Feb. 19, 1929. 1,702,387

H. A. KUHN

COMPOUND IGNOT AND METHOD OF PRODUCING THE SAME

Filed June 16, 1927

Fig. 1.

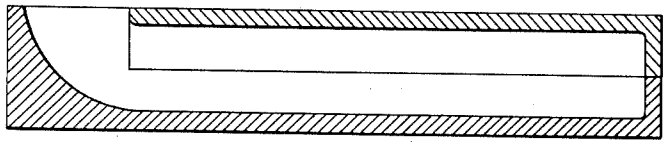


Fig. 3.



Fig. 2.

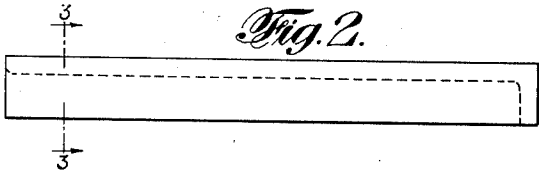


Fig. 5.

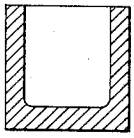


Fig. 4.

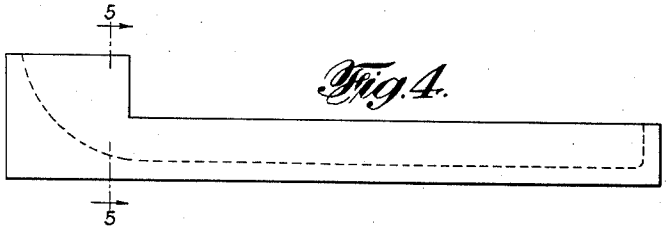


Fig. 6.

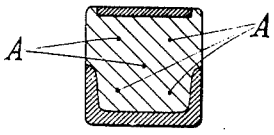


Fig. 7.

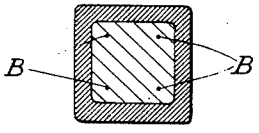


Fig. 8.

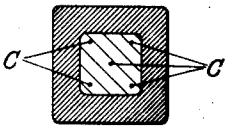


Fig. 9.

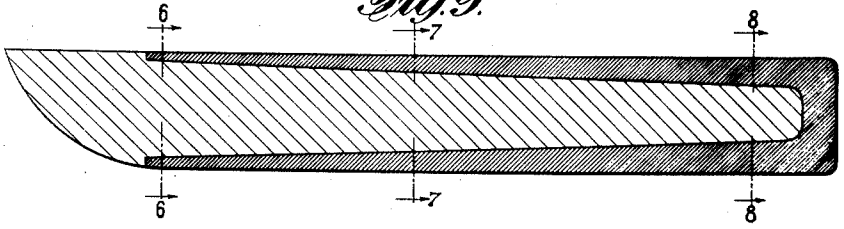
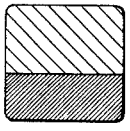


Fig. 10.



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UNITED STATES PATENT OFFICE.

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COMPOUND INGOT AND METHOD OF PRODUCING THE SAME.

Application filed June 16, 1927. Serial No. 199,208.

This invention relates to metallurgy or more especially to the casting in still molds of ingots from metals of different composition in such manner as to form a finished product characterized by zones of the constituent metals in substantially homogeneous form with normal continuity of crystallization throughout the ingot.

Many efforts have been made heretofore to produce an integral compound ingot of the character described. Such an ingot is adapted to many uses, as where a wearing surface of one metal is desired and a body of another, or a sheath of rust-resisting metal and an integral core of cheaper or tougher metal, or a face metal of one strength or character and a backing metal of another strength or character. Innumerable examples of the utility of such a composite metal body will be apparent to those skilled in the art. But despite the extraordinary utility and importance of the subject matter and the attention that has been given to it by engineers, I have not found in the art prior to my invention any practical solution of the problem nor any means for producing a truly integral compound ingot, i. e., one characterized by zones of different metals in substantially homogeneous form and by normal bonding and continuity of crystallization throughout.

Where different metals are poured together in liquid or molten phase as heretofore, they mix to form substantially a complete alloy of the two constituents by virtue of the characteristic of migration and diffusion of fluids. Even if care be exercised to pour the different metals in different zones (as by bottom pouring in a vertical mold) they will merge to form an ingot which is characteristically an alloy throughout its major portion If agitation of the metal in the body of the mold is permitted the alloy becomes substantially homogeneous. If the metals are brought into contact in the presence of the atmosphere a line of oxides is produced which prevents normal crystallization. In centrifugal casting of two or more metals the crystallization is not normal, the crystals being deformed by the centrifugal force as they build up in the mother liquor.

Where one metal in liquid phase is brought in contact with another in solid phase as by pouring a molten metal on a solid or by welding, as heretofore, an abnormal boundary of crystallization is produced between them. The resulting ingot is somewhat analogous in structure to a block of concrete formed by two successive pours where the first batch poured has been permitted to set before the pouring of the second. Each batch will form a block having the internal cohesion characteristic of normal crystallization. But between the two blocks will be a boundary characterized only by adhesion. The rocks and crystals of the meeting surfaces may interlock but there is absent the bonding of the crystals by the amorphous intercrystalline material which is characteristic of the normal setting or freezing of crystalline materials.

In pouring molten metal into contact with solid metal there is a tendency to melt the surface of the solid metal and to permit interlocking crystallization between the two on cooling but this tendency is largely overcome and normal continuity of crystallization is prevented by the instantaneous cooling effect of the solid metal on the molten which produces abnormal crystallization in the latter along the boundary of contact. Further, the presence of atmospheric gases during the contact of the metals results in the formation of a line of oxides along with the abnormal crystals—like a line of dry rubble stone between two masses of concrete—so that on cooling there is little more than adhesion at the boundary which results in cleavage, splitting, etc., in subsequent use or working of the metal.

I have discovered that under certain conditions of casting these difficulties may be avoided, and an integral compound ingot produced in which the major portion of the constituent metals is found, not in the form of a new alloy, but in zones of metal each having substantially the analysis of one of the original constituents and in which there is no abnormal boundary of crystallization but apparently normal and continuous interlocking crystallization throughout the ingot.

I will now explain my invention in connection with the accompanying drawings in which there is illustrated in Fig. 1, in vertical section, a form of mold which may be employed in casting the ingot, in Fig. 2 the upper half thereof, in Fig. 3 a section of such upper half, in Fig. 4 the lower half thereof, in Fig. 5 a section of such lower half, in Figs. 6, 7 and 8, cross sectional views of an ingot cast in accordance with the invention, the sections being taken on lines 6—6, 7—7, and 8—8 re-

spectively of Fig. 9, in Fig. 9 a longitudinal vertical section of an ingot cast according to my invention in a mold such as shown in Figs. 1–5, and in Fig. 10 the cross section of another ingot for purposes of comparison.

In practicing my invention I prefer to employ a horizontal mold which may be of the type shown in Figs. 1 to 5 though any other appropriate type of mold may be employed in which agitation due to pouring is minimized in the body of the mold. It will be apparent that in a mold such as illustrated much of the turbulence ordinarily resulting from pouring may be avoided.

The metals to be used in casting the ingot are first separately melted. If, for example, I desire to cast an ingot such as shown in Fig. 9 having a core of carbon steel and a sheath or coating of chromium or stainless steel, I separately prepare these two metals or alloys for pouring in the customary manner. Care should be exercised however to see that at the time of pouring the metals into the mold the metal which is to form the sheath is at substantially the temperature known to founders as "on the hot side" (which in the case of chromium or stainless steel may be approximately 2900°–3000° F.), and that the metal which is to form the core is at substantially the temperature known to founders as "on the cold side" (which in the case of carbon steel may be approximately 2700° to 2800° F.).

Having so prepared the constituent metals in the form of liquid metal solutions in condition for pouring, the metal which is to form the sheath is first poured into the mold. As will be readily understood this liquid solution, as it is poured in, freezes and solidifies at its boundary of contact with the mold, thus forming a rigid trough or bowl in contact with the walls of the mold and containing within it a body of metal solution the general temperature of which is "on the hot side". Between the body of metal in the liquid phase, having molecular fluidity, and the trough or bowl of metal in the solid phase, having molecular rigidity, there will be no clear line of demarcation, but a zone of viscous, semi-frozen metal in which the continuous crystallization, characteristic of freezing, is in process and is, in general, proceeding inwardly from the rigid zone to the fluid zone with the cooling of the metal.

Meanwhile, and before the pouring of the first metal has been completed, the pouring of the second metal is begun and it is poured in such manner as to form a continuous stream; for example as the stream of the first metal is about to disappear out of the teeming pot the second metal may be poured into this pot so that the stream of steel is continuous. In addition, care must be exercised to pour it so as to produce a minimum of agitation of the metal in the mold and so that the stream enters the mold under the skin of the metal already poured.

This second metal, being substantially cooler than the body of the first metal, appears to flow along the trough or bowl formed in the bottom of the mold by the freezing of the first metal and to displace the hotter liquid portion of the first metal and carry it rearward upward along the sides of the mold and finally over the top thereof as the mold is filled, the first metal continuing to freeze and solidify as it comes in contact with the walls of the mold to form a sheath or coating for the sides and top comparable to that already formed for the bottom of the ingot. The oxide film which is continuously forming on the top of the molten metal floats upward progressively to the top of the mold and is not to any substantial extent broken up or disseminated through the molten mass. The zone of contact between the two metals is not exposed to the atmosphere or to the gases in the mold, it is always under the skin of the molten metal so that no oxide film or the like is permitted to form between the two to produce an abnormal boundary of crystallization or interfere in any way with normal continuous crystallization throughout the ingot as it cools. Agitation within the molten mass is avoided as much as possible to minimize alloying between the respective metals. Thus, the crystallization, begun in the sheath metal, as aforesaid, and that which begins in the body of the somewhat cooler core metal continues progressively in accordance with the normal laws of freezing of such metals and produces a continuous crystallization between the two metals with normal bonding and integral interlocking of the crystals of the two metals in a zone of alloy between them. After pouring, the mold is preferably tilted up somewhat at the pouring end so that the "pipe" will be restricted to that end. The ingot is then allowed to cool and may be worked in the usual manner.

By this method there is produced an integral, composite ingot having a sheath of one substantially homogeneous metal surrounding a core of a different substantially homogeneous metal and characterized by the absence of any structural boundary or line of weakness between them.

It is my understanding of the theory underlying the process described that complete alloying of the metals is prevented and such alloying as occurs is largely restricted to a zone positioned between the zones of substantially homogeneous metal by reason of the difference in temperature of the two metals, the contacting thereof under the skin of the molten mass and the minimizing of agitation. The colder core metal appears to force aside the hotter sheath metal, thus positioning itself centrally of the ingot while at the same time permitting integral solidifi-

cation and crystallization of the metals as the ingot cools. This is borne out by an examination of the metals as they appear in the finished ingot. Such examination makes it clear that while there is sometimes a trace of diffusion of metals throughout the ingot there is substantial alloying only in a limited zone between them; the original metals in substantially homogeneous form are separately positioned in the ingot; there is continuity of normal crystallization throughout the ingot; the amorphous fillings between the crystals show no line of abnormal crystallization; on the contrary they show the integral interlocking of crystals characteristic of normal freezing.

Figs. 6, 7 and 8 represent sections cut from an actual ingot cast as I have described. Fig. 6 represents a section cut from the part of the ingot near the mouth of the mold (see line 6—6 in Fig. 9). Fig. 7 represents a section from the middle of the ingot (line 7—7 of Fig. 9); and Fig. 8 a section from the part of the ingot near the back or closed end of the mold (line 8—8 of Fig. 9). The figures represent such sections after the same have been etched with acid to indicate the zones occupied by the chromium and carbon steels. It will be understood by those skilled in the art that the clear line of demarcation shown by the acid does not indicate an equally clear line of demarcation between the metals. It is merely a function of the acid used. The line formed by the acid indicates the boundary outside of which the section consists principally of chromium steel and within which it consists principally of carbon steel. The line shows the relative positioning of the metals in the ingot and demonstrates the existence of a structure such as I have described and which I believe has never been produced prior to my invention. The positioning of the respective metals in the ingot as described is confirmed by analysis of samples drilled out of the sections. These samples indicate that the major portion of the sheath metal is homogeneous and of substantially the same analysis as that of the metal first poured, that the major portion of the core metal is homogeneous and of substantially the same analysis as that of the metal last poured, that alloying between the sheath and core metals takes place in a limited zone between the two, that a trace of the sheath metal may be sometimes found in the core metal, that there is normal bonding and interlocking of crystals throughout the ingot. For example, if the metal first poured be 14% chromium steel and the metal last poured be ordinary carbon steel, the section outside of the boundary indicated by the acid line in Figs. 6, 7 and 8 is found by analysis to be substantially homogeneous 14% chromium steel, the core substantially homogeneous carbon steel with an alloy of the two extending in a limited zone between the core and sheath metal. Analysis of samples taken from the points marked A in Fig. 6 shows no appreciable evidence of the presence of migrating or alloying of chrome. Analysis of samples taken from the points marked B in Fig. 8 shows 1% to 1½% of chrome present. Analysis of samples taken from the points marked C in Fig. 8 shows 2% to 3% of chrome present. This slight evidence of migration of the chrome in the far end of the ingot is not such as would result from normal alloying of the two metals, it is notably less than has occurred in prior practice.

Comparison of Figs. 6, 7 and 8 indicates that in the ingot from which they were taken the sheath metal was forced by the colder core metal toward the rear or closed end of the mold as well as upward around the sides and top of the mold so that the sheath is much thicker at the bottom end of the mold than at the open or inlet end. Indeed, in Fig. 6, the sheath appears not to have been continuous but to consist of a zone at the bottom and lower sides and a separate zone across the top.

Non-uniformity of sheath depth may be of advantage where articles of different character are to be made from the ingot. Thus the ingot may be cut in a plurality of parts, that from the portion of the ingot nearest the open end being used where the minimum ratio of sheath to core metal is desired and that from the portion of the ingot nearest the bottom or closed end of the mold being used where the greatest ratio of sheath to core metal is needed.

In Fig. 10 I show a typical cross section of an ingot made by pouring into a similar mold and in similar manner first a solution of 80% copper and 20% nickel—the same bing poured at a temperature of about 2300° F.—and second molten carbon steel at a temperature of about 2700°–2800° F. It will be observed that the metal first poured has remained in the bottom of the mold. If instead of the solution stated (80% copper, 20% nickel) Monel metal had been used at a temperature of about 2900° F. the result would be substantially the same as shown in Figs. 6, 7 and 8. Since Monel metal and the solution stated have substantially the same specific gravity, both being heavier when cold than carbon steel, I attribute the formation of the sheathed ingot shown in Figs. 6, 7 and 8 to the difference in temperature of the metals employed—i. e., the temperature of the metal first poured being higher than that of the metal next poured; I attribute the continuity of crystallization to the conditions permitting the metals to contact in fluid phase without atmospheric contact or sufficient temperature difference between them to produce abnormal volatilization of contained compounds; I attribute the restriction of molecular migration within a limited zone, i. e., prevention of ordinary alloying throughout the ingot, to the vis-

cosity of the respective metals due to their temperatures. The resulting composite integral ingot therefore appears to be the result of functions of temperature of the metals rather than of their specific gravities.

While I have described my invention by reference to a specific embodiment thereof, it will be understood that the same is illustrative only and that I do not intend to limit the definition of my invention except as defined by the annexed claims. It will be understood that in describing as metals the materials used in casting ingots according to my invention I intend to include appropriate alloys as well.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A compound ingot comprising zones of different metals in substantially homogeneous form with normal continuity of crystallization throughout the ingot.

2. A compound ingot comprising different metals in substantially homogeneous form in different zones, a zone of alloy between them and normal continuity of crystallization throughout the ingot.

3. A compound ingot comprising a substantially homogeneous core, a substantially homogeneous sheath of different metal with normal and continuous interlocking crystallization throughout the ingot.

4. A compound ingot comprising a substantially homogeneous core, a substantially homogeneous sheath of heavier metal than the core with normal and continuous interlocking crystallization throughout the ingot.

5. A compound ingot comprising a substantially homogeneous core, a substantially homogeneous sheath of heavier metal than the core, a restricted zone of alloy between the sheath and core, with continuous crystallization and bonding of crystals throughout the ingot characteristic of normal freezing of such metals.

6. A compound ingot comprising a sheath of one metallic alloy, a core of another metallic alloy containing only a minor percentage of molecules of the first alloy, a restricted zone of alloy of the two alloys between them and continuous crystallization and bonding of crystals throughout the ingot characteristic of normal freezing of such alloys.

7. A compound ingot comprising metals of different composition separately positioned in the ingot and integrally bound together by a zone of alloy, the structure and bonding of crystals between said metals and said alloy being continuous and free from abnormal boundaries.

8. The method of casting an ingot which consists in pouring a metal into a mold and then pouring a second metal at a lower temperature under the skin of the first metal without substantial agitation.

9. The method of casting an ingot which consists in pouring a metal into a mold thereby producing zones of the metal characterized by molecular rigidity and molecular fluidity and then introducing between the two zones a molten metal at a temperature intermediate that of the two zones.

10. The method of casting an ingot which consists in pouring a metal into a mold thereby producing zones of the metal characterized by a substantial temperature difference and the metal in one of said zones being fluid and then introducing between the two zones a molten metal at a temperature intermediate that of the two zones.

11. The method of casting an ingot which consists in pouring a metal into a mold thereby producing a zone of the metal more viscous than an overlying zone thereof and then introducing into such viscous zone, substantially without agitation and without exposure to oxidizing gases, a molten metal at a temperature below that of the overlying zone.

12. The method of casting an ingot which consists in pouring a metal into a mold thereby producing a zone of the metal more viscous than an overlying zone thereof and then introducing under the skin of the first metal and without substantial agitation a molten metal at a temperature below that of the said overlying zone.

13. The method of casting an ingot which consists in freezing a portion of molten metal partially surrounding another portion of the same metal in liquid phase, introducing under the skin of the first metal and without substantially agitating it, a different metal in liquid phase and at a temperature less than that of the fluid portion of the first metal, permitting the second metal to replace the fluid portion of the first metal within the frozen portion thereof and freezing said displaced portion about the top and sides of said second metal to form an integral sheath therefor on cooling of the ingot.

14. The method of casting an ingot which consists in pouring into a mold successively and in continuous stream two molten metals the first of which is heated to a temperature higher than that of the second and permitting the stream of the second metal to enter into the body of the first metal and to spread therein without substantially agitating the first metal.

15. The process of producing a compound ingot which comprises heating two metals to different temperatures and then pouring the cooler metal into the hotter metal in the absence of oxidizing gases and without substantially agitating the hotter metal.

16. The process of producing a compound ingot which comprises positioning a metal in a mold, permitting rapid cooling of the metal in contact with the floor of the mold, pouring a second metal under the skin of the

fluid portion of the first metal and directing the stream of second metal laterally across the cooling portion of the first metal.

17. The process of producing a compound ingot which includes positioning a molten metal in a mold in zones characterized by molecular viscosity and molecular fluidity, pouring a second metal under the skin of the first while at a temperature below that of the first metal in the fluid zone and directing the stream of the second metal into the viscous zone of the first metal.

18. The process of bonding together two different metals in normal and continuous crystalline structure which consists in forming a pool of one metal and then gently flowing the second metal under the skin of the first metal to produce extending contact between the two metals, under the surface of the first, the pouring temperature of the second metal being lower than that of the first.

19. The process of forming a compound integral ingot of different metals without substantial alloying thereof which consists in pouring the first metal into a mold to form zones characterized by molecular viscosity and molecular fluidity and then gently flowing the second metal, while at a temperature below that of the fluid zone of the first, into the viscous zone of the first, thereby displacing the first metal from the center of the mold and substantially preventing alloying of the two metals except in a restricted zone between them.

In testimony whereof, I have signed my name to this specification.

HARRY A. KUHN.