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The Effect of Interphase in Micromechanical Modeling of Dual-Phase Steel

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Abstract
A novel method to model the interphase between phases in DP steels is introduced and implemented on a specimen created from DP980. Use of the proposed method remedied the problem of underestimation of stress-strain curve by 2D RVEs and also showed that failure initiates at the interphase between phases.

Keywords: *Dual-Phase Steel – Microstructure – Micromechanical Modeling – Mechanical Behavior – Interphase*

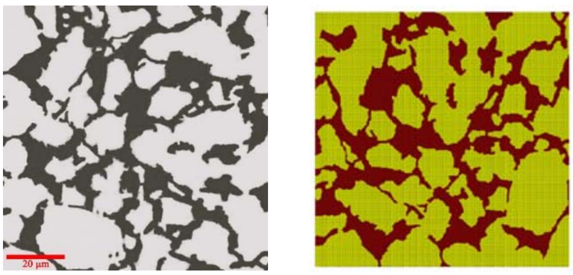
Introduction

Due to their high strength and good formability, Dual-Phase steels are widely used in the automotive industry. Their microstructure consists of hard martensite islands and a soft ferrite matrix. Strain localization is the first stage of failure process in DP steels [1] and is therefore critical to our understanding of their behavior. Although there has been various studies on properties and structure of DP steels [2-4], so far limited attention has been paid to the effect of the interphase between ferrite and martensite phases [5].

In this paper, the micromechanical behavior of DP steel will be investigated using experimental and numerical methods and a novel method for modelling the interface between phases will be proposed.

Materials and Methods

A 3.00 mm thick sheet of DP980 with properties reported in [6], derived from its chemical composition (Table 1), was used to generate the optical micrograph shown in Figure 1(a), which was used to create the RVE shown in (b).



(a) (b)

Figure 1. (a) Optical micrograph of dual phase steel, showing the microstructure of DP980. ($V_m = 33\%$) and (b) the resulting RVE.

Using Matlab's image processing toolbox, the ferrite phase in the binarized optical micrograph were eroded repeatedly to create an empty region between the two phases. This was done based on nano-hardness results of [5], in which martensitic values were observed at the phase boundary, and changed gradually to ferritic in the ferrite phases. In Figure 2, an RVE model created using this method is shown and the resulting space, hereinafter referred to as the *interphase region*, is colored blue.

Material properties of ferrite and martensite phases were re-used from [6]. Properties of elements in the interphase region were determined using interpolation. This interpolation was used for all parameters describing the elastic and plastic behaviors of the material. Eq. (1) was used to interpolate the material parameters for each element in the interface region.

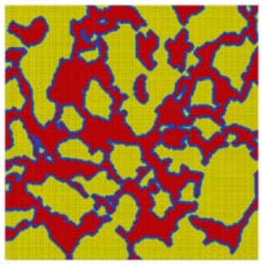


Figure 2. 2D RVE model of DP980 microstructure with the interface region.

$$P_{element} = \left((P_1 - P_2) \times \left(\frac{d_2}{d_1 + d_2} \right) \right) + P_2 \quad (1)$$

In this equation, $P_{element}$ is the value of the parameter in question for the element, d_1 and d_2 are the closest distance between the element and the first and second phases and P_1 and P_2 are constants referring to values of the parameter in their respective phases. To interpolate plastic properties, stress values of ferrite and martensite were calculated at points of equal strain so they would be comparable.

Result and Discussion

Mesh sensitivity was studied in [6] for the 2D RVE model and five different element sizes were investigated. As shown in Figure 3, the increased number of elements can help the simulations to have smoother grain boundaries between ferrite and martensite phases.

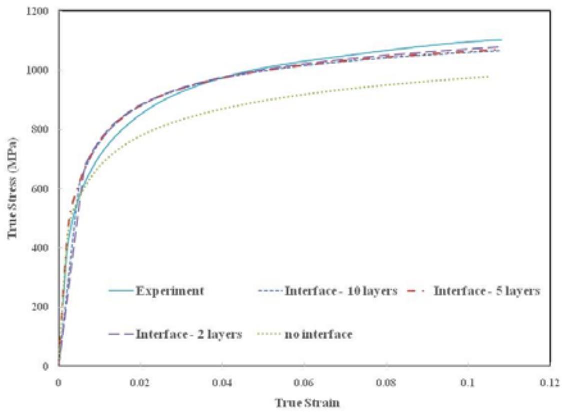


Figure 3. Simulation results for different models

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Table 1. Chemical compositions of low carbon steel, used in this study and [6]

Element	C	Mn	Si	P	S	Cr	Ni	Al	Mo	V	Cu	Co
Mass contents %	0.2	1.1	0.22	0.004	0.02	0.157	0.083	0.011	0.046	0.008	0.121	0.019

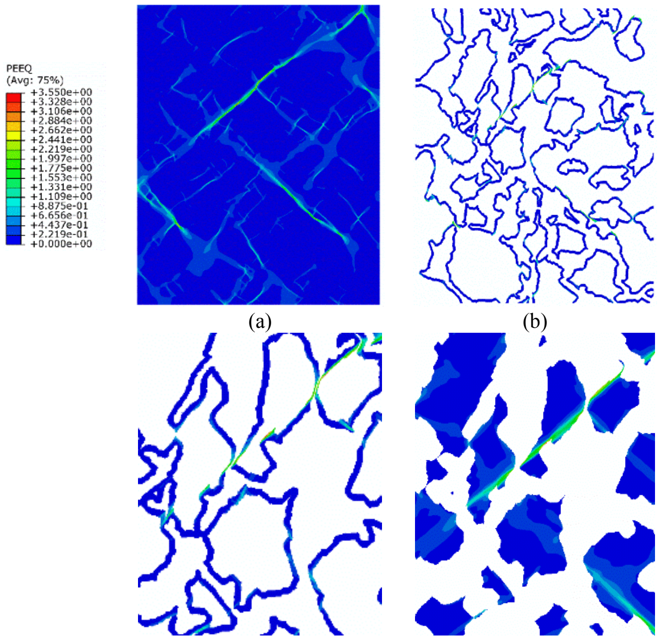

Figure 4. Distribution of equivalent plastic strain in the RVE in (a) whole model, (b) the interface, (c) part of the interface and (d) part of the ferrite phase. ($\varepsilon = 0.108$)

Figure 3 shows results of simulations for different models. It is evident that although RVEs incorporating the interphase can model the stress-strain response better than the RVE without interphase, increase of interphase resolution has negligible effect on the results.

One major problem of 2D RVEs in previous works was underestimation of the stress-strain curve, which lead to use of computationally expensive 3D RVEs [6]. This is solved by the proposed model. Figure 4 shows distribution of equivalent plastic strain in the RVE with interface at $\varepsilon = 0.108$. Shear bands seen in the figure mark the failure paths in the RVE. Figure 4(c) and (d) show that a significant number of these shear bands begin to form in the interphase region and then propagate to the ferrite phase. This is because martensite grains undergo much less deformation than the ferrite grains, and the mismatch between the values of deformation in two phases causes deformed bands at the interphase and ultimately, in the softer ferrite phase.

According to Figure 4, strain localization occurs mainly at two types of locations: (1) in ferrite grains within the neighborhood of martensite islands, where the martensite grains have much less deformation than the neighboring ferrite phase and the difference between deformation of the two phases causes the initiation of voids in the interphase; and (2) in closely spaced martensite grains, where the existence of some harder phase grains close to one another results in stress/strain localization.

Conclusion

In this study, the micromechanical behavior of DP steel was investigated using experimental and numerical methods and a novel method for modeling the interphase region between phases was proposed. Use of this method resulted in better prediction of stress-strain curve and also showed that failure initiates in the interphase region. Finally two types of initiation mechanism were reported in ferrite and interfaces phases.

References

1. Paul, S.K., *Real microstructure based micromechanical model to simulate microstructural level deformation behavior and failure initiation in DP 590 steel.* Materials & Design, 2013. **44**: p. 397-406.
2. Thomser, C., et al., *Modelling the mechanical properties of multiphase steels.* Computer Methods in Materials Science, 2007. **7**: p. 42-46.
3. Sun, X., et al., *Predicting failure modes and ductility of dual phase steels using plastic strain localization.* International Journal of Plasticity, 2009. **25**(10): p. 1888-1909.
4. Shen, H., T. Lei, and J. Liu, *Microscopic deformation behaviour of martensitic–ferritic dual-phase steels.* Materials science and technology, 1986. **2**(1): p. 28-33.
5. Kadkhodapour, J., A. Butz, and S. Ziaei Rad, *Mechanisms of void formation during tensile testing in a commercial, dual-phase steel.* Acta Materialia, 2011. **59**(7): p. 2575-2588.
6. Ayatollahi, M.R., et al., *3D Micromechanical Modeling of Failure and Damage Evolution in Dual Phase Steel Based on a Real 2D Microstructure.* Acta Mechanica Solida Sinica, 2016. **29**(1): p. 95-110.