Texture and Anisotroy: Applications

Dr.-Ing. 郭 瑞 昭

1. Deformation Textures in Metals
2. Annealing Textures in Metals
3. Applications of textures

Commerical purity aluminium (AA1xxx)

Application:

The pure aluminum foil is found its application in electrolytic capacitors. The surface area of capacitors can be increased through an etching process. Narrow channels along <100> directions into foil, i.e. cube texture are desired.

Composition of AA1050:

Commercial pure aluminum contains iron and silicon more than 1% wt.

Nominal compositions of aluminium alloys for can bodies.

	Si%	Fe%	Cu%	Mn%	Mg%	Zn%
AA3004	0.3 max	0.7 max	0.25 max	1–1.5	0.8–1.3	0.25 max
AA3104	0.6 max	0.8 max	0.05–0.25	0.8–1.4	0.8–1.3	0.25 max

Commercial purity aluminium (AA1xxx)

Effect of Fe:

Small amounts of iron changes the annealing texture from pure cube to a retained rolling texture.

Effect of Fe and Si:

Si and Fe lead to the formation of a-Al-Fe-Si phase in the form of plates or rods up to 10 mm. PSN at the Al-Fe-Si particles leads to a random texture and with weakening rolling (R) texture.

Effect of T and strain:

An increase in temperature or a decrease in strain rate reduced the relative drop in cube {001}<100> and the relative increase in rolling texture components of Cu {112}<111> and S {231}<346> at the higher strain.

Commercial purity aluminum (AA1xxx)

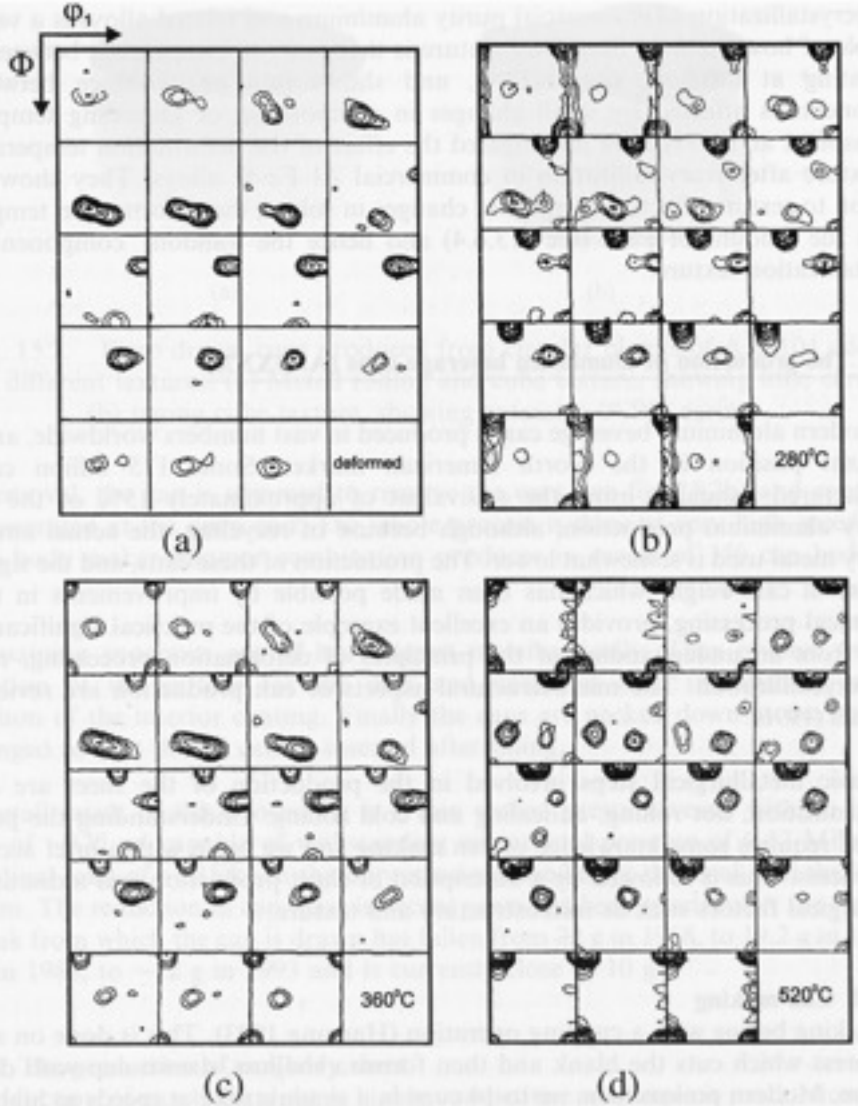


Fig. 15.1. Effect of annealing temperature on the recrystallization texture of 95% cold-rolled, Al-0.007%Fe alloy; (a) As rolled, annealed at: (b) 280°C, (c) 360°C, (d) 520°C, (Lücke 1984).

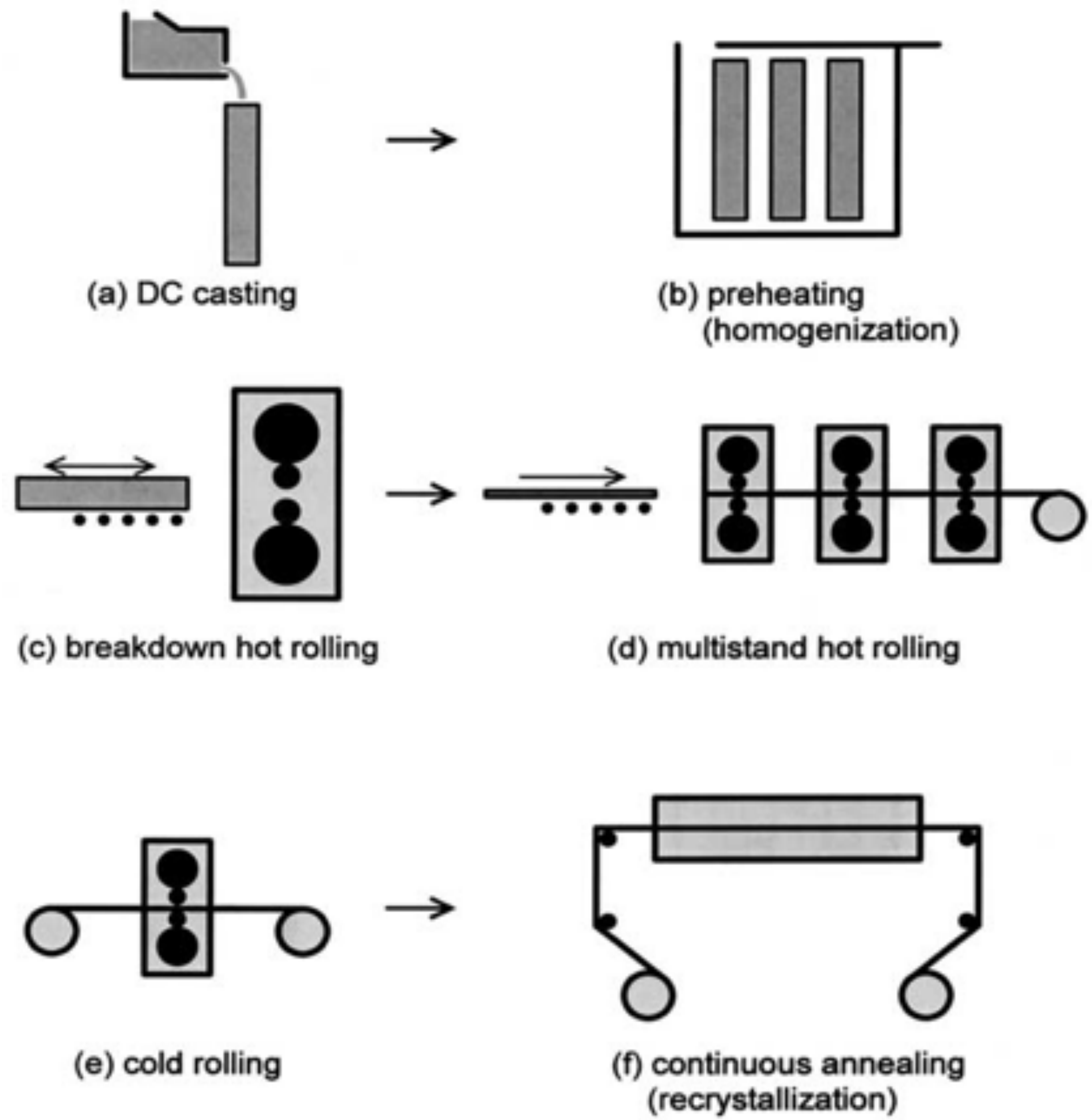
Al-Mg-Si automotive sheet (AA6xxx)

Table 15.3
Processing routes for AA6xxx automotive sheet, showing the effect on the final texture, of an intermediate anneal before cold rolling.

	Breakdown hot rolling 25–40 mm plate (transfer guage) Recrystallized to 200 μm grains Strong cube texture	
	Tandem mill hot rolling 3–6 mm strip (hot band) Hot-deformed microstructure Rolling texture	
↙	**Coiling** Partly recrystallized microstructure Fine Mg_2Si precipitation Rolling + Cube texture	↘
Intermediate anneal Fully recrystallized Precipitates coarsen Cube texture		**No intermediate anneal** Partly recrystallized Fine Mg_2Si precipitates Rolling + Cube texture
↓	**Cold rolling** 0.8–1.22 mm sheet Deformed microstructure	↓
Rolling texture		Rolling texture
↓	**Solution treatement** Recrystallized to ~20–30 μm grains Precipitate dissolution	↓
Weak cube texture		**Strong cube texture**
	Forming	
	Age-hardening during paint-bake	

In addition to the parameters discussed above, there are other means of controlling the final texture, which are not discussed here, including the alloy composition, the exit temperature of tandem rolling and the amount of the cold rolling reduction.

Al-Mg-Si automotive sheet (AA6xxx)



Aluminium berage cans (AA3xxx)

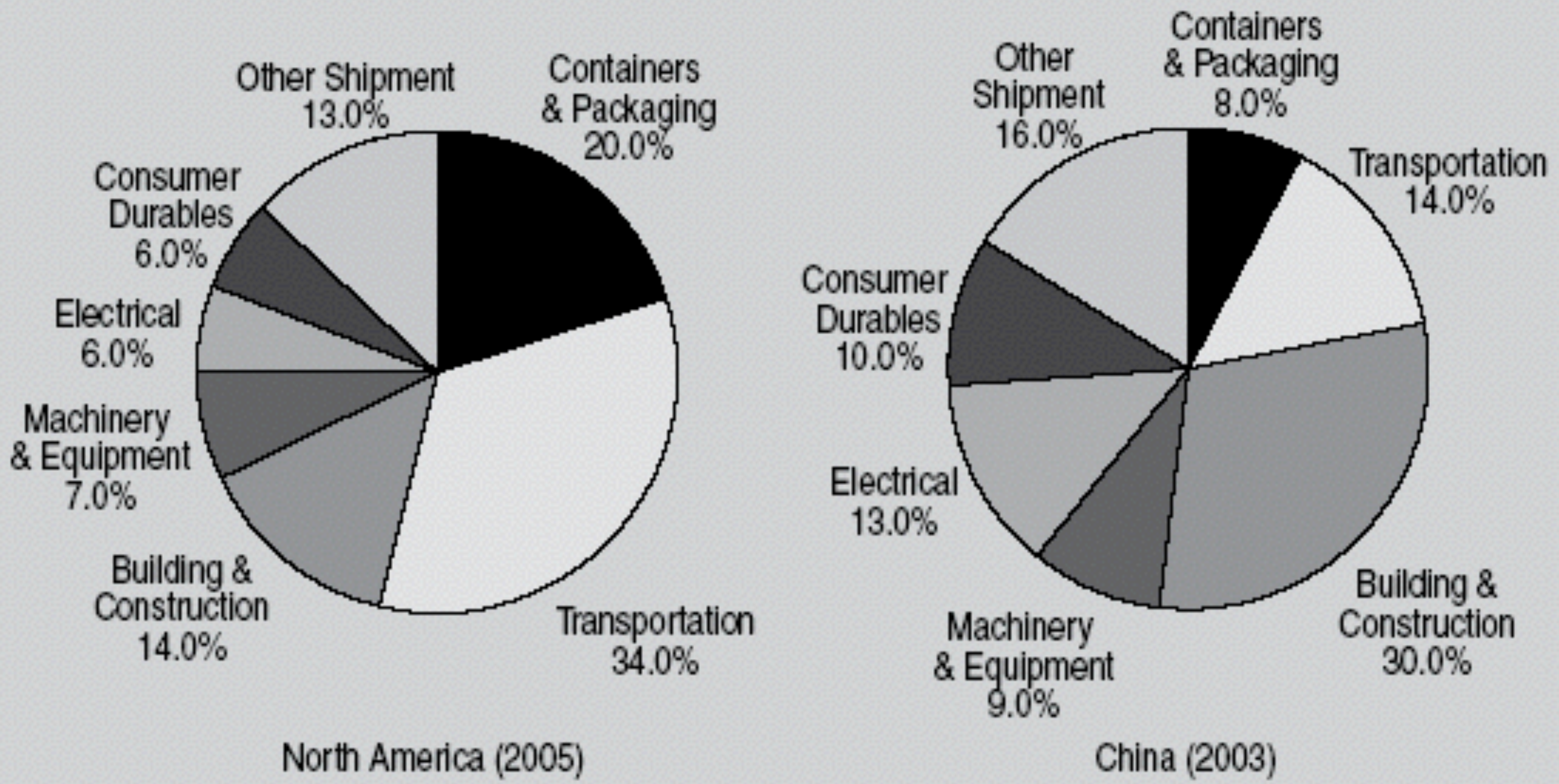


Figure 2. The current market share by application sectors.[4,10]

S. Das and W. Yin, JOM, 59(2007) 83-87

Aluminium berage cans (AA3xxx)

Aluminium beverage cans are fabricated from two parts:

- can body (generally made from 3104 sheet)
- can end (typically made using 5182 due to its higher strength)

Good sheet formability is required for the body making process: blanking, cupping and finally drawing and ironing the side-walls.

Anisotropy in the mechanical behaviour of the sheet must be minimised to limit the formation of so-called 'ears' on the deep drawn cup.

Aluminium beverage cans (AA3xxx)

Cupping

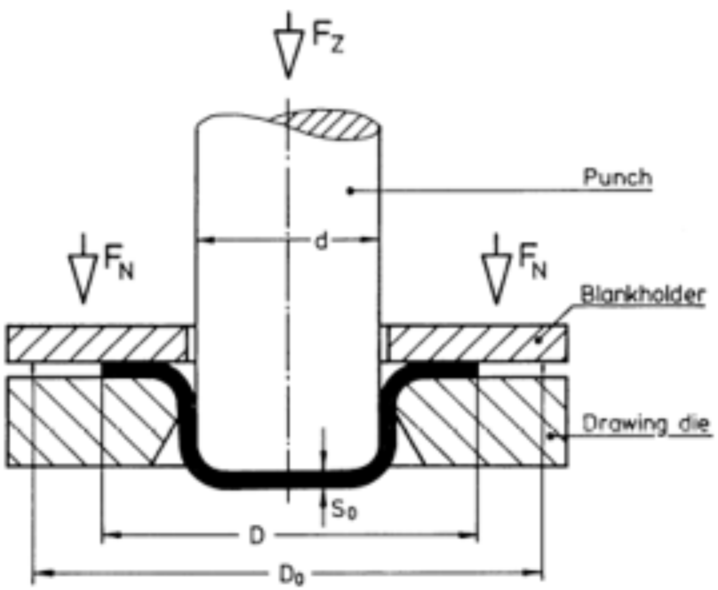
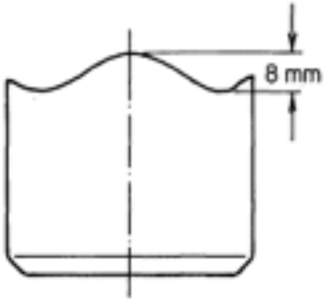


Fig. 1. Deep-drawing.



Drawing and Wall-ironing

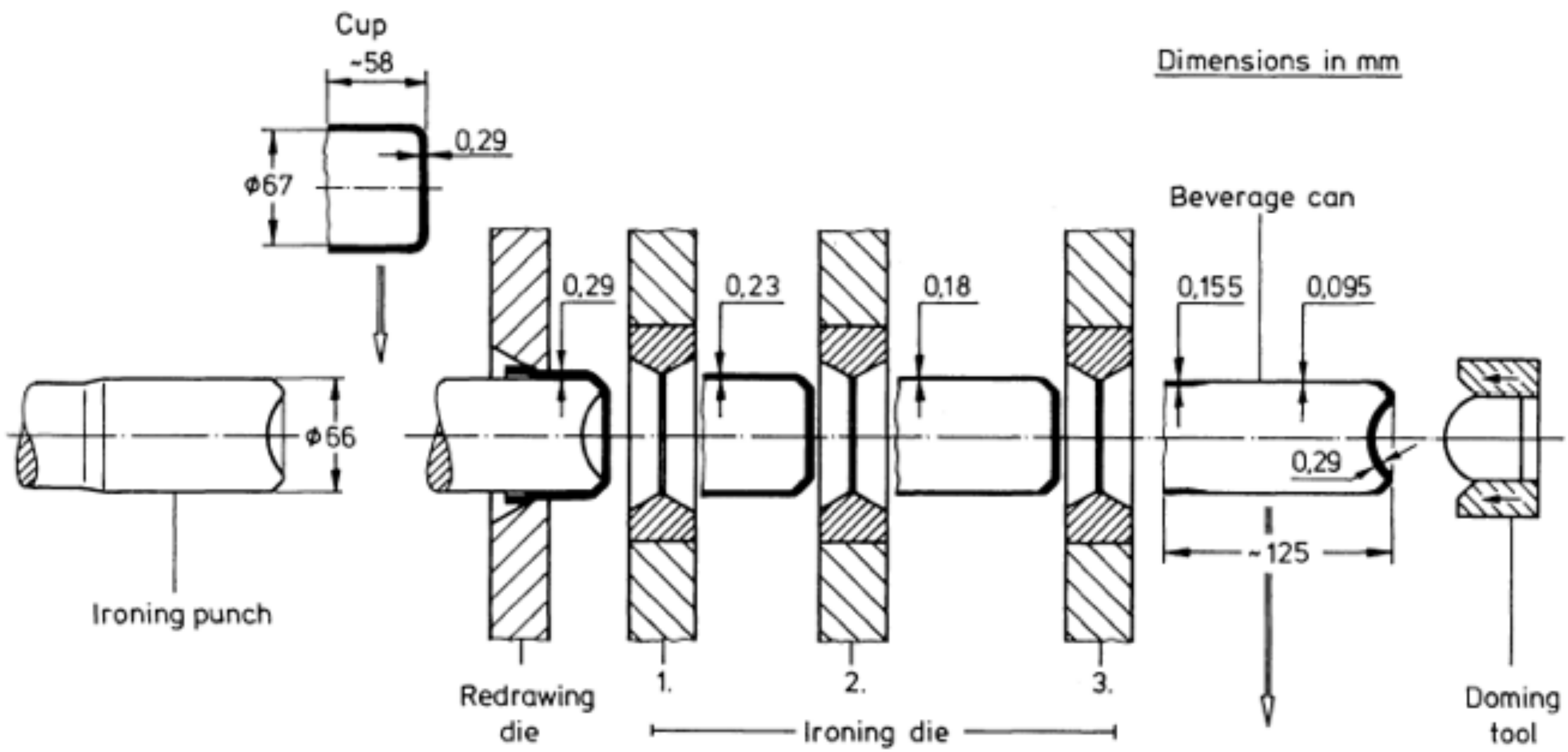


Fig. 7. Drawing and wall-ironing.

Flanging

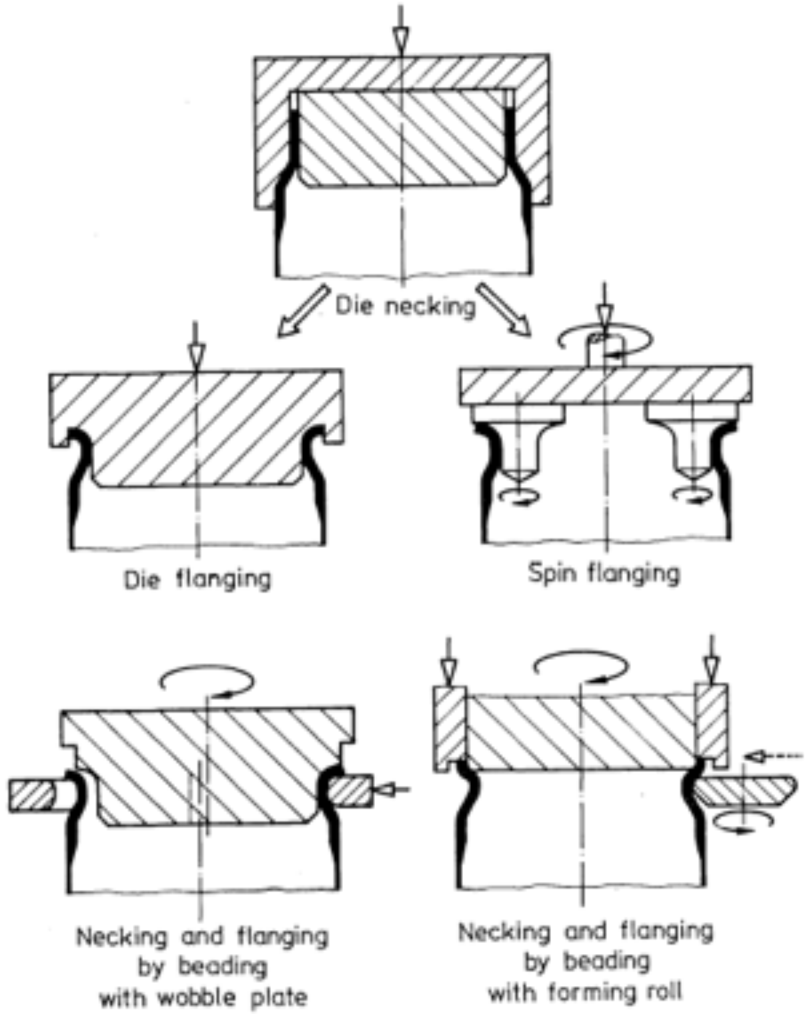


Fig. 11. Necking and flanging systems.

End of beverage can

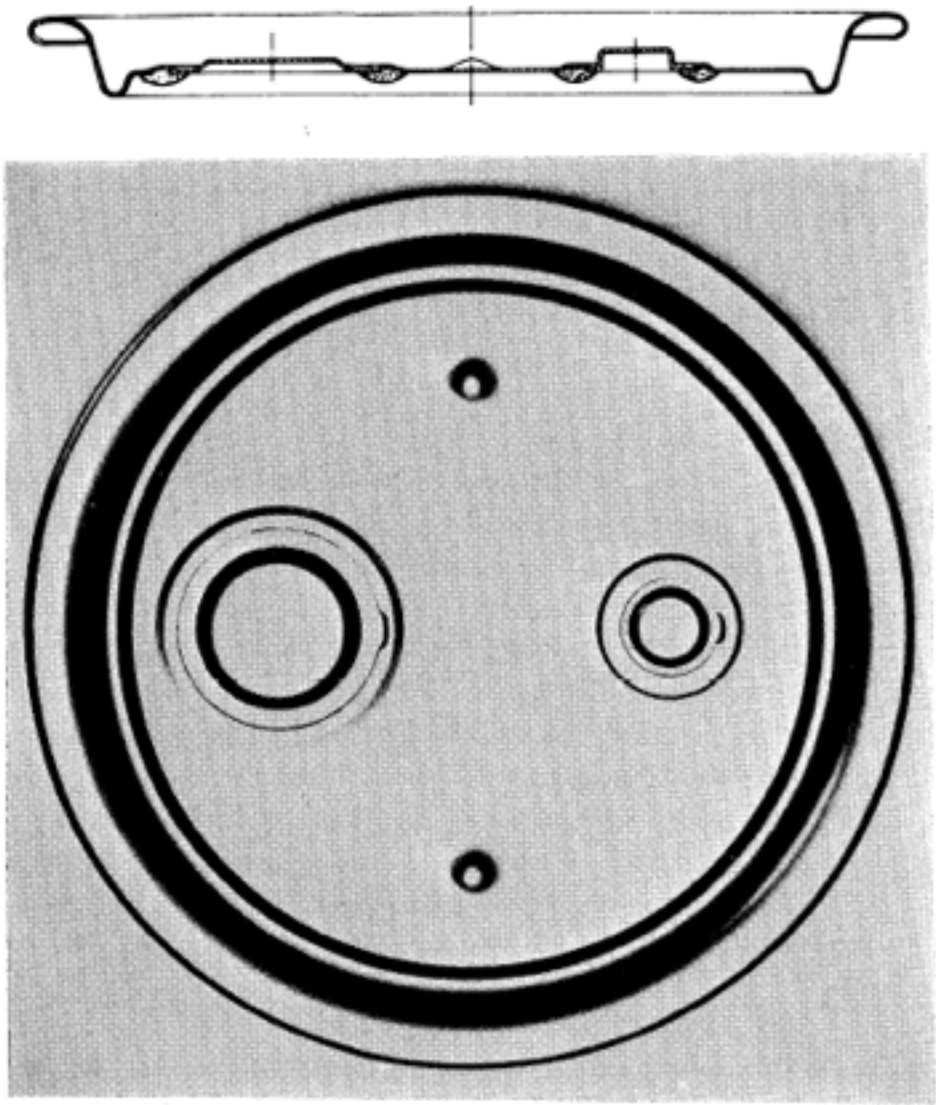


Fig. 15. Steel end for beverage cans.

Development of microstructure and texture

As-cast microstructure:

Features of the cast ingot are intermetallic phases ((FeMn)Al_6, Mg_2Si) , eutectic microsegregations and grain with 100 μm.

Homogenisation:

Objectives of homogenisation are the elminination of microsegregations, transformation of β-(FeMn)Al_6, and Mg_2Si in dispersoids.

microsegregations (removed during heating)

β-(FeMn)Al_6, in α-Al15(FeMn)3Si2 (desired due to hardness)

Mg_2Si (dissolves and helps the formation of α-Al15(FeMn)3Si2)

Development of microstructure and texture

Hot rolling and recrystallization:

A strong cube texture is required after RX. The RX texture is dominated by cube component (preserved in hot rolled microstructure) and random component (particle stimulated nucleation /PSN of RX).

A higher rolling temperature promotes the cube texture and restricts the random texture.

Development of microstructure and texture

Cold rolling:

The requirement for deep drawing of can bodies is good formability and low earing.

After cold rolling the strength of the cube texture is reduced and cold-rolling texture is developed (Brass, Copper and S).

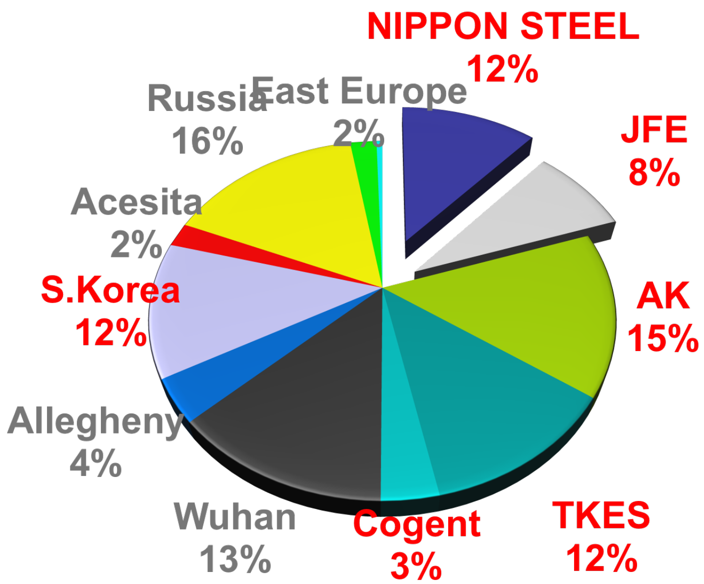
The +-45 earing can be minimized if the cube texture is maximal.

Major texture components in cold-rolled can body sheet.

Texture	Name	Earing
$\{100\}\langle 001 \rangle$	Cube	4-fold 0/90° etc.
$\{110\}\langle 001 \rangle$	Goss	2-fold 0/180°
$\{110\}\langle 112 \rangle$	Brass	4-fold 45° etc.
$\{112\}\langle 111 \rangle$	Copper	4-fold 45° etc.
$\{123\}\langle 412 \rangle$	S (~R)	4-fold 45° etc.

Impact on Materials

2007 World Installed Production of Grain Oriented Silicon Steel*



Total = 2.1 Million (MT)

* Data Courtesy of Sumitomo Corporation

Requirements of Silicon Steel sheets

Requirements:

1. Easy magnetisation

    composition/ high Silicon → brittle and not cold rolling

    concentration levels of carbon, sulfur, oxygen and nitrogen must be kept low

    orientation/ <100> direction

    purity

2. Low hysteresis loss

    as the same 1

3. Low eddy current loss

    grain size, ↓

    sheet thickness, ↓

    stress ↓

Requirements of Silicon Steel sheets

Requirements in the Armco process:

1. The nucleation of {110}<001> grains
2. These grains must be able to grow
3. Grains of other orientation should not grow

{110}<001> orientation first appears during the initial hot rolling as a friction-induced shear texture at and near the surface.

Normal rolling texture consists of {112}<110> and {111}<110>

Silicon Steel sheets

Armco process

13540-1350°C

Nippon steel process

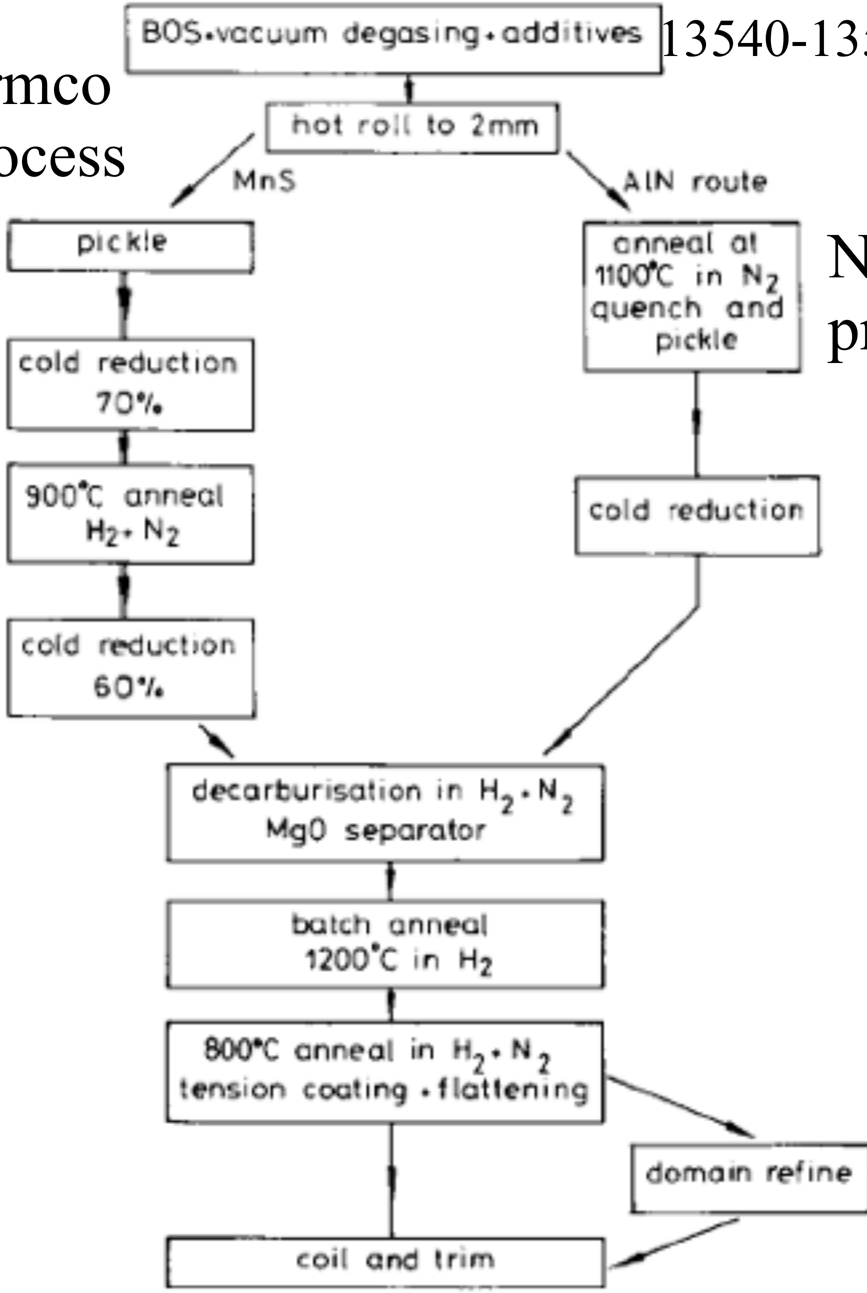


Fig. 3 *Production route of conventional (via MnS route) and high-permeability (via AlN route) grain-oriented silicon iron*

The basis of the Goss process is to heat the silicon iron strip to around 1200C, to induce the secondary recrystallisation of large grains with [00l](l 10) texture, which were predominant because the presence of manganese sulphide (MnS) suppresses the growth of other grains.

Silicon Steel sheets

Requirements in the Armco process:

1. Provision for the nucleation of {110}<001> grains

2. These grains must be able to grow

3. Grains of other orientation must not grow

Silicon Steel sheets

During hot rolling, small MnS particles are precipitated as the steel cools and, at the same time, some crystals with the Goss texture are formed along with many other orientations.

-The desired {110}<001>orientation appears during the initial hot rolling as a friction-induced shear texture at and near the surface.

-During cold rolling {112}<110> and {111}<110> texture are formed. Therefore, two “light” cold rolling stages are applied.

- Goss grains survive at the centers of transition bands

-some Goss grains appear in the annealing texture after decarburising anneal, they are larger than those of the other oreintations

-they grow by abnormal grain growth during the final texture anneal

Silicon Steel sheets

These MnS particles are resistant to rapid coarsening and, by preventing normal grain growth, keep the matrix grain size small during high temperature annealing.

The possibility of undesirable orientations by surface nucleation process is eliminated by addition of sulphur to the MgO coating.

Silicon Steel sheets

After the cold rolling, nuclei with the Goss texture recystallise during the decarburisation anneal. (1st recrystallization)

The grain size, at this stage, is around 0.02 mm diameter, and this increases in the Goss-oriented grains at over 800C, during the high-temperature anneal when the MnS (inhibitor) retards the growth of other grains.

During this secondary recrystallisation process, the Goss grains each consume 106-107 primary grains and grow through the thickness of the sheet to diameters of 10 mm or more. All grains do not have the ideal Goss orientation, but most are within 6" of the ideal [l01] (110), this is the best that can be achieved with MnS as a grain growth inhibitor. (2nd recytsallization)