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The effect of microstructural morphology on damage in multi-phase materials

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Industrial background

Important engineering examples of multi-phase materials are metal matrix composite and dual phase steel (DPS). DPS is often used in complex shaped structural parts of a car-body (figures) due to its unique combination of strength and ductility.

Material properties and failure

We consider a general dual phase material with a microstructure that comprises hard particles embedded in a soft matrix (fig. b). The stress–strain response displays a combination of these phases (fig. a).

Goal

We need a better understanding of the failure mechanisms to improve the failure characteristics. We focus on the effect of the distribution of phases (morphology) on damage.

Microstructural model

To systematically study the effect of the distribution of phases, we use a structured microstructural model. We statistically compare many random distributions using their damage response. Therefore, the model is discretized using finite elements. We apply a ductile damage criterion (cf. Rice & Tracy).

Damage statistics

The microstructure is described by an indicator function $I$. We compare different distributions by averaging $I$ around damage hot-spots (e.g. as highlighted): $\bar{I} = \sum [D_i I_i] / \sum [D_i]$

Result

The resulting $\bar{I}$ – interpreted as probability of hard phase around damage hot-spots – is shown (r) together with the interpretation (l). We observe a preferred orientation of hard bands leading to high stress and soft bands for high strain in the damage hot-spot chosen in the center.

Conclusion

- We have set-up a statistical framework to identify the influence of the microstructural morphology of damage.
- We have identified a critical morphology for damage.

Outlook

(1) Apply the damage statistics to:
- investigate the influence of the sub-surface microstructure;
- do experimental verification;
- study damage propagation

(2) Systematically vary microstructural parameters to identify their respective influence on damage (mechanisms).

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