Texture Variation at Hot Rolling Gauge of AA1050 Alloy and its Effect on Earing Behaviour

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Abstract

The influence of hot rolling texture on the development of cold rolling and recrystallization texture in a commercial AA1050 aluminium alloy has been investigated. A large variation in texture at the hot rolling gauge has been created by varying rolling parameters. Although cold rolling and annealing result in a significant change in microstructure, variation in texture created during hot rolling remains. The results show that texture and, thus, earing behaviour of AA1050 alloy at different processing stages can be described as a function of texture at the hot rolling gauge. The effect of cold rolling is also discussed.

Keywords: *AA1050, hot rolling, microstructure, texture, earing*

1. Introduction

Commercial production of aluminium alloys such as AA1050 involves a number of thermo-mechanical processing steps, which may include homogenization of the cast ingot, pre-heating, hot rolling, cold rolling, and annealing. All these steps influence the development of crystallographic preferred orientations (texture) which have a significant effect on material's behaviour. Earing in aluminium alloys, as an example, is mainly controlled by texture [1-2]. The rolling texture results in 45° ears whereas the cube recrystallization texture leads to 0°/90° ears. By varying the processing parameters a variety of textures can be obtained which causes different earing profiles.

Many attempts were made to predict the earing behaviour of aluminium alloys using texture [3-4]. A primary concern in most cases is to control the strength of the cube recrystallization texture relative to that of the deformation texture. In other words, one should try to produce a balance of cube and other texture components such that the overall anisotropy is minimized.

In the present work, the effect of hot rolling condition on the development of microstructure, texture and earing in AA1050 alloy was investigated. A correlation between earing and texture, especially the texture at hot rolling gauge, has been examined.

2. Experimental Procedure

The material used was a commercial purity AA 1050 alloy containing 0.32% Fe and 0.10% Si. It was prepared by DC casting, homogenization at 600°C, pre-heating, hot rolling, cold rolling and annealing. The starting ingot material had a predominant random texture with an average grain size of about 250 μm.

The evolution of microstructure and texture of AA 1050 alloy has been investigated. Samples were taken from the hot rolling gauge, in the as cold rolled and finally annealed conditions. In order to obtain a wide range variation in texture, hot rolling has been performed within a large process window. The coiling temperature at the hot rolling gauge was within the range of 300°C and 230°C, and the thickness was between 8 mm and 3.5 mm. Subsequently, the material was cold rolled to various end thicknesses. A final annealing was performed at 400°C which ensured that the material was fully recrystallized.

The X-ray pole figure analysis was used to measure bulk texture. The measurement was made at the mid-thickness of the samples. Orientation distribution functions (ODFs) were calculated from four incomplete pole figures. The volume fraction of texture components were then calculated from corresponding ODFs with a spread parameter $\phi_0 = 11°$ [5]. Earing values have been measured on samples from the hot rolling gauge, cold rolled sheet and annealed sheet and calculated using the following equation:

$$earing\% = \frac{average\ of\ 0/90\text{-}ears - average\ of\ 45\text{-}ears}{average\ of\ 0/90\text{-}ears + average\ of\ 45\text{-}ears} \times 200\%$$

3. Results and Discussions

3.1. Microstructure and texture evolution during hot rolling

The control of earing behaviour of aluminium sheet is often essential to meet stringent product property requirements specified by the customer. From a commercial production point of view, this control should cover two aspects: one is either to control the average earing value as low as possible, or to meet a specifically required target value as established by the customer; the other one is to eliminate the spreading of earing values in the coil.

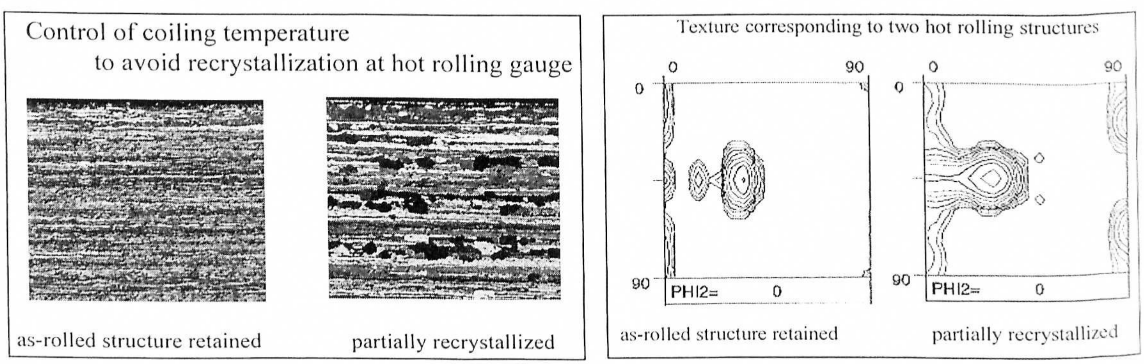


Fig. 1 Microstructures and textures observed in AA 1050 alloy at the hot rolling gauge with different coiling temperatures.

A significant variation in earing values can be observed in a commercial coil if the processing parameters are not properly controlled. A large variation in earing values reflects a large variation in microstructure and texture. In order to eliminate earing variation in the coil, an uniform microstructure at the hot rolling gauge is preferred. A sufficiently low coiling temperature to avoid recrystallization will provide a positive contribution to the earing variation in the end product.

When the coiling temperature is properly controlled, a fully retained rolling structure is created at the hot rolling gauge, while a partially recrystallized microstructure can be observed when the coiling temperature being too high. Examples of these two microstructures are shown in Fig. 1(a). Difference in textures corresponding to two microstructures at the hot rolling gauge is shown in Fig. 1(b), ODF sections with $\phi2 = 0°$.

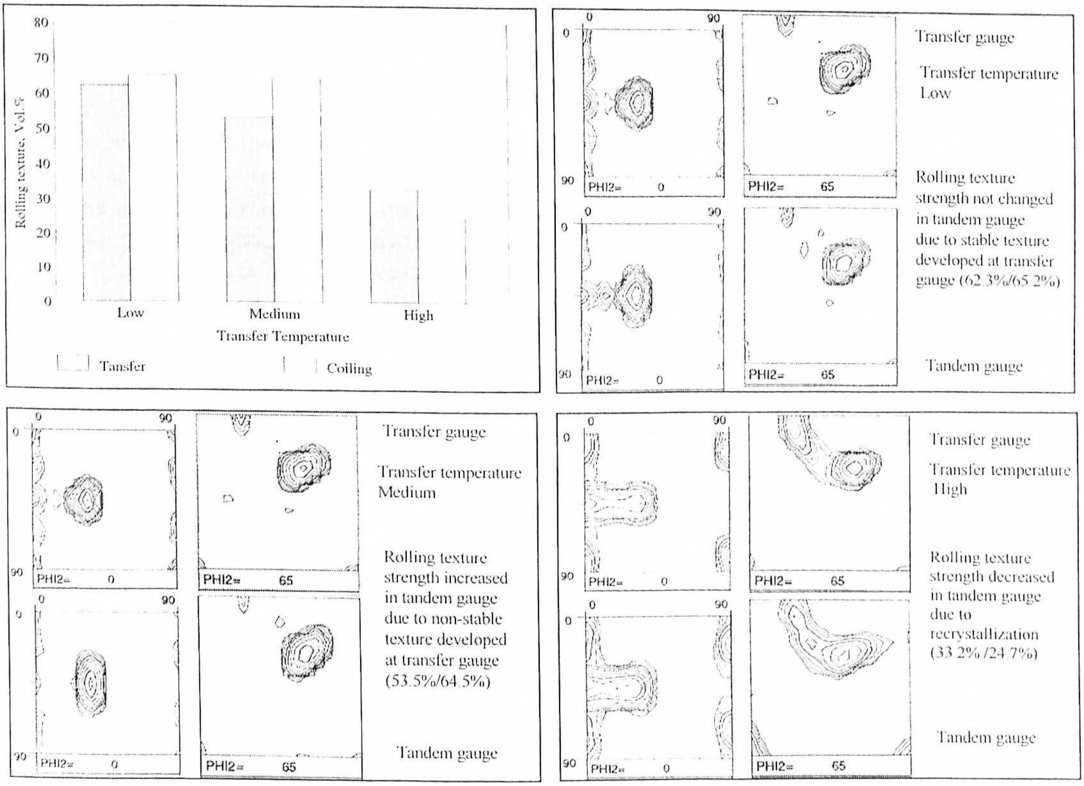


Fig. 2 Texture evolution during hot rolling - correlation between textures developed at the transfer gauge and at the coiling gauge with various transfer temperatures.

Texture evolution during hot rolling, especially the effect of initial texture at the intermediate (transfer) gauge on the texture development during the final stage hot rolling in coiling mill in AA 1050 alloy, is demonstrated in Fig. 2. In this figure, the volume fraction of rolling texture at the intermediate gauge and at the coiling gauge is given as a function of the transfer temperature. It is shown that the volume fraction of rolling texture, both at the transfer gauge and at the coiling gauge, increases with decreasing transfer temperature, the coiling temperature being kept constant. However, the change in texture during hot rolling in the coiling mill is significantly different. With a high transfer temperature, the volume fraction of rolling texture decreased during hot rolling in the coiling mill from 33.2% at the transfer gauge to 24.7% at the coiling gauge due to massive recrystallization. With a medium transfer temperature, the volume fraction of rolling texture increased during hot rolling in the coiling mill from 53.5% at the transfer gauge to 64.5% at the coiling gauge due to a non-stable texture developed at the transfer gauge, corresponding to a mixture of retained rolling type and recrystallized microstructures. With a low transfer temperature, the volume fraction of rolling texture hardly changed during hot rolling in coiling mill (from 62.3%

at the transfer gauge to 65.2% at the coiling gauge) due to a stable texture developed at the transfer gauge, corresponding to a fully retained rolling structure.

3.2. Texture at the hot rolling gauge and earing behaviour of AA 1050 alloy

In the foregoing text, it is demonstrated that the control of texture at the transfer gauge is crucial in achieving a good control of microstructure, texture. However, there are many practical difficulties to gather microstructural information at the transfer gauge as compared with that at the coiling gauge. Examples are: (a) in order to retain the microstructure developed at the transfer gauge, samples need to be quenched because of a high working temperature; (b) microstructural analysis is very time consuming, especially if texture measurement is involved. On the other hand, microstructural information at the coiling gauge can be relatively easy to obtain. Due to a relatively thin gauge, an earing test can already be performed on samples from the coiling gauge. This provides a quick and efficient approach to process control once a proper relation of microstructure and texture developed at the transfer gauge and the coiling gauge has been established.

Fig. 3 shows earing in AA 1050 alloy as a function of rolling texture at the coiling gauge obtained from materials with the same hot rolling gauge (4 mm) but various hot rolling conditions. Earing tests were performed in the as hot rolled condition (4 mm), in the as cold rolled condition (1 mm) and in the annealed condition (1 mm). The results show a good correlation between texture and earing values measured on these samples.

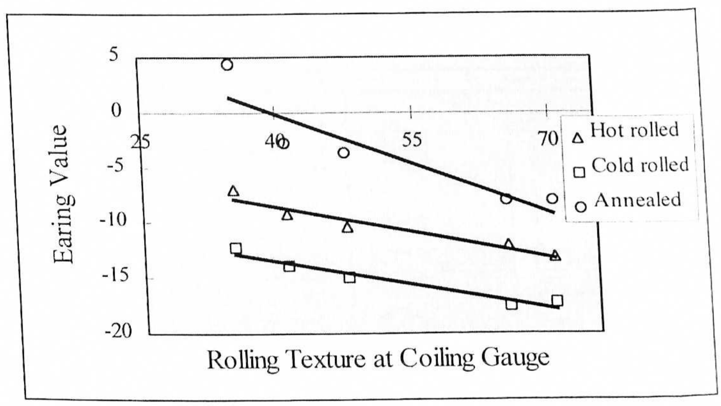


Fig. 3 Texture at the hot rolling gauge and earing under various conditions.

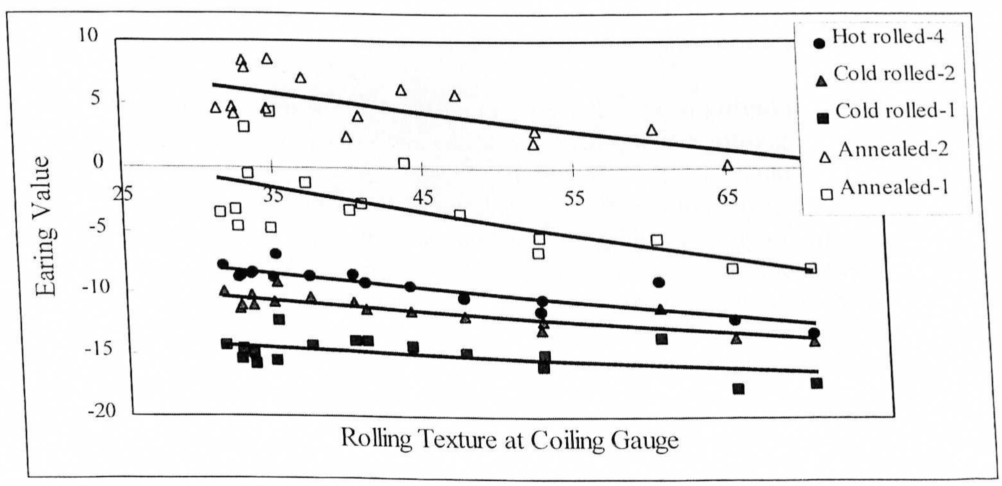


Fig. 4 Statistic analysis showing earing as a function of the rolling texture at the hot rolling gauge in AA 1050 alloy.

A similar correlation has been established in this alloy by a statistic analysis of a large number of production coils. A wide range of volume fraction of rolling texture at the hot rolling gauge was involved, corresponding to a wide spreading in earing values tested under different treatment conditions. These results are given in Fig. 4. Five series of earing values are from as rolled samples at the hot rolling gauge (4 mm), as cold rolled samples (1 and 2 mm) and finally annealed samples (1 and 2 mm). With high volume fractions of rolling texture at the hot rolling gauge, a good relation between the texture and earing is observed, whereas in the low rolling texture regime, a relatively wide spreading in earing values is observed. A weaker rolling texture at the hot rolling gauge results from high processing temperatures, i.e., a high transfer temperature, or a high coiling temperature, or some times a combination. Microstructural examination indicated that a high processing temperature leads often to a non-stable microstructure. Therefore, a large fluctuation in earing values is observed in this regime.

3.3. Effect of cold rolling on earing behaviour of AA 1050 alloy

When hot rolling has been properly done, subsequent cold rolling and final annealing provide further possibility to control earing in AA 1050 alloy.

Fig. 5 shows the earing value as a function of cold rolling reduction in AA 1050 alloy after final annealing. The effect of the coiling temperature on the earing performance of material is also demonstrated. It is indicated that an extremely high cold rolling reduction should be avoided because of the difficulty to gain sufficient amount of cube texture in the fully recrystallized structure to balance with strong rolling texture in the end product. The results showed that a cold rolling reduction above 80% is already too high to achieve a balanced texture in the finally annealed structure. In this case, strong earing with 45° ears will be developed. In extreme conditions, the earing value measured on a fully recrystallized sample can be as high as that measured on an as cold rolled sample. For example, a hot rolled sheet with a gauge thickness of 8 mm and a medium strong rolling texture at the hot rolling gauge (~50% of rolling texture), and subsequently being cold rolled to 1 mm, a very strong rolling texture has been developed during cold rolling. The rolling texture in this material was so strong that an annealing heat treatment did not lead to any change in the texture in the final product, although microstructural examination showed that a fully recrystallized structure has been achieved after annealing. Earing values, both in the as cold rolled and finally annealed conditions, are about 12% with 45° ears. Increasing the coiling temperature can partly compensate for the cube texture. However, this will make the problem of non-stable microstructure and earing variation arise.

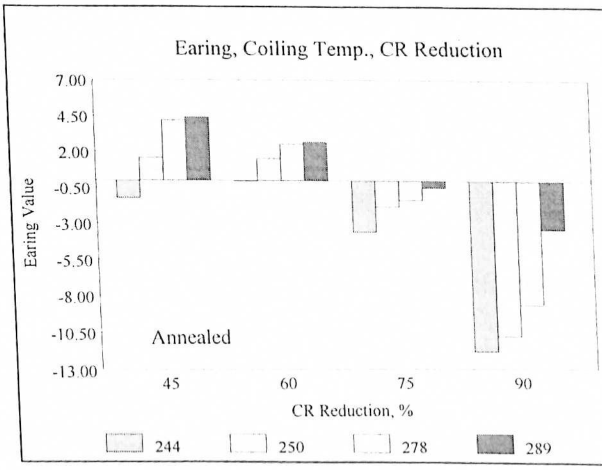
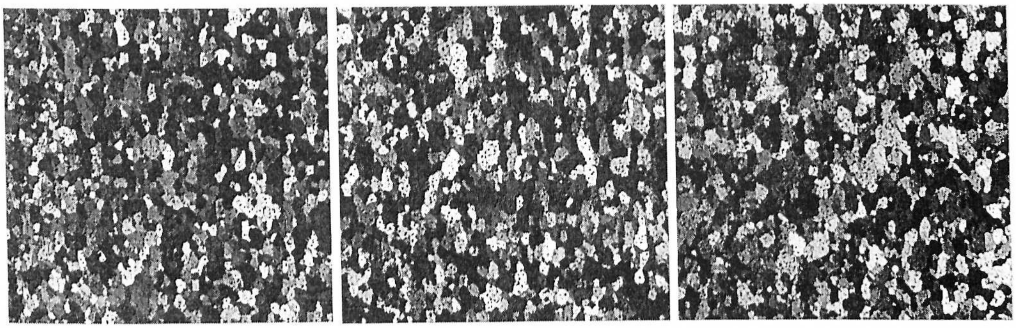


Fig. 5 Earing value as a function of the coiling temperature and cold rolling reduction in finally annealed condition in AA 1050 alloy.

Cold rolling and annealing can result in a significant change in microstructure. However, variation in texture created during hot rolling remains. This can be demonstrated in Fig. 6. The samples had a same cold rolling reduction (from 4 mm to 1 mm) and a same annealing heat treatment. Micrographs given in this figure show that all three samples were fully recrystallized after annealing. The recrystallized structure are very similar to each other. However, as indicated in the attached table, the variation in texture at the hot rolling gauge can still be easily traced at intermediate process stages and in the final product.

Same cold rolling reduction, different texture at the hot rolling gauge



Sample	Texture (HR)	Texture (CR)	Texture (ANN)	Earing (ANN)
1	35.0	50.4	21.2	4.35
2	47.4	62.8	28.1	-2.80
3	70.2	73.1	55.7	-8.03

Fig. 6 Grain structure and earing value of the end product correlated to the texture at the hot rolling gauge, cold rolled and annealed conditions.

4. CONCLUSIONS

The influence of hot rolling texture on the development of cold rolling texture and subsequent recrystallization texture and, thus, on earing, in the end product was investigated. Although cold rolling and annealing result in a significant change in microstructure, variation in texture developed during hot rolling remains. The results show that texture and earing behaviour of the AA1050 alloy is strongly influenced by the initial texture before cold rolling. Earing of the AA1050 alloy at different processing stages can be described as a function of the texture strength at the hot rolling gauge. Cold rolling reduction and annealing can also influence earing performance in the AA 1050 alloy. However, as compared with hot rolling, effect of cold rolling and annealing on earing performance are of secondary importance.

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