Cyclic thermo-mechanical stress, strain and continuum damage behaviors in light alloys during fatigue lifetime considering heat treatment effect

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Abstract:
In this article, thermo-mechanical fatigue behaviors in light alloys have been investigated to find the effect of heat treatments. For this objective, thermo-mechanical fatigue tests were performed on the A356.0 aluminum alloy and the AZE911 magnesium alloy, with and without typical T6 heat treatments. Obtained results demonstrated no significant difference in thermo-mechanical fatigue lifetime of the A356.0 alloy between non-heat-treated and heat-treated test specimens at 250°C of the maximum temperature, which was attributed to the over-ageing phenomenon. As a consequence, this low effect showed that the heat treatment could be eliminated for cylinder heads. However, the thermo-mechanical fatigue lifetime of the AZE911 alloy was significantly affected by the heat treatment. The explanation for the mentioned behavior could be found in the material micro-structure, which was affected by dissolving the brittle intermetallic phase in the matrix of the AZE911 alloy. However, the magnesium alloy still requires more improvements in the fatigue lifetime for a possible substitution in cylinder heads. Continuum damage behaviors showed that higher damage values occurred in the aluminum alloy, in comparison to the magnesium alloy, both for heat-treated and non-heat-treated specimens.

Keywords: light alloys, heat treatment, stress and strain behaviors, thermo-mechanical fatigue, continuum damage mechanics

1) Introduction

Nowadays, light alloys such as aluminum alloys and magnesium alloys have been widely used in components by automotive engineers. This is due to their advantages, which is the ratio of the strength to the weight. Automotive designers tend to strengthen light alloys in order to improve the strength. This problem is more important, when a component, such as the engine cylinder head, is exposed to high temperatures besides mechanical loadings. This temperature for cylinder heads varies between the environmental temperature and 200-250 °C [1] during start-stop cycles. One method to strengthen materials is to apply a heat treatment process.

For aluminum alloys, the heat treatment has been standardized for manufactures. However, manufactures tend to eliminate the process due to the production time and costs [1]. Magnesium alloys have lower strength in comparison to aluminum alloys, but they are lighter. For magnesium alloys, the heat treatment has been still developed in order to obtain the same strength, in comparison to aluminum alloys.