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Microstructure-based material model for thermo-mechanical fatigue of cylinder heads



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Introduction

Thermo-mechanical fatigue (TMF) arises as a consequence of thermal related stresses that developed due to thermo-mechanical cycling loading.

- Engine start-stop cycle results in large temperature variations.
- The constrained condition found in cylinder heads, produces compressive and tensile stresses.
- Continuous thermal cycling produce valve bridge cracking, resulting in cylinder TMF failure (Figure 1).

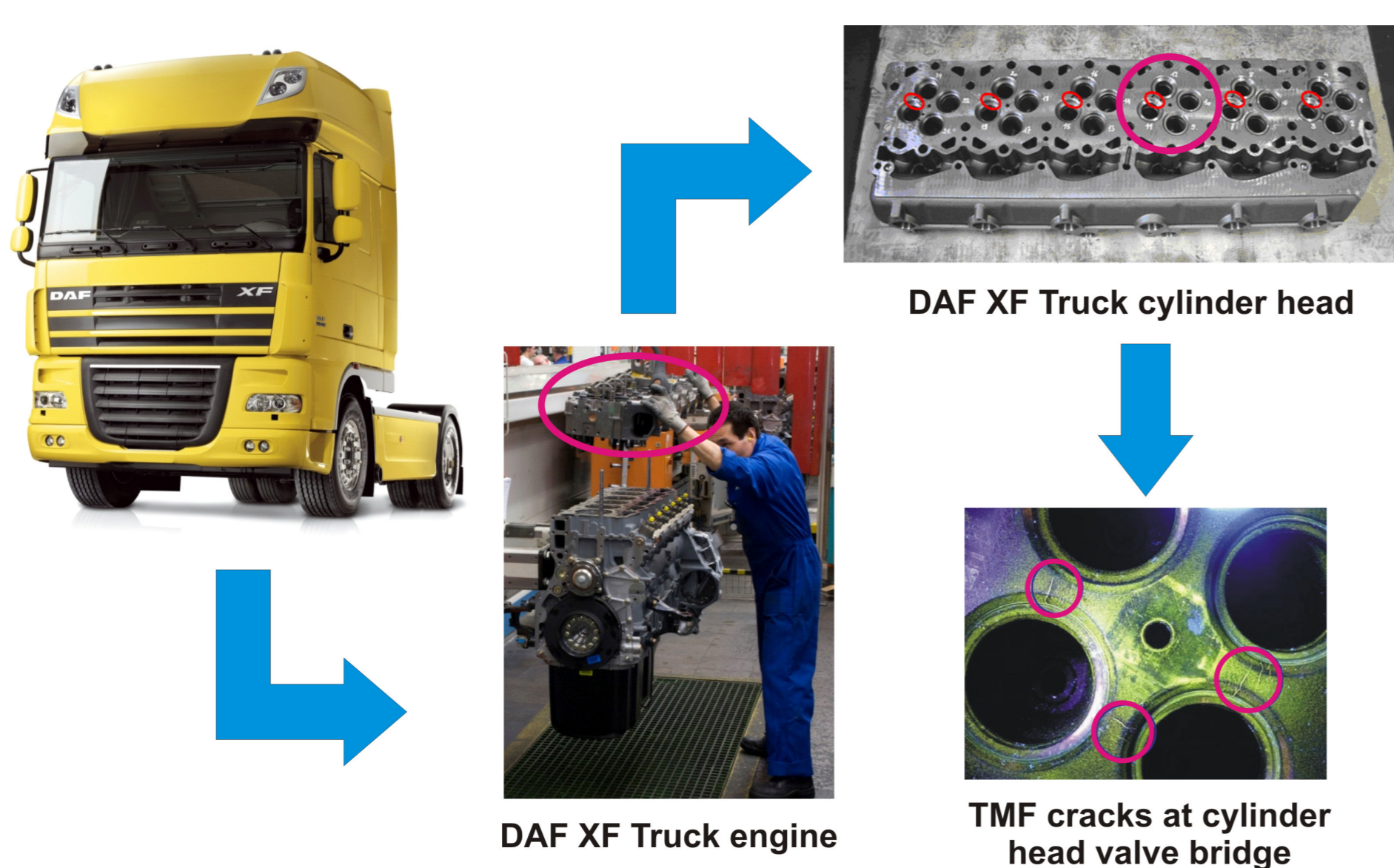
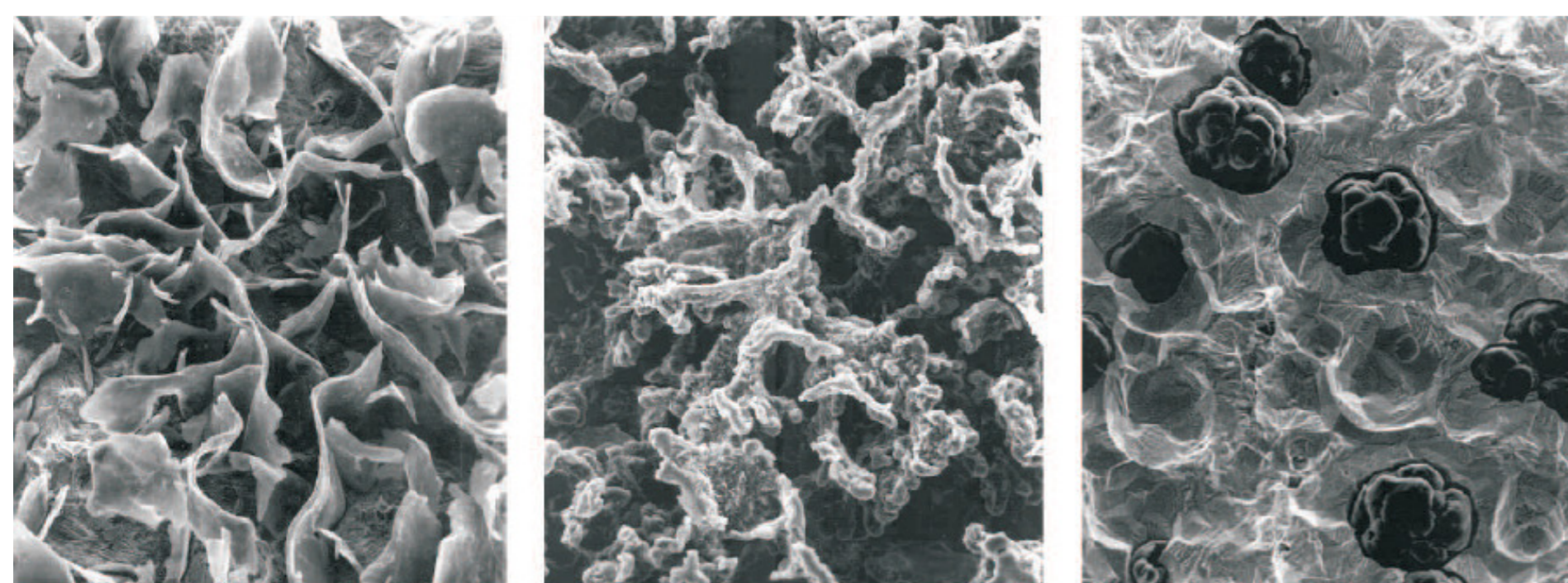


Figure 1: TMF cracks at valve bridges (Courtesy of DAF Trucks N.V.).

Cast iron heterogeneous microstructure (ferrite/pearlite matrix & graphite inclusions, Figure 2), makes prediction of its response at the macro level very complex.



a) Flake graphite b) Compacted graphite c) Spheroidal graphite

Figure 2: Graphite morphologies found in cast irons [1].

Aim of the project Develop a microstructure-based model for TMF life prediction that considers the different microstructural phases, their interaction and impact on TMF response.

Modelling approach

The basic phenomena to include in the model are:

- 3D Representative Volume Element (RVE) since the microstructure is inherently three-dimensional.
- Microcrack initiation & propagation through the graphite-matrix interface.
- Graphite anisotropy of mechanical & thermal properties.
- Microstructural evolution: oxidation.
- Creep & stress relaxation.
- Thermo-mechanical cycling.

Example Figure 3 shows a microstructure-based material model for nodular cast iron [2].

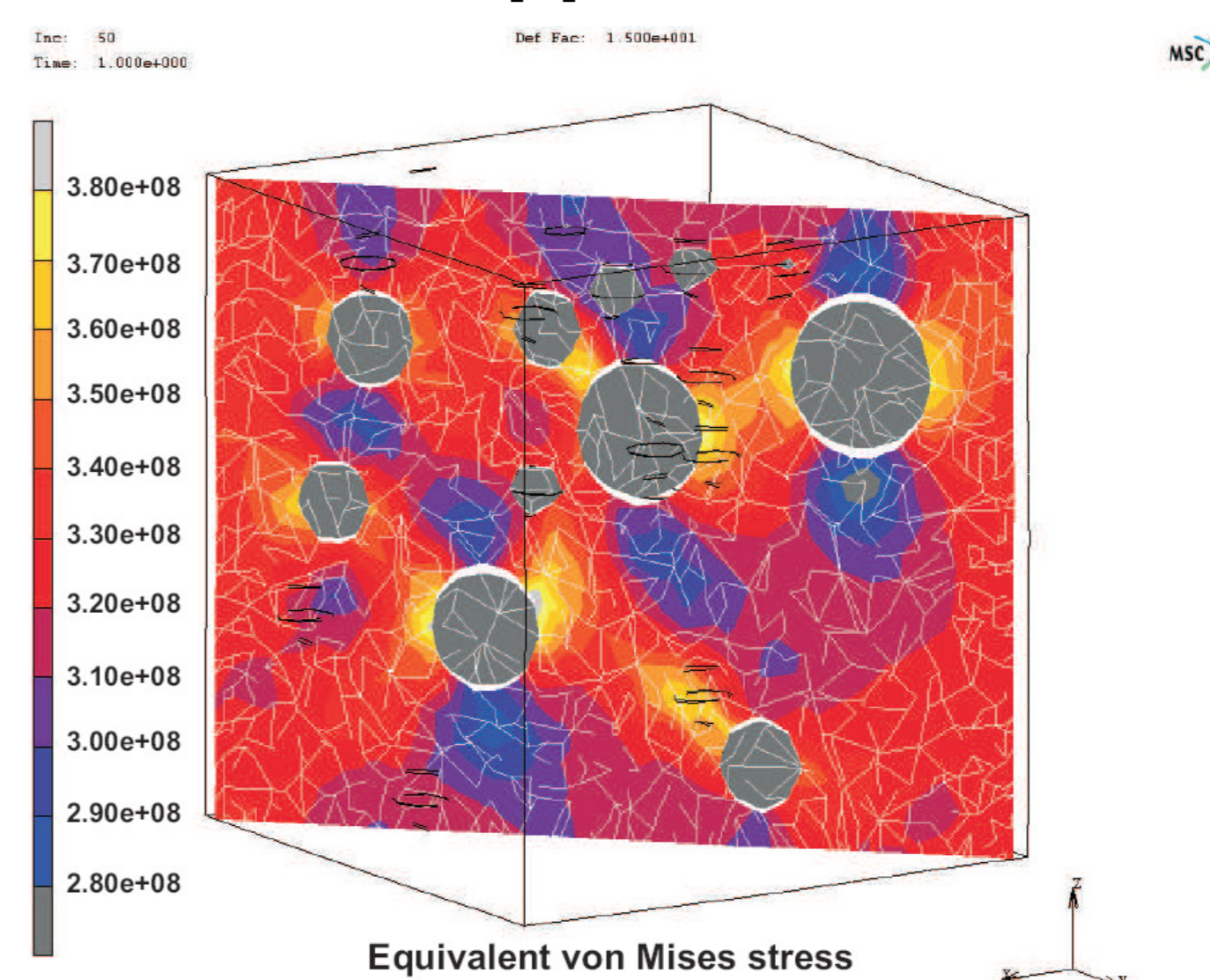


Figure 3: Microstructure-based material model of nodular cast iron under static tensile loading (vertical direction) [2].

Future work

- Improvement of existing cast iron model [2], by including graphite anisotropy and the different matrix phases (pearlite & ferrite).
- Development of cast iron microstructure-based model for thermo-mechanical loading conditions, including microstructural evolution.
- Development of cast iron microstructure-based model for TMF life prediction, where the influence of damage evolution at the micro level is incorporated at the macro level.

References

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2. van der Oord, G.A.H. (2009), Master Thesis, Eindhoven University of Technology, The Netherlands.