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Short Communication

Thermal fatigue of cast irons for automotive application

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ABSTRACT

The thermal fatigue damage constitutes the major problem of the parts subject to a variation in temperature during their operation. Several materials have been used for such structures in order to limit their damage. The facility of implementation and low cost of cast iron constitute an advantage for its use for the Diesel motors.

The aim of this work is to study the thermal fatigue damage of four nodular cast irons for automotive application. For this purpose, experimental test including crack growth tests and metallographic observations were achieved.

The study has revealed the effects of temperature, microstructure and chemical composition of the studied materials on the initiation and the crack growth under thermal fatigue loading.

1. Introduction

The cast iron presents the best compromise between the simplicity of implementation and cost, then remains the privileged material for the Diesel motorizations [1–4].

The exhaust lines are subject to mechanical and thermal loading [5]. The thermal solicitations during acceleration–decelerations and starting up or shutdowns of the vehicle produces thermal fatigue damage coupled with high temperature effects (oxidation and viscoplasticity).

Thermal fatigue facility consists in studying a representative specimen in laboratory. Thermal stresses are the result of both structure and heat gradients effects.

Several tests were developed to appreciate the thermal fatigue effect on the structure among them the test which was developed by Glenny et al. [6] at the end of the Fifties to simulate the thermal fatigue of the turbine blades. A disc simulating the turbine blade is subject to thermal fatigue by the technique of the fluidized beds. In order to appreciate the resistance of the different grades used for exhaust manifolds application, Bucher et al. [7,8] developed a thermal fatigue test. The test consists of generate alternate cycles of heating and cooling on a specimen. The specimen simples, as sheet tape, were curved by cold folding and attached by two fixed bits. The thermal cycle consists of two phases: heating (Joule effect) followed by natural cooling. Meyer et al. [9] developed a thermal fatigue test for light alloy bolts (typically aluminum alloy) of combustion engines. This kind of bench simulates the thermal fatigue process of such bolts. The test consists in heating the local zones of the simples in order to simulate the exposed parts of the combustion room of the engine.

In this paper, we have proposed to investigate the thermal fatigue damage of four nodular cast irons (A, B, C and D) which have different adding elements. We have started with studying the effect of microstructure of 'A' cast iron (which was considered as a standard cast iron). After that, we propose to examine adding elements effects as: silicon, molybdenum and nickel, on the crack growth and oxidation of the studied samples. In the end, we have test the effects of the thermal cycle, imposed on the same grade cast iron specimens ('A' cast iron), on the thermal fatigue damage.

2. Materials

The Chemical analysis has revealed that the cast iron contains an important silicon quantity (3–6%) which improves the oxidation resistance of these materials [10].

The 'D' grade is a nodular cast iron, charged by nickel (Ni) which is a graphitizing element, less energy than the silicon (Si). It refines the microstructure and improves the tensile strength as well as the heat strength and corrosion resistance in very aggressive conditions [11–14].

The molybdenum (Mo) content in A and B cast irons is higher than in C and D. Indeed, it improves the mechanical characteristics at high temperatures and increases the temperature of allotropic transformation [15,16].

The microstructures of the cast irons studied indicate the presence of a ferritic matrix. These micrographs show a reduction of the grains size in B, C and D cast irons compared to A. The graphite nodules have regular forms, the overall spheroid and their average

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