Microstructure, fatigue properties and damage mechanisms of Al-Si-cast alloys

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Abstract

AlSi-cast alloys are widely used in automotive industry for structural elements and for engine components. The rising burning temperatures and increasing firing pressure, due to more stringent emission laws, need novel alloys, with enhanced thermal stability, creep resistance and high temperature strength together with improved fatigue resistance from room to high-temperature. The addition of elements, like Cu, Ni or Mg can improve thermal stability and high temperature strength under static and dynamic loadings.

The present works aims to investigate the influence of strength enhancing elements on microstructure and mechanical properties, especially fatigue performance, of an AlSi7Cu-Mg-cast-alloy. All alloys were produced via chill casting and were hot isostatic pressed (HIP) to avoid the negative effects of solidification, like shrinkage porosity. Afterwards a T6-heat treatment with solution annealing, quenching in water and artificial aging was carried out. All alloys were characterized by microstructural observations in a scanning electron microscope (SEM) and for fatigue testing a servo hydraulic test system was used. To study the influence of additional elements on fatigue performance, the fracture surface, microstructure and crack path were investigated after cyclic loading.

Scanning electron microscopy shows that the microstructure consists of an Al-matrix, eutectic Si and several intermetallic phases (IMP) whose formation is promoted by additional elements. Spherodization of eutectic Si is caused by solution annealing. Fatigue tests show that the higher the amplitude, the shorter the fatigue life of all investigated alloys. In LCF-regime cyclic softening occurs until failure at all strain amplitudes. The addition of strength enhancing elements reduces the fatigue performance in the low cycle fatigue regime (LCF) in comparison to the AlSiCu-Mg-reference alloy. At constant strain amplitudes the addition of alloying elements lead to increased stress amplitudes. Investigations of fracture surfaces show typical regions with a ductile behavior of the matrix, which consist of typical swing striations, and furthermore broken primary precipitates which show rather brittle behavior. After cyclic loading, investigations of the surface of the polished specimens, show a highly deformed Al-matrix which behaves very ductile. Broken phases, like eutectic Si or several intermetallic phases can be seen. Decohesion at the interface between matrix and precipitates are visible as well.