INTEGRATED MATERIAL MODELLING ON THE CRASHWORTHINESS FOR AUTOMOTIVE HIGH-STRENGTH STEEL SHEETS

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Abstract: The aim of this study is to investigate the impact of microstructure features on the crashworthiness for automotive high-strength steel sheets by using multiscale modelling approach on different length scales, which provides a toolkit for the further microstructure design to meet the desired improvement of component performance. An extensive experimental program is designed involving various sample geometries that cover a wide range of stress states and tests are performed under quasi-static and high strain rate conditions and up to 2500 s^{-1} for an automotive dual-phase steel sheet (DP1000). The modified Bai-Wierzbicki (MBW) damage model is extended to a non-local formulation to cope with the simulations for lab and component levels. For the linking between the microstructure and mechanical properties, the representative microstructure model which considers the distributions of grain size, grain shape, crystallographic orientation and misorientation etc., is employed. The bridging between the models at different levels are powered by the virtual experiments and the entire approach is validated by lab-scale experiments and the crash box tests.

1. Introduction

Integrated computational materials engineering (ICME) has been intensively developed for the recent decade driven by the product and process optimisation and new material development. This study employees the ICME principle to explore its potential in the field of ductile damage and fracture particularly under high strain rates. An integrated multiscale modelling approach is established to seamlessly link models working at different length scales and eventually to guide the design of the microstructure for steels with improved damage tolerance.

The crashworthiness is a structural level measure of component properties that matters significantly for the automotive industry. It is normally characterised by crash box tests in case of axial loading, involving large plastic deformation and ductile damage/fracture behaviour under high strain rates and complicated loading history. Therefore, instead of the conventional "microstructure-mechanical property relationship", the study brings the scope one level up to the component performance scale. The impact of the microstructure features, including phase fraction, grain size, shape and crystallographic orientation, second phase morphology, etc. on the corresponding mechanical properties and further on the structural crashworthiness is quantitatively measured via the established multiscale modelling approach, and the result contributes to the new design rules for modern damage-tolerant high-strength steels.

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2. Results

The general methodological flow of the study is illustrated in Figure 1. It starts from the characterisation of the crashworthiness property and the bridging of the performance indicator with the mechanical property profiles via a hybrid experimental and numerical method. The experimental program covers large scale of stress states from quasistatic condition up to 2500 s^{-1} in both lab and component scales. For the up-scaling from mm level to m level, the modified Bai-Wierzbicki (MBW) damage model [1] is extended to a non-local formulation. Furthermore, For the linking between the microstructure and the mechanical properties, the representative microstructure model is employed allowing consideration of the microstructure parameters and at the same time bridging the equivalent quantities from microstructure to macroscopic level by incorporating a crystal plasticity material model. With the established modelling approach, the optimal microstructure can be identified and, in addition, the optimised processing parameters will also be calibrated and applied to production for the validation of the entire approach in both lab and component scales.

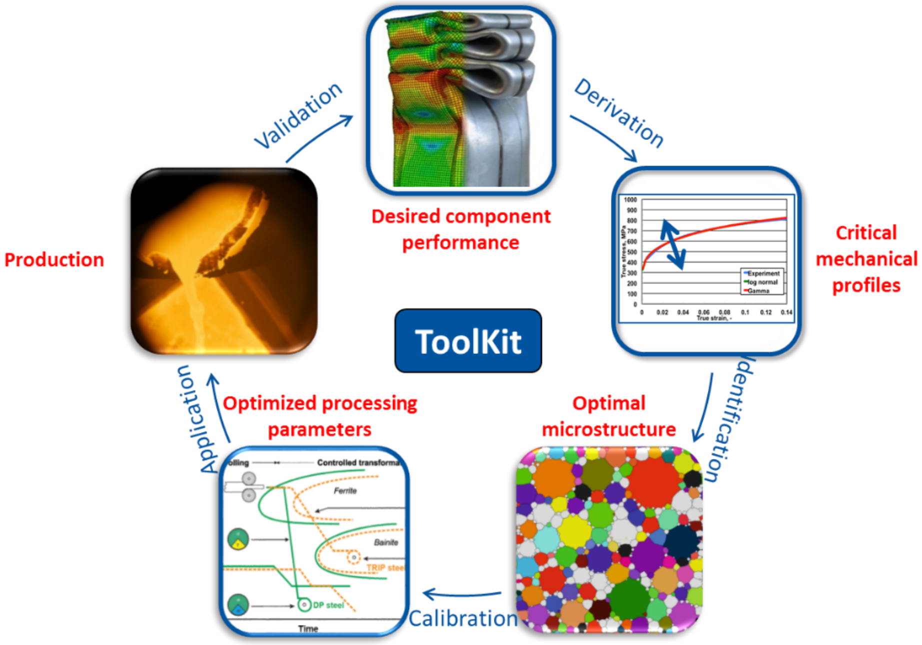

Figure 1. Methodological flow of the multiscale study on the high-strength steel sheets for the crashworthiness property across component level, lab level, microstructure and process routines.

3. Conclusions

The study illustrates the establishment and application of a multiscale modelling approach in the field of ductile fracture under very high strain rates and complex loading history. Based on multiscale verifications of the approach, the study contributes to the in-depth understanding between microstructure and crashworthiness for steel sheets and the derivation of new design rules for modern damage-tolerant high-strength steels.

Acknowledgements

This contribution shows the current research work of the European Project “TOOLKIT – Toolkit for the design of damage tolerant microstructures”. The financial support by the Research Fund for Coal and Steel of the European Commission is gratefully acknowledged.

References

[1] J. Lian, M. Sharaf, F. Archie, S. Münstermann. A hybrid approach for modelling of plasticity and failure behaviour of advanced high-strength steel sheets, *Int. J. Damage Mech.* 2013;22(2):188-218.