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MODELLING OF TEXTURE DEVELOPMENT IN COLD ROLLED FERRITIC-AUSTENITIC STAINLESS STEEL USING SELF-CONSISTENT VISCOPLASTIC MODEL AND FINITE ELEMENT METHOD

MODELOWANIE ROZWOJU TEKSTURY KRYSTALOGRAFICZNEJ W WALCOWANEJ NA ZIMNO STALI FERRYTYCZNO-AUSTENITYCZNEJ Z WYKORZYSTANIEM MODELU SAMOUZGODNIONEGO LEPKOPLASTYCZNEGO ORAZ METODY ELEMENTÓW SKOŃCZONYCH

The paper presents the possibility of applying the finite element method to predict the development of crystallographic texture in the two-phase cold rolled ferritic-austenitic steel. The calculations were carried out using the finite element code Abaqus and the subroutine VPSC5 including visco-plastic self-consistent model. The set of initial orientations was based on experimental texture of the annealed sample. The resulting textures obtained for a finite element situated in the inner area of sample are in a good agreement with the experimental data.

Keywords: texture, simulation, FEM, multiphase materials, visco-plastic self consistent model

W pracy przedstawiono możliwość zastosowania metody elementów skończonych do przewidywania rozwoju tekstury krystalograficznej w walcowanej na zimno stali ferrytyczno-austenitycznej. Obliczenia wykonano z zastosowaniem programu Abaqus opartym na metodzie elementów skończonych w połączeniu z programem VPSC5, wprowadzającym model lepko-plastyczny samouzgodniony. Zbiór orientacji początkowych wygenerowano w oparciu o dane doświadczalne dla próbki w stanie wyżarzonym. Wykazano zgodność obliczonych tekstur z danymi doświadczalnymi.

1. Introduction

In the last years the increased interest in the application of finite element method for prediction of the crystallographic texture is observed. This follows from many advantages of this method, such as: good projection of the stress and strain state and securing of the material continuity (which is very important in multiphase materials modelling).

One can find many publications describing different attempts of FEM application to modelling of the texture development, however the presented methods are mostly limited to single phase materials [1-7]. There are not many ideas of FEM application to two-phase materials. In addition, the existing papers describe mainly simple case of inclusion (first phase) embedded in the matrix (second phase) [8-10].

In this work a computational system based on the finite element method combined with VPSC5 code (visco-plastic self-consistent model) [11] has been proposed and applied to predict texture evolution in two-phase materials.

2. Model of rolling process

The multipass cold rolling process (Fig.1) of a sample with the dimensions of 10×20×80 mm was performed using FE-code Abaqus. The rolls were modelled as a rigid bodies. The assumed parameters of the rolling process are:

- total reduction 90% (9 roll passes, ~10% r.r. per pass)
- roll diameter 500 mm
- friction coefficient 0.25

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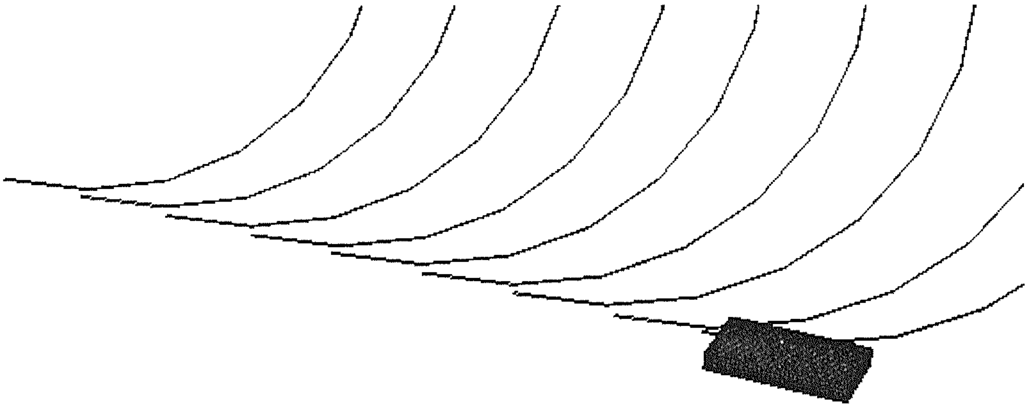

Fig. 1. The sample and the nine rigid rolls

3. Calculations

The calculations were carried out in two steps. In the first one, using Abaqus code the local tensors of deformation gradient for each finite element were calculated. The isotropy of the material was assumed for the calculations in this step (based on the Mises theory) [12]. In the second step, the tensors of deformation gradient for chosen finite element are transmitted to the subroutine VPSC which calculates orientation changes at each time increment using the visco-plastic self-consistent model. The local deformation gradient tensor determined in the first step is considered now as the global one for VPSC5. The orientations of crystallites in the initial state were generated from orientation distribution functions (ODF) calculated from pole figures measured for annealed sample using the neutron diffraction method [13]. It was assumed that 1200 initial orientations for BCC phase and 800 initial orientations for FCC phase (according to volume fraction of phases in experimental sample) are assigned to one finite element. Twelve slip systems <110>{111} and twelve twinning systems <110>{112} for the FCC phase while forty eight slip systems: <111>{110}, <111>{112} and <111>{123} for the BCC phase were assumed.

The advantage of presented approach is that the multi-phase character of the material (the interactions between FCC and BCC phases) is included in processing of only single finite element. Because of this, one can use average mechanical properties (in form of work-hardening curve) of investigated material.

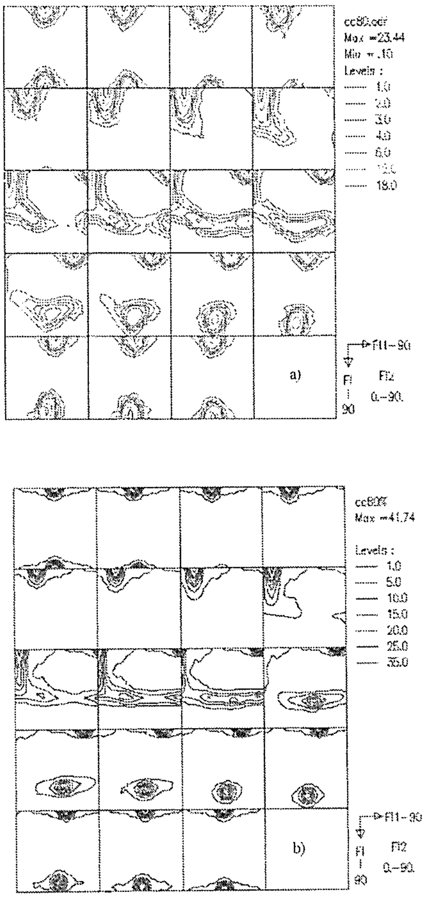

Fig. 2. Orientation distribution function for BCC phase (80% r.r.): a) experiment, b) model

4. Results

The orientation distribution functions obtained from pole figures and calculated by FE-VPSC system for FCC and BCC phases are shown in figures 2 and 3.

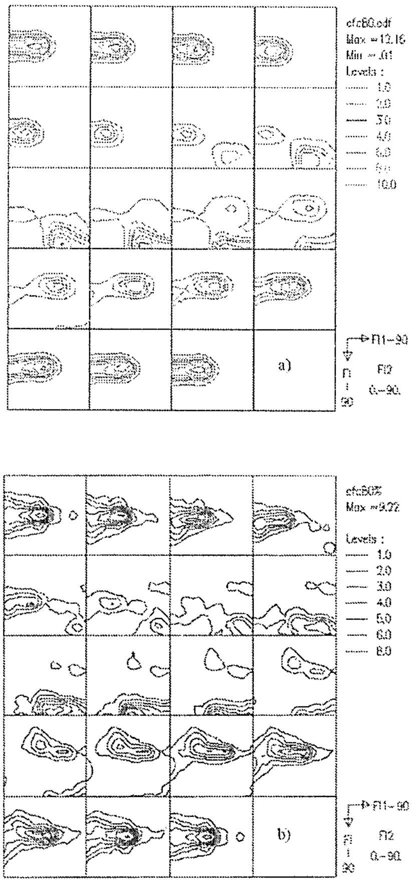

Fig. 3. Orientation distribution function for FCC phase (80% r.r.): a) experiment, b) model

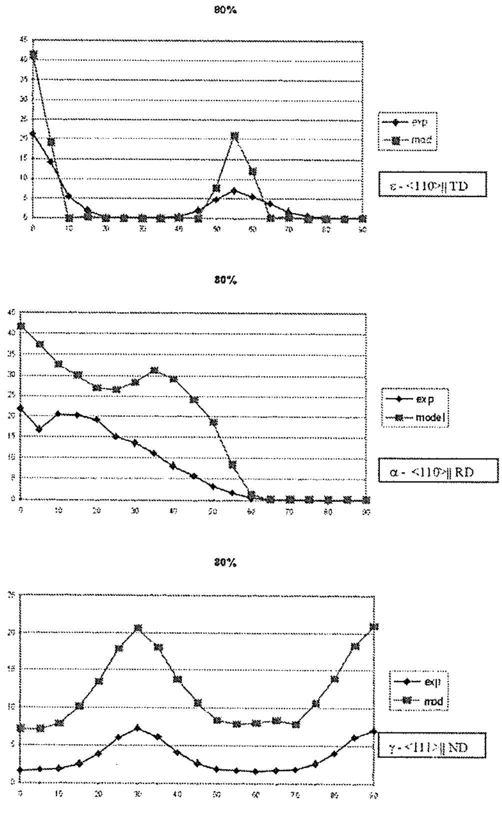

Fig. 4. Comparison of experimental and model skeleton lines for BCC phase at 80% of deformation

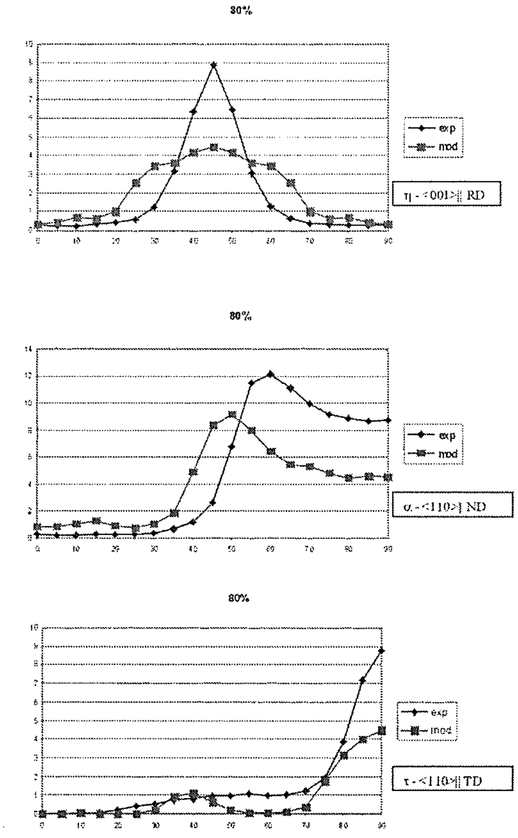

Fig. 5. Comparison of experimental and model skeleton lines for FCC phase at 80% of deformation

5. Discussion

The possibility of applying the finite element method to predict texture development in two-phase materials has been investigated. FE-code program Abaqus with the user subroutine Vumat and VPSC5 code (which introduces the visco-plastic sel-consistent model and calculates the orientation changes) have been used. The sets of 2000 initial orientations has been generated: 1200 for FCC and 800 for BCC phase. The sets have represented the main features of orientation distributions.

The ODF's obtained as a results of modelling were compared with ODF's for commercial ferritic-austenitic UR45N steel [13]. The good agreement between model and experimental results was found. However, analysis of skeleton lines has revealed some differences. Distributions of orientation density along characteristic fibres for both phases have the same local maxima. Only in case of <110>|| RD fibre for BCC phase the maximum is shifted towards {112}<110> orientation. Beside of this the calculated orientation densities for FCC phase are weaker than experimental ones, while for BCC phase the sharper distributions are observed. It can be explained by different behaviour of phases during deformation of the real material [14], while in calculations the same work-hardening curve of typical ferritic-austenitic stainless steel was used for both single and two-phase steels. It might cause the observed differences in orientation distributions.

6. Conclusions

The results obtained in this work have proved that FEM-VPSC5 system can be succesfully used for modelling of formation and development of crystallographic texture during plastic deformation of multiphase materials. The advantages of the proposed approach are as follows:

- all slip systems for both phases and twinning systems for FCC are included
- mechanical properties are included by introducing the work-hardening curve which represents the average properties of investigated material
- modelling of large deformation is possible
- analysis of the samples with various complicated shapes can be performed
- interaction between phases takes place in the volume of each single finite element (not between finite elements)
- arbitrarily sample areas corresponding to volume of one finite element can be studied
- analysis of large sets of orientations is assigned to one finite element

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