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Fatigue crack growth behavior of NBR, HNBR, HNBR ZSC compounds

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Abstract

Due to the insufficiency of reliable data, fatigue life calculations taking the crack propagation phenomena into account, remain scarce. Therefore, this work focuses on the characterization of fatigue crack growth behavior for materials NBR, HNBR and HNBR ZSC in different thermal ageing states at different temperatures. The experimental data base was analyzed using Fracture Mechanics principles, namely crack growth rate in relation with the tearing energy. The tests of the notched pure-shear specimen were performed on a METRAVIB DMA+300 fatigue testing machine. It is found that the crack growth rate is approximately proportional to the tearing energy in the steady propagation range. Furthermore, the test temperature and thermal ageing were observed to be able to weaken the shearing strength.

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Keywords: crack growth behaviour, pure shear, notched sample, fatigue, rubber, nitrile.

Nomenclature

c	crack length	W	strain energy density
N	number of cycles	h	height of the pure shear sample
G	tearing energy		

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1. Introduction

Crack growth behavior is a significant characteristic for the durability assessment of rubber products in tire industries and anti-vibration components, specifically the rubber products cyclically loaded. This kind of cyclic load can lead to the weakening of the strength of rubber products by repeated deformations. Moreover, for the rubber products with cracks, these cracks will expand by the effect of cyclic load. Due to the cumulative feature of fatigue crack, the cyclic strain amplitudes are usually much lower than the fracture strain. A mass of crack experiments in fatigue have been done with tire materials, but much less with technical rubber.

The crack growth behavior can also be affected by thermal ageing and test temperature. The thermal ageing process affects the properties of material by heating rubber product during a certain period. The test temperature can affect the experimental process, by forcing the rubber into its rubbery zone instead of the glassy zone (high temperature) or the opposite (low temperature). In the condition of rubbery zone (high temperature) for example, the rubber exhibits a better elastic properties which can help to reduce the plastic deformation and the viscoelastic displacement. The aim of the fatigue crack growth experiments in this study is to investigate the effect of thermal ageing and of test temperature on crack growth behavior.

1.1. Relationship between crack growth rate and tearing energy

The most commonly used method for analyzing the crack growth behavior is to find the relationship between crack growth rates and tearing energy. Several years ago, LRCCP started to perform investigations on this topic by testing notched pure-shear specimen on a METRAVIB DMA+300 fatigue testing machine. When a specimen containing cracks is under cyclic load, the crack propagation will occur at the tip of the crack. By applying different cyclic strain amplitudes, the corresponding tearing energy will lead to a certain crack growth rate. The equation below is to describe the relationship between the crack growth rate and the tearing energy:

$$\frac{dc}{dN} = f(G) \quad (1)$$

In this equation, c is the crack length, N is the number of cycles and G is the tearing energy at a specific deformation. It is possible to measure this crack growth rate of the specific tearing energy by the notched pure-shear test.

1.2. Machine

The crack growth experimental is performed with a dynamic testing machine METRAVIB DMA+300, which dedicated to the fatigue analysis of advanced materials and industrial components. It makes possible to characterize the mechanical properties of a wide range of materials and their dependence on various parameters: frequency, temperature, stress or strain amplitude, wave form etc. The introduction of crack and the observation of the crack growth can be achieved by cutting and magnifying optical systems. Furthermore, the tests could be performed on a wide range of temperature in the thermal chamber. The machine is shown in Fig. 1.

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