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PROCESS OF PRODUCING COMPOSITE ARTICLES CONTAINING NICKEL

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The present invention relates to the process of manufacturing composite nickel or nickel alloy coated metallic products and, more particularly, to the process of manufacturing composite nickel or nickel alloy coated ferrous products of unitary character and to the products thereof.

It is well known that many proposals have heretofore been made for the manufacture of composite bimetallic products. Practically all of the proposals were based upon the use of a complicated process or the use of fluxes, bonding agents and the like. Many attempts have been made to manufacture composite nickel or nickel alloy coated products by the use of prior art proposals but none of them, as far as I am aware, have been wholly satisfactory when utilized on an industrial scale to produce commercial products.

I have discovered a process which is capable of being employed on an industrial scale to produce nickel or nickel alloy coated metallic products and particularly nickel or nickel alloy coated ferrous products without the use of flux or bonding agent. According to the discovery, nickel or nickel alloy coated metallic products can be duplicated repeatedly and consistently without the production of a large number of seconds or of products having defects.

It is an object of the present invention to provide a process of manufacture which can be carried out on an industrial scale efficiently, economically and practically.

It is another object of the invention to provide a process which is capable of duplicating commercial products of a unitary character continuously and consistently.

It is a further object of the invention to provide a process which can be conducted by relatively unskilled labor and which can be easily and readily controlled to yield a nickel or nickel alloy coated metallic product which is provided with an interfacial alloy of such character and extent as to be capable of withstanding stresses involved in handling, fabricating and other industrial and commercial operations.

Other objects and advantages will become apparent from the following description of a preferred procedure of carrying the invention into practice.

An illustrative and preferred procedure will be described in connection with the production of nickel coated steel. It is to be noted that the following description is merely illustrative and that the two metals are nickel and steel and the product is nickel coated steel. Of course, it is possible to produce other nickel or nickel alloy coated products and specific statements made in the following description are not to be taken as limitations on the invention.

A steel billet about 5" x 5" x 15" was carefully cleaned and centered in an ingot mold about 8" x 8" x 17". In cleaning the billet it was found satisfactory to machine, or otherwise remove the surface skin of the billet, such as by sandblasting, chipping, pickling, washing with a grease remover, such as carbon tetrachloride, sodium triphosphate, etc.

After the cleaned steel billet was properly centered and arranged in an ingot mold, molten nickel having an accentuated temperature of about 2800–2900° F. was cast about the steel billet. The foregoing accentuated temperature is higher than the usual pouring temperature employed in the pouring of nickel. In casting the nickel around the steel billet it was found that the molten nickel should be poured well over the top of the steel billet so that the latter will be completely encased in nickel.

After the nickel steel composite ingot was removed from the mold, it was found that satisfactory results could be obtained by forging the ingot directly after heating to a temperature of at least 2200° F. in a reducing atmosphere without the usual milling and chipping of the ingot. As a result of extensive experiments, it was found that the forging of the heated ingot should be executed as rapidly as possible by giving heavy reductions with each blow in order not to allow the metals to cool to a temperature below 1800–2200° F. It is preferable to work at the highest temperature of about 2200° F. or higher, since the formation of the intermediate alloy takes place more readily when working at the higher temperature. In practical operations, it was found that a reduction of about 10% to about 25% and preferably about 20–25% reduction per blow was necessary to give satisfactory results. In the cases where insufficient reduction per blow were made, numerous defects showed up in the finished product and an excessive number of seconds were produced. It has been found that the first blow is of extreme importance and it is essential to impart to the ingot a blow of sufficient intensity to effect the formation of the intermediate alloy. The intensity of the blow will vary with the size of the ingot but, generally speaking, a blow sufficient to effect about a 10% to about a 25% reduction in area of the ingot has been found to be satisfactory.

After the forging, a slab was produced which was approximately 18" x 40" x 1½". This slab was machined to about 12" x 40" x 1½" by removing rough metal from the sides. The machined slab was hot rolled at about 2150° F. on a 20" mill to a strip having a thickness of approximately 0.200".

The hot rolled strip was then passed once through a continuous furnace at a speed of about 15 ft. per minute and at a temperature of approximately 1700° F. and under reducing conditions. Following this heat treatment, the strip

was pickled in a 10 percent sulfuric-nitric acid solution and both sides of the sheet were ground with #120 emery. The annealed, hot rolled strip was about 12" wide and 0.18" thick and was then cold rolled to approximately 0.038". In carrying out the cold rolling a reduction of about 78% was effected. The cold rolled strip was annealed in a continuous furnace at a speed of about 25 ft. per minute and at a temperature of about 1700° F. and under reducing conditions. The annealed strip was then cold rolled to about 0.023" and a reduction of about 40% was effected. After the cold rolling, the strip was again annealed in a continuous furnace at a speed of about 25 ft. per minute and at a temperature of about 1560° F. and under reducing conditions. This treatment resulted in a soft, ductile sheet with a seleroscope hardness of about 15 and the deep drawing characteristics of mild steel.

The finished sheet had the character of a unitary sheet and possessed properties of both the nickel and the steel. A microscopic examination showed that an interfacial alloy had been formed of such character and such extent as to penetrate deeply into the nickel and the steel and to unite the nickel and steel tenaciously together. It was found that an intermediate or interfacial alloy having a thickness of about 0.00005" to about 0.002" was formed by the present process in finished products having a thickness of about 0.025" to about 0.062". Composite sheets having these intermediate alloys have given satisfactory results in commercial and industrial use.

It is believed that the success of the present process is due to the formation of a durable, permanent, intermediate, non-separable alloy at the interface of the nickel and steel slabs. This intermediate non-separable alloy is of such a unique character and is present to such an extent in depth that the union or bond between the nickel and the steel is sufficient to resist all stresses to which the composite product will be subjected to in commercial and industrial use. This new intermediate, non-separable alloy is present throughout substantially the entire interface so that no pockets, blisters, seams, etc. are present in the finished product. It has been found that the intermediate or bonded alloy is distinctly different from each of the original metals and is different from prior art bonds in the following respects:

1. Hardness.
2. Chemical analysis.
3. Resistance to attack by acids and alkalis.
4. Microstructure.
5. Atomic structure as shown by X-ray diffraction patterns.

It is to be noted that calculations from the X-ray diffraction pattern shown that the edge of the unit cubes of the three constituents (nickel, iron and intermediate alloy) to be about as follows:—

	Angstrom units
Iron	2.85
Nickel	3.50
Intermediate alloy (3% iron)	3.48

It has been found that the composition of the intermediate alloy will vary according to the temperatures and thermal treatment employed, to the character of the original metallic slabs or sheets, to the type and extent of working, etc. In carrying out the present process industrially, the composition of the intermediate alloy has had an iron content varying from about 3.0% to about 4.70%.

It is possible and practical to subject the composite nickel product to many operations. For instance, the composite nickel-steel product may be heated, hot or cold worked, or subjected to other operations without the rupture of the original metals or of the intermediate alloy.

It is to be noted that the new composite nickel-steel product is unique in that it is non-separable, malleable and integral. In passing, it may be mentioned that the composite nickel-steel product may be rolled or drawn to relatively thin sections as the interfacial alloy is present throughout the entire bonding surface and the composite product will not "peel" or "blister" as is very often the case with prior art products which were not thoroughly united over their entire surface.

It is to be observed that a stamped, rolled, drawn, or otherwise fabricated composite nickel-steel product, may be made which will have properties which are a combination of the properties of the original metals. For instance, a sheet or strip of nickel coated steel will combine the corrosion resisting and tough properties of nickel with the resiliency of steel.

It is to be noted that not only can composite nickel-steel sheets or slabs be made, but other composite nickel-steel products can be made in accordance with my invention. Thus, the following products can be made:

1. A nickel coated steel rod.
2. A nickel lined steel pipe.
3. A nickel clad steel pipe.
4. A nickel clad steel angle.
5. A nickel clad steel rectangle and other commercial mill shapes.

It is to be further noted that the present invention has the following advantages over prior art processes and products:

1. Less expensive, due to the application of the nickel over large steel sections, thereby decreasing labor and handling costs.

2. Ability to cast large sections which can be converted into a wide variety of intermediate billet or slab sizes for many different finished sizes and shapes, thus giving flexibility of manufacture.

Although the present invention has been described in connection with one embodiment thereof, it is to be understood that the invention is not limited thereto. As a matter of fact, molten steel may be poured inside of a nickel or "Monel" metal shell and the process carried out as described hereinabove. In some cases, molten steel may be poured against a slab or sheet of nickel or Monel metal or may be poured between slabs of nickel or Monel metal. In other words, the present method is capable of wide applicability and is adapted for the production of a wide variety of composite products. Similarly, the base metal can be a metal other than steel or a ferrous metal and the coating metal can be a nickel alloy such as a nickel-copper alloy, a nickel-chromium alloy, a nickel-iron alloy or the like instead of nickel.

What is claimed is:

1. The process of producing a composite nickel-ferrous coated metallic product of unitary character which comprises preparing a solid ferrous body having clean surfaces in a mold, pouring molten nickel in said mold and in contact with the clean surfaces of said ferrous body at an accentuated pouring temperature of at least 2800° F. to produce a nickel-ferrous ingot, heat-

ing the said ingot to at least 2100° F. in a reducing atmosphere, subjecting the heated ingot to work, controlling the initial work to give a reduction in the cross-section of the ingot of at least about 10% to about 25%, maintaining the ingot at a temperature above 1800° F. during the work, hot rolling the worked ingot at a temperature of about 2150° F. to produce a strip, passing the hot rolled strip at a rate of about 15 ft. per minute through an oven having an effective temperature of at least about 1700° F., pickling the thus treated rolled strip, grinding both sides of said strip with emery to produce a smooth surface, cold rolling the strip to effect about a 78% reduction in cross sectional area, annealing the strip by passing the same at a rate of about 25 ft. per minute through an oven having a temperature of about 1700° F., cold rolling the annealed strip to effect a further 40% reduction in cross sectional area and annealing the cold rolled strip by passing the same at a rate of about 25 ft. per minute through an oven having a temperature of about 1560° F. to produce a nickel-ferrous composite strip of unitary character having ferrous and nickel characteristics.

2. The process of producing a composite steel product coated with nickel, or nickel-alloy which comprises mounting a solid steel billet having clean surfaces in a mold, casting deoxidized nickel at a temperature of about 2900° F. to about 2950° F. around said steel billet to form a bimetallic slab, heating the said cast bimetallic slab in a controlled reducing atmosphere containing about 0.5% to about 3.5% of mixed carbon monoxide and hydrogen, controlling the temperature of said heat to about 2150° F. to about 2350° F., hot working the thus heated bimetallic slab between about 2350° F. and about 1800° F., controlling the initial reduction in cross-section of the slab to at least about 10% to about 25%, annealing the worked slab at a temperature of about 1300° F. to about 1700° F., and cold rolling the annealed slab.

3. The process of producing a composite nickel-ferrous coated body of unitary character which comprises casting molten nickel having a temperature of at least 2800° F. about a ferrous body, heating the nickel coated ferrous body in a reducing atmosphere having a temperature of at least 2100° F., controlling the initial hot working of said heated body to effect a reduction of at least 10 to 25% of the cross sectional area thereof, and subjecting said worked body to further working to reduce it to its final form.

4. The process of producing a composite nickel-ferrous coated body of unitary character set forth in claim 3 in which the molten metal is cast in a deoxidized condition and having a temperature of about 2900° F. to about 2950° F. and in which the nickel coated ferrous body is heated in a reducing atmosphere having a temperature of about 2150° F. to about 2350° F.

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