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PROCESS OF MANUFACTURING COMPOSITE
METALS CONTAINING NICKEL

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The present invention relates to nickel or nickel alloy coated metallic products and more particularly to nickel coated ferrous products of unitary character.

Heretofore, it has been proposed to make nickel or nickel alloy coated products by the use of various procedures. In carrying these procedures out on an industrial scale, various difficulties were encountered which tended to cause defects in the final product and which rendered the continuous production of nickel coated products uncertain. Some of the more important defects which were encountered were the formation of (1) blisters, (2) seams, (3) incomplete bonding throughout the interfaces, (4) slivers, (5) poor ductility in finished product, etc. Various proposals have been made to overcome the defects and to provide a process which can be conducted by relatively unskilled labor at any industrial plant to give consistently good results. As far as it is known, these attempts have not been wholly satisfactory or completely acceptable for use on an industrial scale for one reason or other.

I have discovered a process whereby a nickel coated product can be made continuously and consistently on an industrial scale. According to the discovery, a process is contemplated which involves a combination of steps properly coordinated to each other to produce a special interfacial metallurgical alloy between the nickel or nickel alloy and the base metal of such character and to such an extent that the nickel or nickel alloy and base metal are bonded together thoroughly and continuously throughout the interfaces.

It is an object of the invention to provide a process which is relatively simple, economical and practical, and which can be carried out on an industrial scale by relatively unskilled labor.

A further object of the invention is to provide a process which will produce continuously and consistently nickel coated products with practically no defects or seconds.

Another object of the invention is to provide an easily and readily controllable process which will yield a nickel coated metallic product which is provided with an interfacial alloy of such character and extent as to be capable of resisting severe stresses, shocks, etc. to which it will be subjected in commercial handling, fabricating and other operations.

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

In the foregoing description, an illustrative and preferred procedure will be described in connection with the production of nickel or nickel alloy coated steel. It is to be noted that unless otherwise specified, the two metals are nickel and steel and the product is nickel coated steel.

Sheets or slabs of nickel and steel are first cut to the desired size. Of course, the size will vary according to the desired percentage of nickel on the finished nickel or nickel alloy clad product. Practically any combination may be made by varying original thicknesses of nickel and steel. In the production of a 10 percent nickel coated sheet, for example, a slab of nickel is used which is 8 inches wide, 60 inches long and $\frac{1}{2}$ inch thick, and a slab of steel is used 60 inches long and 6 inches wide and $4\frac{1}{2}$ inches thick. In the present instance, the extra width of the nickel slab permits the sides to be lapped over the sides of the steel billet or slab. These slabs have their surfaces cleaned by an appropriate procedure such as machining, or sand blasting, or pickling, or washing with sodium triphosphate or carbon tetrachloride. In this operation, it is essential to remove grease, dirt, oxide, etc. from the surfaces which are to be united together.

After the surfaces have been prepared and cleaned, the nickel slab is pressed on top of the steel slab. For the purpose of facilitating the handling of the composite nickel-steel slabs, they are secured together mechanically to form a composite nickel-steel slab. For instance, a temporary seal may be provided around the adjacent peripheral edges of the two slabs to unite them mechanically to form a composite slab. The temporary seal may involve crimping the nickel slab over the steel slab as described hereinabove or the temporary seal may involve welding the two metals to each other at their edges. In making a temporary seal by welding, it is important not to follow prior procedures which have been proposed in the prior art which contemplate making a complete seal or weld about the edges inasmuch as the welding is not an essential part of the process but is only a means of assisting to maintain contact between the two metals during heating and prior to hot-working. I have found that it is essential to have the seal or weld discontinuous or interrupted at points. Usually, it is preferred to have several interruptions on each edge of the welded slabs. Of course, if only small slabs are being handled, it is sufficient to have but one interruption on each edge. When the process is operated in accordance with this procedure, I

have found that the defects and number of seconds are greatly reduced.

The nickel and steel slabs, which will be known as the composite slab, are placed in a furnace which is capable of careful control of the temperature. The atmosphere in this furnace is carefully controlled and maintained in a reducing condition, preferably with about $\frac{1}{2}$ -3 per cent carbon monoxide or hydrogen or mixtures containing both. It has been found that a temperature greater than 1800° F. is essential for the production of a satisfactory product. It is preferred to employ a temperature of about 2100° F. to about 2250° F. for a sufficient period of time to insure a uniform temperature throughout the furnace and throughout the composite slab. The time of heating, of course, will vary according to the size and cross-section of the composite slab under treatment. For example, a composite slab having a cross-section of about 5" x 9" in cross-section requires approximately one hour while a composite slab having a cross-section of about 18" x 18" will require approximately five hours at the aforesaid temperatures. It is very important that a sufficient period of time be employed with a controlled temperature and atmosphere in order to insure the following conditions:

1. The avoidance of unequal heating.
2. A uniform temperature distribution through both metals.
3. The prevention of oxidation of either metal.
4. The heating of the composite slab to such a temperature that bonding will occur between the contacting surfaces upon subsequent working.

It has been found as the result of extensive experiments that the reducing atmosphere in the furnace should be controlled to preferably contain at least about 0.5 to about 3.5 per cent of carbon monoxide or hydrogen gas or a mixture containing both. It has been found that in the heating of the composite slab, small amounts of oxide are formed during the early stages of the heating process and it is essential to reduce these oxides by employing an atmosphere of reducing gas having sufficient strength to effectively eliminate the oxides from the surfaces of the composite slab, particularly at the interface of the nickel and steel.

When the composite nickel-steel slab has been heated in accordance with the aforesaid operations, it is withdrawn from the furnace and then hot worked by some mechanical means. In carrying out this hot working, it has been found that it should be conducted as rapidly as possible. The hot working includes forging, pressing, swedging and rolling. It has been discovered, as a result of comprehensive investigations, that it is essential in performing the hot working to effect a reduction in area of the composite slab of about 5 to about 30 per cent per blow or per pass. For best results, a reduction in area per blow or per pass is about 20 per cent with the temperature about 2100° F. For the production of a composite nickel-steel product which is substantially free from defects, it is necessary to utilize the foregoing reduction in area of the composite slab. By repeating the number of passes through the roll, I have been able to produce nickel-steel sheets having a thickness of about 0.200" and thinner such as 0.010" with repeated heatings and rollings.

It has been found that the initial pass through the roll or initial impact with the hammer or the like is of extreme importance and it is essential

that the initial or first pass or the like must be of sufficient intensity as to cause the permanent union of the slabs and to assist in completing the formation of the intermediate alloy. The intensity of the pass or the like will vary with the size of the composite slab but, generally speaking, a pass or the like to effect about a 10% to about 25% reduction in area of the piece has been found to be satisfactory.

Composite nickel-sheets of this character have been heretofore unknown as a regular and uniform commercial product which has been produced on an industrial scale. 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 show 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 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 durable, ductile, 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 and the composite product will not "peel" or "blister" as is very often the case with prior art products.

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 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) Smaller production of seconds and defective articles; (2) more efficient, economical and practical industrial production; (3) greater ease of duplicating commercial products continuously and consistently; and (4) production of article of unitary character better able to withstand stressing involved in handling, fabricating and other industrial and commercial operations.

It is also to be observed that the present invention provides a process of producing a composite nickel-coated metallic product of unitary character which comprises cleaning the surfaces of a nickel body and of a ferrous body, securing the nickel body to the ferrous body with the cleaned surfaces together to form a composite body, heating the said composite body to at least 2100° F. in a reducing atmosphere, subjecting the heated composite body to work, controlling the initial work to give a reduction in the cross section of the composite body of at least about 10% to about 25% and thereafter subjecting said worked composite body to rolling to reduce the same to a nickel-metallic strip of unitary character having nickel and metallic characteristics, maintaining the composite body at a temperature about 1800° F. during the work, hot rolling the worked composite body at a temperature of about 1800° F. to about 2350° 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 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 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-metallic composite strip of unitary character having metallic and nickel characteristics.

Although the present invention has been described in connection with one employment thereof, it is to be understood that the invention is not limited thereto. For instance, other composite products than flat sheets can be made, such as shells or tubes in which the outside or the inside is nickel or "Monel" metal or some other nickel alloy. In the same way, the base metal can be a metal other than steel or ferrous metal. It will be understood that other variations and modifications well known to those skilled in the art is to be considered within the purview of the present invention.

What is claimed is:

1. The process of producing a composite nickel-ferrous coated metallic product of unitary character which comprises cleaning the surfaces of a nickel body and of a ferrous body, securing the nickel body to the ferrous body with the cleaned surfaces together to form a composite body, heating the said composite body to at least 2100° F. in a reducing atmosphere, subjecting the heated composite body to work, controlling the initial work to give a reduction in the cross-section of the composite body of at least about 10% to about 25%, maintaining the composite body at a temperature above 1800° F. during the work, hot rolling the worked composite body at a temperature of about 1800° F. to about 2350° 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. In the manufacture of a nickel or a nickel alloy coated metallic product that improvement which comprises heating a nickel body and a metallic body secured together to a temperature of at least 2100° F. in a reducing atmosphere, controlling the initial work on said heated body to give a reduction in cross section of the body of at least about 10% to about 25% and continuing the working of said body at a temperature above about 1800° F. whereby a composite nickel-metallic product is produced having a nickel alloy bonding the nickel body continuously and uniformly throughout the area of contact with the metallic body, said alloy being ductile, being free from pockets, blisters and seams, and having a different hardness, chemical composition, resistance to corrosion, microstructure, and X-ray atomic structure as shown by a diffraction pattern from the nickel body and the metallic body.

3. In the manufacture of a nickel or a nickel alloy coated ferrous product that improvement which comprises heating a nickel body and a ferrous body secured together to a temperature of at least 2100° F. in a reducing atmosphere, controlling the initial work on said heated body to give a reduction in cross section of the body of at least about 10% to about 25% and continuing the working of said body at a temperature above about 1800° F. whereby a composite nickel-ferrous product is produced having a nickel-iron alloy containing about 2 to about 7% of iron and bonding the nickel body continuously and uniformly throughout the area of contact with the ferrous body, said alloy being ductile, being free from pockets, blisters and seams, and having a face-centered cubic structure with a unit edge of 3.48 Angstrom units.

4. The process set forth in claim 1 in which the heating of the composite body is conducted at a temperature of about 2150° F. to about

2350° F. in a reducing atmosphere containing about 0.5 to about 3.5% of a mixture of carbon monoxide and hydrogen.

5. The process of producing a composite nickel-ferrous coated metallic product of unitary character set forth in claim 1 in which the pickling of the rolled strip is effected with a solution containing sulphuric acid and nitric acid.

6. The process of producing a composite nickel

ferrous coated metallic product of unitary character set forth in claim 1 in which the reducing atmosphere contains hydrogen.

7. The process of producing a composite nickel-ferrous coated metallic product of unitary character set forth in claim 1 in which the initial reduction in cross section of the composite body is at least 20%.

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