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High Strength 3xxx Series Aluminum Alloys With High Recycled Content Produced By Continuous Casting

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HIGH STRENGTH 3XXX SERIES ALUMINUM ALLOYS WITH HIGH RECYCLED CONTENT PRODUCED BY CONTINUOUS CASTING

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Described herein are 3xxx series aluminum alloys obtained from aluminum scrap containing high levels of iron and silicon. The alloys are suitable for the production of various containers, can bodies, as well as building and industrial products, and method of manufacturing them.

High performance alloys such as AA3104, which are used in can bodies, normally have low levels of iron and silicon. Even when the maximum amount of iron allowed is 0.8 wt. % by weight and the maximum amount of allowed silicon is 0.6 wt. %, these amounts are typically reduced to about 0.4 wt. % iron and 0.2 wt. % silicon to meet the mechanical strength and earing requirements. Attempts to use higher amounts of iron and silicon in 3xxx series aluminum alloys have been unsuccessful because by increasing the iron content, more iron remains in solution and increases the loads during metal processing to final thickness. High iron also produces large numbers of coarse FeAl-type particles that are hard to break during subsequent rolling processes.

The methods described herein use continuous casting to produce high performance 3xxx series alloys with >0.5% iron and >0.3% silicon, along with high amounts of magnesium and manganese. By using continuous casting, one can achieve a process with high cooling rates and can break up iron-containing intermetallic particles. Additionally, the hot band can be cold rolled to final gauge without the need for any intermediate annealing.

In the method described herein and as depicted in Figure 1, the alloy is continuously cast to produce a slab. The slab is preheated at temperatures between 500 °C to 570 °C for 0 to 6 hours, which includes a single step or a two-step heating process at temperatures described herein. The material is then hot rolled to 2 mm gauge. The hot band at 2 mm gauge is then cold rolled to a lower gauge depending on the end application. For example, the hot band can be cold rolled to about 0.12 mm if the material is to be used as container stock, or to about 0.25 mm if the material is to be used as can body stock. The performance of these lab-processed materials meet the current production specifications for both container and can body stock. The best combination of strength and elongation was achieved through a two-step high temperature heating (500 °C /570 °C). As shown in the example below, continuously cast material performs similarly to direct chill (DC) cast material. In particular, several cans were formed successfully without any tear off or other common defects that usually occur in DC cast material.

In summary, by having the high levels of iron and silicon in 3xxx series aluminum alloys, it has been found that adequate silicon is left in solution to remove, at the time of pre-heating, any iron that is not precipitated out during the casting operation. By using the CC process, the anisotropy problem is successfully resolved while allowing a composition that includes high levels of iron and silicon. The methods described herein can produce superior performing material with high strength and better formability compared to traditional hot rolled and cold rolled DC cast alloys.

Example 1

A traditional AA3104 sample for use as container stock was continuously cast (Sample ID 1142 in Table 1), along with a high-recycle content AA3104 sample for use as container stock (Sample ID 1201 in Table 1). An AA3104 sample for use as can body stock was also continuously cast (Sample ID 1200). Material from a DC casting production was lab rolled for direct comparison (DC in Table 1). In Table 1, all values are in weight percent, with up to 0.15 wt. % impurities (0.05 wt. % or less for each impurity) and the remainder Al.

Table 1: Chemical Compositions of AA3104 Variants

Sample ID	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Cr**	**Ti**	**Zn**
1142	0.32	0.51	0.15	0.86	0.88	-	0.02	-
1200	0.27	0.54	0.17	0.86	1.04	0.020	0.020	0.11
1201	0.50	0.62	0.20	0.92	1.10	0.049	0.035	0.23
DC	0.33	0.54	0.15	0.94	1.07	0.02	0.02	0.25

All variants were further processed to final gauge following the hot and cold rolling process paths shown in Figure 1. Depending on the final product requirements, the cold rolled material was tested in fully hardened temper (H19), H23 temper, and/or fully softened ‘O’ temper. Sample ID 1142, with nominal composition levels, had better elongations compared to Sample ID 1201. The properties of both materials (Sample ID 1142 and Sample ID 1201) were comparable to the DC AA3104 material. The mechanical properties, including the yield strength (Y.S.), ultimate tensile strength (UTS), and elongation (EI) are shown below in Table 2.

Table 2: Mechanical Properties for Samples 1142, 1201 and 1200 at final gauge processed at different preheat temperatures

Product	**Final Temper**	**Sample ID**	**Preheat Temperature (°C)**	**Y.S. (MPa)**	**UTS (MPa)**	**EI (%)**
Container Stock	H19	1142	500/550	285	298	2.1
			500/570	287	299	2.1
		1201	500/550	312	332	2.1
			500/570	310	324	1.6
		DC	580	275	302	4.7
	H23	1142	500/550	198	226	8.8
			500/570	200	228	9.0
		1201	500/550	212	239	7.0
			500/570	213	238	7.4
		DC	580	166	220	10.4
	O	1142	500/550	64	165	15.0
			500/570	64	166	14.9
		1201	500/550	88	179	8.7
			500/570	71	172	12.3
		DC	580	73	181	16.0
Can body Stock (CBS)	H19	1200	500/550	299	309	2.2
			500/570	277	304	4.5
		DC	590	275	302	4.7

Based on the mechanical properties and microstructural characterization, the following conclusions were drawn. It was observed that there is not huge difference in strength and elongation between the preheat variants (i.e., the one-step preheat and the two-step preheat variants) in O temper. For the can body stock (CBS) material, both 550 °C and 570 °C preheated samples showed the presence of Al_6(FeMn) particles, whereas the DC material did not. This result is likely due to the higher cooling rate of continuous casting as compared to direct chill casting. The continuously cast material preheated at 570 °C contained a slightly higher number density of particles and the total volume fraction of constituent particles was high as well.

For Sample ID 1142, the material that was preheated at 550 °C contained Al_6(FeMn) particles, while the material that was preheated at 570 °C did not contain these particles. Sample ID 1201 contained Al_6(FeMn) particles for both conditions, but the number density of these particles was much lesser than Sample ID 1142 preheated at 550 °C.

The volume fraction of constituent particles was high at higher temperatures. At higher preheat temperatures, Mg_2Si precipitates dissolved while the precipitation of dispersoids continued. Primary constituent particles spheroidized and coarsened during high temperature preheating. Some constituent particles of $Al_6(FeMn)$ may have transformed to alpha-Al(FeMn)Si during high temperature preheating.

Increases in Fe and Si will usually increase the volume fraction of coarse constituent particles, but the difference was very insignificant between Sample ID 1201 (high Fe, Si) and Sample ID 1142. Sample ID 1142 preheated at 570 °C contained coarser dispersoids compared to Sample ID 1201. The volume fraction of dispersoids was high in Sample ID 1201 in both cast + preheat and hot rolled conditions.

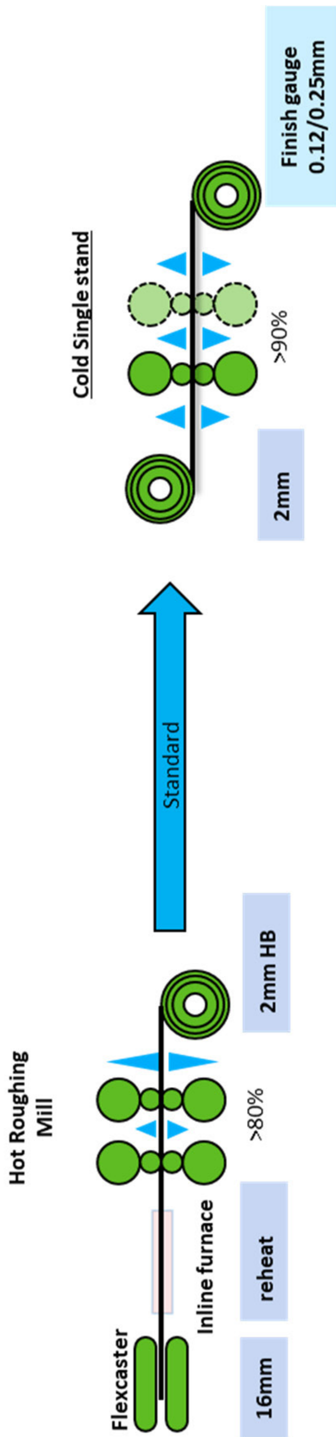

Figure 1 – Processing Route