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METHOD OF MAKING COATED ARTICLES

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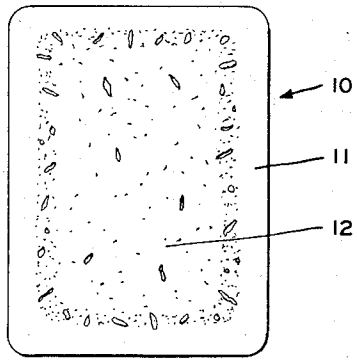


FIG. 1

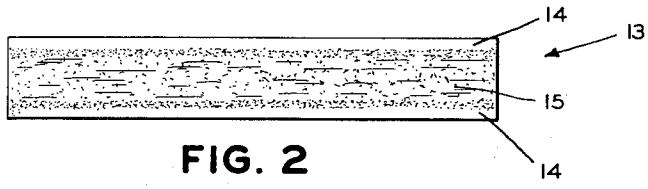


FIG. 2

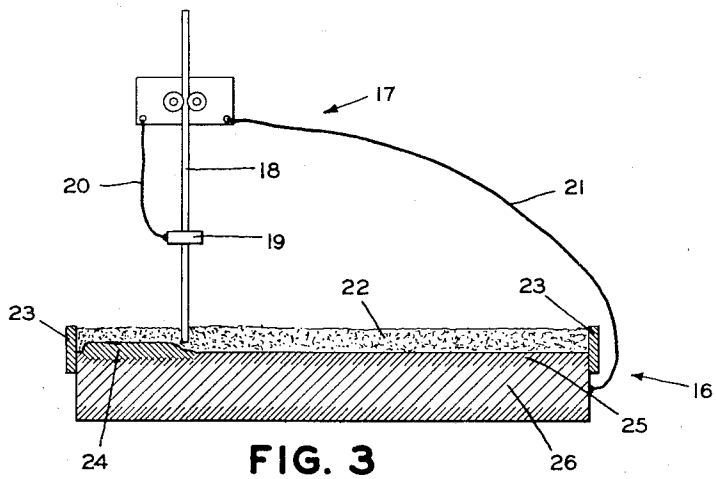


FIG. 3

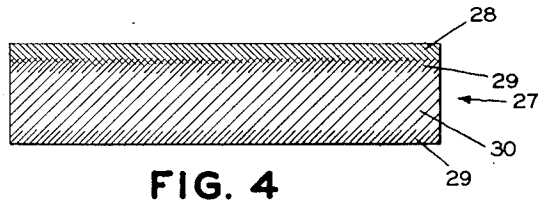


FIG. 4

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METHOD OF MAKING COATED ARTICLES

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7 Claims. (Cl. 29—189)

This invention relates to coated or veneered articles and to the methods employed in their manufacture; more particularly, the invention relates to steel articles coated or veneered with protective metal of special characteristics and to the method employed in manufacturing such coated or veneered steel articles.

In the copending applications Serial Nos. 64,496 and 101,103 filed by Robert K. Hopkins, co-inventor of the subject matter of this application, are disclosed new methods for making coated articles. The new methods briefly include the deposition of fusing metal on the surface of the base metal under a blanket of flux of substantially non-gassing character and of a sufficient thickness to protect the metal depositing operation from the atmosphere. The fusing metal is deposited by means of electric current discharge beneath the flux blanket through a gap, or gaps, between one or more electrodes and the base metal. The current discharge is also effective to melt a depth of the metal of the base so that the fused metal of the base commingles with the deposited metal and forms a part of the coating or veneer. The penetration into the base metal and the analysis of the deposited metal are so chosen that the final coating or veneer is of the required analysis. The coating or veneer is deposited in the form of comparatively wide bands of uniform analysis and penetration; the entire surface of the base metal to be coated or veneered is covered by depositing the necessary number of bands. To assure a continuous coating or veneer the bands are overlapped. The thus coated or veneered base metal may be used as such but in the usual case is rolled or otherwise worked into a finished article.

The working operation converts the coated base metal into the finished article, and in so doing converts the coating or veneer material, which is substantially in the cast condition as deposited, into work refined metal comparable to that of commercial sheets or plates of the same analysis.

We have found that in the commercial production, in accordance with the method briefly described above, of coated or veneered steel articles, especially those intended for use at extremely high temperatures and pressures, as in the refining of petroleum, perfect articles were not invariably produced. The coating or veneer itself was satisfactory but areas were present in which the coating or veneer was not bonded to the base metal or while it was bonded to the base metal there was separation in the base metal below the coating or veneer. These imperfect areas sometimes bulged from the surface of the article and resembled blisters, others were not visible and could only be detected by striking a hammer on the surface of the article and noting the rebound.

A careful study of a large number of blisters revealed that some of them included slag between the coating or veneer and the base metal, or between the separated base metal; others were perfectly clean and evidently free of all solid foreign material. It was concluded that the former were caused by slag inclusions in the steel base and the latter by gas pockets, or dissolved gas, in the steel base. Since none of the blisters occurred above the original surface of the base metal, and as already stated the coating or veneer metal was always of satisfactory character, it became evident that the blisters resulted from the base metal.

It is an object of this invention to provide a novel method for manufacturing steel articles coated or veneered with protective alloy of special characteristics which is characterized by the complete and uniform bond between the protective alloy and the base metal and the absence of unfused areas or blisters between the alloy and the base metal and/or between portions of the base metal adjacent the region of the bond between the alloy and the base metal.

The further objects and advantages of the invention will be better appreciated from a consideration of the following detailed disclosure of the invention taken with the accompanying drawing in which:

Fig. 1 is a sketch representing a deep etched cross-section of a rimmed steel ingot,

Fig. 2 is a sketch representing a deep etched cross-section of a rimmed steel slab,

Fig. 3 is a part sectional schematic view showing a slab being coated or veneered, and

Fig. 4 is an enlarged cross-sectional view showing a coating or veneered plate produced by rolling the slab of Fig. 3.

Carbon steel with or without alloy constituents such as nickel, chromium, molybdenum, manganese, tungsten, vanadium, and the like, is available for the manufacture of pressure vessels, and similar articles which are used under severe service conditions, as rimmed steel, killed steel or semi-killed steel.

Rimmed steel is produced by pouring the molten steel into the usual molds without addition, or with only a slight addition, of quieting materials such as silicon, aluminum, manganese, etc.

(with the exception of aluminum these materials are usually added as ferro-alloys), either in the ladle or in the mold. The steel as thus poured contains qualities of gas which boil off more or less violently as the molten metal cools. The liberation of the gases sets up currents in the molten metal with the result that the metal is violently circulated as it cools.

The metal that solidifies in the early stages is clean and homogeneous. This metal, furthermore, is remarkably free of slag inclusions and segregated impurities and forms the so-called rim of the ingot. The metal that solidifies after the rim metal contains the greater proportion of the gas holes, slag inclusions and segregated impurities of the cast metal. Rimmed steel because of the excellent qualities of the rim is usually broken down into plates directly from the ingot. A sketch representing a deep etched cross-section of a rimmed steel ingot is shown in Fig. 1. Rim **11** is of substantial thickness and includes a substantial proportion of the metal of the ingot. Core metal **12** as shown, includes gas voids, segregations, etc., and is not as uniform as the metal of rim **11**. Probably because of the liberation of gas during solidification rimmed steel and especially the rim thereof will give up little if any gas when reheated to the molten condition.

Slabs of rimmed steel depending on their size and the size of the ingot from which they are made will have a thickness of rim metal at their opposed faces ranging up to three or four inches or more in thickness. The metal between the rim metal, the core metal, since it is consolidated by the breaking down operation, when subjected to a deep etch will show a more or less striated or laminated structure. The deep etched slab of Fig. 2 shows the homogeneous rim metal **14** and the striated or laminated core metal **15**. Plates of rimmed steel generally resemble the slabs; however, due to the added working the rim metal is thinner, though it bears the same proportion to the total metal as in the slab, and the metal between the rim metal is better consolidated.

Killed steel is produced by adding, usually in the ladle, to the molten metal from the furnace substances such as ferro-silicon, ferro-manganese, aluminum, etc., which quiet, or "kill" the steel; the steel after these additions have had their effect, does not boil violently but lies more or less quiescent. The undisturbed cooling and solidification results in an ingot of comparatively uniform metal, with the exception of the metal adjacent the pipe or pipes. While the metal is more or less uniform the gas holes, slag inclusions and the segregated impurities are found throughout the metal of the ingot. Killed steel ingots are not broken down and rolled into plate directly as it is necessary to remove all surface defective metal in an intermediate step. Killed steel probably because of the addition of the quieting materials readily gives up gas when reheated to the molten condition.

Slabs and plates of killed steel when examined after being etched exhibit a more or less pronounced but rather uniform laminar structure throughout their cross-section.

Semi-killed steel is produced by pouring molten metal from the furnace into the ladle with only a relatively small addition of a quieting material such as ferro-silicon. The metal is then teemed into the ingot molds and allowed to cool until a rim of substantial thickness is produced; in some cases aluminum may be added during the teeming operation. The resulting ingot has a rim but the metal within the ingot is of a more uniform character from top to bottom than that of rimmed steel. Slabs and plates of semi-killed steel include a thickness of rim metal adjacent their faces but the metal between the rim metal approximates the character of the metal of killed steel. This type of metal has to some degree, the virtues of both rimmed steel and killed steel.

We have found that uniformly satisfactory results are obtained by using rimmed steel base metal or semi-killed steel base metal or steel base metal having the desirable properties and characteristics of rimmed or semi-killed steel. Thus, the veneering or coating operation is carried out on steel base metal that includes a substantial thickness of metal, defining the surface to be coated or veneered, comparable to the rim metal of rimmed steel, i. e., clean metal which when subjected to a deep etch exhibits a sound structure free from laminations, gas holes and other imperfections, and large quantities of impurities that cause a rough etched pattern; the metal also being such that it will release little if any gas if heated to the molten condition.

To carry out the coating or veneering operation the base metal **16** is positioned under a suitable welding head **17**. Welding head **17** may be of any preferred type and construction but should include arrangements for controlling the feed of electrodes **18** and for controlling the amperage and voltage of the electric current supplied. Welding head **17** may include a current generator or may be provided with current connections from an outside source. One side of the current supply is connected to a contact device or nozzle **19** by cable **20**. Device **19** may be of any preferred construction but should be such as to uninterruptedly supply current to electrode **18** on its way to base **16**. The other side of the current supply is connected to base **16** by means of a cable **21**. While only one electrode has been shown one or a plurality of electrodes may be employed.

Electrode **18** may be solid or hollow or bare or covered and may have any desired cross-section. The electrode or electrodes may include all of the constituents required to form the desired alloy coating or veneer when the metal, fused from the electrodes and the base metal intermingle or they may include only some of the required constituents and the remainder supplied from an external source such as the flux blanket **22**, a metal bar, etc. At present, we prefer to employ a plurality of electrodes that include one or more hollow electrodes and supply the remainder of the required constituents at a controlled rate or rates through the hollow electrode. When the desired coating or veneer is chrome steel, the hollow electrode is preferably of mild steel and the required chrome is supplied as ferro-chrome through the hollow electrode; when the desired coating or veneer is chrome-nickel-steel the chrome, as ferro-chrome, and the nickel, as nickel powder, pellets, wire, etc., are supplied through the hollow electrode which again may be made of mild steel. With nickel-chromium-steel and with other alloy steels it sometimes is preferable to make the hollow electrode and/or one or more of the other electrodes out of a metal other than steel, as for instance, nickel as all of the iron required in the coating or veneer may sometimes be supplied by the metal of base **10** that is fused and by the ferro-chrome.

The surface of base metal **16** to be coated or

veneered is covered with a blanket of flux 22 of sufficient depth to submerge the coating or veneering operation and to protect it, as well as the fused metal, from the atmosphere. The flux blanket 22 is preferably confined at the area to be coated or veneered by dam or dams 23.

The flux should be such that it will not liberate deleterious gas, either as to quantity or kind, during the metal depositing operation, and will not add substantial quantities of undesirable ingredients to or remove substantial quantities of desirable ingredients from the molten metal but will flux out impurities. A wide variety of fluxes may be used satisfactorily. Silicates in general, either simple silicates or mixtures thereof, or complex silicates or mixtures thereof, are satisfactory fluxes. Aluminates, titanates and similar compounds are likewise satisfactory. The flux need not be composed of reacted materials but may be made up of their dried or calcined unreacted components. Thus, in the case of calcium silicates the flux may be made up of CaO and SiO_2, in the case of manganese silicates it may be made up of MnO and SiO_2. At present, silicates of the alkaline earth metals, manganese, aluminum and iron are preferred as fluxes.

To initiate the coating or veneering of base metal 16 the end of the electrode 18 is fed to the surface of base metal 16 and a ball of steel wool or other arc starter interposed between the electrode and the base. The end of the electrode is covered with flux and the energy circuit closed. The initial flow of current will fuse the arc starter and, thus, provide an ionized path for the flow of current between the electrode and the surface of the base metal. The heat generated by the dissipation of the electrical energy will fuse a depth of the metal of the base 16, the metal of the electrode and any metal passed to the region of the gap between the electrode and the base metal with the result that all of this metal will intermingle into an alloy bead 24 of substantially homogeneous composition that is integrally fused or bonded to the base metal 16. The heat generated, furthermore, will fuse the flux and, thus, provide a molten flux blanket that protects the operation from the atmosphere. The electrode 18 and base metal 16 are moved relative to each other to cover the surface of work 16.

In order that alloy bead 24 may have the desired composition the operation is so controlled that there is continuously fused predetermined proportions of metal of the base 16 and metal from the electrode and/or metal from other sources.

The heat generated by the flow of electric energy through the gap between the end of electrode 18 and the surface of the base metal 16 penetrates into base metal 16 with a result that a depth of base metal 16 greater than that fused is highly heated. The metal of base metal 16 above the alloy line is, of course, heated to such a temperature that it is rendered sufficiently fluid to freely intermingle with the fused metal derived from the electrode. A depth of metal below the alloy line while not heated high enough to render it fluid is heated high enough to render it mobile or plastic so that it will free contained gases and allow glomeration of segregated or dissolved solid impurities. We have found that in order to prevent the formation of blisters either between the alloy and the base or in the base it is essential that the rim metal 25 be of such thickness that none of the core metal 26 is heated sufficiently high to attain the mobile or plastic condition mentioned. Since beads 24 of a wide range of thickness may be deposited with a wide range of penetrations into base metal 16 it should be obvious that it is not possible to set forth in linear dimensions the satisfactory thickness of the rim layer 22; however, the above criteria should be enough to enable skilled workers in the art to obtain satisfactory results.

The bead depositing operation is repeated until all of the surface of base metal 16 required is coated or veneered. To assure a continuous coating or veneer every bead of which is bonded to the base as well as to its adjacent bead, the beads are overlapped somewhat.

The base metal may be coated on one side only or it may be coated on both sides. Also, the composition of the coating on one side may be different from that of the coating of the other side. A portion of the coating on one side may also be of different analysis from another portion of the coating on the same side.

The coated base metal 16 may be used as such but in the usual case it will be converted into the finished article by a working operation. While the coated metal may be cold worked, the more usual practice is to hot work it. The working operation may consist of rolling into plates, sheets, rolled forms, etc., or it may consist of forging into forged plates, sheets, forged shapes, etc.

The coating or veneer as deposited is in the coarse grained condition of cast metal and while satisfactory for some purposes it is not suitable for all kinds of service; also, the surface of the coating or veneer as deposited while resonably smooth is not sufficiently smooth for all kinds of service. Furthermore, as deposited, the coating or veneer is thicker than is necessary for the requirements of the usual service.

The working operations convert the coating or veneer into fine grained worked refined metal comparable to the best available commercial sheet or plate; also, the surface of the coating or veneer is made as fine and smooth as the surface of commercial sheet or plate. The working operations reduce the thickness of the coating or veneer and by proper proportioning of the coated slab and proper working the thickness of the coating or veneer can be reduced to meet the requirements of the intended service.

The working operations, as stated, may be of any preferred character but in the usual case the coated or veneered slab will be rolled into plate or sheet from which may be fabricated vessels of all types and especially pressure vessels for the petroleum, chemical and other processing arts. Fig. 4 shows a cross-section of a rolled plate or sheet 27. The coating or veneer 28 as shown, is separated by a substantial thickness of rim metal 29 from the core metal 30.

We claim:

1. The method of forming an integral alloy coating on a steel base having a zone of finite depth of clean and homogeneous metal adjacent the surface to which the coating is to be applied which comprises discharging electric current under a blanket of flux to fuse metal of said zone and the metal required to form the desired coating when alloyed with the fused metal of said zone, and controlling the metal fusing operation to fuse a depth of said zone substantially less than the total depth of said zone.

2. The method of forming an integral alloy coating on a steel base having a zone of finite

depth of substantially gas free, clean and homogeneous metal adjacent the surface to which the coating is to be applied and a zone of coarser and dirtier metal adjacent to the clean zone which comprises discharging electric current under a blanket of flux to fuse metal of said clean zone and the metal required to form the desired coating when alloyed with the fused metal of said clean zone, and controlling the metal fusing operation to fuse a depth of said clean zone substantially less than the total depth of said clean zone.

3. The method of forming an integral alloy coating on a steel base having a zone of finite depth of substantially gas free, clean and homogeneous metal adjacent the surface to which the coating is to be applied and a zone of coarser and dirtier metal adjacent to the clean zone which comprises discharging electric current under a blanket of flux to fuse metal of said clean zone and the metal required to form the desired coating when alloyed with the fused metal of said clean zone, and controlling the metal fusing operation to fuse in part the metal of the clean zone and to heat the metal of the coarse zone insufficiently to free impurities.

4. The method of forming an integral alloy coating on a rimmed steel base which comprises passing electric current between the end of an electrode and the rimmed surface of the steel base to fuse a depth of the rim metal and to deposit as fusing metal the remainder of the constituents required to form the desired alloy coating, controlling the metal fusing operation so that metal of the base below the rim metal is not heated high enough to release the impurities and gases held therein, and maintaining a blanket of flux on said base to protect the metal fusing operation.

5. The method of forming an integral coating on a rimmed steel base which comprises passing electric current between the end of a consumable electrode, made up of constituents of the desired alloy coating, and the rimmed surface of the steel base beneath a blanket of flux to fuse metal of the electrode and metal of the base, and controlling the metal fusing operation to fuse the electrode and the base metal in the proper proportions to obtain the desired alloy coating, the metal fusing operation being controlled to fuse in part metal of the rim and to heat the metal below the rim metal insufficiently to release gases and impurities.

6. The method of manufacturing alloy coated steel articles from steel base metal having a zone of finite depth of clean and homogeneous metal adjacent the surface to be coated, which comprises, discharging electric current under a blanket of flux to fuse metal of said zone and an added metal to form the desired coating, controlling the metal fusing operation to fuse a depth of said zone substantially less than the total depth, and working the coated metal to form the desired article.

7. The method of manufacturing alloy coated rimmed steel articles which comprises passing electric current between the end of a consumable electrode made up of constituents of the desired alloy coating and the rimmed surface of the steel base beneath a blanket of flux to fuse metal of the electrode and metal of the rim, controlling the metal fusing operation to fuse the electrode and the rim metal in the proper proportions to obtain the desired alloy coating, the metal fusing operation being controlled to heat the metal below the rim metal insufficiently to release gases and impurities, and working the coated metal to form the desired article.

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