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Study of the fatigue behavior of the polychloroprene rubber with stress variation tests

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Abstract

In this study we study the fatigue behavior of a polychloroprene rubber using designed specific variable amplitude tests to gather insight into such material behavior. Firstly, increasing force amplitude block load tests were carried out that permits us to determine the stress amplitude at which fatigue damage is significant. In a second series of tests block programmed tests were carried out. During these tests the hysteresis energy and stiffness were also measured. These measurements bring out possibly a competition between two mechanisms the crystallization effect and the effect of crack propagation. The first mechanism tends to increase the stiffness while the second decreases the stiffness.

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Keywords: Rubber, Fatigue Behavior, Strain-Induced Crystallization,block load tests, stengtehening mechanism

1. Introduction

Rubber and rubbery materials are widely used in industry because of their ability to undergo large deformation and damp energy. Therefore, knowledge of the mechanical characteristics and, in particular, the fatigue behaviour is a very active topic of research.

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For the past sixty years researchers have looked for fatigue criteria in order to shorten experimental fatigue campaigns. Lately, energetic criteria have been investigated coupling several techniques (Le Saux et al. 2010 [1], Ayoub et al. 2012 [2]) or focusing on the study of a single parameter (Mars 2001 [3], 2002 [4] with, for example, Cracking Energy Density). Lacroix 2004 [5] and then Poisson et al. 2011 [6] have been working with the hysteresis energy and their crack initiation approach provided good results regarding fatigue life predictions of a polychloroprene rubber. These authors [6] developed a Haigh diagram for a polychloroprene rubber (fig 1) and observed that below a force ratio of R=0.2, fatigue lives decrease with increase of R-ratio, whereas above this threshold value, the fatigue lives increase clearly: fatigue lives at R=0.5 are more than 10 times greater than those at R=0.2. The suggested mechanism is possible strain-induced crystallization of the polychloroprene rubber that influences the fatigue life above R=0.2 [7]. Polychloroprene rubber is known for being subjected to strain-induced crystallization (SiC) and it was shown by (Le Cam 2008 [8]), for example, that when cracks occur in such an elastomer there is competition between crack propagation and the transformation due to strain-induced crystallization (SIC).

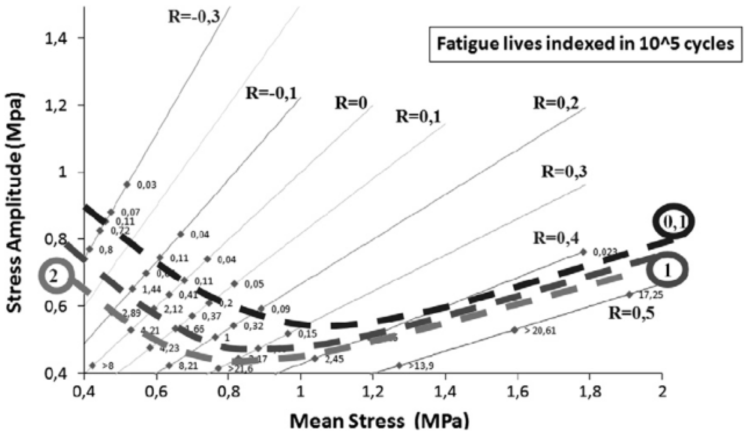

Fig. 1. Haigh Diagram after Poisson et al. [6]

The aim of this study was to investigate hysteresis energy and stiffness evolution during carefully programmed block force tests in order to gain insight into the damage evolution in an elastomer.
The outline of the present paper is as follows: Section 2 presents the details of the experimental procedure; Section 3 describes and discusses the block program tests. In Section 4, a short discussion is presented and Section 5 focuses on conclusion and perspectives.

2: Experimental protocol, material and specimen

2.1.Specimen, material and fatigue tests

The material studied during this research was a vulcanized polychloroprene rubber (CR) filled with N990 carbon black (Table 1). The specimen used were dumbbell-shaped made of a rubber part 30 mm long, bounded to two metal grip parts at each extremity that were subsequently attached to the fatigue machine with screws (Fig 2). Those specimens were molded at 175°C by an injection press for 4 minutes. The fatigue tests were conducted with a servo-hydraulic fatigue-testing machine at room temperature. The fatigue campaign was focused on uniaxial force-controlled tests with a sinusoidal signal at a frequency of 5Hz. All tests were conducted at a force ratio of R=0.1 with R defined by (1):