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Application of Complementary Beam Techniques to Study Deformation Mechanisms in Heterogeneous Materials for Automotive Industry

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The increasing demand on power and efficiency in automotive industry increases the thermo-mechanical loads and power densities in combustion engines. New materials are required, which combine light weight with sophisticated high temperature strength and creep resistance to meet the requirements. AlSi and AlCu alloy systems are developed for structural parts to improve long-term stability and reduce thermal fatigue damage. In such alloys a composite-like heterogeneous microstructure is formed during casting. The Al_2Cu phase in AlCu systems and Si phase in AlSi systems acts as reinforcement of a soft α-Al phase. The microstructure morphology (interconnectivity) and the matrix stiffness have significant influence on stress distributions, deformability and crack formation. Therefore, not only composition, but also thermal history (i.e., cooling rates after casting and heat treatments) play an important role for material properties.

Two current projects, the "μ-Fe Sensitivitätsanalyse"and "OptiAlloy" funded by the Bayrischen Forschungsstiftung, deal with non-destructive characterization of heterogeneous cast light alloys by complementary applications of high sophisticated beam techniques. Several diffraction and imaging experiments were performed to measure microstress (neutron diffraction), characterize damage initiation and propagation (synchrotron tomography) and to relate them to the microstructure's morphology (transmission electron microscopy and synchrotron tomography). Photons, electrons and neutrons were used as probe particles according to their interaction with metal and spatial resolution limitations, applicable for the specific problem.

Neutron diffraction (Stress Spec, FRM2, Garching, Germany) results show elastic and plastic deformation between the brittle primary phase (AlSi and Al_2Cu network) and α-Al matrix. Big gauge volume and high penetration depths allow in situ acquisition of strains during high temperature tensile testing. Strain measurements under load and after unloading were performed to distinguish between micro- and macrostress contributions. Synchrotron tomography (parallel beam) with absorption contrast imaging of AlCu alloys and phase contrast imaging of AlSi alloys (low-Z contrast between Al and Si) helps to qualify microcracks within the microstructure in 3D.

Two independent characteristics could be identified as mainly responsible for crack sensitivity of AlSi and AlCu alloys: First the morphology of the brittle reinforcing phase (isolated particles versus interconnected network) as crack inducing parameter and second the ductility of the α-Al matrix (accommodating stresses by plastic deformation) as crack growth inhibitor.

Country/Organization invited to participate

Austria

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