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[54] **LOW-EARING CAN STOCK**

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[51] **Int. Cl.** **C22f 1/04**

[58] **Field of Search** ..... 148/11.5 A, 32

[56] **References Cited**

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[57] **ABSTRACT**

Improving the properties of aluminum sheet in work hardened temper by controlling the hot rolling conditions employed in producing such sheet.

14 Claims, No Drawings

LOW-EARING CAN STOCK

This application is a continuation of copending application Ser. No. 90,033 filed on Nov. 16, 1970, and now abandoned.

With respect to any disclosure content of this application in common with said copending application and with applicant's prior application Ser. No. 712,314 (now U.S. Pat. No. 3,571,910), the latter being a division of Ser. No. 660,132 (now U.S. Pat. No. 3,397,044) filed Aug. 11, 1967, the present application is entitled to the filing date of Aug. 11, 1967, and any earlier date applicable to said disclosure content on the basis of subject matter in common with antecedent applications Ser. No. 573,776 filed Aug. 8, 1966, and Ser. No. 379,782 filed July 2, 1964, both abandoned.

This invention relates to techniques for making aluminum sheet of improved properties, particularly as regards providing increased ductility of the metal for cold rolling purposes and avoiding excessive 45° earing of the metal as an incident to drawing operations. The methods aspects of the invention, which are directed to preconditioning the metal structure for improved plastic flow in work hardened temper, are adapted to making can stock and other light-gage cold rolled sheet products as well as reroll stock suitable for cold rolling to make work hardened sheet.

As used herein, the term "aluminum" includes commercial grades of the metal itself as well as aluminum base alloys containing upwards of 90% aluminum by weight. Alloys which have been found especially responsive to treatment in accordance with the invention include 3003, 3004, 5050 and 8079 (Aluminum Association designations), and other manganese-containing alloys with and without magnesium.

Aluminum sheet for use as can stock and for other purposes is conventionally produced by regular mill practices which may include such operations as continuous casting, homogenizing, hot rolling, annealing, and cold rolling. Suitable hot working temperatures for aluminum alloys fall generally in the range of about 500°–950° F., but particular practices vary widely depending on a variety of considerations. With respect to formability and other characteristics of the final cold rolled sheet, such properties as strength and elongation are conventionally controlled either by annealing the metal prior to cold rolling and controlling the cold rolling reduction to achieve the desired work hardened temper, or by temper annealing after cold rolling.

A major advantage in using highly cold worked sheet for subsequent forming operations, including drawing, cupping and the like, is the prospect of obtaining increased strength of the finished article. On the other hand, complex forming operations ordinarily are accomplished more readily with fully annealed sheet. It becomes necessary, therefore, to seek a realistic balance between these two considerations, particularly with non-heat treatable alloys for which control of strength and formability depends largely on cold working practices.

It has also been recognized that the amount of cold working involved in making work hardened aluminum sheet has a bearing on the type and extent of earing which occurs during subsequent drawing operations. Earing (the formation of scallops around the top edge of a drawn part) is a manifestation of differences in the directional properties of the sheet metal used. The predominant earing configurations are those oriented either at 90° (parallel and orthogonal to the rolling direction) or at 45° positions. Excessive 45° earing indicates an undesirable condition of the sheet likely to present problems in drawing, such as difficulties in transferring drawn cups between successive stages of the fabricating operations. It is also desirable, of course, in dealing with excessive earing or problems occasioned by earing, to avoid practices which cause reduced ductility of the metal in work hardened temper, because such practices would tend to increase the extent of edge trimming required and the amount of scrap thereby generated.

Various attempts to control the earing behavior of work hardened aluminum sheet have traditionally involved varying the annealing and cold rolling operations without regard to the effect of prior hot rolling practices. Such approaches not only have been substantially ineffective to reduce 45° earing to satisfactory levels for many alloys, but have necessarily accomplished increased ductility at the expense of reduced strength.

In accordance with the present invention it has been discovered that aluminum sheet which, in highly cold worked condition ordinarily would exhibit as much as 10% earing (45°) during drawing, may be prepared by a method which substantially reduces its 45° earing tendency to 5% or less. Thus, by hot rolling the metal prior to cold rolling, and commencing the hot rolling operation at a temperature of at least 925° F. (preferably about 950°–1,150° F. but below the melting point), the metal becomes preconditioned for improved plastic flow characteristics in its work hardened temper resulting from subsequent cold rolling.

The selected hot rolling temperature will depend to some extent on the alloy being rolled, and the final product desired, but in general terms will be from about 50° to as much as 300° F. above the run-of-the-mill temperature commonly used for hot rolling the particular alloy. Furthermore, although the total reduction achieved during hot rolling may be conventional, it has been found helpful for purposes of the invention to employ somewhat heavier drafts and hence slower rolling passes than otherwise might ordinarily be employed, at least for the initial ingot breakdown operations when using a large ingot. In other respects the remaining operations such as continuous hot rolling, annealing, and cold rolling may be carried out in conventional manner, and there seems to be no particular criticality within normal variations of the operating conditions involved in these companion steps.

The conventional processing of a 3004-type alloy, as reported in Metals Handbook (ed. 1958), typically involves an ingot breakdown operation in the temperature range of 750°–925° F., with continuous hot rolling at 300°–850° F. In this respect, for purposes of comparison, the preferred practices of the present invention for the same alloy system include preheating (stabilizing) the ingot at about 1,025° F., followed by an initial heavy reduction of the ingot at a metal temperature above 950° F. Although the difference in temperature conditions may seem slight at first impression, it will be noted that the minimum initial hot rolling temperature is considerably higher than mid-range values of the prior practice and even exceeds the extreme upper limit of the reported range. In addition, there is no basis in the reported prior practice referred to above for cor-

relating a high hot rolling temperature with achievement of improved properties of the metal in work hardened condition following subsequent cold rolling.

The practice of the invention is not limited to a particular combination of hot and cold rolling operations, but is adapted in the hot rolling respect to produce coilable reroll stock suitable for sale to customers who would perform the subsequent cold rolling and fabricating operations.

The invention is applicable not only to cast ingots of the type ordinarily employed in large plate mill operations, but also to strip cast metal of various types including those produced by a variety of well-known processes.

The controlled hot rolling operation of the present invention may be applied to the metal in cast condition, with or without prior homogenizing, or may be conducted following initial rolling or other working of the metal at a lower temperature. Ordinarily the metal temperature at the conclusion of hot rolling will be low enough (typically about 550° F.) that an annealing operation is described prior to cold rolling. However, if the hot rolling is completed at a temperature in the annealing range a separate annealing operation may be obviated.

Cold rolling of the preconditioned metal may be extensive enough, in terms of the resulting reduction in thickness of the metal, to produce substantially "full hard" (-H19) temper, or may be controlled to achieve a selected intermediate temper, with or without the interposition of full or partial annealing in the course of or following cold rolling.

A further benefit of the present invention, independently of earing behavior, is the improved ductility which can be obtained. Thus, in cold rolling 3003 alloy to a final gage as thin as 0.0025 inch, a prior hot rolling operation at 1,060°–1,070° F. has been found successful for substantially eliminating edge cracking even during cold rolling from 0.021 inch to final gage without any prior annealing.

The following examples illustrate the presently preferred practices of the invention:

EXAMPLE I

In preparing aluminum sheet of an alloy conforming substantially to Aluminum Association specification 3004, using conventional mill equipment (including a 170 inch reversing mill for ingot breakdown purposes, a 130 inch reversing hot mill for reducing the slabbed ingot to an intermediate gage suitable for continuous hot rolling, a 120 inch 4-stand continuous hot mill for further gage reduction to product coilable reroll stock and a 5-stand continuous mill for cold rolling to final gage, with provision for recrystallization annealing treatment of the reroll stock prior to cold rolling), it has been found satisfactory to operate in the following manner:

a. providing an ingot of conventional size having, for example, a thickness of about 16–24 inches;

b. heating the ingot for homogenization purposes at a metal temperature of 1,025°–1,075° F., for about 12 hours;

c. stabilizing the ingot at 1,025° F. in preparation for initial ingot breakdown operations;

d. promptly reducing the ingot at a minimum input metal temperature of about 950° F. to a thickness of about 6 inches in the 170 inch mill, using heavy slow drafts to break down the cast structure, thereafter proceeding with further hot rolling in the 130 inch mill to a slab thickness of about 0.850 inch;

e. finishing the hot rolling sequence in the 120 inch continuous mill to a convenient reroll gage such as about 0.110 inch, the metal temperature at the conclusion of continuous hot rolling being about 550° F. or higher, typically about 560°–570° F. for this particular alloy;

f. annealing the reroll stock at 750°–800° F. for about 2 hours to effect recrystallization of the metal structure; and

g. cold rolling to final gage of about 0.017 inch in the 5-stand mill to produce a work hardened sheet of substantially -H19 temper.

Using this practice, the resulting sheet is found to have improved earing properties apparently resulting primarily from the initial high temperature breakdown procedure, the sheet being substantially free of 45° earing (i.e. only about 1.5 to 3.5%) in connection with subsequent drawing operations, and thereby being adapted for various drawing, cupping and related practices commonly involved in can-making operations.

For purposes of comparison, using essentially the same practices and procedures except for hot rolling the ingot at about 810° F., the final sheet product at 0.017 gage exhibited an unsatisfactory 45° earing characteristic of 7 to 9%.

EXAMPLE II

An ingot measuring 20" × 46" × 198" was produced from an aluminum base alloy containing:

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
.09	.48	.11	.98	1.44	.01	.04	.01	Bal.

After homogenizing for 12 hours at 1,025°–1,075° F. the ingot was processed in the following manner:

Hot rolled to 0.110 inch
1,000° F. into 170 inch breakdown mill
556° F. exit from 4-stand mill at 0.110 inch
Annealed at 0.110 inch 750°–800° F., 2 hour soak
Cold roll 0.110 inch – 0.013 inch (88% cold work)

Properties of the work hardened sheet included:

Tensile strength	45,800 psi
Yield strength	40,500 psi
% Elongation in 2 inches	4.0%
Earing (45°)	4.5%

Again, by way of comparison, an ingot of essentially the same composition was processed in like manner except for hot rolling initially at 850° F. without prior homogenizing. The resulting sheet exhibited the following properties:

Tensile strength	52,600–53,600 psi
Yield strength	46,000–46,900 psi
% Elongation in 2 inches	6–7%
Earing (45°)	9.2%

It will be noted that only half as much earing was found for the sheet rolled at 1,000° F. as for the sheet rolled at 850° F.

The method employed for determining earing properties described herein involves using a circular sheet specimen of about 58 mm. diameter and a punch diameter of 33 mm., to make a cup approximately 16 mm. deep, with 10W motor oil as lubricant and using just sufficient clamping force to prevent wrinkling. Percent earing is measured as the ratio of the peak-to-valley height of ear divided by the cup depth from its bottom to the valley.

The controlled hot rolling practices of the present invention are useful in conjunction with cold rolling operations which provide a reduction of approximately 50%, but reductions of 80% or more are preferred. The invention is particularly adapted for manufacturing can stock and other light-gage sheet products having a thickness of about 0.005–0.020 inch.

While presently preferred practices of the invention are described in the foregoing specification, it will be apparent that the invention may be otherwise variously embodied and practiced within the scope of the following claims.

What is claimed is:

1. In the art of making aluminum sheet suitable for drawing, cupping and similar operations, including can-making operations, the method of achieving improved forming characteristics of the sheet in work hardened condition, particularly as regards avoiding excessive 45° earing of the metal during subsequent drawing operations, which comprises:

hot rolling the metal in successive stages to produce reroll stock of an intermediate coilable thickness,

commencing said hot rolling at a metal temperature above 950° F.,

said temperature being selected to provide for preconditioning the metal structure as the hot rolling operation proceeds whereby subsequent cold rolling produces work hardened sheet of reduced 45° earing tendency compared to sheet prepared by hot rolling the metal initially at a lower temperature, and

cold rolling the metal from said intermediate thickness into work hardened sheet.

2. The method of claim **1** in which the metal is provided in the form of a cast ingot, including heating the ingot to homogenize the metal and hot rolling said ingot to produce a slab of intermediate thickness.

3. The method of claim **2** in which said hot rolling includes passing said slab through a multistand continuous hot mill to produce said reroll stock.

4. The method of claim **3** in which said hot rolling is completed at a metal temperature of approximately 550° F.

5. The method of claim **1** which includes annealing said reroll stock prior to cold rolling.

6. The method of claim **1** including a plurality of cold rolling passes.

7. The method of claim **1** in which said cold rolling is effective to produce work hardened sheet of substantially -H19 temper.

8. In the art of rolling aluminum, including hot rolling the metal into coilable reroll stock, the method which comprises:

commencing said hot rolling at a selected temperature above 950° F.,

continuing in successive stages to a reroll thickness on the order of 0.1 inch without reheating the metal between stages;

said hot rolling being effective for preconditioning the metal structure of said reroll stock whereby subsequent cold rolling produces work hardened sheet of improved ductility in -H19 temper, compared to sheet made in the same manner except for initially hot rolling the metal at a lower temperature in the range from 50° to 300° F. below the selected hot rolling temperature.

9. Aluminum reroll stock made by the method of claim **8.**

10. In the art of rolling aluminum, including casting the metal and hot rolling the metal casting, the method which comprises:

commencing said hot rolling above 950° F. at a metal temperature effective for preconditioning its plastic flow characteristic in work hardened temper;

continuing to reduce the metal thickness as the hot rolling operation proceeds to an intermediate coilable thickness; and

cold rolling the metal from said intermediate thickness into sheet having a thickness of about 0.005–0.020 inch, said sheet being adapted for drawing in its work hardened condition with less than 5% earing (45°).

11. The method of claim **10** including preheating the metal casting at about 1,025°–1,075° F.

12. The method of claim **10** wherein said cold rolling provides a reduction in thickness of at least 80%.

13. The method of claim **10** including a forming operation which comprises drawing the sheet in its work hardened condition without annealing the metal following said cold rolling.

14. In the art of rolling aluminum, including hot rolling an aluminum ingot to break down its cast structure and cold rolling the metal from an intermediate reroll thickness into sheet, the method of making cold rolled sheet of improved ductility which comprises:

commencing said hot rolling at an ingot temperature above 950° F.;

continuing from the initial ingot thickness to said intermediate reroll thickness in successive stages as the hot rolling operation proceeds;

annealing the metal at a reroll thickness on the order of 0.1 inch; and

cold rolling the metal from said reroll thickness to produce work hardened sheet of substantially -H19 temper.

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Dedication

3,802,931.—*Linton D. Bylund,* Richmond, Va. LOW-EARING CAN STOCK. Patent dated Apr. 9, 1974. Dedication filed Oct. 1, 1981, by the assignee, *Reynolds Metals Co.*

Hereby dedicates to the Public the entire term of said patent.

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