

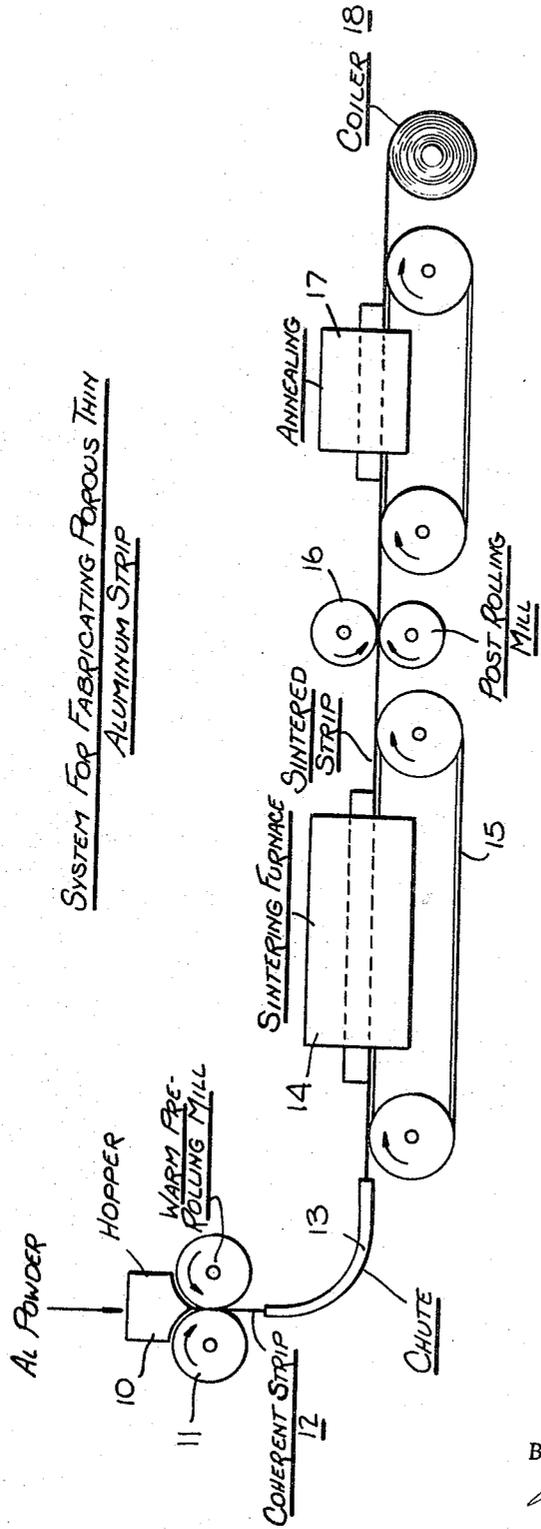
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METHOD OF FORMING POROUS ALUMINUM STRIP

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METHOD OF FORMING POROUS ALUMINUM STRIP

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ABSTRACT OF THE DISCLOSURE

The invention is a method for forming porous aluminum strip by feeding aluminum powder to the nip of warm pressure rolls that are maintained at a temperature between about 100° and 300° F., compacting said powder in said rolls under sufficient pressure to compact the powder into a strip of between 40% and 85% theoretical density and subsequently sintering in a non-oxidizing atmosphere at a temperature between about 600 to 665° C.

This application is a continuation-in-part of application Serial No. 303,843, filed August 22, 1963, and now abandoned.

This invention relates to porous aluminum strip and is particularly useful for the manufacture of porous aluminum foil and sheet.

Porous aluminum products in sheet form are generally unavailable since because of the difficulty in processing aluminum there have been no convenient methods to date for manufacturing the product. The closest material available is a chemically etched solid aluminum sheet. The chemical etching increases the surface area of the aluminum sheet but, however, does not make it porous.

Thin, porous aluminum sheets or strips are useful in a variety of applications, such as for wicking or filtration purposes, as a liquid-liquid separation medium, and as a bearing surface. Of particular value is the use of porous aluminum sheets in electrolytic condensers in place of etched aluminum strips of the type currently employed. In electrolyte condensers, porous aluminum strips, by reason of their large internal porosity and surface area, afford improved condenser performance and capacity per unit volume of metal.

In conventional terminology, aluminum foil is sheet having a thickness of less than about 0.005". Anything above 0.005" is merely referred to simply as "sheet." This invention is particularly adapted to the manufacture of porous aluminum foil having a thickness of between about 0.002" and 0.005". Preferred foils have a thickness of at least about 0.003". This invention is also applicable to the manufacture of porous aluminum sheet having a thickness of between 0.005" and 1/8".

There are two types of porosity, both of which can be obtained by means of this invention as desired. One type of sheet or foil produced by this invention is permeable to the passage of air and other fluids, as determined by various conventional means. Alternatively, it is possible to produce porous but non-permeable products. Such porous but nonpermeable products do not have the interconnecting porosity necessary for permeability, but they do have a plurality of pores which substantially reduces the weight per unit volume of material while at the same time increasing the effective surface area.

In the process of this invention, porous aluminum sheet and foil is manufactured by shaping particulate aluminum, optionally containing additional alloying materials in particulate form up to about 10% by weight of the aluminum, through the nip of a rolling mill whose rolls are maintained at a temperature of from about 100° F. to 300° F. and which are set to compact the

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particulate aluminum of a predetermined density. Where permeable sheet or foil is the desired product, the density of the compacted material will not exceed about 60% of the theoretical density. When porous, but substantially non-permeable products are desired, the density, upon compaction, will not exceed about 85% of the theoretical density and will, of course, be greater than about 60% of the theoretical density.

An essential feature of the method of this invention is the so-called warm rolling at the temperature specified. Cold rolling, i.e., rolling at room temperature without heating of the rolls, will not sufficiently compact and agglomerate the particles to achieve the desired properties. Hot rolling, i.e., rolling above the recrystallization temperature, on the other hand, will cause premature oxidation and/or the formation of overdense, non-porous materials. After the rolling operation has been completed, the material, which is in an agglomerated but fairly weak state, is then transported carefully to a sintering furnace, maintained at a sintering temperature for the particular composition. Generally, a temperature of from about 600° C. to 655° C. is employed for sintering and this temperature is maintained for a period of from about 5 to 30 minutes. To avoid oxidation, sintering is carried out in a protective, i.e., a nonoxidizing atmosphere. Representative nonoxidizing atmospheres include atmospheres of hydrogen, dissociated ammonia and the various inert gases such as argon, neon, and the like.

The moisture content of the atmosphere should be restricted such that the atmosphere in the vicinity of the strip being sintered has a dew point of -30° F. or drier.

Care should be taken in setting the rolls to assure that a compaction pressure of at least 40% of theoretical is achieved, since below that, the results are generally unsatisfactory.

In many instances, it is desirable to include along with the particulate metals a quantity of an organic lubricant having a boiling point within the range of 100° C. to 600° C., in an amount up to about 2% by weight. This organic lubricant serves to keep the rolls from sticking during rolling and serves to facilitate uniform mixing and agglomeration of the metal particles. The lubricant should not be present in the final product and hence should be one that is inert and volatilizes completely without leaving any residue.

As mentioned above, up to 10% by weight of other metals can be combined with aluminum, such as, for example, copper, magnesium, manganese, zinc, titanium, silicon and other materials capable of alloying with aluminum. These secondary materials can be added in their particulate elemental form or in the form of particulate alloys with aluminum.

The shape of the particulate metals is relatively unimportant in that they can be in the form of powder, needles, flakes, wire clippings, scrap turnings, and the like. Generally, to avoid handling problems, it is preferred that the particles have at least one dimension in excess of 3 microns and that the particles be capable of passing through a 10 mesh sieve.

As is apparent from the drawing, this invention is easily adapted to the continuous manufacture of long, uninterrupted lengths of porous aluminum foil and sheet. The figure shows schematically a system for continuously fabricating porous aluminum strip in accordance with this invention.

Further details in the method of this invention will be ascertained from the following, which represents the preferred mode of carrying out the invention.

Referring to the figure, there is shown a hopper adapted to feed metallic powder vertically between the rolls of a rolling mill. Supplied to the hopper is pure

aluminum powder, the particle size distribution of which varies from -40 mesh with 90 weight percent -325 mesh material, to -40 mesh with 0 weight percent -325 mesh material. Intermingled with the aluminum powder is a volatile organic hydrocarbon lubricant, the mixture being compressed in mill 11. Preferably, the percentage by weight of the lubricant does not exceed 2%.

The rolls of the mill are heated to a temperature of about 100° C. to 300° C. by any standard means, such as electrical, gas-fired or induction heaters. In practice, a roll speed of two to several hundred feet per minute may be used, depending upon the various roll factors discussed hereinafter.

As the powders pass between the rolls, they are compressed and simultaneously heated so that a coherent strip 12 emerges therefrom.

The porosity and thickness of the coherent strip 12 are varied by adjusting the roll gap, roll diameter, lubricant content or powder particle characteristics. The fabrication of thin strip is favored by using closely spaced rolls of small diameter, relatively regular powder, and high lubricant concentrations.

Coherent strips emerging from warm rolling mill 11 are conveyed down the chute 13 into a sintering furnace 14 provided with a conveyor belt 15 for conducting the strip therethrough.

The sintered strip, which is now possessed of considerable strength and ductility relative to its strength and ductility in the unsintered condition, may be used in the "as is" condition or further processed to decrease porosity to some specified level, to improve surface finish, or both. This is done by passing the strip through a second rolling mill 16. If maximum strength is desired, the strip is used in the cold worked condition. If maximum ductility is required, the strip is passed through an annealing furnace 17 and wound into coils or coiler 18.

If one wishes to process relatively small quantities of material, a batch type of operation might be substituted for the continuous operation described above. In batch operation, the material emerging from the rolling mill would be coiled, transferred to a furnace and sintered in a protective atmosphere for 5 to 30 minutes at a temperature of 600° C. to 655° C. After sintering, processing

would be much the same as described for the continuous operation.

Having thus described the invention, that which is desired to be claimed is:

5 The method of producing aluminum strip having a porous surface and porous interior which comprises feeding aluminum powder to the nip of warm pressure rolls, effecting compaction of the powder to strip form in said rolls by maintaining the rolls at a temperature between 10 about 100° and 300° F. and under sufficient pressure to compact the mass of powder therebetween to at least 40% but not more than about 85% of its theoretical density, and thereafter sintering the resulting porous aluminum strip in a nonoxidizing atmosphere at a temperature with- 15 in the range of about 600° to 655° C.

References Cited

UNITED STATES PATENTS

1,663,445	3/1928	Davis	29—183.5
1,930,287	10/1933	Short et al.	75—208
1,982,587	11/1934	Wilkins	29—183.5
1,988,861	1/1935	Torausch et al.	75—222
2,134,366	10/1938	Hardy	75—208
2,155,651	4/1939	Goetzl	75—222
2,332,746	10/1943	Olt	75—208
2,341,732	2/1944	Marvin	75—214 X
2,386,544	10/1945	Crowley	75—222
2,746,741	5/1956	Naeser	75—208
3,144,330	8/1964	Storchheim	75—226
3,194,858	7/1965	Storchheim	75—214
3,290,145	12/1966	Daugherty	75—214

OTHER REFERENCES

- 35 Iron and Steel Engineer, vol. XXXVI, No. VII, July 1959, pp. 118-124.
 Metals Handbook, vol. 1, American Society for Metals, Metals Park, Ohio, 1961, page 9.
- 40 L. DEWAYNE RUTLEDGE, *Primary Examiner*.
 CARL D. QUARFORTH, *Examiner*.
 R. L. GRUDZIECKI, *Assistant Examiner*.