Correlation Between tan δ and Bashore Rebound for Polyurethane Elastomers

INTRODUCTION

The damping parameter, tan δ, is a basic parameter related to the viscoelastic response of a polymer. It can be defined in several ways, one of which is in terms of the ratio of the component vectors of the complex elastic modulus, $|E|$; that is, as E''/E', where E' is the real or elastic component and E'' is the imaginary, inelastic, or viscous component.[1] The importance of this damping parameter has been well established in the study of polymer structure–property relationships. Moreover, the dependence of a more use-oriented parameter, such as the resilience or rebound, on tan δ has been investigated.[2] The development of a quantitative relationship has been suggested by the work of Raphael and Armeniades[3] relating the results of a rebound tester and a torsion pendulum. The present note confirms the previous studies in this area by illustrating a quantitative dependence between tan δ and the impact resilience of polyurethane elastomers.

EXPERIMENTAL

Samples of various polyurethane elastomers were compression molded into thin sheets (20 mils) and small cylinders (1 in. diameter ×0.5 in. thick). These samples included both polyester (polyethylene adipate)- and polyether (polytetramethylene ether)-based systems which were cured with various curatives [4,4′-methylenebis(2-chloroaniline), 3,3′-dichlorobenzidine, and triisopropylamine]. They varied in hardness from Shore 55A to 75D (at 23°C). The testing was done at three temperatures in order to increase the spread of the response variables.

Damping Parameter

The dynamic measurements yielding tan δ were made on the Rheovibron Dynamic Viscoelastometer (IMass, Accord, Mass., 02018) using small samples (1.4 × 0.125 × 0.020 in.) at a vibration frequency of 110 Hz. The three temperatures, 6°, 24°, and 80°C, were obtained by means of the environmental chamber supplied with the Vibron instrument.

Impact Resilience

The impact resilience was obtained by means of a vertical rebound test[4] utilizing the Bashore resiliometer. The measurements were made at the aforenoted temperatures either in a controlled room (24°C) or by use of an environmental chamber (6° and 80°C).

RESULTS AND DISCUSSION

The data obtained, in terms of tan δ and % rebound, were plotted on a semilog graph as shown in Figure 1. Such a plot indicated a straight-line relationship between the log of tan δ and the % rebound over the range studied. From this relationship, the resilience of the material can readily be obtained from tan δ data.

It can also be noted from Figure 1 that there was no distinction between the polyether- and polyester-based polyurethanes. They both fell on the same curve.

The two data points which fell far below the curve were of special interest. These were obtained on samples which were in the glassy state under the test conditions. In this viscoelastic state, the magnitude of E'' decreases and E' reaches a maximum value. This results from the restricted molecular motion of the polymer, thereby producing a low damping value. Under these conditions, that is, below the glass transition, the

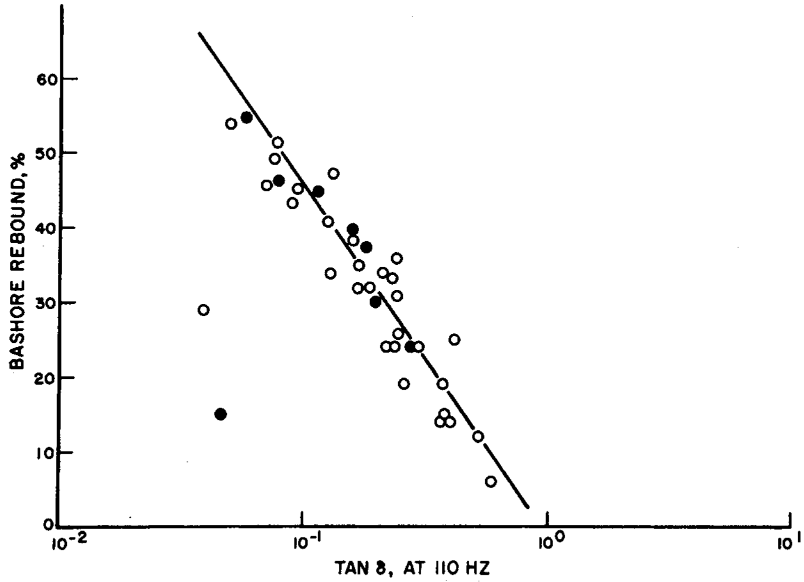

Fig. 1. Bashore rebound as a function of tan δ for polyurethane thermoplastics: (O) polyester based; (●) polyether based.

established relationship is not valid. Therefore, under normal conditions when the sample is between the leathery and rubbery flow regions, the determined correlation is applicable and provides a use-oriented parameter from the measurement of a basic viscoelastic response.

References

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4. ASTM Test D2632-67, *Impact Resilience of Rubber by Vertical Rebound, 1972 Annual Book of ASTM Standards*, Pt. 28, American Society for Testing and Materials, Philadelphia, Pa., p. 104.

BERNARD L. WILLIAMS

Rubber Chemicals Department
Organic Chemicals Division
American Cyanamid Company
Bound Brook, New Jersey 08805

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