July 13, 1965 S. STORCHHEIM 3,194,658

FABRICATION OF CORROSION RESISTANT IRON STRIP

Filed March 5, 1963 3 Sheets-Sheet 1

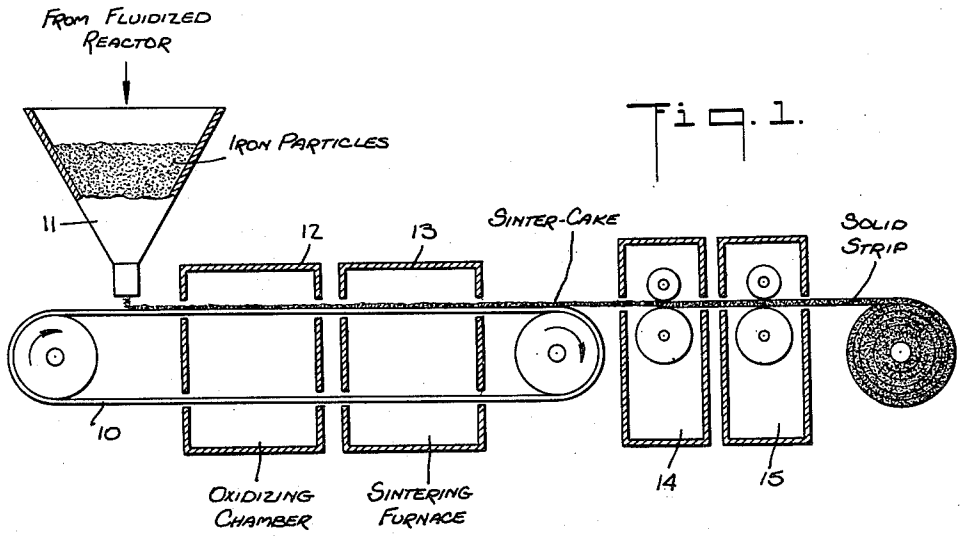


Fig. 1.

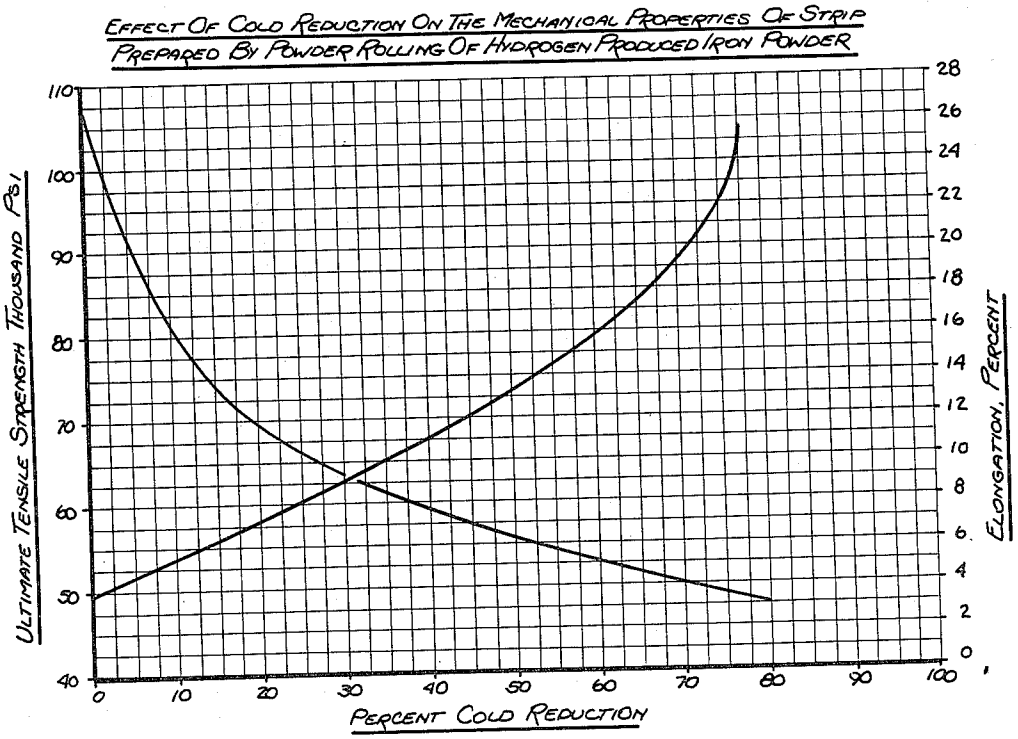


Fig. 2.

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FABRICATION OF CORROSION RESISTANT IRON STRIP

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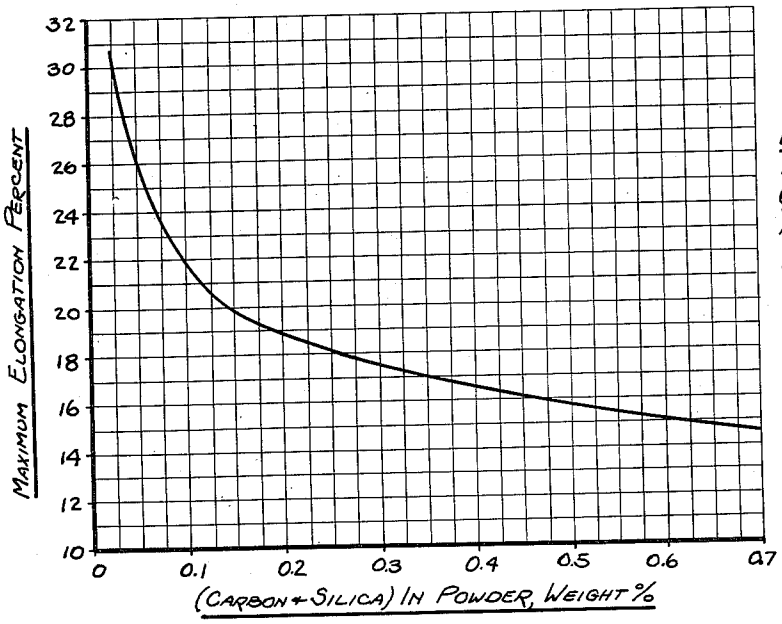


Fig. 3. EFFECT OF CARBON AND SILICA CONTENT ON MAXIMUM ELONGATION OBTAINABLE IN POWDER FABRICATED IRON STRIP

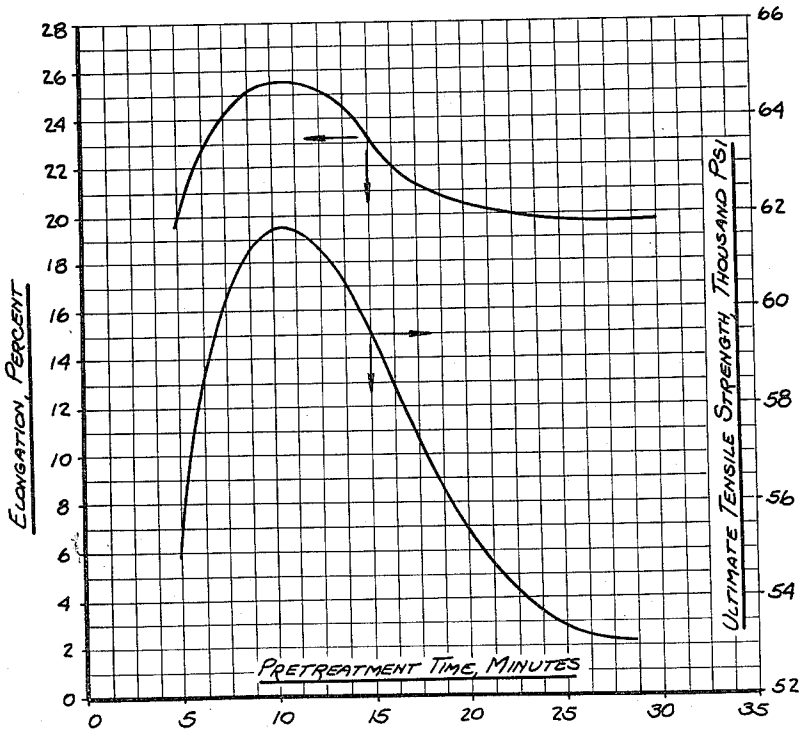


Fig. 4. MECHANICAL PROPERTIES OF POWDER FABRICATED IRON AS A FUNCTION OF PRETREATMENT CONDITIONS

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FABRICATION OF CORROSION RESISTANT IRON STRIP

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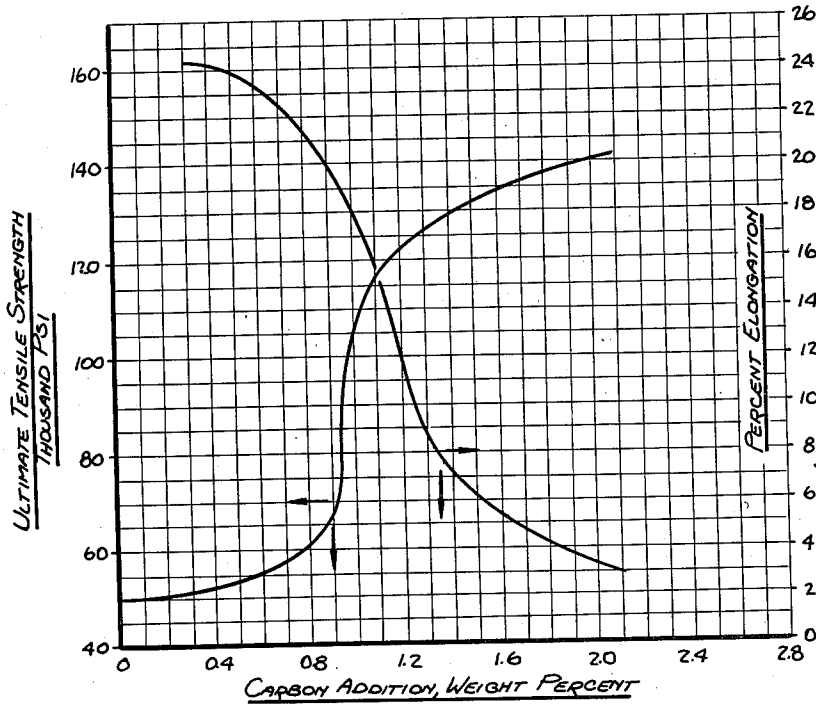


Fig. 5.

EFFECT OF CARBON ADDITION ON MECHANICAL PROPERTIES OF POWDER FABRICATED IRON STRIP

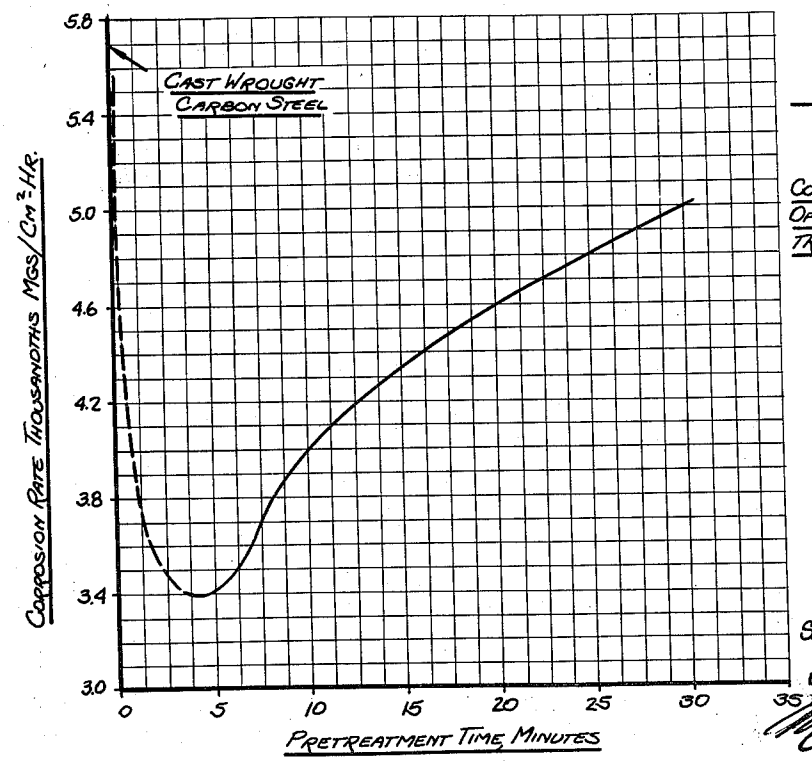


Fig. 6.

CORROSION RESISTANCE OF STRIP VS. PRETREATMENT TIME

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FABRICATION OF CORROSION RESISTANT IRON STRIP

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3 Claims. (Cl. 75—206)

This application is a continuation-in-part of my two copending applications Serial No. 49,982, filed August 16, 1960, now abandoned, and Serial No. 60,374, filed October 4, 1960, now U.S. Patent No. 3,163,527.

This invention relates generally to a process for converting metallic particulates into metal shapes, such as strip, rod and consolidated sheets, and more particularly to a process for continuously converting iron particulates into metal shapes having a high order of corrosion resistance and improved mechanical properties.

In my above-identified copending application Serial No. 49,982, there is disclosed a technique for converting an ore into a spongy product or sinter-cake, as distinguished from discrete metallic particles, and hot-rolling the spongy product to consolidate it into a fully densified shape.

The source of the sponge or sinter-cake may be (a) a chemical reduction process involving the reduction of ore with a reducing gas such as hydrogen or carbon monoxide, as in the production of sponge iron from iron ore, (b) a chemical reducing process involving the reduction of a metal halide with a more active metal, as in the production of sponge titanium, or (c) an electrolytic reducing process involving the reduction of an ore with electric current, as in the production of copper or nickel. In the processing of a reduced ore from a chemical reduction process, as typified by the production of an iron in a fluidized bed, or the production of titanium from its halide, the reduced ore is first sintered to form a strong, dense, easily handled, sinter-cake which is then hot-rolled into strip in a rolling mill.

The primary object of this invention is to provide an improved process for hot-rolling sinter-cake formed of iron-based particles.

I have discovered that the above-described process can, in the case of iron, be significantly improved so that the iron shape yielded thereby has superior properties, both from the mechanical standpoint and from the standpoint of corrosion-resistance.

More specifically, it is an object of the invention to provide a process for converting iron-based particles taken directly from an ore reduction system and to pass these particles through a sintering furnace to produce sinter-cake which is then hot-rolled, the particles before or after sintering but in advance of hot working being oxidized to impart corrosion resistant properties to the ultimate product.

For a better understanding of my invention, as well as other objects and further features thereof, reference is made to the following detailed description to be read in conjunction with the accompanying drawing, wherein:

FIG. 1 shows schematically a process in accordance with the invention; and

FIGS. 2, 3, 4, 5 and 6 are graphs explanatory of the process.

Referring now to the drawing, there is shown a continuous system for converting iron particulates into a consolidated shape, the system comprising an endless conveyor belt **10** which carries iron particulates deposited thereon through a hopper **11** at the input end thereof successively through a steam treatment chamber **12** and a sintering furnace **13**, the particles being converted continuously into sinter-cake which then passes through first

and second hot-rolling mills **14** and **15**, which consolidate the sinter-cake into solid strip which is then coiled about coiler **16**.

The iron particulates may be in any form, from fine powders, granules, shot or relatively large chunks. The iron particles used as a raw material in the process may be obtained from any number of known sources, although the preferred source is a fluidized bed reduction unit, as disclosed in the above-noted copending application. Such a unit operating on high-grade ore is capable of delivering iron particulates which can be converted into sinter-cake and then into high-grade strip. In the fluidized bed reduction unit, heated hydrogen, carbon monoxide or other reducing gas is passed through a finely divided bed of iron ore, such that each particle in the bed is surrounded by the reducing medium. By proper velocity control of the fluidizing gas, the bed or iron ore particles can be expanded and supported by the gas stream so that favorable conditions are created to promote the desired reaction. Furthermore, because of the turbulence and mixing which occurs in the bed, the temperature is very uniform and the reaction temperature can be closely controlled.

The heated iron particles discharged from the ore reduction unit or derived from some other source, are fed in loose form through the steam reaction chamber, where the particles are superficially oxidized by live steam before being fed through the sintering furnace, where the particles are interbonded to form a sponge-like or sinter-cake product. In the case of carbonyl iron powder or iron powder, the sintering temperature is in the order of 800° to 1300° C., the period of sintering depending on the mesh fraction distribution of the particles and the surface activity of the particles.

From the sintering furnace the sinter-cake emerges in a continuous self-supporting web which is then conveyed successively through the rolling mills **14** and **15** which is at a temperature sufficiently high to hot-work the sinter-cake. By "hot-working" as used herein, is meant the plastic deformation of metal at such temperature and rate that strain hardening does occur, the lower limit of temperature being the recrystallization temperature.

I have found that by oxidizing the iron particles either before sintering to form sinter-cake or after the cake is formed that under proper conditions of oxidation, the particles or agglomerates of the metal have a thin oxide coating thereon which is not sufficiently thick to prevent later consolidation in the rolling mills wherein the coatings are ruptured at the grain boundaries. Upon metallographic examination after rolling, it has been found that the oxidation treatment produces a cellular network of iron oxide within the matrix which limits progressive corrosion and improves mechanical properties.

The application of steam as shown in the drawing is in advance of sintering, but it is also possible to carry out the invention by post-sintering oxidation applied to the sinter-cake mass before it enters the hot rolls in the final stages of the process.

The process in accordance with the invention appears to be competitive with conventional casting and rolling operations currently being used for the fabrication of steel strip and has, in addition, the capability of yielding a product with superior mechanical properties, superior corrosion-resistance properties or both, as shown by the data of Table I. With such superior mechanical properties it is now possible to use a lower grade and cheaper iron powder to achieve the desired end result of producing mill products. Heretofore, one of the greatest deterrents to economical conversion of iron powders, reduced from the ore (no liquid stage refinement) has been the inability to make acceptable mill products from relatively impure powders so produced.

TABLE I

Mechanical properties and corrosion resistance of powder fabricated and cast-wrought products

Material	Ultimate Tensile Strength, p.s.i.	Elongation, percent	Corrosion Rate in Tap Water at 60° F., mgs./cm.²/hour
Low-carbon cast wrought steel	55,000	23	0.0057
Strip prepared from powders treated in steam for 5 minutes	55,000	20	0.0034
Same as above, but pre-treated for 10 minutes	62,000	26	0.0041

The oxidizing treatment promotes corrosion resistance throughout the finished mill products, rendering them less subject to corrosion damage. As a result, strip prepared from such material is, as a whole, more corrosion-resistant than cast-wrought material of the same composition. Thus, one is able to utilize such strip in corrosive environments which might otherwise require the use of more costly iron alloys containing chromium and nickel.

The results obtained from the steam treatment are based on the reaction between water vapor at about 400° F. and iron to produce a magnetic oxide which forms a protective skin which is impervious to vapor. The chemical equation of this reaction is as follows:

$$3Fe+4H_2O \gtrless Fe_3O_4+4H_2$$

Excellent mechanical properties can be obtained by the instant process, provided that the starting materials used are not severely contaminated. I have obtained as-rolled strengths of 50,000 p.s.i. with elongations of 26%. As shown in FIG. 2, cold-working can further increase strength to over 100,000 p.s.i. with a corresponding elongation of 3%. Although high-strength strip can be produced from the lower grades of iron powder, the elongation of such material is not as high as above, although perhaps adequate in certain applications. The constituents which appear to be most detrimental in their effect on strip ductility are carbon and silica, the relationship being as shown in FIG. 3.

It has been found that significant improvement in the mechanical properties of powder-fabricated iron strip can be achieved by suitable pretreatment of the feed powders prior to processing. This effect is illustrated by the data of FIG. 4, which indicate that a marked improvement in strength, from 55,000 to 61,000 and in elongation from 20% to 25%, are obtained by a 10-minute pretreatment of the powder. Improved strength can also be obtained by adding carbon or other suitable alloying agents to the iron powders before processing. The effect of carbon additions is illustrated by the data of FIG. 5, ultimate tensile strength increasing from 50,000 to 140,000 p.s.i. and elongation decreasing from 25% to 3% by the addition of 2.1 weight percent carbon to the powdered starting materials.

It has been found feasible to impart, as of now, up to a 40% improvement in corrosion resistance of powder-fabricated iron strip by the pretreatment technique mentioned. FIG. 6 shows the effect of pretreatment times on the corrosion of powder strip produced by the invention. It will be noted that the corrosion rate obtained after a 5-minute pretreatment time is 0.0034 mgs./cm.²-hour, in water at 60° F., or only 0.6 times that exhibited by conventional cast-wrought material exposed to tap water under the same conditions.

While there has been disclosed a preferred process for the fabrication of corrosion-resistant iron strip in accordance with the invention, it will be appreciated that many changes and modifications may be made therein without, however, departing from the essential spirit of the invention as defined in the annexed claims.

I claim:

1. The method of forming solid, iron-based strip comprising passing iron-based particles through a heating zone to effect agglomeration of the particles to form hot sinter-cake, conveying said sinter-cake through a hot rolling zone to densify said cake into a solid shape and treating said iron-based particles before they enter the hot-rolling zone with steam at a temperature and for a period sufficient to form a vapor-impervious magnetic oxide skin thereon which is ruptured in hot rolling at the grain boundaries whereby in the resultant strip there is a cellular protective network of said oxide.

2. The method as set forth in claim 1, wherein said particles are steam-treated before entering the heating zone.

3. The method as set forth in claim 1, wherein said particles are steam-treated after leaving the heating zone.

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