A method for producing a master alloy for use in aluminum casting processes in which an aluminum melt containing 0.02–6 percent by weight titanium and 0.01–2 percent by weight boron is produced under conditions under which the boron is bound to titanium in the form of titanium diboride, whereafter the melt containing titanium diboride is held under agitation at a temperature ranging from the melting point of the material to 900°C for a period of at least 15 minutes and at most 9 hours.
The present invention relates to a method for producing a master alloy which can be added to an aluminum melt before the melt solidifies, thereby to obtain finer grain size of the cast aluminum product with subsequent increase in the quality of the same.

It is known that in order to obtain a satisfactory product from an aluminum casting process, for example, it is necessary to add a substance which facilitates the formation of crystals during the period of solidification, the substance preventing the aluminum melt from solidifying to a coarse-crystal product. To this end, different grain refining substances are generally incorporated in the aluminum as master alloys, which are added to the aluminum melt in solid form, for example in the form of small ingots or a wire which is continuously fed into the melt. The master alloy may also be added in a molten state.

The master alloys previously used have comprised mainly titanium, boron and a combination of titanium and boron. Typical master alloys contain 2–10 percent by weight titanium in aluminum, 0.3–5 percent by weight boron in aluminum and 2–10 percent by weight titanium together with 0.3–5 percent by weight boron in aluminum. A usual composition is one containing 5 percent by weight titanium and 1 percent by weight boron in aluminum. Master alloys of this type are available commercially.

It has now been surprisingly found that by producing a titanium-boron-aluminum master alloy in a special manner it is possible to improve considerably the grain refinement while using considerably lower total quantities of titanium and boron than has been possible with the hitherto commercially available master alloys.

Master alloys containing titanium and boron are normally produced by dissolving the required quantities of titanium and boron in an aluminum melt at temperatures in excess of approximately 1,200°C. When practicing this method, it is first necessary to dissolve a specific quantity of titanium before adding the boron. The boron is added in the form of a boron salt, normally potassium borofluoride (KBF₃). The boron salt is dissolved in the melt and the liberated boron then readily combines with the titanium present in the melt. It is also possible to disperse fine-grain titanium diboride in the melt. In accordance with the present invention there is produced a master alloy which is intended to be added to an aluminum melt to afford a grain refining effect during the solidification period, an aluminum melt containing 0.02–6 percent by weight titanium and 0.01–2 percent by weight boron being produced, in which the boron is bound to the titanium in the form of titanium diboride, by either first dissolving titanium at a temperature such that the quantity added passes into solution, and then adding boron, or by dispersing titanium diboride in an aluminum melt, and the method is characterized by the step of maintaining the melt containing titanium diboride at a temperature between the melting point of the mixture and 900°C while stirring the melt and for a period of time of at least 15 minutes and at most 9 hours.

If large quantities of titanium, for example of the order of 10 percent by weight, are to be dissolved, it is necessary, for thermodynamic reasons, that the temperature during the dissolution phase reaches at least 1,200°C. Consequently, it is naturally necessary to cool the aluminum melt rapidly down to a temperature below 900°C, in order to prevent the occurrence of undesirable reactions. Since it is difficult to rapidly cool the alloy to a temperature immediately above the melting point a particularly suitable method for carrying out such a cooling process is one in which alloy is cast in small, water-cooled moulds, whereafter the metal is remelted at a temperature below 900°C.

The titanium content of the master alloy is preferably 0.2–2 percent by weight and the boron content is preferably 0.1–1 percent by weight and the temperature used during the dissolution phase is from 1,200°C to 1,500°C. The alloy is then cooled to the holding temperature between the melting point and 900°C. A preferred holding temperature is 680°C–720°C and a preferred holding time is from 45 minutes to 2.5 hours. Subsequent to the heat treatment process, the pre-alloy can be used directly or subsequently to solidifying, although it is normal practice to decant the molten master alloy to prevent the formation of large agglomerates of titanium diboride and other impurities from accompanying the master alloy.

The conditions prevailing in the aluminum-titanium system are evident from available constitutional diagrams, from which it can be seen that pure aluminum solidifies at approximately 660°C and that a peritectic solidification line exists from a titanium content of roughly 0.5 percent by weight at 665°C to the stochiometric composition for Al₃Ti at roughly 37.5 percent by weight Ti. In order that Al₃Ti can be formed, the content of Ti at 665°C must thus be at least 0.15 percent by weight. At 900°C the liquid solubility for titanium equals 1 percent.

When titanium and boron are dissolved in aluminum, a compound between titanium and boron, Ti₅B₄, is rapidly formed, Al₅Ti crystallizing out at reduced temperature during the holding period to embrace the compound. The formation of Al₅Ti presumes that the concentration of Ti in the system exceeds the content necessary for forming Al₅Ti at the temperatures in question. In this particular instance, a titanium concentration gradient is obtained around the Ti₅B₄ grains. This concentration gradient is obtained as a result of the fact that titanium is disassociated from titanium diboride and is replaced therein with aluminum. This enables the titanium diboride and aluminum diboride to have the same crystal structure and to replace each other in the crystal lattice.

It is thus necessary to exceed the solubility limit or liquidcurve in the constitutional diagram for Al₅Ti, which can be effected by raising the concentration of titanium or by changing the position of the solubility curve by means of appropriate additives. In this way, Al₅Ti will crystallize around the Ti₅B₄ grains and form small crystals, which constitute the actual crystallization nuclei. The formation of Al₅Ti takes place during the holding time at the aforementioned temperature interval of the invention. If the titanium content of the master alloy is of such magnitude that Al₅Ti can be formed in the whole melt, large quantities of Al₅Ti crystals will be formed, which when the master alloy is used will dissolve and give high titanium contents to the final product, but will of course also act as crystallization nuclei to a lesser extent, owing to the fact that these crystals will become considerably larger and fewer than those which are formed around the Ti₅B₄-grains.
The initially irregular grains of TiB₂ will, after approximately 1 hour, have been embraced by a more regularly shaped crystal shell comprising substantially Al₃Ti. The formed crystals added to the aluminum melt are able to refine the grains rapidly and effectively. If the master alloy is not subjected to the crystallization of Al₃Ti around the TiB₂-particles during the holding period and during simultaneous agitation of the system, TiB₂ will form aggregates which will be practically totally precipitated out by gravitational separation, and will either not be included during the casting process or will be entrained with the casting material, thereby rendering its use impossible for, for example, foil rolling, where the agglomerated TiB₂-particles cause the foil to be torn during the rolling operation. For the same reason, a large quantity of TiB₂ will fall to the bottom of the furnace without fulfilling its function as a grain refining agent, whereupon it becomes necessary to add the TiB₂ in excessive quantities, which considerably impairs the economy of aluminum casting processes using this agent. A large addition of grain refining agent also causes a large quantity of titanium to be dissolved in the melt. An increase in the titanium content of aluminum gives rise to several undesirable effects, such as the formation of feathery grains and changes in the conductivity of the final product.

The new master alloy of the present invention can be used in considerably small quantities or with a lower content of titanium and boron, since it is possible to utilize actively all the titanium and boron present therein.

It is obvious that the final, desired aluminum melt can be considered totally as a master alloy and that the melt can be treated in a manner whereby titanium and boron are first dissolved at higher temperatures and the whole melt than maintained at a temperature of approximately 700°C for a period of 1 hour under agitation. In this way grain refinement would be equivalent to that obtained with the master alloy of the present invention. However, such treatment of an aluminum melt is expensive, extremely difficult to carry out technically and gives an undesirable content of titanium in the product. It is, instead, particularly desirable to produce a master alloy which can be used in continuous casting processes externally of the furnace in a special container or in the actual pouring stream. The master alloy of the present invention is particularly suited for this purpose, since it can be passed to the melt just before the melt is to be transferred to the mould and immediately blended with the melt. In this way, the grain refining agent is able to exert its influence immediately and a superior product is obtained with a considerably smaller total quantity of titanium and boron in the finished product.

What I claim is:

1. A method for preparing a master alloy intended to be added to an aluminum melt for refining the grains of the aluminum during solidification thereof comprising the steps of:
   a. preparing an alloy melt consisting essentially of 0.02-6 percent by weight of titanium and 0.01-2 percent by weight of boron, the balance being aluminum and wherein the boron is bound to titanium in the form of titanium diboride, and
   b. maintaining the alloy melt at a temperature between the melting point of the alloy and 900°C, for a period of time of at least 15 minutes and at most 9 hours with agitation until the grains of titanium diboride in the alloy become embraced by a crystal shell comprising substantially Al₃Ti.

2. A method according to claim 1 wherein the cooling step comprises cooling the alloy melt to a temperature below the melting point of the alloy and then re-heating the cooled alloy to a temperature between the melting point of said alloy and 900°C.

3. A method according to claim 2 wherein the step of cooling the alloy melt to a temperature below the melting point of the alloy comprises casting the alloy melt into cooled moulds.

4. A method according to claim 1, wherein the titanium is present in an amount of 0.02-2 percent by weight, based on the total weight of the alloy.

5. A method according to claim 1, wherein the boron is present in an amount of 0.01-1 percent by weight, based on the total weight of the alloy.

6. A method according to claim 1, wherein the alloy melt is maintained at a temperature of 680°C-720°C.

7. A method according to claim 6, wherein the alloy melt is maintained at 680°C-720°C for from 45 minutes to 2.5 hours.

8. A method according to claim 1 wherein the step of preparing the alloy melt comprises dispersing titanium diboride in molten aluminum.

9. A method according to claim 1 wherein the step of preparing the alloy melt comprises adding titanium and boron to molten aluminum at a temperature above about 1,200°C.

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