more regarded suitable for further use, and (iii) especially the occurrence of broken feet.

On average it was found that the ingot moulds according to the invention had a 10% increase in life-span, while the work needed and costs incurred for maintenance of these ingot moulds were reduced by about 50%.

CLAIMS:

1. Cast-iron ingot mould for use in the production of steel ingots, wherein the cast-iron consists of iron, carbon, silicon, manganese, sulphur, phosphorus and usual impurities, characterized in that at least at a region at the mould foot, the amounts of these elements by weight are, in combination:-

Carbon	(C)	about 3.8	-	4.7	%
Silicon	(Si)	about 0.55	-	1.15	%
Manganese	(Mn)	about 0.74	-	1.3	%
Sulphur	(S)	about 0.01	-	0.035	%
Phosphorus	(P)	about 0.14	-	0.195	%

rest iron and usual impurities,

and in that the Si-content is smaller than the Mn-content.

2. Ingot mould according to claim 1 wherein the S-content is between 0.015 and 0.025%.

3. Ingot mould according to claim 1 or claim 2 wherein the Si-content is between 0.55 and 0.75% and the Mn-content between 0.74 and 0.95%.

4. Ingot mould according to claim 1 or claim 2 wherein the Si-content is between 1.0 and 1.15% and the Mn-content between 1.1 and 1.3%.

5. Ingot mould according to any one of the preceding claims wherein the P-content is between 0.16 and 0.18%.

6. Ingot mould according to any one of the preceding claims wherein outside the said region at the mould foot the cast-iron of the ingot mould has a P-content about 0.06% lower than in the said region at the mould foot.

7. Method of manufacturing an ingot mould according to claim 1 wherein before casting the mould a cast-iron composition consisting of, by weight:

C	about 3.8	-	4.7	%
Si	about 0.55	-	1.15	%
Mn	about 0.74	-	1.3	%
S	about 0.01	-	0.035	%
P	about 0.08	-	0.13	%

rest iron and usual impurities,

is enriched with P by the addition of suitable amounts of an iron-phosphorus alloy and is then used to cast the ingot mould.