

Feb. 5, 1963

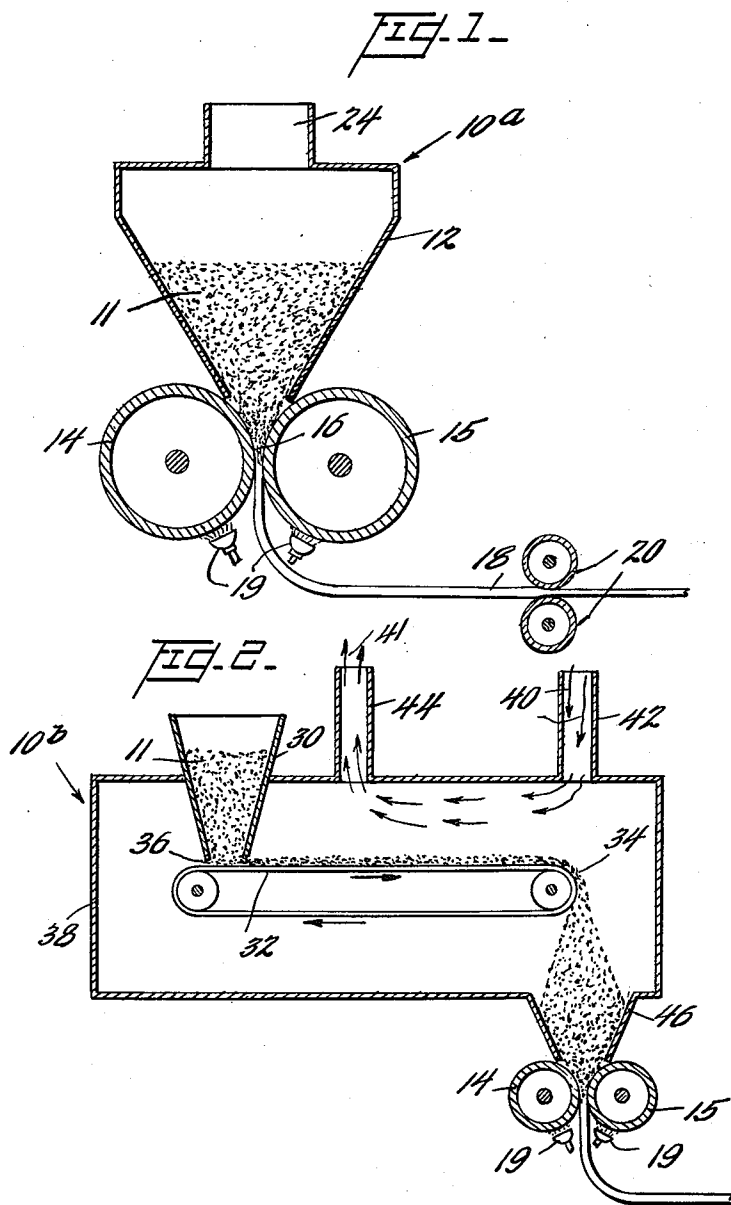
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3,076,706

METHOD OF FORMING WROUGHT ALUMINOUS METAL

Filed Oct. 21, 1958

3 Sheets-Sheet 1



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Fig. 3.



Fig. 4.

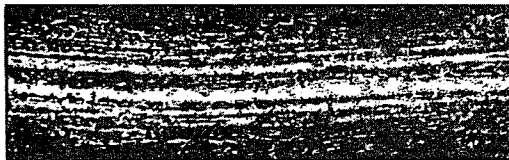


Fig. 5.



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Fig. 6.

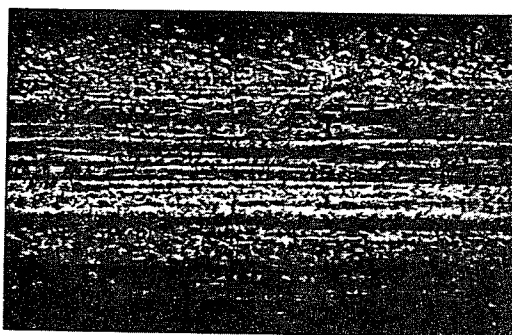


Fig. 7.



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3,076,706

METHOD OF FORMING WROUGHT
ALUMINOUS METALT. Stevens Daugherty, Chesterfield County, Va., assignor
to Reynolds Metals Company, Richmond, Va., a cor-
poration of DelawareFiled Oct. 21, 1958, Ser. No. 768,686
12 Claims. (Cl. 75—211)

This invention relates to a novel system for producing continuous lengths of solid aluminous metal from cast particles of such metal, by a single rolling operation without subsequent sintering. The solid metal so produced is suitable for subsequent rolling and heat treating operations, such as those conventionally used for rolling down and annealing aluminum strip when making plate, sheet or foil.

The invention contemplates the use of cast particles of aluminous metal (i.e., aluminum and alloys containing at least 51% of aluminum). A minor proportion of the particles may consist of other metals, but in any event the total weight of the aluminum in the particles used for the purposes of the invention is at least 51% of the total weight of the particles as a whole.

One of the principal advantages of the practice of the invention is that no special non-oxidizing or reducing atmosphere is necessary at any stage, either during the production or preparation of the cast particles, or during the subsequent production of strip from the particles. Moreover, no pre-rolling compacting, such as by extrusion is required. This is a surprising accomplishment, because a tough oxide skin forms instantaneously on aluminous particles whenever they are exposed to air, and special steps to eliminate or break down this skin have generally been regarded as essential to successful compacting of aluminous particles.

Non-aluminum powders do not present as difficult a problem as aluminum powders in connection with rolling the powders to consolidate them down to strip, because non-aluminous metals can generally be pressed together into a solid body by simple application of pressure, aided, if necessary, by sintering, which is the heating of metal particles to a temperature close to their melting point, with the result that they coalesce where they are in contact. The oxide film which forms around aluminum particles is a special obstacle to such operations, because the oxide film, although thin, is strong and of very high melting point, so that it interferes with the bonding of the unoxidized aluminum in adjacent particles, and is so resistant to reduction that sintering presents a difficult problem. While it is known that aluminum powders can be passed through rolls to form a "green compact," the problems of consolidating the green compact by sintering or otherwise are severe. While it has been accomplished in some cases by special and expensive techniques, and while porous bearings and the like have been made from aluminum powders on a steel backing strip, no process suitable for commercial production of solid aluminous strip from powder has heretofore been devised. The present invention accomplishes this purpose, and permits strip to be produced in a remarkably economical manner.

An essential element of the process of the invention is preheating of the cast particles before they are passed through the set of rolls which consolidate them into solid strip. If preheating is omitted, it is still possible to consolidate the particles into an apparently solid strip in one roll pass, but such strip, or any rolled down product of such strip, will blister when it is subsequently heat treated, as in the course of conventional annealing. Since some degree of annealing or other subsequent heat

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treatment is usually necessary, and since latent blisters are objectionable as sources of weakness, it is necessary to avoid consolidating the cast particles while they are cold, in the successful practice of the invention. In general, the upper limit of preheating must be below the temperature at which the metal begins to melt (incipient melting temperature), but above the temperature required to avoid blisters, which in practice means between about 450° F. and about 1200° F. The preferred preheating temperature is near the upper end of the range, both to avoid blisters and to save power, and in general is in the range of about 750° F. to about 1000° F., depending upon the particular alloy being rolled.

Preheating has its most favorable effects near the upper end of the preheating temperature range, but a counter-vailing consideration is the tendency of the hot particles to stick together, at elevated temperatures. The invention requires that the particles be free flowing as well as preheated as they enter the rolls, in order to prevent the occurrence of voids in the strip as a result of uneven feeding of the particles into the roll nip. Consequently, sticking must be prevented. This can be accomplished by limiting the preheating temperature, and also by using larger sized particles, which have less surface areas in contact with each other than smaller particles of like shape. One of the reasons why conventional atomized particles (cast in air by aspiration of molten aluminum into a jet of compressed air or steam) are difficult to preheat successfully is that these particles are very fine (all less than 200 mesh) and have a definite tendency to stick together in the usable range of preheating temperatures.

Preheating of the cast aluminous particles also makes possible higher rolling speeds, corresponding to strip speeds at the exit side of the initial roll stand of 50 feet per minute and higher. Such speeds are much faster than those possible where cast particles are rolled cold, or where conventional 99% aluminum atomized cast particles (all of less than 200 mesh size) are rolled at any temperature, from cold to fully preheated.

However, when the rolls are operated at high speeds, a problem of sticking arises, which necessitates cooling of the rolls. Such cooling may be obtained by the action of a pair of water sprays located on the side where the strip emerges and directed toward the periphery of the rolls in such manner that the impinging water is heated and vaporized by the heat of the rolls during their rotation. Only an amount of water is sprayed which will all avaporate from the rolls before they come back into contact with the incoming particles, because excess water or water adhering to the rolls might impair the quality of the rolled strip and possibly present an explosion hazard if allowed to roll into contact with the heated particles. Alternatively, the rolls may be cooled internally, such as by internal circulation of water or other cooling medium.

After the preheated cast particles have been consolidated in a single pass through the rolls into a solid metal strip, the useful characteristics of the strip are preferably improved by at least one subsequent reduction pass, in the course of which the particles are further worked and the broken oxide film around the original particles is further distributed in the strip. These broken particles of oxide film can be further distributed by further rolling operation. These particles of aluminum oxide are not detrimental to the strip, but, on the contrary, improve its strength, because they interrupt the planes of weakness which might otherwise extend through the strip. Consequently, the strip produced in accordance with the invention can have properties better than like strip produced from like aluminous metal by conventional ingot

casting and rolling practices. However, when the strip has been rolled down substantially, the oxide is ordinarily so well distributed that its effect on the strength is negligible.

The strip produced in accordance with the invention has the unexpected and valuable property that its surfaces are particularly suitable for anodization. Anodized strip produced in accordance with the invention, including the rolled down strip, is relatively free of grain delineations and elongations apparent on the surface of the strip, and consequently possesses superior surface luster and uniformity of appearance, when particles of like alloy are used.

The pressure on the metal particles at the nip of the rolls should be at least several thousand pounds per square inch, sufficient to fully consolidate the particles into a solid metal strip. The exact amount of pressure is determined by the rolling conditions, as a practical matter, because the rolls are set with a limited initial clearance, and develop rolling pressure as they are forced apart by the metal in the nip, against the restraining force of the mill frame. The characteristics of the particular aluminous metal being rolled are one of the factors influencing the amount of pressure required and developed in the roll stand.

The cast particles suitable for use in practicing the invention are of a size which is at least large enough to be retained on a 200 mesh U.S. Standard Sieve, because smaller aluminum particles are known to present an explosion hazard, and this would be an obstacle in the handling and rolling of such smaller particles in an air atmosphere. Moreover, the problem of sticking after preheating requires at least this minimum particle size, and makes it desirable to use larger particles, preferably at least large enough to be retained on 40 mesh. There is no specific upper limit on the size of cast particles which can be used in practicing the invention, except that for a mill having work rolls of a given diameter, there is an inherent upper limit on the size of the particles that can be fed into the rolls and compacted successfully in accordance with the invention. The particles should also be of a free flowing shape, and not stick together when preheated, so that they can be fed continuously into the nip of the rolls.

Aluminous particles can be cast by various techniques to provide the requisite size and shape for rolling in accordance with the invention. For example, molten aluminous metal can be poured over a plate having holes through which the metal passes and falls off in button-shaped drops, preferably into a pan of water. The solidified drops ordinarily have a diameter in the order of about $\frac{3}{8}$ inch. A modified atomizing technique could be used to cast sufficiently large particles, but this is not preferred, because of the accompanying fines that have to be screened out. Instead, the preferred method of making the desired aluminous particles is to cast them centrifugally, which is economical and permits good control of particle shape, size and distribution by selection of the size of the openings through which the metal is cast, and more importantly, by varying the rotational speed which produces the centrifugal force.

The larger centrifugally cast particles tend to be spheroidal, and the smaller centrifugally cast particles are acicular (needle-like) in shape. The spheroidal particles are free flowing and roll satisfactorily, even in relatively small rolls (e.g., 5 inch diameter). The acicular particles are also found to be free flowing, and their shape apparently aids in passing the particles into the nip of the work rolls, and in consolidating them in the nip in the most uniform and rapid manner. Those acicular particles having an apparent density between about 0.75 and 1.02 grams per cubic centimeter, and of which at least about 80% have a particle size in the range between about 40 and 60 mesh, are presently preferred for the purposes of the invention.

Aluminous particles are centrifugally cast, for example, by continuously pouring molten aluminous metal into the top of a cylindrical pot revolving about a vertical axis and having side openings through which the molten metal is thrown radially outwardly from the pot as a result of its centrifugal action. In lower ranges of speeds the particles are found to be spheroidal, and in higher ranges of speeds the particles are smaller and assume an acicular shape. The particles at least partially solidify in the air, and can be fully air cooled or else caught in a container of water. In either case, they are characterized by a bright surface, indicating that they are relatively unoxidized as compared to conventional atomized powders. The latter are made by aspiration into a stream of compressed air or steam, which expels them in finely divided form. Conventional atomized particles are finely divided (in the order of about 300 mesh) and present such an explosion hazard that they must be specially collected, with resultant added expense. By limiting the speed of the rotating pot, centrifugally cast particles can be formed in sizes safely above the explosive range, and this makes them especially suitable for the purposes of the present invention. The centrifugal casting of aluminous particles is described and claimed in the copending application Serial No. 754,014, filed August 8, 1958, by Vernon D. Claiborne and Leland R. Payton, and in the copending application Serial No. 728,584, filed April 15, 1958, by Leland R. Payton (U.S. Patent 2,994,102). Further details are given in the examples of this application.

For a better understanding of the invention and its other objects, details, and advantages, reference is now made to the present preferred embodiments of the invention which are shown, for purposes of illustration only, in the accompanying drawings. In the drawings:

FIG. 1 is a diagrammatic view of apparatus for preheating and rolling centrifugally cast aluminous particles into solid metal strip;

FIG. 2 is a corresponding view of a modified species of the apparatus shown in FIG. 1;

FIG. 3 is a 50 magnification photomicrograph of an etched surface of strip as initially produced in accordance with the invention, the surface being on a section taken normal to the strip and parallel to the direction of rolling;

FIG. 4 is a 200 magnification photomicrograph similar to FIG. 3, but showing the strip after 94% reduction by subsequent cold rolling;

FIG. 5 corresponds to FIG. 4, but shows the reduced strip after annealing (at 650° F.) and consequent recrystallization;

FIGS. 6 and 7 correspond to FIGS. 4 and 5, but show the strip after 83% reduction by cold rolling subsequent to initial consolidation.

Referring now to the drawings, and initially to FIG. 1, the illustrated apparatus 10a receives aluminous centrifugally cast particles 11 in a hopper 12, which feeds them to a pair of work rolls 14 and 15. These rolls have a nip 16 through which the particles 11 are fed and rolled under high pressure to consolidate them into a solid metal strip 18. The strip forming rolls 14 and 15 are driven at equal peripheral speeds by any suitable means (not shown). Although not essential, it is preferable to pass the strip 18 through one or more subsequent pairs of work rolls 20 to work the metal and reduce it to gauge, without sintering at any stage. The subsequent rolling follows conventional practices as to temperatures and other conditions (including any desired annealing) suitable for the particular metal and the desired final gauge and properties, such as temper.

The particles 11 are preheated by any suitable means before they are fed into the hopper 12, or they may be heated while in the hopper. What is important is the temperature of the particles 11 as they are fed into the work rolls 14 and 15. A pair of sprayers 19 are located on the side of the rolls 14 and 15 near the emerging sheet

18, and direct a cooling stream of water or the like against the rolls 14 and 15. The amount of the cooling stream is regulated to insure that all of the liquid has evaporated from the roll surfaces before they rotate back into contact with the particles 11.

In the variant form of apparatus 10b shown in FIG. 2, the particles 11 are fed from a feed hopper 30 onto a moving belt 32 which passes them through a discharge point 34. The moving belt 32 and the feed hopper outlet 36 are enclosed in a heating furnace 38. Heated air or other gas 40 is fed into the furnace chamber through one or more inlet ducts 42, to heat the particles on the moving belt 32, and the exhaust air 41 is withdrawn through one or more outlet ducts 44. The heated particles are discharged into a second hopper 46, and thence are passed into the nip of compacting rolls 14 and 15 corresponding to those described above in connection with FIG. 1.

Various modifications will be obvious, such as feeding layers of particles of different alloys between the rolls 14 and 15, in order to produce various core and cladding effects. Moreover, one or more solid metal strips can be fed between the rolls 14 and 15 with the particles, such as one strip against one of the rolls 14 or 15 for purposes of forming a backing strip, or two such strips against one of the rolls 14 and 15 to form double backing layers, or one or more strips can be fed through the rolls with the particles on both sides, so that such strip or strips would be covered on both sides by a layer of the solid metal formed from the particles.

The following examples are illustrative of the invention:

Example 1

A charge of molten aluminous metal containing at least 99% aluminum was held in the melting furnace and discharged into a hollow cylindrical casting pot made of cast iron, having an outside diameter of 3 inches, and having 0.052 inch diameter openings through its side wall on $\frac{3}{8}$ inch centers and arranged in ten rows. The pot was rotated about its vertically-disposed central axis at about 3943 r.p.m. and molten aluminum was fed into its open top at a temperature in the pot of 1345° F. The particles cast from the pot were acicular in shape, and have the following representative screen analysis:

	Percent
Held on 10 mesh.....	Trace
Through 10, held on 20 mesh.....	20.1
Through 20, held on 30 mesh.....	41.9
Through 30, held on 40 mesh.....	26.8
Through 40, held on 50 mesh.....	9.8
Through 50, held on 60 mesh.....	1.1
Through 60 mesh.....	.3

These acicular particles were preheated to a temperature of about 900° F. in an air furnace equipped with a circulating fan and heated by electrical resistance heaters. The heated acicular particles were immediately transferred to a hopper leading to a pair of compacting rolls having their axes lying in a common horizontal plane. The rolls were 6 inches in diameter, with a 7 inch face, and had an initial roll gap setting of 0.052 inch. During rolling the rolls had a calculated pressure of about 12,000 p.s.i. on the particles. The particles flowed freely from the hopper into the roll nip, and were compacted by the rolls into a strip 7 inches wide and 0.098 inch thick, and having a density of 2.71 grams per cubic centimeter. The strip speed was 54 feet per minute, and at that speed the strip was well formed and strong, and needed relatively little trimming along the edges to eliminate incompletely rolled areas.

The as-rolled strip had a fibrous character resulting from the broken-up remains of the oxide walls of the original particles, as illustrated in the 50× photomicrograph in FIG. 3. Tests shown a tensile strength of 20,916 p.s.i. (ultimate) and 18,300 p.s.i. (yield), with an elongation of 14% along a 2 inch length. After being given suf-

ficient cold-rolled reduction (e.g., 83% and 94%) to permit full recrystallization upon being annealed at 600° F., the strip was found to have strength and elongation characteristics corresponding to those of strip of 99% aluminum (1100 Alloy) produced by rolling down large ingots in accordance with conventional mill practice (based on the figures reported in American Society for Metals Handbook, 1948 edition, page 771, Table 1). FIGS. 4 and 6 show 200× photomicrographs of samples of the strip produced in accordance with this Example 1, after being reduced 83% and 94%, respectively, by cold rolling. FIGS. 5 and 7 show corresponding photomicrographs of the strip after 600° F. annealing, and demonstrate that full recrystallization takes place. This would not have been possible if the original particles had not been thoroughly bonded together by contact of unoxidized aluminum in each particle with unoxidized aluminum in adjacent particles.

Example 2

Aluminous particles were produced as in Example 1, except that the pot speed was 400 r.p.m., and the particles were larger and of spheroidal shape. About 95% of the particles were capable of passing a 5 mesh screen and of being retained on a 10 mesh screen. The same preheating, rolling and testing procedures were followed, and substantially the same results were obtained.

Example 3

Particles of 99% aluminum metal were produced as in Example 1, except that the pot speed was 2300 r.p.m. The particles were acicular in shape, and had the following screen analysis.

	Percent
Held on 10 mesh.....	0.9
Through 10, held on 20 mesh.....	23.4
Through 20, held on 30 mesh.....	35.3
Through 30, held on 40 mesh.....	34.0
Through 40, held on 50 mesh.....	6.3
Through 50, held on 60 mesh.....	0.06
Through 60 mesh.....	Trace

These particles were preferred for use with 6 inch rolls. Where the same rolling and testing procedures were followed, the results were substantially the same as in Example 1.

Example 4

The aluminous meal of Examples 1-3 is of the non-heat treatable type, but the invention is also applicable to heat-treatable aluminous metals, of which a common example is 6061 Alloy (approximately 96.55% aluminum, Si 0.60%, Fe 0.70%, Cu 0.30%, Mn 0.15%, Mg 1.00%, Cr 0.2%, Zn 0.20%, Ti 0.15%, other constituents up to 0.10%). This alloy was formed into the particles of Example 1, and preheated and initially rolled into strip as in Example 1, but with a roll gap initial setting of 0.02 inch, and a resultant initial strip gauge of 0.060 inch. The initial strip was coilable and had full density, and tests showed it to have a tensile strength of 30,000 p.s.i. (ultimate) and 25,000 p.s.i. (yield) and elongation (along 2 inch length) of 12%. After reduction by cold rolling to 0.030 inch gauge, the strip was given standard solution and aging treatments (see 16-20 hour age example in American Society for Metals Handbook, 1948 edition, page 822), and was then tested and found to have strength and elongation characteristics corresponding to those of the same alloy when similarly treated after being rolled down from ingot according to conventional mill practice.

Example 5

Another heat-treatable alloy, 7075 (Si 0.50% max, Cu 1.1% to 2.0%, Mn 0.30% max, Mg 2.1% to 2.9%, Cr 0.18% to 0.40%, Zn 5.1% to 6.1%, Ti 0.20% max, others each 0.05% max, others total 0.15%, balance aluminum), was preheated and rolled and reduced as

in Example 4, except that the preheat temperature was 800° F., the roll gap initial setting was 0.052 inch, the gauge of the initial strip was 0.095 inch, and the cold rolling was to 0.045 inch gauge. The initial strip was coilable, strong, and of full density, and when the reduced strip was given standard solution and aging treatments (see 24 hour aging test on page 823 of the 1948 A.S.M. Handbook), and was tested, it was found to have strength and elongation characteristics corresponding to those of the same alloy when similarly treated after being conventionally rolled down from ingot.

Example 6

Another alloy which is like the aluminous metal of Example 1 to the extent that it is also work-hardenable and non heat-treatable, is 3003 Alloy (Si 0.6% max, Fe 0.7%, Cu 0.2% max, Mn 1% to 1.5%, Zn 0.1% max, others each 0.05 max, others total 0.15% max, balance aluminum). When cast into particles substantially in the manner described in Example 1, the particles are acicular but somewhat finer than in Example 1 (e.g., about 16.4% retained on 30 mesh, 70.4% passing 30 and retained on 40 mesh, 13.2% passing 40 and retained on 50 mesh, and a trace passing 50 mesh). These particles were preheated and rolled as described in Example 1, with roll gap initial settings of 0.026, 0.035, 0.052 and 0.080 inch producing initial strip gauges of 0.070, 0.072, 0.084 and 0.108, respectively. When further cold rolled and annealed as described in Example 1, the strip was similarly found to have strength and elongation characteristics of corresponding commercial strip of 3003 Alloy.

In each of the above examples, it was found necessary to cool the compacting rolls, which was done by spraying water on the surfaces of the rolls adjacent the newly-formed strip, in as great an amount as possible while still insuring complete evaporation so that the roll surfaces would be dry when coming into contact with the particles. When this was done, sticking of the strip metal to the rolls was avoided when rolling continuously at about 54 feet per minute. This cooling gives a roll temperature adjacent the inlet roll nip intermediate between, and preferably about half way between, the boiling point of water (212° F.) and the preheat temperature used. It is desirable to have the rolls as hot as possible, while still avoiding sticking on the rolls because cold rolls have been found to give ragged strip edges, which increase the amount which must be trimmed along the edge and recycled. After the rolls are sufficiently heated, the as-rolled edges become quite uniform and require little trimming.

Hammer milling the acicular particles mentioned in the above examples tends to shift the screen analysis so that there is a reduction of the percentage of smaller particles and a corresponding increase of percentage of larger particles. The milled particles are more free flowing when fed into the rolls.

In all of the above examples, the strip was found to be free of blisters at all stages.

One of the problems encountered when anodizing strip produced in the conventional manner is a streaked appearance resulting from elongation of grains visible on the anodized surface. Strip produced in accordance with the invention, even after substantial cold reduction, shows substantially no grain elongation on the surface of the strip upon being anodized, provided that the particles used are of substantially the same alloy. This is surprising, because the original particles beneath the surface in the strip are drawn out during rolling, and especially during cold reduction. This anodizing effect is illustrated in the following example:

Example 7

The strip produced in accordance with Example 1, was anodized in each of its successive stages in Example 1, i.e., in its as-rolled initial condition and in its cold rolled condition after 83% and 94% reduction, respectively, and after annealing following each of said stages of reduc-

tion. In each case, the strip was electropolished in a 2.5% fluoboric acid bath at 85° F. for 12 to 15 minutes and then was anodized in a 17% sulfuric acid anodizing bath, at 70° F. for about 10 minutes, using 15 volt direct current, and a current density of 12 to 15 amperes per square foot. In each case the anodized surface was streak-free, as a result of substantial absence of grain elongation visible on the anodized surface.

While present preferred examples of the method, apparatus and product of the invention have been given, it will be recognized that the invention is not limited thereto but may be otherwise variously embodied and practiced within the scope of the following claims.

What is claimed is:

1. The method of making a solid strip of aluminous metal, comprising the steps of: preheating cast particles of aluminous metal, substantially all of which are coarser than 200 mesh and individually covered with a surface layer of aluminum oxide, to a temperature in the range between about 450° F. and the incipient melting temperature of the aluminous metal while maintaining the preheated particles in free-flowing condition; feeding the particles at a temperature in such range and in free-flowing condition to the nip of a set of work rolls; and rolling the particles under pressure between the rolls to form a fully densified and self-supporting strip.

2. The method of making a solid strip of aluminous metal, comprising the steps of: preheating cast particles of aluminous metal, substantially all of which are coarser than 200 mesh and individually covered with a surface layer of aluminum oxide, to a temperature in the range from about 750° F. to about 1000° F. while maintaining the preheated particles in free-flowing condition; feeding the particles at a temperature in such range and in free-flowing condition to the nip of a set of work rolls; and rolling the particles under pressure between the rolls to form a fully densified and self-supporting strip at the rate of at least 50 feet per minute.

3. The method of making a solid strip of aluminous metal, comprising the steps of: preheating cast particles of aluminous metal, substantially all of which are coarser than 40 mesh and individually covered with a surface layer of aluminum oxide, to a temperature in the range between about 450° F. and the incipient melting temperature of the aluminous metal while maintaining the preheated particles in free-flowing condition; feeding the particles at a temperature in such range and in free-flowing condition to the nip of a set of work rolls; and rolling the particles under pressure between the rolls to form a fully densified and self-supporting strip.

4. The method of making a solid strip of aluminous metal, comprising the steps of: preheating cast particles of aluminous metal, substantially all of which are coarser than 200 mesh and individually covered with a surface layer of aluminum oxide, to a temperature in the range between about 450° F. and the incipient melting temperature of the aluminous metal while maintaining the preheated particles in free-flowing condition; feeding the particles at a temperature in such range and in free-flowing condition to the nip of a set of work rolls; and rolling the particles under pressure between the rolls to form a fully densified and self-supporting strip through the rolls at a rate of at least 50 feet per minute, the approaching roll surfaces adjacent the roll nip being at a temperature above the boiling point of water and below the temperature of the particles entering the rolls.

5. The method of making a solid strip of aluminous metal, comprising the steps of: preheating cast particles of aluminous metal, substantially all of which are coarser than 200 mesh and individually covered with a surface layer of aluminum oxide, to a temperature in the range between about 450° F. and the incipient melting temperature of the aluminous metal while maintaining the preheated particles in free-flowing condition; feeding the particles at a temperature in such range and in free-flowing

condition to the nip of a set of work rolls; and rolling the particles under pressure between the rolls to form a fully densified and self-supporting strip through the rolls at a rate of at least 50 feet per minute, the approaching roll surfaces adjacent the roll nip being at a temperature about half way between the boiling point of water and the temperature of the particles entering the rolls.

6. The method of making a solid strip of aluminous metal, comprising the steps of: preheating cast particles of aluminous metal, substantially all of which are coarser than 200 mesh and individually covered with a surface layer of aluminum oxide, to a temperature in the range between about 450° F. and the incipient melting temperature of the aluminous metal while maintaining the preheated particles in free-flowing condition; feeding the particles at a temperature in such range and in free-flowing condition to the nip of a set of work rolls; and rolling the particles under pressure between the rolls to form a fully densified and self-supporting strip, the step of rolling being carried out in an atmosphere of air and said roll surfaces disengaging themselves from the strip on the exit side of the roll nip.

7. The method of making a solid strip of aluminous metal, comprising the steps of: preheating cast particles of aluminous metal, substantially all of which are coarser than 200 mesh and individually covered with a surface layer of aluminum oxide, to a temperature in the range between about 450° F. and the incipient melting temperature of the aluminous metal while maintaining the preheated particles in free-flowing condition; feeding the particles at a temperature in such range and in free-flowing condition to the nip of a set of work rolls; and rolling the particles under pressure to form a fully densified and self-supporting strip in a single pass between the rolls at a rate of at least 50 feet per minute while cooling the rolls to reduce the temperature of the approaching surfaces of the rolls adjacent the roll nip to a temperature below the temperature of the particles being fed to the rolls.

8. Method for the conversion of molten aluminous metal to a fully densified rolled product of aluminous metal, comprising the steps of: centrifugally casting molten aluminous metal to produce acicular particles of said metal, said particles being individually covered with a surface layer of oxide and being substantially all retainable on a 200 mesh sieve; heating the cast particles; feeding the particles at a temperature between about 450° F. and the incipient melting temperature of the aluminous metal and in free-flowing condition to the nip of a pair of work rolls; maintaining the approaching roll surfaces adjacent the roll nip at a temperature below the temperature of the particles entering the rolls; and rolling said particles in a single pass between said rolls to form a fully densified and self-supporting aluminous metal product at the rate of at least 50 feet per minute.

9. The method of producing a fully densified rolled product from molten aluminous metal, comprising the steps of: centrifugally casting molten aluminous metal to form particles of said metal, said particles being individually covered with a surface layer of aluminum oxide and being substantially all retainable on a 200 mesh sieve;

feeding such particles in free-flowing condition at a temperature between about 450° F. and the incipient melting temperature thereof to the nip of a set of work rolls; and rolling the particles under pressure to form a fully densified and self-supporting aluminum metal product.

10. The method of producing a fully densified rolled product from molten aluminous metal, comprising the steps of: centrifugally casting molten aluminous metal to form acicular particles of said metal, said particles being individually covered with a surface layer of aluminum oxide; feeding such particles, substantially all of which are above 40 mesh, in free-flowing condition at a temperature between about 450° F. and the incipient melting temperature thereof to the nip of a set of work rolls; and rolling the particles under pressure and in direct contact with said rolls to form a fully densified and self-supporting aluminous metal product.

11. The method of making a continuous length of aluminous metal, comprising the steps of: preheating particles of aluminous metal, substantially all of which are coarser than 60 mesh and individually covered with a surface layer of aluminum oxide, to a temperature in the range from about 750° F. to about 1000° F.; feeding the preheated particles in free-flowing condition to the nip of a pair of work rolls; and rolling the particles in a single pass between said rolls to form a fully densified and self-supporting length of aluminous metal.

12. The method of producing a fully densified rolled product of aluminous metal, comprising the steps of: centrifugally casting molten aluminous metal to form free-flowing metallic particles substantially all of which are coarser than 200 mesh; screening out any particles which are not retainable on a 60 mesh sieve; preheating such cast particles coarser than 60 mesh to a temperature of at least above 450° F. and sufficiently below the incipient melting temperature thereof that the particles remain free-flowing at the preheat temperature; feeding the particles at substantially the preheat temperature and in free-flowing condition to a pair of work rolls having opposed surfaces defining a gap therebetween, the particle-engaging roll surfaces adjacent the inlet roll nip being at a temperature below the temperature of the particles entering the rolls; and rolling the particles under pressure between the rolls in a single pass to form a fully densified and self-supporting aluminous metal product.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,076,706

February 5, 1963

T. Stevens Daugherty

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 49, for "avaporate" read -- evaporate --; column 5, line 73, for "shown" read -- showed --; column 6, line 48, for "meal" read -- metal --; line 53, for "Cr 0.2%" read -- Cr 0.25% --; column 10, line 12, after "mesh" insert -- size --.

Signed and sealed this 3rd day of December 1963.

(SEAL)

Attest:

ERNEST W. SWIDER

Attesting Officer

EDWIN L. REYNOLDS

Acting Commissioner of Patents

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