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NON-EARING ALUMINUM ALLOY SHEET

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ABSTRACT OF THE DISCLOSURE

Aluminum alloy sheet containing 4 to 5.5% magnesium, 0.2 to 0.7% manganese, the balance being essentially aluminum, in the state resulting from a cold rolling reduction which effects a reduction in the thickness of at least 85% and subsequent annealing, possesses a high level of strength together with the capability of being drawn into cups which exhibit substantially no earing.

BACKGROUND OF THE INVENTION

In recent years aluminum alloy sheet has found increasing acceptance in applications where it is drawn or deep drawn to form cup-like shells which are useful for containers among other things. In the drawing operation, as is known, the sheet is substantially deformed and often exhibits a scalloped appearance around the rim of the drawn shell. This effect is termed earing and the removal of these "ears" produces a substantial amount of scrap waste. There has been an increasing desire for aluminum alloy sheet material which is sufficiently workable to be deep drawn into cup-like shells without earing. A sheet is considered to exhibit substantially non-earing characteristics when drawn into a shell whose diameter is at least 40% less than that of the starting material from which it is drawn and the shell exhibits a maximum earing of not more than 3% of its depth. Further, it is highly desirable that in addition to this workability, the material exhibit a moderate or substantial strength level so that it can withstand forces and pressures to which a drawn shell may be subjected while employing a minimum of material. One application for such drawn cups is in the food and beverage container field. If an aluminum alloy sheet can be drawn into can-like containers with substantially no earing and the cans possess a moderate, as opposed to a low, strength level, this material is considered to have highly desirable properties.

DESCRIPTION OF THE INVENTION

Aluminum-magnesium-manganese alloy sheet as provided herein has a thickness of 0.008 to 0.032" and is composed of an alloy consisting essentially of 4 to 5.5% magnesium, 0.2 to 0.7 manganese, the balance being aluminum and incidental elements and impurities. The maximum amounts of impurities in the alloy are as follows: 0.2% copper, 0.4% iron, 0.3% silicon, 0.1% titanium, 0.2% chromium, other impurities being limited to 0.05% each and a total of 0.15%. In a preferred embodiment the manganese content is further restricted by relating such to magnesium content in accordance with the following relation:

$$\text{Percent } M_n = 1.700 - 0.9 \ln (\text{percent Mg}) \pm 0.1\%$$

When the manganese content is so restricted the sheet exhibits an optimum combination of formability and strength. Preferred limits for magnesium and manganese are, respectively, 4.2 to 4.8% and 0.25 to 0.5%.

For the sheet to perform as desired, it is essential that it be in the state resulting from a cold rolling reduction of at least 85%, and preferably at least 90%, of the thickness of the material before cold rolling followed by

a recrystallization of the grain structure which is effected by an annealing treatment. If a reduction substantially less than 85% is employed the resulting sheet will not exhibit the non-earing characteristics described herein. It is somewhat surprising in this connection that introducing a severe amount, 85% or more, of cold work into the sheet improves its formability in drawing operations. In performing the cold reduction it is preferred that the temperature of the sheet as it leaves the rolls not exceed 200° F. The use of water base lubricants is helpful in maintaining this temperature level. Annealing may be effected by heating the sheet to about 600° F. for a sufficient time for its internal structure to recrystallize. If desired, the strength of the annealed sheet can be increased, while not seriously impairing its non-earing characteristics, by a further or secondary cold reduction of up to 30% of the thickness of the annealed sheet.

The alloy composition may be provided as a continuously cast ingot which may be homogenized by heating for about 24 hours at a temperature of 800° F. or more but below the melting point. The ingot is then prepared for rolling and hot rolled to some intermediate thickness, typically about 0.15 inch, according to conventional hot rolling practice and may then be annealed by heating to about 700° F. This material is then cold rolled to a reduction of at least 85% and subsequently annealed.

In the fully annealed state the sheet exhibits a yield strength of 18,000 p.s.i. and a tensile strength of 41,000 p.s.i. together with an elongation of about 22% in 2 inches. After the secondary cold reduction of the annealed sheet it exhibits increased strength, the extent of the increase being dependent on the extent of the cold reduction. Referring to Table I there is listed the as rolled tensile properties for cold reductions of 10, 20 and 30%.

TABLE I

	Tensile strength, p.s.i.	Yield strength, p.s.i.	Elongation in 2 inches, percent
Reduction:			
10 percent	45,000	35,000	14
20 percent	49,000	41,000	10
30 percent	52,000	45,000	8

It can be seen that the annealed strength levels are increased quite appreciably by the secondary cold rolling. It is also highly significant that this strength can be imparted to the sheet without seriously diminishing the non-earing characteristic. If the secondary cold reduction goes beyond 30% of the thickness the non-earing characteristics are seriously impaired.

Another important property for sheet when used for making drawn shells, especially where intended to serve as food containers, is the strength level exhibited after a thermal exposure. In producing such containers the flat sheet may be covered with an organic coating which is baked at an elevated temperature of up to about 350° F. or more for about 10 or 15 minutes. On approximation of the maximum effects of such a thermal exposure can be achieved by heating the sheet for 20 minutes at 400° F. and then determining its properties. Cold rolled sheet samples such as those used in the tests depicted in Table I were exposed to a 400° F. temperature for 20 minutes and the tensile properties determined. These properties are indicated in Table II.

TABLE II

	Tensile strength, p.s.i.	Yield strength, p.s.i.	Elongation in 2 inches, percent
Reduction:			
10 percent	43,000	25,000	19
20 percent	45,000	29,000	15
30 percent	46,000	32,000	14

It can be seen in viewing Table II that the sheet retains rather substantial strength levels after such a thermal exposure which, when coupled with the sheets non-earing characteristic, likewise retained after the thermal exposure, renders the sheet highly suitable for the production of drawn cups or containers.

Drawing the sheet into cup-like shells increases the strength of the sheet because of the cold work inherent in the drawing process. Accordingly, the improved sheet exhibits highly useful strength levels when drawn into a shell. To illustrate, reference should be made to Table III where a comparison is made between the improved sheet and two commercial sheets which are popularly used in drawing cup-like shells because of their good strength and non-earing characteristics. In the table sheet A is the improved sheet. Sheet B is composed of known aluminum alloy 3004 which contains, nominally, 1.2% manganese and 1% magnesium. Sheet C is composed of known aluminum alloy 5052 which contains, nominally, 2.5% magnesium and 0.25% chromium. In the table two values are indicated for each property. The first value represents the condition as drawn and the second indicates the strength after a 20 minute exposure to a temperature of 400° F. The cups were No. 303 cups and were drawn from fully annealed material.

TABLE III

	Tensile strength, p.s.i.	Yield strength, p.s.i.	Elongation in 2 inches, percent
Sheet:			
A	49,000	40,000	7
	46,000	33,000	15
B	33,000	31,000	3
	33,000	28,000	5
C	40,000	35,000	4
	37,000	30,000	8

It is readily apparent from Table III that the improved sheet demonstrates somewhat higher strength than the other sheet products when drawn into cup-like shells.

From the foregoing it is readily apparent that the improved sheet provides a useful new material for use in drawing cup-like shells which are substantially free from earing. The drawn shells exhibit a higher strength level than those drawn from presently available non-earing commercial alloy sheet products.

While the invention has been described with particular references to preferred embodiments and practices, it is to be understood that the claims are intended to embrace any and all embodiments and practices as fall within the true scope and spirit of the invention.

What is claimed is:

1. A method of producing non-earing aluminum alloy sheet comprising:

(1) providing a body of aluminum alloy consisting essentially of 4 to 5.5% magnesium, 0.2 to 0.7% manganese, the balance being aluminum and impurities, the maximum amounts of said impurities being as follows: 0.2% copper, 0.4% iron, 0.3% silicon, 0.1% titanium, 0.2% chromium in the form of a wrought material suitable for cold rolling;

(2) cold rolling said wrought material to effect a reduction in its thickness of at least 85% to produce a sheet product having a thickness of 0.008 to 0.032 inch;

(3) annealing said sheet product to fully recrystallize its grain structure.

2. The method according to claim **1** wherein the annealed sheet product is further cold rolled to a reduction in thickness of up to 30%.

3. An aluminum-magnesium-manganese alloy sheet of 0.008 to 0.032 inch in thickness, the alloy consisting essentially of 4 to 5.5% magnesium, 0.2 to 0.7% manganese, the balance being aluminum and impurities, the maximum amounts of said impurities being as follows: 0.2% copper, 0.4% iron, 0.3% silicon, 0.1% titanium, 0.2% chromium, said sheet being in the condition resulting from a cold reduction of at least 85% to produce an extra hard internal structure followed by annealing to recrystallize said extra hard structure, the sheet being characterized by a tensile strength of 40,000 p.s.i., a yield strength of 18,000 p.s.i., an elongation of 20% together with substantial freedom from earing when drawn into a shell having a diameter at least 40% smaller than the starting material.

4. The sheet according to claim **3** wherein said annealed sheet has received a secondary cold reduction of up to 30%.

5. A method of producing non-earing aluminum alloy sheet comprising:

(1) providing a body of aluminum alloy consisting essentially of 4.2 to 4.8 magnesium, 0.25 to 0.7% manganese, the balance being aluminum and impurities, the maximum amounts of said impurities being as follows: 0.2% copper, 0.4% iron, 0.3% silicon, 0.1% titanium, 0.2% chromium, in the form of a wrought material suitable for cold rolling;

(2) cold rolling said wrought material to effect a reduction in its thickness of at least 90% to produce a sheet product having a thickness of 0.008 to 0.032 inch;

(3) annealing said sheet product to fully recrystallize its grain structure.

6. An aluminum-magnesium-manganese alloy sheet of 0.008 to 0.032 inch thickness, the alloy consisting essentially of 4.2 to 4.8 magnesium, 0.25 to 0.7% manganese, the balance being aluminum and impurities, the maximum amounts of said impurities being as follows: 0.2% copper, 0.4% iron, 0.3% silicon, 0.1% titanium, 0.2% chromium, said sheet being in the condition resulting from a cold reduction of at least 90% to produce an extra hard internal structure followed by annealing to recrystallize said extra hard structure, the sheet being characterized by a tensile strength of 40,000 p.s.i., a yield strength of 18,000 p.s.i., an elongation of 20% together with substantial freedom from earing when drawn into a shell having a diameter at least 40% smaller than the starting material.

7. The method according to claim **5** wherein the annealed sheet product is further cold rolled to a reduction in thickness of up to 30%.

8. The sheet according to claim **6** wherein said annealed sheet has received a secondary cold reduction of up to 30%.

References Cited

UNITED STATES PATENTS

2,245,166	6/1941	Stroup	75—147
2,841,512	7/1958	Cooper	75—147
3,232,796	2/1966	Anderson	148—11.5
3,359,085	12/1967	Anderson	148—11.5

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