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Mini Review

Studies on the Time-Dependent Behavior of Semi-Crystalline Polymers

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Abstract

Semi-crystalline polymers consist of amorphous and crystalline phases, and exhibit time-dependent behavior. They offer important advantages over other materials, such as good chemical resistance and attractive mechanical properties. This paper provides a brief review of experimental studies on the time-dependent behavior of semi-crystalline polymers.

Introduction

More than two-thirds of polymeric products used for applications such as fluid transportation, packaging, electronics, civil infrastructures, aerospace, medicines and automotive, are now made of semi-crystalline polymers (SCP) [1-5]. One of the challenges for these applications lies on the proper characterization and prediction of SCP's time-dependent properties which are often demonstrated through the relaxation and creep behavior. So far, numerous experimental studies have been carried out using changes in the relaxation or creep behavior to characterize SCP's time-dependent properties. This article provides a brief review on the previous work in this area.

Discussion

Time-dependent behavior of SCP is often characterized using relaxation and creep tests [6,7]. According to Khan and Lopez-Pamies, knowledge of the relaxation and creep processes is essential for developing a good understanding of SCP's mechanical behavior [8]. Relaxation (i.e., at constant deformation) and creep (i.e., at constant loading) can be observed in many polymers at room temperature [9,10], which for some SCP is known to show a drastic stress decrease at the beginning of the relaxation, but the stress decrease reaches an asymptotic-like limit after a short period [3,11]. Strobl and coworkers determined the viscous stress and quasi-static stress in the relaxation behavior [12]. Zhang and Jar constructed the master curves for relaxation modulus versus time based on the horizontal and vertical shift of a series of relaxation tests, found two transitions for the drop of relaxation modulus with time [13]. Stress recovery could be observed after unloading to a predetermined deformation level. According to Castagnet, the stress responses in relaxation and recovery are different for SCP, and the stress change in relaxation after loading is larger than that in recovery after unloading when the strain change is the same for the loading and unloading before relaxation and recovery respectively [14]. It is also known that creep behavior contains 3 distinctive stages, which are primary, secondary, and tertiary creep stages [15,16]. The creep strain rate drops rapidly at the primary stage, followed by a nearly constant creep strain rate at the secondary stage, and then increase of the strain rate at the tertiary stage [17]. Khan performed numerous experimental investigations on time-dependent behavior considering diverse loading histories, proposed that test methods containing complex loading histories can reveal some singular deformation characteristics, which could present challenges for the simulation of SCP's deformation behavior [10]. Recently, Tan and Jar [18] proposed the use of a multiple-relaxation (MR) test to characterize SCP's relaxation behavior, which demonstrated the change of relaxation behavior with the increase of the deformation. Although work in the past have paid particular attentions to creep and relaxation behavior after tensile loading [12,15,17-19], studies on the creep and recovery behaviors after unloading are limited in the literature [21-24]. Studies reported so far showed that recovery and creep behavior after strain reversal could show unusual stress and deformation responses, respectively [21-23,25]. For the creep behavior after the strain reversal, Dusunceli found that strain could change non-monotonically with the increase of time [23].

Conclusion

The brief review presented here summarizes some of the past research work on the experimental characterization of the time-dependent behavior of SCP. While creep and relaxation after tensile loading have been extensively studied, creep and recovery after strain reversal, especially their unusual, nonmonotonic deformation and stress response, respectively, require further investigation before the time-dependent SCP's behavior could be fully understood. For this purpose, new test methods are needed to characterize the recovery and creep behaviors.

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