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Numerical modeling of phase transformation during grinding process

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Abstract

The rapid heating and cooling in a grinding process may cause phase transformations. This will introduce thermal strains and plastic strains simultaneously in a workpiece with substantial residual stresses. The properties of the workpiece material will change when phase transformation occurs. The extent of such change depends on the temperature history experienced and the instantaneous thermal stresses developed. To carry out a reliable residual stress analysis, a comprehensive modelling technique and a sophisticated computational procedure that can accommodate the property change with the metallurgical change of material need to be developed. The objective of this work is to propose a simplified model to predict phase evolution during given temperature history for heating and cooling as encountered during grinding process. The numerical implementation of the proposed model is carried out through the developed FORTRAN subroutine called PHASE using the FEM commercial software Abaqus®/standard. Micro-structural constituents are defined as state variables. They are computed and updated inside the subroutine PHASE. The heating temperature is assumed to be uniform while the cooling characteristics in relation to phase transformations are obtained from the continuous cooling transformation (CCT) diagram of the given material (here AISI 52100 steel). Four metallurgical phases are assumed for the simulations: austenite, pearlite, bainite, and martensite. It was shown that at low cooling rates high percentage of pearlite phase is obtained when the material is heated and cooled to ambient temperature. Bainite is formed usually at medium cooling rates. Similarly at high cooling rates maximum content of martensite may be observed. It is also shown that the continuous cooling transformation kinetics may be described by plotting the transformation temperature, directly against the cooling rate as an alternative to the continuous cooling transformation diagram. The simulated results are also compared with experimental results of Wever [20] and Hunkle [21] and are found to be in a very good agreement. The model may be used for further thermo-mechanical analysis coupled with phase transformation during grinding process. © 2017 Penerbit UTM Press. All rights reserved.

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