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Application of modified Kitagawa-Takahashi diagram for fatigue strength assessment of cast Al-Si-Cu alloys

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Abstract

This paper presents comprehensive fatigue test results utilizing small-scale specimens extracted from AlSi8Cu3 and AlSi7Cu0.5Mg aluminium-cast crankcases and cylinder heads. The experimental results act as basis to set-up a defect size-based material model applying the Kitagawa-Takahashi approach and the modification by El-Haddad and Chapetti. The round samples were manufactured from three different component locations to achieve a variation in microstructure and micropore sizes. Fractographical analyses were executed to examine the size and shape of the crack-initiating micropores. Mostly shrinkage pores were detected within the investigated alloy specifications, except the Na-modified alloy, where a significant occurrence of gas pores was observed. Elaborated crack propagation tests were performed to determine the long crack threshold $\Delta K_{eff,th}$ and analyse the short crack region. Kitagawa-Takahashi, El-Haddad and Chapetti models were worked out combining fatigue strength, fractographical as well as fracture mechanics characteristics. The Kitagawa-Takahashi and El-Haddad approach mostly revealed non-conservative results over all data sets including several alloy specifications. The application of the Chapetti model, which additionally considers short crack growth, led to an improvement of the practicability of the defect-based model compared to the fatigue test results. Finally it is shown that the Chapetti approach was well appropriate to set-up a generalized, local microstructure-dependent fatigue assessment, especially for the investigated AlSi7Cu0.5Mg cylinder head samples. It can be concluded that the main influence on the fatigue strength was the micropore size, as well as the heat treatment and eutectic modifier, whereas the micropore shape seemed to have less significance. Hence, an application of defect-based models, such as the Kitagawa-Takahashi, El-Haddad and Chapetti approach using simplified pore size parameters such as an equivalent diameter, enables a proper local fatigue assessment of light weight cast aluminium components.

Keywords: fatigue strength, micropore size, fractographic analyses, Kitagawa-Takahashi diagram

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