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PROCESS FOR THE PRODUCTION OF FINE GRAINED ALUMINUM ALLOY STRIP

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ABSTRACT OF THE DISCLOSURE

A process for the production of a strip of a manganese-containing aluminum alloy which yields a fine grained product with mechanical properties which make the strip of outstanding value for formability, especially for deep-drawing. The process comprises homogenising a cast billet of the alloy at a temperature over 560° C., hot-rolling, cold-rolling and annealing the cold-rolled strip in two stages, first at a temperature below the temperature of complete recrystallization at least during five hours and in the second stage above that temperature.

SUMMARY OF THE INVENTION

This invention relates to the production of strip of manganese-containing aluminum alloys. Such strip is used for the production of seamless deep-drawn containers of aluminum foil because these alloys have a capacity for elongation and fine grain size which make them of outstanding value for formability and particularly for deep-drawing.

Normally deep-drawn containers of aluminum foil are made from strip of 0.05 to 0.3 mm. thick, and generally 0.1 mm. thick, and the strip should have a tensile strength of from 10 to 13 kg./mm.^{2}, an extension greater than 20%, an Erichsen depth of at least 7.5 mm., and more than 2000 grains per mm.^{2}.

In the production of the strip cast billets are homogenised, hot-rolled, cold-rolled and annealed. Now, however, the manganese-containing alloys when annealed show a tendency to grain coarsening. In order to produce a fine grain H. Hug (Metall Vol. 9 (1955) pages 176 to 180) proposed that the billets should be heated at as high a temperature as possible before the hot-rolling. A relatively short heating time is enough, while at lower temperatures the same effect cannot be obtained even with long heating times.

However, it has been found in practice that in spite of the high-temperature heating of these billets a fine grain is obtained only when the rolled strip is heated very quickly in the annealing step. However, this is not possible in the usual furnaces with such large coils of strip as are produced today. Short heating times can be attained only in continuous annealing furnaces but these are expensive in construction and operation. Although an additional reason for annealing in a continuous furnace is that the elongation is higher than after a usual heating in a batch furnace, it is still desirable to find a process which will give a deep-drawable fine-grained strip on annealing even in a batch furnace of the kind present in all rolling mills. Our object in this invention is to provide such a process.

According to the invention a cast billet of the alloy is homogenised at a temperature above 560° C., hot-rolled to strip, cold-rolled and then, while it is in the condition resulting from cold-rolling, is annealed in two stages, in the first of which it is held for at least five hours in the temperature range of 160° C. up to just beneath the temperature of complete recrystallization, and in the second of which it is heated above that temperature. Preferably the strip is heated in the first stage for at least ten hours in the temperature range of 200° C. to a temperature just beneath the temperature of complete recrystallization. The temperatures referred to in this specification are those that the metal attains.

The process according to the invention enables the use of a usual batch furnace for the annealing and nevertheless gives fine-grained strips which also have the necessary properties for the production of seamless containers. In the conventional processes the initial temperature of the hot-rolling is above 500° C. In the present invention it is preferred to make this initial temperature from 400 to 480° C. This lower hot-rolling temperature in combination with the other features of the process according to the invention brings about further improvement of the properties of the strip.

Intermediate annealing may be effected during the cold-rolling, but preferably there is no such intermediate annealing, and in any case it is essential that at the beginning of the annealing after the cold-rolling the strip should be in the state resulting from at least 60% cold-work.

During the first stage of the annealing the temperature range from 160° C. to a temperature just below that of complete recrystallization may be traversed in the prescribed time at a slow rate of heating, but preferably the heating takes place more or less quickly up to a temperature just below the temperature of complete recrystallization, and this temperature is maintained for at least five hours before the second stage of heating above the temperature of complete recrystallization begins. It is, of course, desirable that the two stages should be continuous, but the strip can be allowed to cool down between them. The two-stage annealing is easy to carry through and makes economic use of a batch oven in a rolling mill.

The recrystallization temperature depends on the composition of the alloy and its pre-treatment before annealing and can be determined by tests. As is well known the so-called recrystallization temperature is in fact a temperature range, at the lower end of which the recrystallization begins and only at the upper end of which is recrystallization complete. In the present invention the temperature reached in the first annealing stage may advantageously lie within the range of recrystallized at the end of this stage.

The invention can be applied to alloys of various compositions, being particularly applicable to those known as AlMn alloys, which usually contain up to 2% manganese, and which may also contain other metals in small amounts, such as iron, magnesium, copper and so forth. Although magnesium in an amount above 0.1% is advantageous in producing a fine grain in the annealed strip, the magnesium-containing alloys have bad lacquer adhesion and high cold strength, which renders the cold rolling difficult. Advantageously an AlMn alloy with less than 0.1% magnesium is used, and particularly an alloy containing from 0.5 to 1.6% manganese, from 0.1 to 0.6% silicon, from 0.2 to 0.8% iron and from 0 to 0.3%

copper, zinc in an amount less than 0.1%. The invention may also be applied to other manganese-containing aluminum alloys, and specifically to AlMgMn alloys containing from 0.3 to 1.3% manganese, 0.3 to 5.0% magnesium, 0.1 to 0.6% silicon, 0.2 to 0.8% iron and 0 to 0.3% copper, the balance being aluminum; to

AlMgSi(Mn)

alloys containing from 0.6 to 1.4% magnesium, 0.2 to 1.6% silicon, 0.1 to 1.0% manganese, 0.2 to 0.8% iron and 0 to 0.3% copper, the balance being aluminum; and to AlCuMg(Mn) alloys containing from 0.2 to 1.2% magnesium, 0.1 to 0.6% silicon, 0.1 to 0.5% manganese, 0.2 to 0.8% iron and 1.8 to 3.0% copper, the balance being aluminum.

The advantages of the invention are shown by a series of tests made on strip produced from billets of an AlMn alloy containing 1.2% manganese, 0.6% iron, 0.3% silicon and 0.1% copper. The billets were homogenised by heating at 630° C. for 24 hours, hot-rolled to 7 mm. and then cold-rolled to 0.1 mm. Six different treatments were applied and the resultant strips were tested as set forth below. It will be seen that the alloy used was free from magnesium, and its temperature of complete recrystallization was about 340° C.

Treatment 1

The billet was hot-rolled at a temperature of 550° C. and the strip was annealed in a batch furnace, attaining a temperature of 370 to 400° C. in five hours, which was above the recrystallization temperature.

Treatment 2

More of the same cold-rolled strip that was used in Treatment 1 was heated to a temperature of 370 to 400° C. by passage through a continuous annealing furnace in the course of a few seconds.

Treatment 3

The initial hot-rolling temperature of the billet was 420 to 430° C. In the first stage of the annealing the strip was heated through the temperature range of 200 to 340° C. in a period of somewhat more than 10 hours, and in the second stage it was heated to 390° C.

Treatment 4

The initial hot-rolling temperature of the billet was 550° C., in the first stage of the annealing the strip was held at 330° C. for 20 hours, and in the second stage the strip was held for 5 hours at a temperature within the range of 350 to 380° C.

Treatment 5

The initial hot-rolling temperature of the billet was 450° C., and the annealing was effected as in Treatment 4.

Treatment 6

The initial hot-rolling temperature was again 450° C., and the annealing was effected as in Treatment 4. However in the course of the cold-rolling the strip when reduced to a thickness of 0.5 mm. was subjected to intermediate annealing for 5 hours at 380° C.

The annealed strips were all tested. In each case the tensile strength and the extension of parallel-sided strips 15 mm. wide over a test length of 180 mm., the Erichsen depth according to DIN 50 101 and the number of grains per mm.^{2} after a Barker oxidation by comparison with a standard grain table (Kostron Table, 500 times magnification).

The results are given in the table below.

TABLE

	Tensile strength, kg./mm.^{2}	Extension, percent	Erichsen depth, mm.	Number of grains per mm.^{2}
Treatment:				
1	11.95	14.2	6.2	2,000
2	13.2	22.6	7.4	7,000
3	11.3	20.6	----------	6,500
4	12.4	26.8	7.25	5,500
5	12.5	28.5	7.8	6,000
6	12.6	17.6	6.5	----------

It will be seen that when the strip was heated too rapidly to a temperature above the recrystallization temperature in Treatment 1 the desired values were not obtained and in particular the number of grains was too low. On the other hand all the desired values were obtained when a continous annealing furnace was used as in Treatment 2. Likewise the desired values were all obtained in Treatments 3, 4 and 5, but Treatment 5 shows that with a lower hot-rolling temperature somewhat better results are obtained for the Erichsen depth and number of grains. In Treatment 6 the desired values were not obtained. The examined especial alloy must not undergo an intermediate annealing during cold rolling.

We claim:

1. A process for the production of strip of a manganese-containing aluminum alloy which comprises homogenising a cast billet of the alloy at a temperature over 560° C., hot rolling the billet to strip, cold-rolling the strip and, while it is in the condition resulting from more than 60% reduction by cold-rolling, annealing it in two stages, in the first of which it is held for at least five hours in the temperature range of from 160° C. to just below the temperature of complete recrystallization, and in the second of which it is heated above the recrystallization temperature.

2. A process according to claim **1** applied to an AlMn alloy free from, or containing less than 0.1% magnesium.

3. A process according to claim **2** in which the alloy contains from 0.5 to 1.6% manganese, from 0.1 to 0.6% silicon, from 0.2 to 0.8% iron, from 0 to 0.3% copper, and zinc in an amount less than 0.1%, the remainder being aluminum, this alloy being cold-rolled without intermediate annealing.

4. A process according to claim **1** applied to an alloy containing from 0.3 to 1.3% manganese, 0.3 to 5.0% magnesium, 0.1 to 0.6% silicon, 0.2 to 0.8% iron and 0 to 0.3% copper, the remainder being aluminum.

5. A process according to claim **1** applied to an alloy containing from 0.6 to 1.4% magnesium, 0.2 to 1.6% silicon, 0.1 to 1.0% manganese, 0.2 to 0.8% iron and 0 to 0.3% copper, the remainder being aluminum.

6. A process according to claim **1** applied to an alloy containing from 0.2 to 1.2% magnesium, 0.1 to 0.6% silicon, 0.1 to 0.05% manganese, 0.2 to 0.8% iron and 1.8 to 3.0% copper, the remainder being aluminum.

7. A process according to claim **1** in which in the first annealing stage the strip is held for at least ten hours in the temperature range of 200° C. up to just below the temperature of complete recrystallization.

8. A process according to claim **1** in which the temperature of the billet at the beginning of the hot rolling is from 400 to 480° C.

9. A process according to claim **1** in which the cold rolling is effected without any intermediate annealing.

10. A process according to claim **1** in which during the first annealing stage the strip is held for at least five hours at a temperature below the temperature of complete recrystallization.

11. A process according to claim **1** in which in the first annealing stage the temperature range is traversed by slow heating up throughout five hours and more.

12. A process according to claim **1** in which the temperature reached in the first annealing stage is so high that the strip is partially recrystallized at the end of this stage.

13. A process according to claim **3** in which the strip is annealed in the first stage for twenty hours at 330° C. and in the second stage for five hours in the range of 350 to 380° C.

14. A process according to claim **1** in which the strip is rolled to a thickness of from 0.05 to 0.3 mm.

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