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SUPERPLASTIC ZINC/ALUMINIUM ALLOYS

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ABSTRACT OF THE DISCLOSURE

In a method of producing superplastic zinc/aluminium alloy sheet by rolling a body of alloy consisting predominantly of zinc and aluminium and exhibiting the zinc/aluminium eutectic structure, the improvement in combination therewith comprising rolling the body of alloy at a temperature between 20 and 200° C. to produce a sheet whose thickness is reduced by between 50% and 99% based on the starting thickness. The body of alloy may be first rolled in a preliminary stage at a temperature between 200 and 350° C. to achieve between 40% and 99% reduction based on starting thickness. The alloy sheet produced may be subsequently formed at a temperature of 275 to 325° C. to a desired shape.

BACKGROUND OF THE INVENTION

This invention relates to superplastic alloys of zinc and aluminium. Superplastic alloys are alloys which can undergo large deformations at low flow stresses and relatively slow strain rates.

Superplastic zinc/aluminium alloys based upon the eutectoid composition at 22 wt. percent of aluminium are known. They are produced by heat treatment of the alloy above the eutectoid temperature (275° C.) to homogenise the alloy structure, followed by cooling (particularly by quenching), and working at a lower temperature to develop a fine equiaxed grain structure.

SUMMARY OF THE INVENTION

The present invention particularly relates to a method for making superplastic zinc alloys based upon those alloys which at least initially include the Zn/Al eutectic structure.

The invention consists in a method of producing superplastic zinc/aluminium alloy sheet, comprising rolling at a temperature between 20 and 200° C. a body of alloy consisting predominantly of zinc and aluminium and exhibiting the zinc/aluminium eutectic structure to produce a sheet having a thickness between 1% and 50% of the

starting thickness (i.e. a reduction of between 50% and 99% based on starting thickness).

The alloy is preferably reduced by at least 70% based on starting thickness by the method according to the previous paragraph, and more preferably by between 75 and 95%.

The body of alloy may be either in the as cast state or as rolled in excess of 200° C. The process may be carried out by rolling the alloy as cast, without any intermediate heat-treatment.

The alloy may consist of zinc and aluminium alone, containing only incidental impurities. The eutectic structure is shown at from 1% to 19.8% aluminium, the eutectic composition being 5% aluminium. Alternatively, one or more further alloying elements may be present provided that the eutectic structure is not destroyed. Examples of these are copper in an amount of up to 5% by weight, preferably only up to 1%, and magnesium in an amount of up to 1% by weight, preferably only up to 0.25%. Such additions affect strength, hardness and creep-resistance. The body of the alloy may be chill-cast or continuously cast rolling stock.

The initial thickness of the body to be treated may vary but a range from 0.5 to 6 inches is preferred.

It is preferred, especially where the alloy contains one or more further alloying constituents in addition to zinc and aluminium, to roll the alloy in a preliminary stage at a temperature between 200 and 350° C. to achieve between 40% and 99% reduction based on starting thickness, and more preferably between 40% and 60% reduction. This preliminary stage is hereafter referred to as initial hot rolling.

The percentage reduction in both the preliminary stage of initial hot rolling and in the stage of cooler rolling according to the invention is based on the thickness at the beginning of that stage.

The advantages of this initial hot rolling appear to be that surface and internal defects of the cast alloy are healed up, cracking is reduced or eliminated at the subsequent cooler rolling, and rolling loads are minimised to increase the economy of the process.

It appears that the working of the alloy deforms the lamellar eutectic and any primary phases present into a fine equiaxed grain structure.

The invention also consists in a body of superplastic zinc/aluminium alloy sheet when manufactured by the method according to the invention.

DETAILED DESCRIPTION

The invention will be further described by way of example only, with reference to the table given below:

TABLE 11

	Alloy, percent				Processing				
					Hot rolling		Finish rolling		
	Al	Cu	Mg	Cast	Percent reduction	Temp. ° C.	Percent reduction	Temp., ° C.	VFT
1	5.5	0.5	0.1	CM	50	250	80	100	205
2	5.5	0.5	0.1	C	50	250	87	100	80
3	5.3			C			93	100	125
4	5.3			C	50	300	87	100	180
5	5.0	0.13		C	50	300	87	23	220
6	5.2	0.15	0.03	DCC	50	300	87	100	110
7	5.2	0.15	0.03	DCC	50	250	87	23	90
8	5.2	0.15	0.03	DCC	50	200	87	23	80
9	5.1		0.07	C	50	300	87	23	100
10	5.2	0.15	0.10	DCC	50	300	87	100	70
11	6.9	3.7		C	50	250	87	100	105
12	12.2			C	50	300	87	100	335
13	5.0	0.49	0.1	G	80	300	87	100	265
14	5.0	1.0		C	50	300	87	23	235
15	5.2	0.15	0.03	DCC	50	300	87	23	90

In the Table, the metal percentages are by weight of alloy, the balance in all cases being zinc.

The alloy stock is either ¾ inch chill cast (C), a ¾ inch direct-chill continuous casting (DCC) or 2 inch production trial chill cast (G). Material CM was ¾ inch chill cast material machined to ½ inch thickness before working.

Percentage reduction is based in all cases on the thickness at the beginning of that stage.

VFT signifies vacuum forming time, measured in seconds as for a sheet nominally 0.05 inches in thickness at 300° C. This is a known measure of superplasticity and is carried out by (i) clamping a disc of alloy over the end of a tube of internal diameter 3.2 inches maintained in a thermostated air enclosure, (ii) applying a differential pressure of one atmosphere across the disc, and (iii) measuring the time taken to form the disc into a dome of 1.15 inches depth, i.e. to increase the relevant area by 50%. A suitable probe is used to establish when the relevant condition is reached. While no limitation on the method according to the invention is intended in terms of the VFT achieved, it has been found that VFT values of less than about 300 seconds are of most general usefulness.

While superplasticity is a complex phenomenon which can be greatly affected by variations in time, temperature, composition and processing, and exactly reproducible results can only be obtained with difficulty, a number of general observations may be made by comparison between the above examples, as follows:

(a) The VFT is reduced by increasing the extent of finish rolling. This is shown most clearly from a comparison of Examples 1 and 2, but is also indicated from Examples 3 and 4.

(b) The VFT is reduced by decreasing the finish-rolling temperature to within the range employed in the method according to the invention. This is shown from a comparison of Example 1a, given in comparative table 1A below and Example 3 of table 1 (no initial hot rolling), and of Example 2a of table 1A and Example 5 of table 1 (also showing that finish rolling is the governing factor). Example 6 compared with Example 7 or 8 also follows the above pattern.

TABLE 1A

	Alloy, percent				Processing: Finish rolling: Percent reduction	Processing: Finish rolling: Temp., °C.	VFT
	Al	Cu	Mg	Cast			
1a	5.0			C	93	350	350
2a	5.0	0.13		C	93	300	405
3a	5.0	1.0		C	93	300	640

The Examples given in the above Table are given for the purposes of comparison only, and are outside the scope of the present invention.

(c) The VFT is reduced by decreasing the initial hot rolling temperature. This is best shown by comparing those examples where the finish rolling is effected to 87% at 23° C., that is Examples 7 and 8. Generally, the lower the initial hot rolling temperature the lower the VFT. Similar conclusions can be tentatively drawn from those examples where finish rolling is effected to 87% at 100° C. Clearly starting dimensions, casting methods, and alloy compositions are also variables which may have some influence on vacuum-forming-times.

(d) The VFT can be reduced by starting with as fine a cast structure as possible and so assisting the working processes in achieving a fine grain structure. In the examples given the cast structure becomes finer in the sequence from the 2 inch chill cast production trial to the ¾ inch chill cast to the ¾ inch direct chill continuous casting.

(e) The lower the working temperature within the range 20°–200° C., the lower the VFT (compare Examples 6 and 15 of Table 1), although problems of cracking may emerge at temperatures as low as 20° C.– 50° C. 100° C. is, for this reason, the preferred working temperature.

Composition has a more complex effect. It may affect the fineness of the cast structure and, more important, may alter the eutectic composition, i.e. the level of aluminium necessary to achieve a completely eutectic structure.

Generally it is desirable to start with a completely eutectic structure in order to achieve the minimum VFT, for example contrast Examples 4 and 12. The complete eutectic structure occurs at 5% Al in the binary alloy but an addition, for example of Cu (to increase strength), increases the necessary Al level. Therefore additions to a 5% Al alloy may increase the VFT. If required, these effects may be taken into account by suitable modification of the Al level to compensate for the effects of additions on the eutectic composition, for example alloys 2 and 11.

When the above alloys are to be used in subsequent sheet-forming operations, the useful forming temperature range is from 200° C. to the melting point. However, since forming is slower at lower temperatures and since structural stability deteriorates at higher temperatures, the preferred forming-temperature range is from 275° to 325° C. It will be appreciated that the additional step of subsequently forming the superplastic alloy, together with the formed bodies so produced, also constitutes an aspect of the present invention.

When the alloys are formed in this fashion above 275° C. there appear to be advantages over the known eutectoid alloys in that on air or furnace cooling from above 275° C. the aluminium-rich phase present transforms to a lamellar Zn/Al structure and the alloys becomue considerably more creep-resistant, as Table 2 below shows. Other properties such as strength, hardness and bend ductility may improve as well but these depend to some extent upon composition and processing history.

TABLE 2

	Alloy properties: U.T.S.[a] A	U.T.S.[a] B	Hardness [b] A	Hardness [b] B	Flow stress [c]	Minimum creep rate [d] A	Minimum creep rate [d] B
3	21,400		38			9.8×10^{-1}	
4	25,600		38			5.7×10^{-1}	1×10^{-2}
5	23,200	30,750	39	63	1,250	4×10^{-1}	1.3×10^{-3}
6	53,800	50,150	97	110		2.7×10^{-3}	1.9×10^{-4}
9	47,400	43,100	89	86	650	7.3×10^{-3}	3.3×10^{-4}
10	52,850	51,400	97	110		6×10^{-3}	1.4×10^{-4}
11	36,450	51,550	74		900	2.6×10^{-2}	1.1×10^{-3}
12	25,700	33,450	48	62		1.4×10^{-1}	2×10^{-2}
13	55,650		93	104	1,350	1.6×10^{-3}	1×10^{-4}
14	35,600	44,000	55	95	1,600	2.5×10^{-2}	

[a] Parallel to rolling direction at 23° C., 0.1 min.$^{-1}$ (p.s.i.).
[b] 5 kg. load for 20 seconds (V.P.N.).
[c] Parallel to rolling direction at 300° C., 0.2 bin.$^{-1}$ (p.s.i.).
[d] Parallel to rolling direction at 23° C. and 5,000 p.s.i. (percent per hour).

NOTE.—A=As rolled; B=After simulated forming treatment, i.e., 30 minutes at 300° C. and air cooled.

The invention will be still further described with reference to the following example.

A zinc-based alloy having the following composition; 5.5% Al, 0.57% Cu, 0.009% Fe, 0.003% Pb, 0.001% Cd, remainder Zn was cast on a Hazelett continuous casting machine to give a strip of 0.5 inches thickness and 40 inches width, the total weight of the strip being 5 tons. This strip was rolled at 240° C. (hot rolling) to reduce its thickness by 44% to 0.28 inches.

Samples of the hot-holled sheet were rolled as follows:

(1) 0.28 inches at 100° C. to 0.072 inches (74% reduction)

(2) 0.28 inches at 100° C. to 0.051 inches (82% reduction)

(3) 0.28 inches at 100° C. to 0.028 inches (90% reduction)

Vacuum forming tests were carried out, by the method described above, at 300° C. and gave the following results:

	Seconds
(1) 0.072 inches	255
(2) 0.051 inches	95
(3) 0.028 inches	30

We claim:

1. A method of producing superplastic zinc/aluminium alloy sheet from a body of alloy consisting essentially of zinc and aluminium, the amount of aluminium being from 1% to 19.8% by weight, the amount of any copper present as a further alloying element being up to 1% by weight, and the amount of any magnesium present as a further alloying element being up to 1% by weight, whereby the alloy exhibits the zinc/aluminum eutectic structure, said method comprising finish rolling said body of alloy at a temperature between 20 and 200° C. to produce a sheet whose thickness is reduced by between 50% and 99% based on the starting thickness.

2. A method as claimed in claim **1**, wherein the alloy is reduced by at least 70% based on starting thickness.

3. A method as claimed in claim **2**, wherein the alloy is reduced by between 75% and 95% based on starting thickness.

4. A method as claimed in claim **1** wherein the finish rolling is carried out at 100° C.

5. A method as claimed in claim **1** wherein the initial thickness of the body of alloy is between 0.5 and 6 inches.

6. A method as claimed in claim **1** further comprising hot rolling the body of alloy in a preliminary stage at a temperature between 200 and 350° C. to achieve between 40% and 99% reduction based on starting thickness.

7. A method as claimed in claim **6** wherein the alloy is reduced by between 40% and 60% based on starting thickness.

8. A method as claimed in claim **1** wherein the alloy contains up to 0.25% by weight of magnesium.

9. A method as claimed in claim **1** further comprising subsequently forming the alloy sheet at a temperature of 275 to 325° C., to a desired shape.

References Cited

UNITED STATES PATENTS

3,632,454	1/1972	Marshall et al.	148—11.5 R
3,676,115	7/1972	Hare et al.	148—115 R
3,340,101	9/1967	Fields, Jr. et al.	148—11.5 R
3,420,717	1/1969	Fields, Jr. et al.	148—11.5 R

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