Iran Polym J (2013) 22:25–32
DOI 10.1007/s13726-012-0100-8

ORIGINAL PAPER

Viscoelastic behavior of NBR/phenolic compounds

Azadeh S. Mirabedini · Mohammad Karrabi · Ismaeil Ghasemi

Received: 6 June 2012 / Accepted: 2 October 2012 / Published online: 21 November 2012

Abstract NBR/phenolic interpenetrating networks (IPNs) offer a wide variety of mechanical and physical properties at moderately high temperature. This temperature stability along with oil and fuel resistance property has made IPNs appropriate candidates for various applications. In the present work, NBR compounds containing 5, 7 and 12 phr of Novolac, as a curable phenolic resin was formulated using a two-roll mill. Low and high acrylonitrile NBR; KNB 35L and Europrene N4560 were selected in the compound and the same condition of mixing was applied in the blend preparation stage. Curing test, followed by a cooling period and the stress relaxation test were carried out consecutively and automatically in a rubber process analyzer. The samples presented various relaxation times. The relaxation curves were well estimated by Maxwell model and the Prony coefficients were determined. Furthermore, compression test was performed on the samples, so that the set or permanent deformation of each sample was measured. The results of both tests have indicated that by adding phenolic resin into the NBR matrices, the viscoelastic behavior of the compounds become more elastic, to the detriment of the viscous component. This phenomenon would be due to IPN formation in the compounds. In addition, by increasing the phenolic resin content in the compounds, the difference between maximum and minimum torque ($M_H - M_L$) value became greater, which is an indicator of higher cross-link density and IPN formation. Swelling test results confirmed more extensive cross-links in the compounds by addition of more resin into the compound.

A. S. Mirabedini · M. Karrabi (✉) · I. Ghasemi
Rubber Department, Iran Polymer and Petrochemical Institute,
PO Box: 14965-115 Tehran, Iran
e-mail: m.karabi@ippi.ac.ir

Keywords Rubber · NBR/phenolic · Relaxation time · Maxwell model · Prony estimation

Introduction

Combinations of polymer matrices with organic particles and preparation of polymer blends have been developed over the past decades to prepare hybrid materials with improved properties. These materials possess unique properties like those of polymer systems but with improved physico-mechanical and thermal properties [1, 2]. Acrylonitrile-*co*-butadiene rubber (NBR) or nitrile rubber is an amorphous random copolymer which is extensively used in automobiles, aircraft, tank and military applications such as seals, gaskets, O-rings, etc. [3]. By further modification of the NBR-based compounds, they can also be used in the aerospace industry for structural bonding of metals because of their excellent bond durability [4–7]. Acrylonitrile (ACN) content of NBR varies from a minimum of 15 % to a maximum of 50 %. ACN helps to improve properties such as hardness, tensile strength, resistance to fuels and oils and gas impermeability [8]. However, rubber compositions based on NBR have still problems due to inferior tack, limited stability at high temperature and some elastic responses such as poor compression set [3]. The history of nitrile-phenolics development goes back to the early 1950s [9]. Novolac type of phenolic resin has been used as reinforcing and also cross-linking agent in numerous NBR applications. Phenolic resin is used for several reasons including improvement in thermal stability and resistance to swell in oil/fuel because of free volume reduction.

The interpenetrating polymer networks (IPNs) are novel type of polyblends consisting of two or more networks which are at least partially interlaced on a polymer scale

Springer