Success Story
COMET

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ZPT+
Non-destructive testing and Tomography Plus
Programme: COMET – Competence Centers for Excellent Technologies
Programme line: K-Projects
COMET subproject, duration and type of project:
Sub-project 2.2., 09/2014 – 08/2018, multi-firm

Worldwide first in-situ tomography and thermo-mechanical fatigue (TMF) experiments on cast Al-Si diesel piston alloys

Cast Aluminimum-Siliconm piston alloys are in high demand in various automotive applications. The thermo-mechanical performance of these alloys is heavily dependent on their inner structure. By means of in situ TMF tests combined with non-destructive in-situ synchrotron tomography experiments we were able to identify crack initiation sites and observe the propagation and accumulation of damage three dimensionally. These results enable us to gain further understanding of the microstructural features which affect the sequence of propagation of cracks during TMF conditions which is of utmost importance for the optimization of the TMF-resistance of Al-Si piston alloys

Success Story Long Version

Cast Al-Si alloys are used in automotive components like pistons due to their relatively high strength-to-weight ratio as well as excellent castability and heat conductivity. However, the rising demand for more efficient combustion engines, pushed by environmental regulations, is leading to thermo-mechanical conditions at the limits of operability of conventional Al-Si piston alloys. The microstructure of these alloys is formed by interconnected 3D hybrid networks of eutectic and primary Si as well as intermetallic phases embedded in a comparatively soft Al matrix. Particularly, the piston bowl rim area in modern diesel engines must be able to withstand thermo-mechanical fatigue (TMF) conditions in a temperature range between room temperature to 380 °C with thermal cycles of a few seconds during service (thermal cycles caused by the change from idle-running to full-throttle motor conditions). This usually leads to the formation of TMF cracks that can rapidly propagate and result in the failure of the pistons. As a consequence, piston alloys must be optimized to fulfill the TMF requirements without losing the light-weight advantage and recyclability provided by Al alloys.

Damage in Al-Si piston alloys occurs in a localized manner and, as such, 2D investigations are insufficient to univocally identify or even find crack initiation sites (low number density of cracks). Furthermore, it is still unknown which microstructural features affect the sequence of propagation of cracks during TMF conditions. Until now, this was mainly investigated with means of conventional 2D- and ex-situ tomography experiments. Within the sub-project 2.2., for the first time worldwide, in-situ TMF tests combined with non-destructive in-situ synchrotron tomography experiments on Al-Si piston alloys at the ESRF in Grenoble have been conducted, to study TMF damage evolution in these alloys. Fig.1 shows a 3D visualization of cracks (red) through primary Si particles (blue) of a cast AlSi12Cu3Ni2Mg piston alloy which already exist after the first half cycle of the TMF test.

bmwfw Federal Ministry of Science, Research and Economy
bmvit Austrian Ministry for Transport, Innovation and Technology

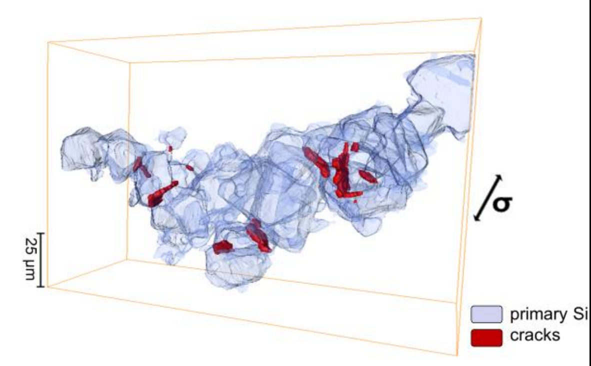

Fig. 1: 3D visualization of cracks (red) through primary Si (blue) parallel to the sample length after the first half TMF cycle of a cast AlSi12Cu3Ni2Mg alloy. The Al-matrix and the aluminides are transparent in the 3D view.

The combined in-situ TMF tests and synchrotron tomography experiments will provide a more detailed understanding of during the TMF testing occurring damage mechanisms and their development sequence. The testing of different piston alloys, will enable us to develop a quantitative relationship between 3D architecture of the alloys, their composition and the microstructural features affecting the damage accumulation during TMF and in turn contribute to the development and optimization of alloys with the highest TMF resistance at the bowl rim area of the piston. Finally, the through these novel in-situ experiments aquired data will help to develop a knowledge-based alloy design supported by experimental observations and finite element simulations.

Impact and effects

Contact and information

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