Textures and Microstructures, 1993, Vol. 22, pp. 53–58
Reprints available directly from the publisher.
Photocopying permitted by license only

ON THE DEVELOPMENT OF THE BRASS-TYPE TEXTURE*

TORBEN LEFFERS

Materials Department, Risø National Laboratory, DK-4000 Roskilde, Denmark

(Received February 2, 1993)

It is demonstrated that a number of the conclusions drawn by Singh, Ramaswamy and Suryanaryana (1992) in an investigation of the texture development in rolled austenitic steel are in direct contravention of various recent observations on the texture development in brass by the present author and coworkers. And it is demonstrated that these conclusions are without specific justification in the results quoted.

KEY WORDS Copper-type and brass-type rolling texture, mechanical twinning, deformation models.

1. INTRODUCTION

The development of two different types of rolling texture in fcc materials, the copper-type and the brass-type texture, is one of the classical problems in texture research. Wassermann (1963) suggested an explanation for the formation of the brass-type texture which was widely accepted. According to Wassermann mechanical twinning transforms orientations in the vicinity of $\{211\}\langle 111\rangle$ to orientations in the vicinity of $\{110\}\langle 001\rangle$ (or $\{552\}\langle 115\rangle$). Wassermann's original work did not include any quantitative model for texture formation without twinning. Quantitative texture simulations, e.g. Kallend and Davies (1972) and Van Houtte (1978), showed that the above twinning process (with a substantial volume fraction of twins) could lead to the brass-type texture when combined with the Taylor model (Taylor, 1938). Wassermann's "twinning theory" with the later additions implies (i) that the initial development of the brass-type texture (at moderate reductions) is identical to that of the copper-type texture, (ii) that this initial development follows the Taylor model and (iii) that the initial *deviation* of the brass-type texture from the copper-type texture (claimed to appear after reductions of ~50%) is caused by a volume effect of the deformation twins. However, already Leffers and Grum Jensen (1968) showed that the actual microstructure in rolled brass does not agree with Wassermann's ideas: the volume fraction of twinned material is too small to have a decisive *direct* effect on the texture (see section 4 in the present work for more recent observations). As described in sections 2 and 3 detailed texture investigations also turn out to disagree with Wassermann's ideas.

Nevertheless, Singh, Ramaswamy and Saryanarayana (1992), in an investigation of the rolling texture in austenitic stainless steel, still use the Wassermann concept in the interpretation of their results. In the present work it is argued that

---

* This paper is a comment on "Development of Rolling Textures in an Austenitic Stainless Steel" by C. D. Singh, *et. al.* (1992), *Textures & Microstructures* **19**, pp. 101–121.

this interpretation is without any experimental justification. It should be underlined that the present work does not aim at casting any doubt on the *observations* quoted by Singh *et al.*

2. TEXTURE DEVELOPMENT

Together with Juul Jensen (Leffers and Juul Jensen, 1988, 1991) the present author has demonstrated that the development of the copper-type and the brass-type texture in initially texture-free materials is different from the very beginning. This conclusion was based on texture measurements by neutron diffraction on three different batches of copper and three different batches of brass (with 15% zinc). The results, expressed as the development of the texture component {211}⟨111⟩ (the "copper component"), are shown in Figure 1. As quoted by Leffers and Juul Jensen (1991) there are a number of other investigations indicating that the two types of fcc rolling texture develop differently from a very early stage, e.g. Truszkowski, Dutkiewicz and Szpunar (1969), Tobisch and Mücklich (1973), Donadille, Valle, Dervin and Penelle (1989)—even though this is not stated explicitly by the authors.

Based on their investigation of austentitic steel with a strong initial texture, Singh et al. (1992) now repeat the traditional statement (e.g. Wassermann, 1963) that the development of the brass-type texture (in their steel "cold-rolled" at 473 K) follows the development of the copper-type texture up to about 50% reduction. As compared with the statement to the opposite effect by Leffers and

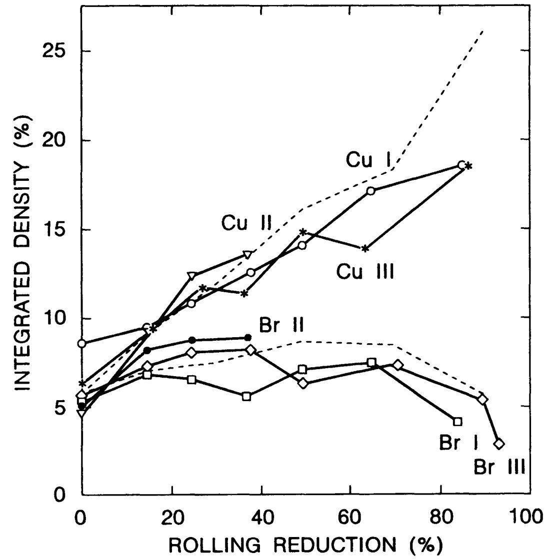

Figure 1 The development in integrated orientation density within 15° from {211}⟨111⟩ in three batches of copper and three batches of brass as investigated with neutron diffraction by Leffers and Juul Jensen (1988, 1991). The figure is quoted from Leffers and Hansen (1992) who have added simulated developments as dashed curves (for details about the simulations see section 3).

Juul Jensen quoted above, the statement of Singh *et al.* has a very weak basis (or no basis): there is no comparison with the development of the copper-type texture in a material with a similar initial texture, and, even in spite of the strong initial texture, the texture development in the austenitic steel is not too different from the texture development in brass as reported by Leffers and Juul Jensen. For instance, the orientation density of the {211}⟨111⟩ component varies with rolling reduction in very much the same way as the {211}⟨111⟩ density in brass in Figure 1: it starts at 3.5 at zero reduction (in the "hot band"); it increases moderately to 4.8 at 30% reduction and then decreases moderately to 4.1 at 50% reduction—as opposed to the monotonous increase in copper as shown in Figure 1. One should notice that the orientation density quoted by Singh *et al.* is not quite the same as the integrated orientation density (within 15°) quoted in Figure 1. But one must assume that the *developments* in density and integrated density can be compared.

3. MODELLING OF THE BRASS-TYPE TEXTURE

Singh *et al.* claim that the initial texture development in their steel (up to about 50% reduction) agrees fairly well with the Taylor model (Taylor, 1938). In Figure 1 the dashed curves, simulating the development of the copper-type and the brass-type texture, refer to the Taylor model (with relaxed constraints and added random stresses) and the modified Sachs model (Pedersen and Leffers, 1987), respectively. The Taylor model produces a monotonous increase in the {211}⟨111⟩ density—as opposed to the behaviour of brass in Figure 1 and to the behaviour of the steel of Singh *et al.* The modified Sachs model, on the other hand, provides a good simulation of the development of the brass-type texture, not only for the development in {211}⟨111⟩ density as shown in Figure 1. This is demonstrated in Figure 2 showing the experimental {200} pole figure for brass rolled to 50% reduction together with the corresponding pole figure simulated with the modified Sachs model. For comparison Figure 2 also shows two simulated Taylor {200} pole figures for 50% reduction, one with relaxed constraints and added random stresses (as used in the copper simulation in Figure 1) and one with full constraints and no random stresses; neither of the Taylor pole figures provide an adequate simulation of the brass texture. The degree of reduction selected in Figure 2 is 50%, but experimental and simulated pole figures for lower reductions show exactly the same trends (e.g. Leffers and Juul Jensen, 1988).

The reason why the modified Sachs model (and not the Taylor model) is capable of simulating the development of the brass-type texture at moderate reductions is clear: the "bundle" structure (Leffers and Bilde-Sørensen, 1990) in brass (and probably in the steel of Singh *et al.*) leads to single glide (or glide on one single slip plane) in many grains from the initial stage of deformation. This means that neither of the two types of grains (with or without bundles) fulfill the Taylor requirement of equality between microscopic and macroscopic strain, e.g. Leffers and Juul Jensen (1991) and Leffers and Hansen (1992). The bundle mechanism may be seen as an *indirect* effect of twinning, as opposed to the *direct* effect discussed in section 4 (for a detailed discussion see Leffers and Bilde-

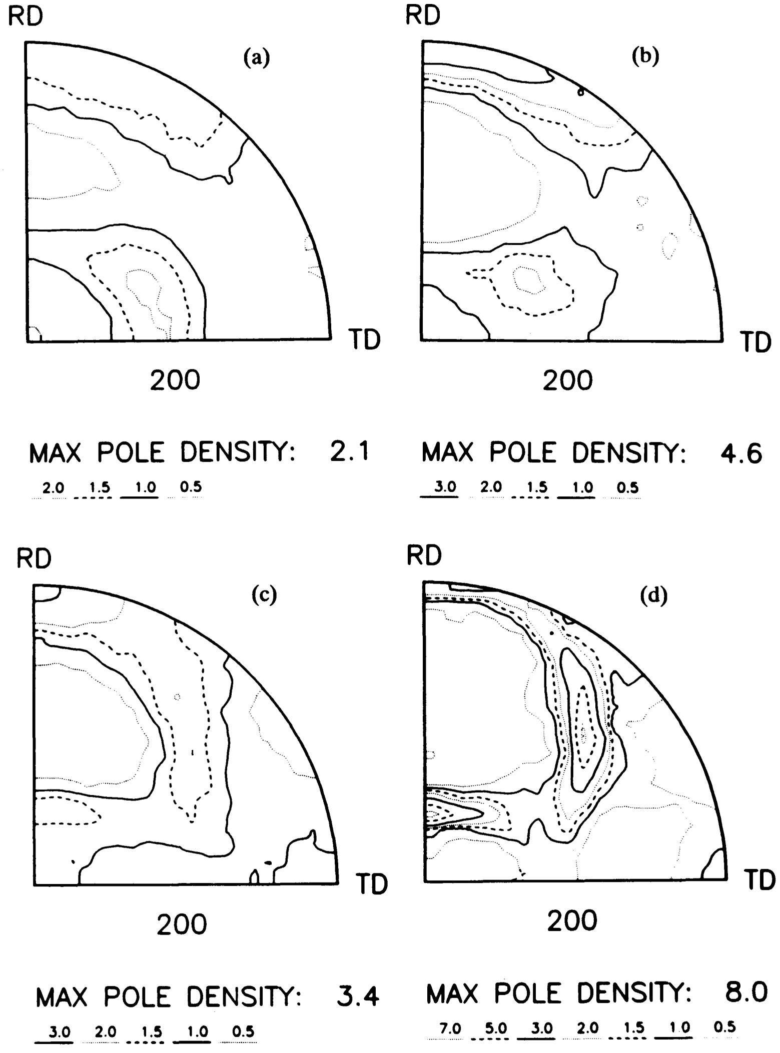

Figure 2 Experimental {200} pole figure for brass rolled to 50% reduction (a) and the corresponding pole figure simulated with the modified Sachs model (b), both from Leffers and Hansen (1992). For comparison simulated {200} pole figures (again 50% reduction) for the Taylor model with relaxed constraints and added random stresses (c) and for the Taylor model with full contraints and no random stresses (d) are also shown, both from Leffers and Juul Jensen (1992).

Sørensen). In an investigation of the orientation distribution of the twin lamellae in brass rolled to moderate reduction (40%) Leffers and Van Houtte (1989) also demonstrated that the deformation pattern is of a modified-Sachs type rather than a Taylor type.

As discussed by Leffers and Hansen (1992) it is less clear why the modified Sachs model also provides a fairly good simulation of the brass-type texture at higher reductions where shear banding is the predominant deformation mode (see section 4).

4. THE EFFECT OF DEFORMATION TWINS

Quantitative microstructural investigations of brass rolled to moderate reductions (e.g. Leffers and Bilde-Sørensen, 1990) have shown that the volume fraction of twinned material (estimated to be of the order of a few percents) is far too small to have a significant direct volume effect on the texture—which also agrees with the observations by Duggan, Hatherly, Hutchinson and Wakefield (1978). Without any microstructural investigation Singh *et al.* repeat the traditional Wassermann statement that the "initial stage" in the transition from the copper-type to the brass-type texture (stated to start at ~50% reduction) is caused by a volume effect of the mechanical twins. After the observations by Leffers and Bilde-Sørensen such a statement, with no support in microstructural observations, is very questionable (and so is the whole concept of an *initial* transition stage at ~50% reduction, cf. section 2).

For the continued development of the brass-type texture at higher reductions in the austenitic steel Singh *et al.* refer to the suggestions by Duggan *et al.* (1978): overshooting caused by the closely spaced twin lamellae (again an *indirect* twin effect), subsequent shear banding and eventually reestablishment of more homogeneous slip. This is probably basically correct—even though Leffers and Bilde–Sørensen have suggested some modifications.

CONCLUSIONS

A number of the statements made by Singh *et al.* (1992) about the texture development in austenitic steel are in direct contravention of the observations by the present author and coworkers on the texture development in brass, and they are without any justification in the results quoted. This applies in particular to the following statements: (i) the initial texture development is similar to that in copper, (ii) the initial texture development follows the Taylor model, and (iii) the initial deviation from the copper-type texture may be explained as a volume effect of the deformation twins.

References

Donadille, C., Valle, R., Dervin, P. and Penelle, R. (1989). *Acta metall.* **37,** 1547.

Duggan, B. J., Hatherly, M., Hutchinson, W. B. and Wakefield, P. T. (1978). *Metal Sci.* **12,** 343.

Kallend, J. S. and Davies, G. J. (1972). *Phil. Mag.* **25,** 471.

Leffers, T. and Bilde-Sørensen, J. B. (1990). *Acta metall. mater.* **38,** 1917.

Leffers, T. and Grum Jensen, A. (1968). *Trans. Met. Soc. AIME* **242,** 314.

Leffers, T. and Hansen, N. (1992). In *Modelling of Plastic Deformation and Its Engineering Applications*. S. I. Andersen *et al.*, eds., Risø National Laboratory, Roskilde, 57.

Leffers, T. and Juul Jensen, D. (1988). *Textures and Microstructures* **8/9,** 467.

Leffers, T. and Juul Jensen, D. (1991). *Textures and Microstructures* **14–18,** 933.

Leffers, T. and Juul Jensen, D. (1992). In *Modelling of Plastic Deformation and its Engineering Applications*. S. I. Andersen *et al.*, eds., Risø National Laboratory, Roskilde, 323.

Leffers, T. and Van Houtte, P. (1989). *Acta metall.* **37,** 1191.
Pedersen, O. B. and Leffers, T. (1987). *Constitutive Relations and Their Physical Basis.* S. I. Andersen *et al.,* eds., Risø National Laboratory, Roskilde, 147.
Singh, C. D., Ramaswamy, V. and Suryanarayana, C. (1992). *Textures and Microstructures* **19,** 101.
Taylor, G. I. (1938). *J. Inst. Metals* **62,** 307.
Tobisch, J. and Mücklich, A. (1973). *Texture* **1,** 211.
Truszkowski, W., Dutkiewicz, J. and Szpunar, J. (1969). *Bull. Acad. Polon. Sci.* **17**(6), 53.
Van Houtte, P. (1978). *Acta metall.* **26,** 591.
Wassermann, G. (1963). *Z. Metallk.* **54,** 61.