

# The effect of Mn content on the texture of aluminium alloys in cold rolled and annealed state

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**Abstract.** The crystallographic texture greatly influences the properties of the cold rolled and hot rolled semi-products. As semi-products undergo further shaping (and heat treatment) before reaching their final condition, it is important to know their crystallographic texture. During our research, three different alloy aluminium alloys were tested (3003, 3103, unalloyed Al sheet) with different Mn content. In the first step the initial hot-rolled sheets were cold rolled to ~1 mm thickness without intermediate annealing. In the second step the sheets were cold rolled to 3 mm and annealed. In parallel, an intermediate annealing was applied at ~3 mm thickness for the 3103 alloy and subsequently cold rolled to 1 mm and annealed. The annealings were performed at 300°C for 3 hours in an air furnace. The resulting textures are characterized by the volume fractions of the main texture components, which were calculated from the orientation distribution function (ODF). The dominant texture components were determined for the different alloys in different states.

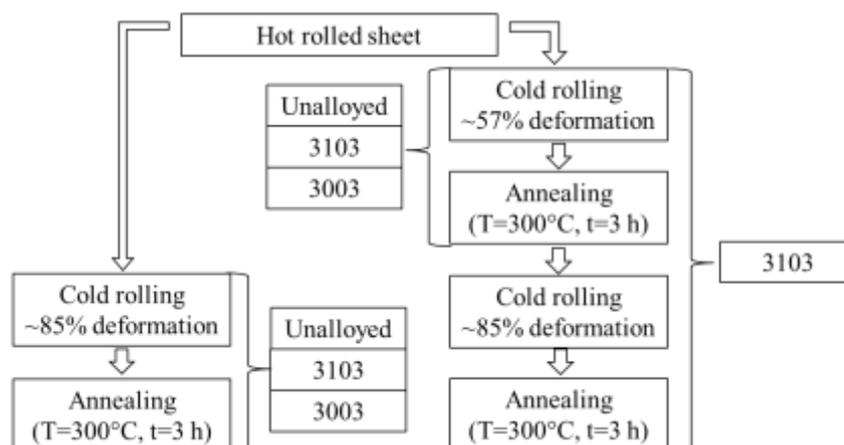
## 1. Introduction

When some fraction of the grains within a polycrystalline metallic structure is oriented in one or more preferred directions, the crystal structure is called textured. The isotropy of the macroscopic properties depend on the texture (for example Young's modulus, Poisson's ratio, formability, magnetic, electric properties etc.) [1, 2]. Thus, texture greatly influences the formability of semi-products therefore knowing the crystallographic texture is essential to. In most cases, the rolling process is followed by an annealing heat treatment. After improper annealing, the deformation texture may be preserved, furthermore, it can even be strengthened. For other cases, recrystallization texture can be developed which, in some cases can be stronger than the deformation texture [3-7]. In case of deep-drawing, the most spectacular failure caused by texture is earing. The semi-product used for deep drawing is prepared by the combination of rolling and annealing steps. The stronger is the crystallographic texture, the stronger the anisotropy will be and because of this, different magnitude of earing will occur at deep drawing [8, 9]. Aluminium alloys are the most commonly used materials for rolling. The 3xxx aluminium alloys are typically used as raw materials for deep-drawing technologies. The aim of this research is to describe the effect of Mn content on the variation of crystallographic texture during cold rolling and annealing treatments of aluminum sheets.



## 2. Experiments

A research plan was established to investigate the texture variation through the applied thermomechanical treatments of the examined Al alloys. Figure. 1 shows the established research plan. The anisotropy of the cold rolled sheets and the softened sheets were examined by X-ray diffraction.



**Figure 1.** Research plan

### 2.1. Rolling

The examined aluminium sheets were obtained in hot rolled state with ~8 mm (unalloyed), 6 mm (3003) and 7 mm (3103) thickness from Arconic-Köfém Ltd. The sheets were cold rolled in multiple rolling steps to different thicknesses using a Von Roll experimental duo roll stand. The same deformations were used for all three raw materials. The deformations were calculated with eq (1).

$$D = \frac{h_0 - h}{h_0} * 100 \quad (1)$$

Table 1. shows the number of rolling passes (marking) and the thickness of the examined samples. The 0 passes correspond to the initial, hot rolled sample.

**Table 1.** The rolling steps and the thickness of the samples during cold rolling

		Number of passes	0	1	2	3	4	5	6	7	8
		Deformation [%]		17,86	11,30	18,63	25,78	16,88	19,53	24,76	30,32
<b>Unalloyed</b>	Thickness [mm]	8	6,57	5,83	4,74	3,52	2,93	2,35	1,77	1,23	
<b>3003</b>	Thickness [mm]	6	4,93	4,37	3,56	2,64	2,19	1,77	1,33	0,93	
<b>3103</b>	Thickness [mm]	7	5,75	5,10	4,15	3,08	2,56	2,06	1,55	1,08	

### 2.2. Annealing

After the cold rolling, the sheets were annealed at 300°C for 3 hours in an air furnace. In the case of sheets without intermediate annealing, the annealing was the final step. For samples treated with intermediate annealing, the annealing was also performed after the fourth rolling step.

### 2.3. Texture examination

The texture examinations were carried out with a Bruker D8 Advance X-ray diffractometer equipped with an Eulerian cradle. The examination parameters were: CoK $\alpha$  radiation, 40 kV tube voltage 40 mA

tube current. The samples were tilted from  $0^\circ$  to  $75^\circ$ . The defocusing (absorption) error was corrected with aluminium powder. The measured pole figures were evaluated and the ODF was synthesized using the equipment's own, TexEval software. Volume fractions of the main rolling and recrystallization texture components were calculated with  $15^\circ$  deviation ( $\Delta$ ). Table 2. summarizes the main rolling and recrystallization texture components with their Miller indices and Euler angles according to the Bunge system [9-11].

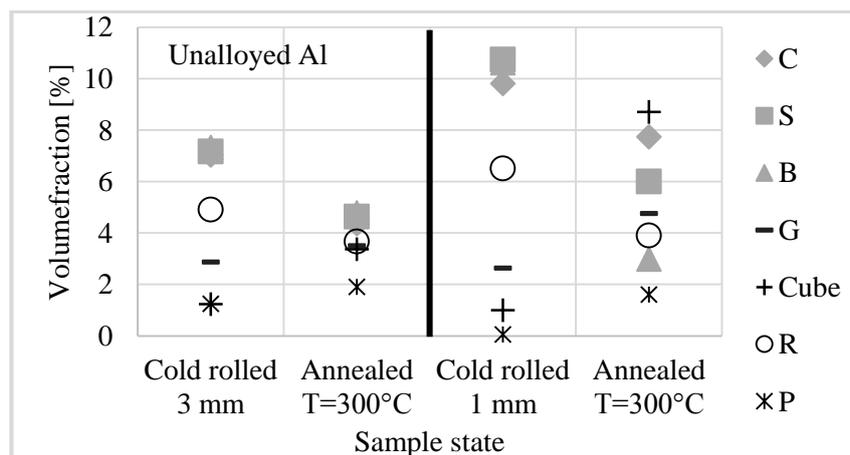
**Table 2.** The designations, Miller indices and Euler angles of the main texture components after rolling and recrystallization (approximated) [9-11]

Designation	Miller indices $\{hkl\}\langle uvw \rangle$	Euler angles			
		$\varphi_1$	$\Phi$	$\varphi_2$	
C	$\{112\}\langle 111 \rangle$	$90^\circ$	$30^\circ$	$45^\circ$	<i>Rolling Texture Components</i>
S	$\{123\}\langle 634 \rangle$	$59^\circ$	$34^\circ$	$65^\circ$	
B	$\{011\}\langle 211 \rangle$	$35^\circ$	$45^\circ$	$0^\circ/90^\circ$	
G	$\{011\}\langle 100 \rangle$	$0^\circ$	$45^\circ$	$0^\circ/90^\circ$	<i>Recrystallization Texture Components</i>
Cube	$\{001\}\langle 100 \rangle$	$0^\circ$	$0^\circ$	$0^\circ/90^\circ$	
R	$\{124\}\langle 211 \rangle$	$53^\circ$	$36^\circ$	$60^\circ$	
P	$\{011\}\langle 122 \rangle$	$65^\circ$	$45^\circ$	$0^\circ/90^\circ$	

### 3. Results

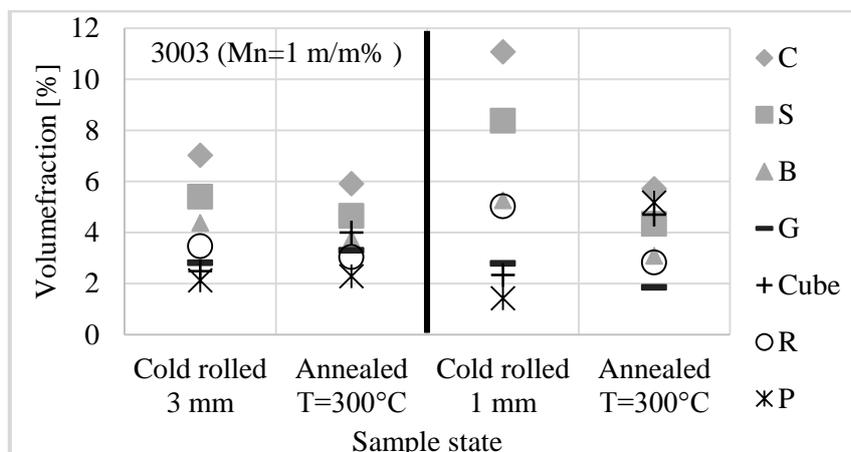
#### 3.1. The effect of Mn content

Figure 2. shows the texture component volume fractions of the unalloyed aluminium sheet in the cold-rolled and annealed state (thickness is 3 and 1 mm). It can be observed that the rolling texture-components are dominated after cold rolling. After higher deformation, a stronger rolling texture was obtained (1 mm thickness versus 3 mm thickness). In the case of 3 mm thickness, the volume fraction of the strongest recrystallization (Cube) and rolling (C) texture components are roughly the same after annealing.



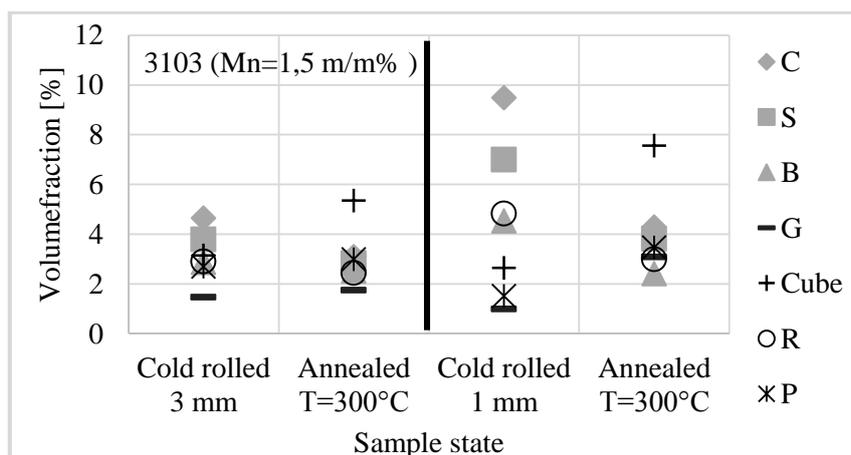
**Figure 2.** The volume fractions of texture components in the case of unalloyed aluminium

Figure 3 shows the results of the 3003 aluminium sheet in the cold-rolled and annealed state (thickness is 3 and 1 mm). The volume fractions of rolling texture-components are getting stronger as the deformation increases. After annealing, the values of the volume fractions of rolling and recrystallized components approach each other.



**Figure 3.** The volume fractions of texture-components in the case of 3003 aluminium

Figure 4 shows the texture components of the 3103 aluminium sheet in the cold-rolled and annealed state (thickness is 3 and 1 mm). At 3 mm thickness, a weak texture is formed after cold rolling. In the case of 1 mm thickness, a high rolling texture is obtained. After annealing, the values of the volume fractions of rolling and recrystallized components approach each other.

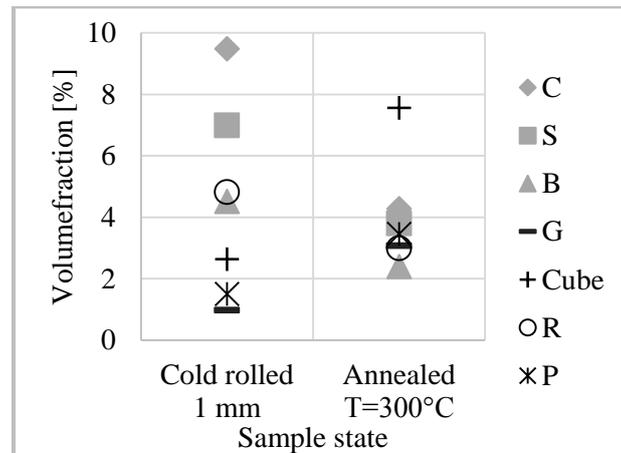


**Figure 4.** The volume fractions of texture-components in the case of 3103 aluminium

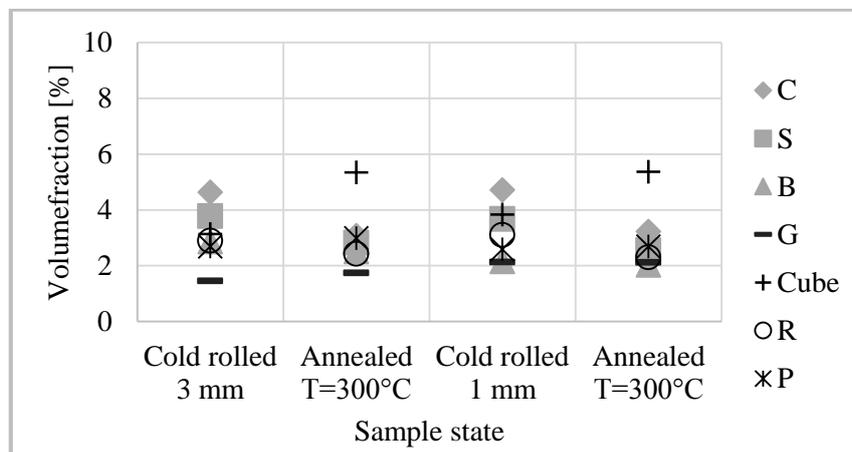
Comparing Figs. 3-5 it can be seen that as the Mn content increases to 1.5 m/m%, the volume fractions of rolling texture components are decreased, thus, a weaker rolling texture is obtained compared to the other alloys with lower Mn content. Also, the volume fractions of recrystallization texture components are smaller compared to the other two alloys.

### 3.2. The effect of intermediate annealing

Figure 5 shows the volume fractions of the texture components on the 1 mm sheet which was treated without intermediate annealing, while Figure 6 shows the volume fractions of the texture components on the 1 mm sheet which was treated by intermediate annealing. After rolling steps, a weaker rolling texture formed compared to the previous case. After annealing the Cube texture component is dominated, but it is weaker than the previous case.



**Figure 5.** The volume fractions of the texture components on the 1 mm sheet which was treated without intermediate annealing



**Figure 6.** The volume fractions of the texture components on the 1 mm sheet which was treated with intermediate annealing

#### 4. Conclusions

Based on the results it can be stated that the increase of the Mn content decreases the volume fraction of rolling texture components after cold rolling. Also, it decreases the volume fractions of recrystallization texture components after each thermomechanical treatment scenario. The Cube texture component is the most characteristic of recrystallization texture components for all three alloys.

With intermediate annealing, a smaller texture, that is, favourable rolling and recrystallization textures can be achieved for subsequent applications compared to treatment without intermediate annealing.

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