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3,299,482 GRAY IRON CASTING PROCESS AND COMPOSITION

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This invention relates to improvements in the foundry production of gray iron castings for applications such as engine blocks, brake drums and the like articles where good wear properties and high strength are demanded, and especially to compositions for use in the continuous process of making such castings in a foundry.

In the making of gray iron castings, for example, for engine blocks, the cope and drag halves of the mold flask are rammed with green sand using any of the many commercially employed methods, for instance, sand slinging, jolt squeeze, diaphragm molding, blow squeeze. The mold cavities are cleaned of loose sand and where applicable a mold wash is applied and either air dried or dried with a gas flame. Individual cores or assemblies of several cores made by conventional oil sand, shell sand, furan resin sand or other methods are then properly set into the mold cavities either manually or through the aid of core setting fixtures. The cope is then placed on the drag half of the mold and held in place under its own weight or through external clamps, wedges or weights. The mold is now ready for pouring with molten metal.

The metal ingredients of the casting composition may be melted by any of the commercially available processes such as cupola, electric furnaces such as direct arc, indirect arc or induction types or an air furnace or combinations in a duplex type operation.

The typical charge, for example, to a cupola consists of coke, pig iron, steel scrap, foundry returns, cast scrap, briquetted borings, limestone, fluxes of various types and supplemental ferro alloys to assist in adjusting the silicon, manganese and in some cases carbon content. These are melted in accordance with conventional cupola practice to produce a molten gray iron with a tapping temperature of 2750° F. to 2950° F.

The molten metal may be used directly to fill ladles to pour castings but to obtain a more uniform composition it is preferred to hold or collect several tons in a receiver ladle or a holding furnace where composition variations in the cupola iron may be minimized or compensated for through additions.

The metal is checked for chilling tendency with any one of a number of accepted means such as chill wedges or blocks and an inoculation of the iron made during filling of the pouring ladles. The ladles are then transferred to the pouring line and the molds filled at the prescribed temperature (2550° F. to 2650° F.) at a proper rate.

After pouring, the molds are slowly transported on the pouring line conveyor cars to the shakeout station. In the case of cylinder blocks for example, this takes about ¼ hr., sufficient to permit the castings to solidify. The cope is then removed and the solidified casting is placed on a cooling line conveyor after gate removal. The castings are now at a temperature of about 1600° F. The castings continue to cool for about 1¼ hours until the core knockout station is reached. The exterior of the casting is now about 1100° F. or less and the bores still about 1450° F.-1500° F. The castings are sent over shakeout tables where the burned out cores and remaining green sand are removed.

The castings are again hung on the cooling line conveyor and after several hours of cooling bringing the

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temperature of the castings down to about 300° F., are brought by the conveyor to the cleaning and inspection station. Here the castings are cleaned by shot blasting chipping and grinding. They are also usually inspected and gaged and water tested for leakage in the water jacketed areas.

Satisfactory castings for use, for example, as engine blocks require that the hardness of the material be suitable for machining and free of chilled spots to avoid tool breakage such being possible with a hardness in the range 170 to 241 Brinell preferably 170 to 229 and that the engine bores also have a hardness above 170 Brinell to avoid a high incidence of bore wear and oil consumption. These results have normally been possible with a cupola composition of the following general character:

	Percent
Total carbon -----	3.10 to 3.40
Silicon -----	1.80 to 2.10
Manganese -----	0.60 to 0.90
Phosphorous -----	Maximum 0.15
Sulfur -----	Maximum 0.12
Chromium -----	Maximum 0.12
Iron -----	Balance

where the cooling of the castings was properly controlled as described above. However, this has not been always possible and repeated field complaints of a high incidence of bore wear and oil consumption on engines revealed on investigation that the bores were quite soft, as low as 110 Brinell and had a microstructure unsuitable for the type of service to which the castings were to be subjected. For example, the microstructure had as much as 50% free ferrite whereas a normal of 5% or less was acceptable. Similar conditions were obtained with brake drum castings. There it was essential that a proper wearing surface of adequate and uniform hardness be obtained without the presence of hard spots due to chill or primary carbides. Further investigation showed that most of the soft blocks were either the result of normal shutdown of the foundry molding and cooling line conveyors described above such as for lunch hour, shift changes or overnite stoppage or due to unforeseeable line stoppages because of equipment failures. In each of these instances the castings were retained for extended periods in the mold or on the cooling line conveyors prior to core knockout. Such permitted the bores to self-anneal because of the slow cooling rate through the secondary graphitizing range of approximately 1450° F. to 1200° F.

A solution to a major part of the problem was to continue the line movement described above over the normal shut-down periods such that the mold shakeout and core knockout operations could be accomplished in a minimum length of time. This would require running the foundry with staggered shifts in the various departments along the foundry molding, shakeout and cleaning lines. This would require additional physical space for the accumulation or storage of foundry mold flasks and banking of blocks after shakeout. It was not practically feasible. Moreover, this approach would not solve the problem of a line shutdown.

The only alternative was to treat or modify the gray iron composition to stabilize the microstructure during the periods of slow cooling to minimize the production of soft bores and poor wearing surfaces on the castings. In this connection it had been found that these soft castings were evidenced by the formation of substantial amounts of free ferrite and that control of this action if possible, could be beneficial.

It was known that certain alloying elements such as chromium in the range 0.20 to 0.40% and combinations of chromium, molybdenum, nickel or copper could alter the microstructure so as to render it more resistant to

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the effects of heat soaking. Also, it had been suggested as a result of small laboratory experiments using induction melting with pure iron that a pearlitic microstructure was possible in gray iron by the use of a tin alloying element. It was not known, however, what would happen if tin was added, for example, to cupola iron on a continued production basis and in high volume or by other commercial procedures or the effect of tin build-up in the base iron. Nor was it known what the effect of tin would be on complex commercial castings from the standpoint of wear and machinability or the ability to reproduce the desired wear properties in complex commercial castings. Moreover, tin had for many years been considered as an undesirable element in iron and steel and to have an inherent embrittling effect on gray iron and was held responsible for any cracks produced in castings.

After considerable experimental work and many, many foundry trials, it was found that if tin in certain critical quantities in the range 0.04 to 0.10 was used in gray iron compositions of the above general character, that it was possible to obtain satisfactory castings substantially free of soft bores and having high wear resistant surfaces by the normal production methods that had previously caused the above described difficulties when normal or abnormal stoppages occurred in the casting line. Also, that castings were possible that had a uniform hardness throughout and which were free of chill spots that would make machining difficult and costly on tools. The amount of tin to use in this range was dependent upon the carbon equivalent (carbon + $\frac{1}{3}$ silicon) the amount increasing with increased carbon equivalency.

Thus, it was found that the problems enumerated above could be entirely overcome by employing a composition essentially composed of the following ingredients and especially where the castings required high wear resistant surfaces and sections of uniform hardness, the amounts given being percent by weight of the total composition:

	Percent
Total carbon -----	3.05 to 3.45
Silicon -----	1.70 to 2.10
Manganese -----	0.50 to 0.90
Phosphorus -----	Maximum 0.15
Sulfur -----	Maximum 0.12
Chromium -----	Maximum 0.15
Tin -----	0.05 to 0.08
Iron -----	Balance

By the use of this composition satisfactory gray iron castings for engine blocks and brake drums were obtainable having uniformity of structure and whose microstructure in those areas of the casting that demand good wear properties and high strength consists of graphite flakes in a matrix of fine pearlite containing not more than 5% uniformly dispersed free ferrite. The graphite flakes will be of type A in major amounts with minor amounts of other types permissible except type C which it is preferred be absent. The graphite flakes will have an average size in the range 4 to 7 according to ASTM specification A-247. Massive flake graphite when present is conducive to graphite tear-out by boring tools and the production of porous appearing articles and is therefore also preferably avoided. It can be substantially avoided by control of the carbon and silicon levels as indicated. Moreover, the Brinell hardness range (3000 kg.) for this composition will be between about 187-241 BHN at ambient temperature and its minimum ultimate tensile strength will be about 32500 p.s.i.

Where the composition is to be used for casting cylinder blocks it is preferred that the carbon equivalent (carbon + $\frac{1}{3}$ silicon) be maintained in the range of 3.76 to 4.15% and that the tin content preferably be between .05 to .08%.

The tin addition may be employed in any of its avail-

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able forms such as metallic tin but its purity should be such that it is substantially free of lead, antimony and arsenic i.e., no more than a trace be present as shown by spectographic examination. In order to prevent oxidation losses, the tin is preferably added to the cupola iron during filling of the pouring ladles by the simple addition of cast and preweighed chunks of metallic tin.

When the tin is used in amounts less than .04%, adequate protection against self-anneal during periods of line cessation or breakdown become questionable and the ferritic content substantially exceeds the 5% minimum. Hence, at least .04% is essential and .05% preferable for consistent result as noted above. Between .05 to .08% is found adequate for normal production operations with compositions within the limits set forth above. In special cases 0.04 to 0.10% may be employed. Tin, in amount above 0.10% may be used but does not add anything to improve the microstructure of the castings and is found to be economically unjustified. Amounts in excess of .25% will result in a loss of tensile and impact strength.

Further, in addition to the benefits described above obtained by modification of the gray iron composition with tin for foundry operations, the following were also found:

(a) The repair rate on castings due to internal shrinkage and the need for impregnation of the castings because of porosity was materially reduced.

(b) Chilled spots in the castings were no longer evident, thus, substantially eliminating tool breakage.

(c) The bore hardness in cylinder block castings was maintainable in a much narrower and higher range of hardness than that possible where tin was not used.

(d) The critical tin addition made possible acceptable castings of chemical analyses which might be expected to be too soft or excessively hard.

(e) Oxidation losses of tin in the cupola were found to be extremely low with a 90 to 95% recovery of all tin used.

From the above description of the invention it will be evident that the process of making gray iron castings substantially free of soft areas and which will provide machinable surfaces of high wearing properties and substantially uniform hardness is improved by the addition of critical amounts of tin to the composition.

It will be understood that all changes and modifications coming within the spirit and intent of the invention and the appended claims and all equivalents are contemplated.

We claim:

1. In a continuous process of making gray iron castings not susceptible to self annealing after pouring in the mold, and prior to core knockout, where said casting are slowly cooled on a moving line subject to stoppages which would cause such self-annealing of the castings and a soft matrix in the wear areas of the castings having a hardness substantially below 170 Brinell and a microstructure containing in excess of 5% uniformly dispersed free ferrite, the step which consists in adding to the molten gray iron composition prior to pouring, between 0.04 to 0.25% by weight of the composition of tin to substantially eliminate self annealing and to facilitate the production of castings having a matrix in the wear area thereof of between 170 to 241 Brinell hardness and a microstructure of fine pearlite containing not more than about 5% uniformly dispersed free ferrite, regardless of said line stoppages.

2. The process as claimed in claim 1 wherein said tin content is between 0.04 to 0.10%.

3. In a continuous process of making gray iron castings for engine blocks and brake drums not susceptible to self annealing after pouring in the mold, and prior to core knock-out, where said castings are slowly cooled on a moving line subject to stoppages which would cause

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such self-annealing of the castings and a soft matrix in the wear areas of the castings having a hardness substantially below 170 Brinell and a microstructure containing substantial amounts of uniformly dispersed free ferrite in excess of 5%, the step which consists in making said castings from a molten metal composition consisting essentially by weight percent of

	Percent
Carbon -----	3.05 to 3.45
Silicon -----	1.70 to 2.10
Manganese -----	0.50 to 0.90
Phosphorus -----	Maximum 0.15
Sulfur -----	Maximum 0.12
Chromium -----	Maximum 0.15
Iron -----	Balance

and adding to the composition between 0.05 to 0.08% by weight of the composition of tin to substantially eliminate self annealing and to facilitate the production of castings having a matrix in the wear area thereof of between 187 to 241 Brinell hardness at ambient temperature and a microstructure of type A graphite flakes in a matrix of fine pearlite containing not more than about 5% uniformly dispersed free ferrite, regardless of said line stoppages.

4. A process as claimed in claim 1, wherein the tin content is between 0.05 to 0.08% by weight of the composition.

5. In the continuous process of making gray iron cylinder block castings not susceptible to self annealing after pouring in the mold, and prior to core knock-out, where said castings are slowly cooled on a moving line subject to stoppages which would cause such self-

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annealing of the castings and a soft matrix in the cylinder bore areas of the castings having a hardness substantially below 170 Brinell and a microstructure containing in excess of 5% uniformly dispersed free ferrite productive of soft cylinder bores, the step which consists in preparing a molten gray iron composition having a carbon equivalent of about 3.76 to 4.15% and adding to the molten iron prior to pouring between 0.05 to 0.08 percent by weight of the composition of tin to substantially eliminate self annealing and to facilitate the production of castings having cylinder bore surfaces of 187 to 241 Brinell hardness at ambient temperature and a microstructure of type A graphite flakes and substantially free of type C graphite flakes in a matrix of fine pearlite containing not more than about 5% uniformly dispersed free ferrite, regardless of said line stoppages.

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