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ALUMINUM ALLOY SHEET

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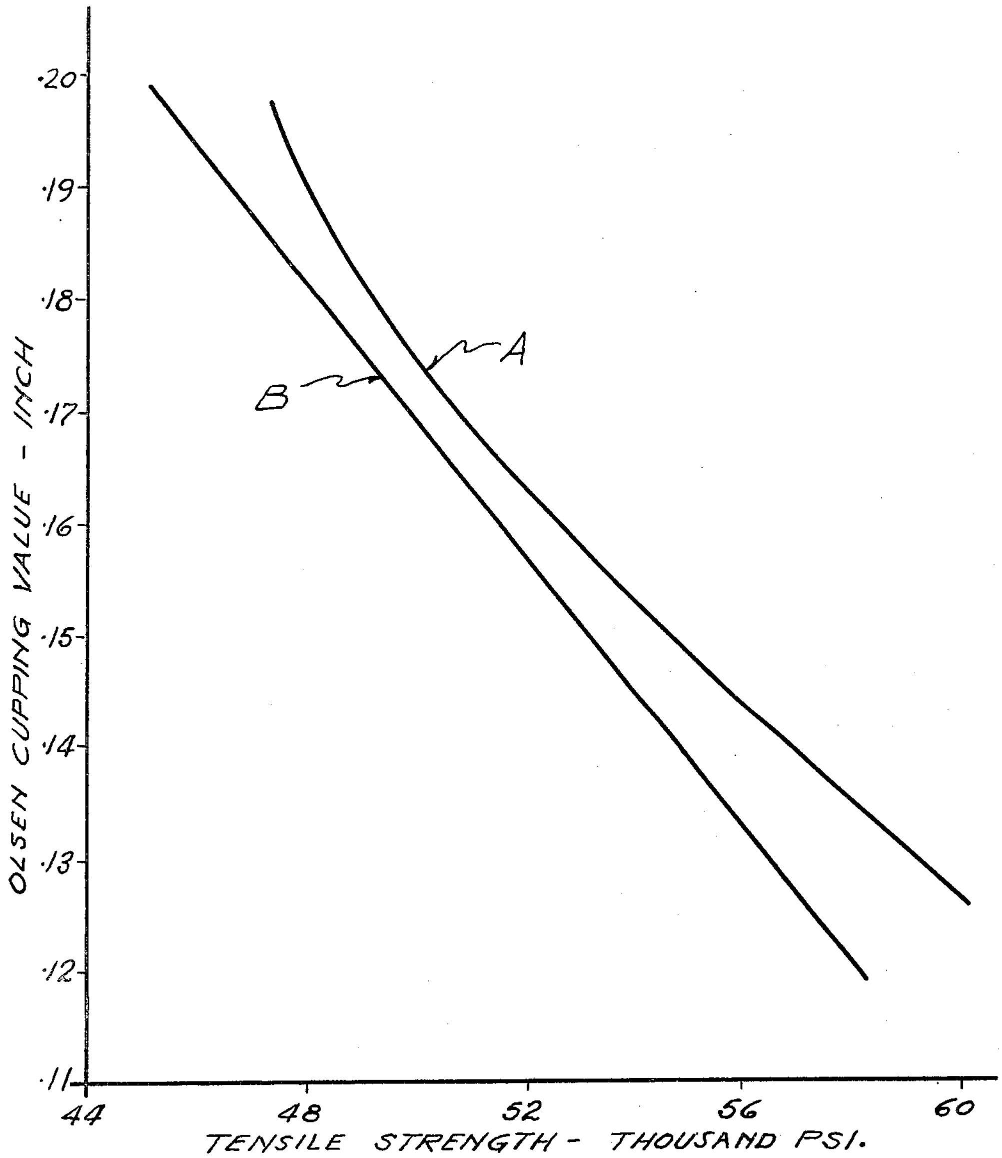

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3,502,448
ALUMINUM ALLOY SHEET

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ABSTRACT OF THE DISCLOSURE

Work hardened aluminum alloy sheet, 0.008 to 0.017 inch thick, in the extra hard temper and containing 4 to 5.5% magnesium, 0.2 to 0.7% manganese, the balance being essentially aluminum, possesses a combination of strength and formability which make it especially useful for aluminum can ends. To achieve such, the manganese content is related to the magnesium content according to the following relation:

Percent Mn=1.700 —0.9 (1n percent Mg)±0.15%

The extra hard temper is achieved by cold rolling to effect a reduction in thickness of at least 85%.

BACKGROUND OF THE INVENTION

In recent years aluminum alloy sheet has found increasing acceptance in applications involving its use as an end on a can, or the like, for beverages, food and other goods. These can ends usually include some sort of easy open feature such as the integral drawn rivet pull tab feature described in U.S. Patent 3,191,797. This type of feature is one of the prime reasons for the increasingly widespread use of aluminum sheet in can ends but also creates certain problems in selecting a suitable material. First, the can end must have sufficient strength to safely contain the material within the can, and this strength must be retained after exposures to the baking temperatures employed in curing the coatings applied to the can ends. Second, the material must be sufficiently workable to be fashioned into an integral rivet easy open type can end. For instance, referring to the above-mentioned U.S. Patent 3,191,797, it becomes immediately apparent that a can end is subjected to a rather substantial deformation in forming the integral rivet employed to secure the easy open tab to the can end. While several aluminum alloy sheet compositions might have sufficient strength before and after any baking operations, many lack the required formability. Conversely, while some have the required formability, they often exhibit a strength level so low as to require an economically excessive thickness to provide a sufficiently strong can end. It is generally desired to maintain a rejection level of not more than five failures in 10,000 easy open can end rivet forming operations. This is a rather severe formability requirement for the can end material which also must be strong enough to be of sufficiently thin gauge to economically compete with other materials.

STATEMENT OF THE INVENTION

Work hardened aluminum-magnesium-manganese alloy sheet as provided herein has a thickness of 0.008 to 0.017 inch 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, all other impurities being limited to 0.05% each and a total of 0.15%. It is

highly preferred that the total of all the impurities not exceed 0.5%. The preferred range for magnesium is 4.2 to 4.8% and for manganese it is 0.25 to 0.5%. The percentages are by weight. In addition to the aforementioned composition limits, it is essential that the manganese content be further restricted by relating such to the magnesium content in accordance with the following relation:

Percent Mn=1.700 —0.9 (1n percent Mg)±0.15%

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% of the thickness of material in the recrystallized state to provide an extra hard internal structure. The sheet in this state exhibits tensile and yield strengths of, respectively, 57,000 p.s.i. and 53,000 p.s.i., an elongation, in 2 inches, of 3% or more together with an Olsen cupping value of 0.14 inch. Further, after an exposure of 20 minutes to a baking oven temperature of 400° F., the sheet is characterized by tensile and yield strengths of, respectively, 53,000 and 45,000 p.s.i., an elongation of 8% and an Olsen cupping value of 0.16 inch.

DETAILED DESCRIPTION

A further understanding of the invention will proceed from this detailed description and from the drawing which is a plot demonstrating the improved strength and workability of the improved alloy.

The composition limits mentioned in the preceding paragraph must be closely followed in order to achieve the combination of strength and workability required which characterizes the improved sheet.

If the manganese content exceeds that established by the equation, the formability falls below that at which integral rivet easy open can ends can be consistently manufactured on a commercial scale. If it falls below that established by the equation, the strength is decreased below the level contemplated by the invention.

The alloy composition as set forth herein may be provided as a continuous cast ingot. The ingot may be homogenized by heating for about 24 hours at a temperature of at least 800° F. but below the melting point. The ingot is then prepared for rolling and hot rolled to some intermediate thickness, usually about 0.15 inch, according to conventional hot rolling practice and may then be annealed by heating to about 600° F. for a period of time sufficient to recrystallize the internal structure. Next, this material is cold rolled to effect a reduction in thickness of at least 85%, and preferably 90% or more to provide sheet ranging in thickness, 0.008 to 0.015 inch. 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. This cold reduction imparts to the sheet and extremely hard temper. While the sheet in this temper is characterized by a high degree of strength, it also exhibits a very good degree of formability such that integral rivets can be drawn as shown in the various patents, such as U.S. 3,191,797, covering this type of easy open feature. It is also highly significant that sufficient strength is retained after a thermal exposure comparable to that encountered in the production of can ends where a coating is applied to the sheet and baked. A thermal exposure of 400° F. for 20 minutes is a conservative approximation of the more severe baking treatments normally encountered in can end fabrication.

As indicated earlier, a combination of strength and formability, both before and after thermal exposures of 20 minutes at 400° F., is desired in can end sheet material. Alloy sheet of similar composition and temper fall short of the improved sheet in the combination of workability and strength.

To illustrate the strength of the improved sheet, it is compared to a sheet product of similar composition. The respective compositions are listed in Table I in which sheet A is in accordance herewith. Sheet B is the product presently employed by the can industry in making easy open type can ends.

TABLE I

Sheet	Mg	Mn	Fe	Si	Cu	Cr	Ti	Zn
A	4.54	0.37	0.21	0.10	0.01	0.02	0.02	0.01
B	4.45	0.01	0.19	0.08	0.02	0.00	0.01	0.01

Each alloy was continuously cast to provide an ingot which was homogenized by heating for 24 hours at a temperature of 900° F. after which it was brought to a temperature of about 750° F. and then hot rolled to provide plate approximately 0.15 inch thick. This plate was then annealed at 600° F. to recrystallize the grain structure after which it was cold rolled without any intermediate annealing to sheet 0.013 inch thick. This cold reduction of over 90% imparted to the sheet an extremely cold hard temper. Tensile test specimens were removed from the sheet and, on testing, indicated the average tensile data set forth in Table II. Also included in the Table is an Olsen cupping value which is a measure of the formability of the sheet. This test is widely recognized in the industry and is described in the Procedings of ASTM 20, Part II, p. 398, 1920.

TABLE II

Sheet	Tensile strength, p.s.i.	Yield strength, p.s.i.	Elongation in 2 inches, percent	Olsen cupping value
A	57,000	53,000	4	0.14
B	52,000	48,000	4	0.155

It can be seen in Table II that the improved sheet exhibits a significant improvement in strength, about 10%, over sheet B although the latter demonstrates a higher Olsen cupping value.

Additional samples of sheets A and B were exposed to a temperature of 400° F. for 20 minutes, an approximation of the conditions encountered by the sheet when an organic coating is applied thereto and cured in a baking oven. It is after such an exposure that the properties of the sheet are of great importance since these are the properties which will be exhibited by the sheet when provided as a can end. The average properties, strength and Olsen cupping, for sheets A and B after the thermal exposure, are listed in Table III.

TABLE III

Sheet	Tensile strength, p.s.i.	Yield strength, p.s.i.	Elongation in 2 inches, percent	Olsen cupping value
A	53,000	45,000	8	0.16
B	48,000	40,000	8	0.18

It can be seen in Table III that the improved sheet, sheet A, continues to demonstrate an approximately 10% higher strength level than sheet B. While the Olsen cupping value for sheet A is lower than that of sheet B, it has proven adequate in forming integral rivets on can ends.

The combination of both superior strength and formability of the improved sheet is best demonstrated in the figure which is a chart plotting the tensile strength versus Olsen cupping value for sheets A and B. It becomes immediately apparent in the figures that for any given

level of strength, the improved sheet, sheet A, is characterized by a significantly higher Olsen cupping value than sheet B.

In addition to standard tensile tests, another measure of the strength capacity of a sheet to serve as a can end is the pressure deflection characteristic. This characteristic is determined by providing a beverage can with its end fashioned from the sheet being tested. Pressure is applied within the can and gradually increased until the can end buckles and plastically deforms. The pressure at which the can end buckles is then designated as the buckle pressure. In buckling tests comparing sheets A and B, it has been found that 0.0135 inch thick can ends of sheet A withstand the same pressure as 0.0145 inch thick can ends of sheet B, which is the sheet currently employed widely in easy open beer can ends. This represents a rather significant savings in material.

From the foregoing it is apparent that the improved sheet provides a useful new material for use in integral rivet easy open type can ends. It demonstrates a clear improvement in combining workability and strength such that such can ends can now be fashioned from a substantially thinner sheet gauge.

What is claimed is:

1. A work hardened aluminum-magnesium-manganese alloy sheet of 0.008 to 0.017 inch in thickness that has received a reduction in thickness of at least 85% by cold rolling to provide an extra hard internal structure, said aluminum alloy consisting essentially of 4 to 5.5% magnesium, 0.2 to 0.7% manganese, the manganese content being related to the magnesium content in accordance with the following:

$$\text{percent Mn} = 1.700 - 0.9 \text{ (ln percent Mg)} \pm 0.15\%$$

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, all other impurities being limited to 0.05% each and a total of 0.15%, said sheet being characterized in said extra hard condition by a tensile strength of 57,000 p.s.i., a yield strength of 53,000 p.s.i. and an elongation, in 2 inches of 3%, together with an Olsen cupping value of 0.14 inch and further characterized after an exposure of up to 20 minutes to a temperature of up to 400° F. by a tensile strength of 53,000 p.s.i., a yield strength of 45,000 p.s.i., an elongation of 8% and an Olsen cupping value of 0.16 inch.

2. The sheet in accordance with claim 1 which has received a cold reduction of at least 90%.

3. The sheet in accordance with claim 1 which contains 4.2 to 4.8% magnesium and 0.25 to 0.5% manganese.

4. The sheet in accordance with claim 1 in the state resulting from a thermal exposure.

References Cited

UNITED STATES PATENTS

2,601,206	6/1952	Fritzlen	75—147
3,187,428	6/1965	English	148—11.5

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