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Formation of Austenite and Ferrite Preferred Orientation During Cold-rolling of Dual and Single-phase Steels

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Abstract. The aim of this contribution was to compare the real structure of single-phase with dual-phase steel after cold-rolling. The preferred orientation was studied as a function of thickness reduction of samples. Type and rate of determined preferred orientation depending on material and thickness reduction were studied by X-ray diffraction. The significant differences between intensities and types of texture components were investigated.

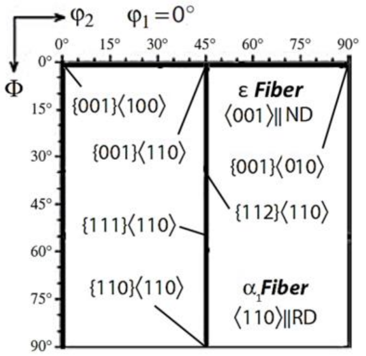
Introduction

Duplex steels are dual-phase steels with approx. 50/50 proportion of ferrite and austenite phases. Because of the combination of properties of both phases in dual-phase microstructure, duplex steels are distinguished by good properties in many environments, where the standard austenitic and ferritic steels are usually used [1]. Due to very frequent presence of preferred orientation (texture) in these materials, analysis and consequent interpretation of the texture is crucial, especially in material engineering. The importance of study of texture resides in the anisotropy of most material properties. Because of different mechanical properties of ferrite and austenite phases, their behaviour during deformation can be different in dual-phase steel in comparison with single-phase steels [2].

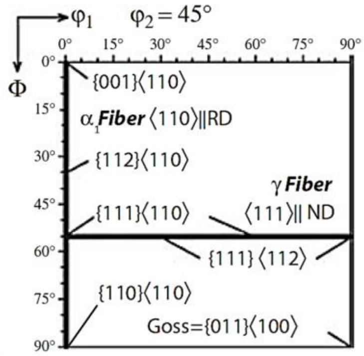
Orientation distribution function (ODF) is usually used for texture interpretation. The ODF is usually described using Euler space defined by Euler angles φ_1, Φ, φ_2 in Bunge notation [3]. The ODF denotes the bulk density of crystals with the orientation defined by Euler angles and the multiple of a random distribution unit. Euler angles of materials are presented in the range (φ_1, Φ, φ_2) ∈ <0°; 90°> for cubic crystal and orthorhombic sample symmetries. The ODF is usually interpreted using texture components and textures with fibre components, shortly fibres. For materials with different crystallographic symmetry or lattice, material, chemical and phase composition, and thermo-mechanical properties, the typical texture components and fibres can be varied [2, 3, 4], see Fig. 1. These fibres are usually interpreted according to rolling (RD), transversal (TD) and normal (ND) directions.

The typical texture components and fibres (α_1, ε, γ) of deformed bcc – body centred cubic and (α, τ, η) of fcc – face centred cubic materials are interpreted in Fig. 1. According to stacking fault energy (SFE), two main types of fcc material textures exist: Brass – with small SFE and Copper – with high SFE. Brass type usually contains Brass (Bs) and Goss (G) texture components [3], see Fig. 1. The potential difference between duplex and austenite steel may be caused by the difference in SFE, which depends on chemical composition.

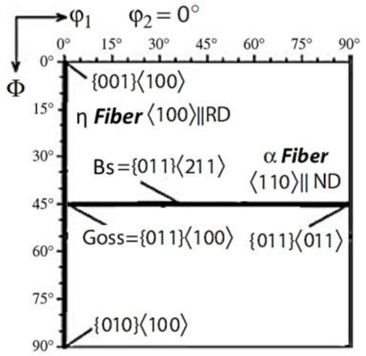
According to [5], the SFE of austenite steel is around 18 mJ/m^2 and for phase of duplex steel, the SFE is 10 mJ/m^2.



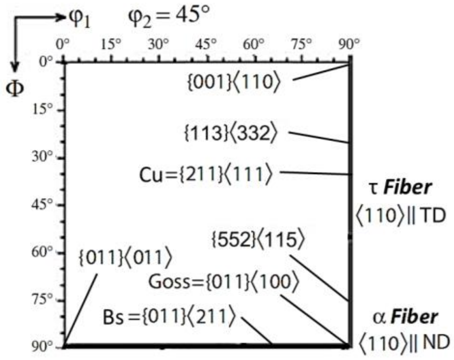
(a) φ_1 = 0° section of bcc material



(b) φ_2 = 45° section of bcc material



(c) φ_2 = 0° section of fcc material



(d) φ_2 = 45° section of fcc material

Fig. 1 Illustration of typical texture components and fibres of deformed cubic materials [3]

Experiment

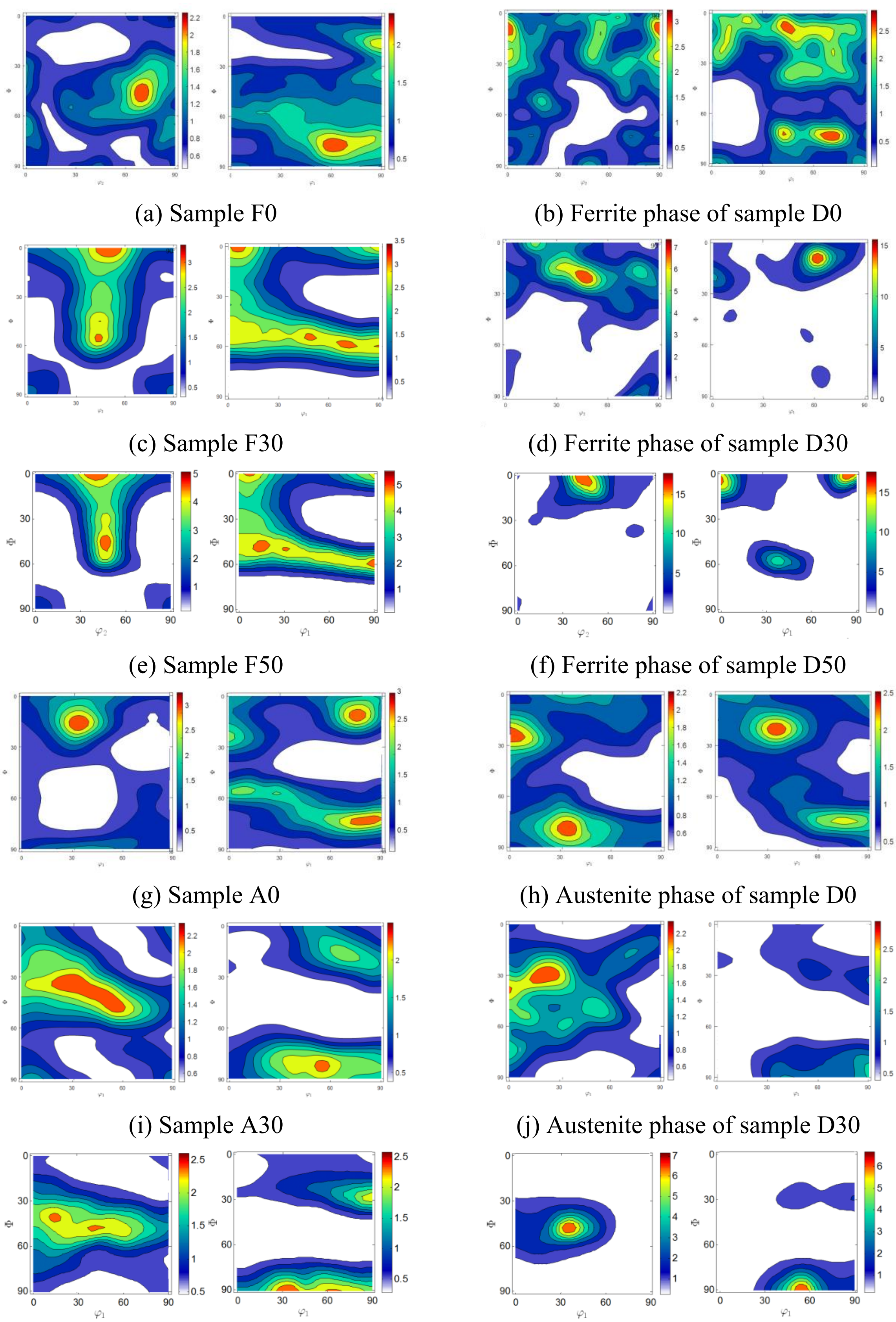
The plate shape samples of size 19×120 mm^2 and different thicknesses were made of AISI 420 (ferritic), AISI 304 (austenitic), and AISI 318LN (duplex) type of stainless steels. The samples were cold-rolled with 0, 10, 20, 30, 40, and 50 % reduction of thickness so that the final thickness of all samples was 1.5 mm. For this reasons, samples made of ferritic, austenitic and duplex steel were marked as F0–F50, A0–A50 and D0–D50, respectively.

The *X'Pert PRO MPD* diffractometer with cobalt radiation was used for surface analyses of the rolled samples by X-ray diffraction (XRD). The texture analysis was based on ODF calculation from experimental pole figures which were obtained from three diffraction lines *{110}*/*{220}*, *{200}*, *{211}* of ferrite phase and *{111}*/*{311}*, *{200}*, *{220}* of austenite phase. The *MATLAB*^{TM} toolbox *MTEX* software was used for processing of all experimental data [6].

Results and discussions

ODF sections of samples with 0, 30 and 50 % deformation (reduction of thickness) are shown in Figs. 3. Because of grinding surface during samples preparation, the initial textures of samples without deformation (F0, A0 and D0) were composed of grinding texture components.

The typical texture components and fibres were observed in the ferritic samples F0–F50, see Figs. 3a, 3c, 3e. The strength of the mentioned texture components and fibres increased with deformation. The dominant α_1 and γ-fibres, which contain *{001}*<*110*> (rotated cubic),



(a) Sample F0 (b) Ferrite phase of sample D0

(c) Sample F30 (d) Ferrite phase of sample D30

(e) Sample F50 (f) Ferrite phase of sample D50

(g) Sample A0 (h) Austenite phase of sample D0

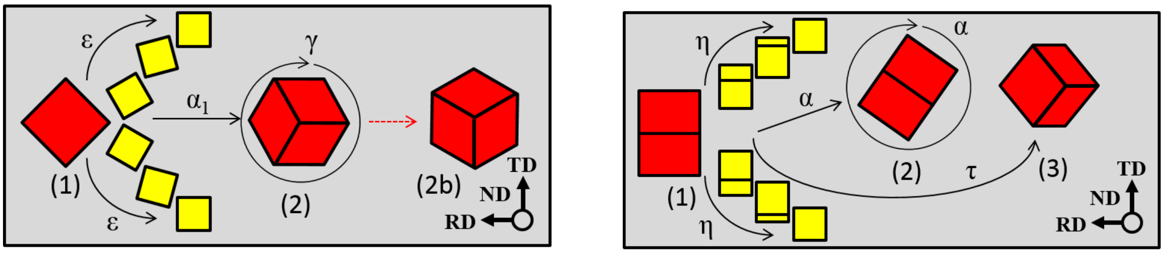
(i) Sample A30 (j) Austenite phase of sample D30

(k) Sample A50 (l) Austenite phase of sample D50

Fig. 3 ODFs in the $\varphi_1 = 0°$ (left) and $\varphi_2 = 45°$ (right) sections for ferrite phases, and $\varphi_2 = 0°$ (left) and $\varphi_2 = 45°$ (right) sections for austenite phases

{*112*}<*110*> and {*111*}<*110*> texture component, were generated during cold-rolling, see Fig. 4a.

Grains transitioned from the rotated cubic {*001*}<*110*> to the cubic component {*001*}<*100*> during rolling of the austenitic samples A0–A50, see Figs. 3g, 3i, 3k. The G component {*110*}<*001*> was generated after 30 % deformation. Rotating these grains around <*100*>||RD axis, the *η*-fibre was formed. If grains with G orientation rotates around <*110*>||ND axis, the *α*-fibre and Bs texture component could be observed, see Fig. 4b. The *τ*-fibre is composed only of G and Cu texture components. However, the Cu texture component is more common for materials with high SFE.



(a) Ferrite grains – *(1)* {*001*}<*110*> (rotated cubic), *(2)* {*112*}<*110*> and *(2b)* {*111*}<*110*> texture component

(b) Austenite grains – *(1)* G, *(2)* Bs and *(3)* Cu texture component

Fig. 4 Typical orientation of bcc (left) and fcc (right) materials during rolling

The mutual influence of ferrite and austenite phases and mainly different mechanical properties of both phases result in limitation of movement of ferrite (Figs. 3b, 3d, 3f) and austenite (Figs. 3h, 3i, 3l) grains during deformation. The harder ferrite phase (ferrite – 400 HV and austenite – 362 HV) keep energy until deformation exceeds a certain limit. This released energy results in sudden ferrite grains rotation to another discrete orientation. From this reason, the observed texture components were very strong and not typical for this deformation of bcc materials or phases. However, typical texture components were generated in the sample with higher deformation.

Texture components of austenite phase of duplex steel (Figs. 3h, 3i, 3l) were stronger in comparison with single-phase steel. With increasing of deformation, Bs and G texture components were observed. In spite of very small SFE (10 mJ/m^2), the unusual Cu texture component was analysed too. The majority of grains had Bs orientation for the sample with 50 % deformation.

Conclusions

The present study showed:

- The type and rate of texture components were different for dual and single-phase steels.
- The higher rate of texture was accompanied by increasing degree of reduction of single-phase samples.
- The typical texture components and fibres were observed for cold-rolled single-phase steels. The generation of Cu texture component of austenitic steel, which is more common for materials with high SFE, is less frequently analysed.
- The textures for both the phases of duplex steel were stronger in comparison with single-phase steels. The presence of fibres was limited and mostly discrete texture components were observed. For high deformation of austenite phase, only Brass component developed texture, which is typical for steels with low SFE.

Acknowledgement

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