

Micromechanical Modeling of Ferrite/Pearlite steels

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Abstract. Micromechanics is the analysis of composite or heterogeneous materials on the level of the individual phases that constitute these materials. In this project micromechanical structure of ferritic/pearlitic steels was modeled by two methods. First SHA model (stacked hexagonal array) and second the real microstructure of the steels. FE analysis was performed to investigate the influence of some parameters such as volume fraction and aspect ratio of the second phase on deformation behavior and also macroscopic and microscopic responses to tension and shear. The stress-strain curves from FE analysis of both models and experimental results obtained from some papers were similar. Afterward, a comparison between averages strains in different types of steel were performed that shows a rise by increasing pearlite volume fraction in steels.

1. Introduction

The main aim of micromechanics is to predict the properties of the materials by considering the properties of their constituent phases. By controlling microstructure an optimum mechanical properties can be achieved for structural materials. For studying the effect of morphology of second phase on stress-strain curve, FE analysis was performed preliminary [3, 4]. The Stacked Hexagonal-Array (SHA model) was proposed by Tvegaard [2] and widely used after that for two-phase material. Ishikawa et al. (2000) [1] reported the axisymmetric Voronoi cell model to estimate the behavior of ferrite-pearlite steels.

In this study, SHA model was used to model some types of steels with different pearlite volume fraction and aspect ratio. Also, their metallographic photo was used to make the microstructure model. By applying tension a comparison was made between stress-strain curves of SHA and microstructure model and also with the experimental results from Ishikawa et al. [1]. Applying shear to the microstructure model gave basic model of metal cutting and average strains of each phase were obtained.

2. Experiment, Results and Discussion

In the first section of this study SHA and real microstructure models were compared in the case of response to tension. In SHA model, the pearlite phase is modeled as nodules in the ferrite domain which are like arrays of hexagonal. These can be simplified to cylinder and FE analysis can be done considering it as axisymmetric model. The volume fraction, morphology and the neighboring factor of the pearlite nodules can be adjusted in this model. The model and parameters are shown in Fig 1 & 2 [1]. The microstructure model, based on metallographic image of the steel, was created in CAD software. FE modeling was performed in PATRAN and the analysis was done by LS-DYNA.

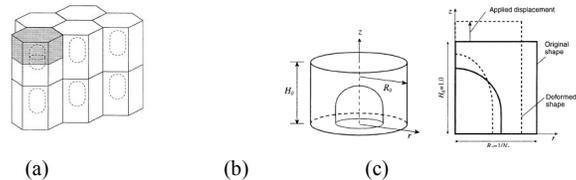


Fig.1. The SHA model: (a) the hexagonal model, (b) axisymmetric model, (c) simplified model after applying tension (Ishikawa et al.)

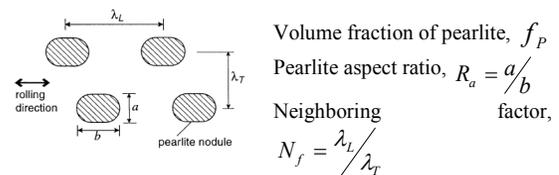


Fig.2. Parameters of Pearlite phase in the SHA model (Ishikawa et al)

The FE modeling of both models can be seen in Fig. 3. First, 20% strain in z direction were induced in both models and then their stress-strain curves were obtained by means of the Power-law formula below,

$$\sigma = K\varepsilon^n, \dots\dots\dots (1)$$

K and n for steels were achieved from experimental results [1]. In FE analysis n and K for each phase were obtained from the theory used by Ishikawa et al [1].

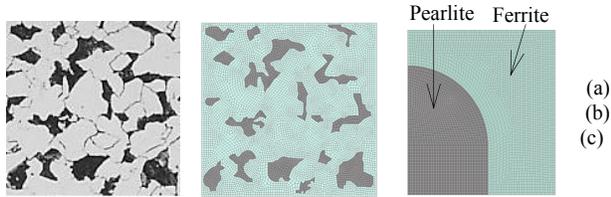


Fig.3. FE modeling for (18.8% pearlite) steel D1: (a) Microstructure photo (Ishikawa et al.) (b) FE model, (c) SHA model

In the Fig. 4 and Fig 5 the FE stress-strain curves and comparison between different models can be seen.

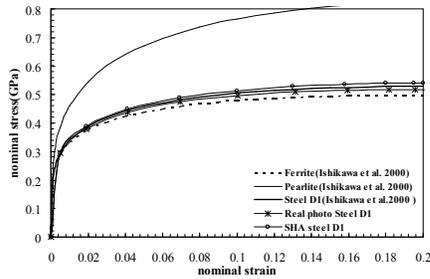


Fig.4. Stress-strain curve for Steel D1 ($f_p = 18.8\%$, $R_a = 1.6$, $N_f = 1.1$)

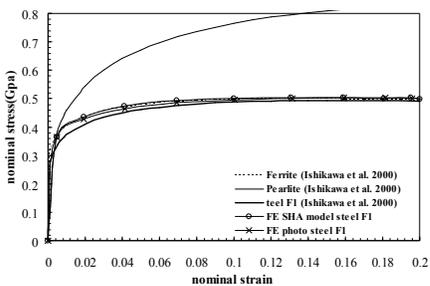


Fig.5. Stress-strain curve for Steel F1 ($f_p = 2.6\%$, $R_a = 1.0$, $N_f = 1.0$)

In Fig. 6 and Fig. 7 the stress and strain distributions for both models after applying displacement for inducing 20 % strain, can be seen.

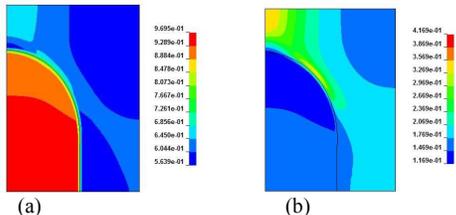


Fig.6. Stress and strain distribution in SHA model after inducing 20% strain: (a) von mises stress, (b) plastic strain.

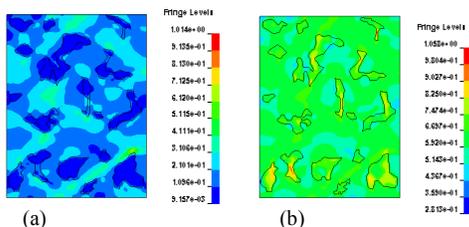
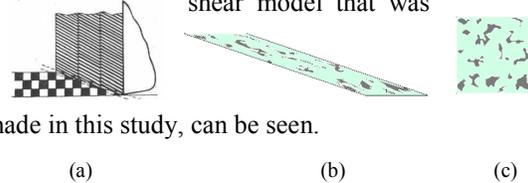


Fig.7. Stress and strain distribution in microstructure model after inducing 20% strain: (a) von mises stress, (b) plastic strain.

As it is shown, the maximum stresses in both models are of the same order but it is not true about the plastic strain that maybe caused by random distribution.

In the second section, the microstructure models were created for steels D1 and F1 and also 1045(55% Pearlite).Then similar displacements in horizontal direction were applied to them and the average strain of each phase were studied. This study is important in metal cutting since the metal going through primary shear zone in machining process can be modeled as simple shear. In Fig.8 the metal cutting model and the shear model that was



made in this study, can be seen.

Fig.8. Shear model: (a) metal cutting model (A.Bhattacharyya), (b)Study model before and after applying 200% shear strain

A comparison between averages strains in mentioned types of steel were performed (Table 1) that shows a rise by increasing pearlite volume fraction in steels.

Table 1. Average strains in two phases

	Ferrite	Pearlite
Steel F1	1.7190	0.6495
Steel D1	1.8766	0.9255
Steel 1045	2.3972	1.1936

3. Conclusions

The first section present the SHA model and microstructure model of ferrite/pearlite steels in applying tension. The stress-strain curves from both models show good matching with experiments [1].This verifies the accuracy of both methods of modeling. In the second section a simple shear was created. Average strains in the steels with different pearlite volume fraction, shows a rise by increasing volume fraction. This point can be very useful in metal cutting.

4. Acknowledgements

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