TA Instruments

Thermal Analysis & Rheology

Thermal Analysis Application Brief

Polypropylene Impact Resistance by Dynamic Mechanical Analysis

Number TA-130

SUMMARY

Impact resistance is a critical end-use property for many commercial plastic products. Dynamic mechanical analysis (DMA) provides a convenient method for evaluating impact resistance in materials such as polyethylene-modified polypropylene.

INTRODUCTION

The ability of plastics to withstand a sudden impact is important in applications such as children's toys and car bumpers. Many pure plastics including polystyrene and polypropylene do not have very good impact properties. Hence, a second polymer may be added to improve this capability. In general, the added polymer improves impact resistance because it exhibits low temperature molecular motions which "absorb and dissipate" the additional energy available at impact, thereby preventing bond-breaking (shattering).

Traditional techniques for measuring impact resistance require lengthy sample preparation and are often not reproducible. For example, the ASTM Drop Weight Impact (DWI) method D-3029 requires an impact measurement on as many as 30 samples to obtain good statistical results. In addition, each sample must be prepared by high quality injection molding, followed by temperature conditioning at -29°C for 24 hours before testing.

Dynamic Mechanical Analysis (DMA) provides a fast, easy-to-use alternative to DWI measurements. DMA measures the modulus (stiffness) and damping (energy dissipation) properties of materials as the materials are deformed under periodic stress. The damping information obtained can be correlated with impact properties in materials such as polyethylene - modified polypropylenes.

EXPERIMENTAL

In DMA, the sample is clamped between the ends of two parallel arms, which are mounted on low force flexure pivots allowing motion in only the horizontal plane. An electromagnetic motor attached to one arm drives the arm/sample system to a strain (amplitude) selected by the operator. As the arm/sample system is displaced, the sample undergoes a flexural deformation. A linear variable differential transformer (LVDT) mounted on one arm measures the sample's response to the applied stress. The sample can be evaluated at a fixed frequency determined by the operator, or at the sample's resonant frequency as determined primarily by sample geometry and temperature. The latter (resonant) mode is more sensitive to subtle damping transitions in the sample, and hence is preferred for impact resistance studies. In this example, polyethylene - modified polypropylene samples containing different levels of polyethylene were evaluated from -150 to 70°C while heating at 5°C/minute in nitrogen. The samples were mounted vertically to yield rectangles with approximate dimensions 19.1 mm long x 12.1 mm wide x 3.18 mm thick.

RESULTS

Figure 1 shows typical DMA frequency and damping curves for an impact-modified polypropylene. The four damping peaks are the result of different molecular motions (relaxations). The two higher temperature damping peaks (37°C and 5°C) are associated with the α and β transitions of polypropylene. The lower temperate peaks at -50°C and -110° are due to the polyethylene impact-modifier. Studies on a series of polypropylenes modified with different levels of polyethylene indicate that the intensity of the -110°C damping peak correlates well with the ASTM D-3029 Drop Weight Impact values.

Figure 2 shows the composite plot of DMA damping curves for six different formulations. A graph of tan δ peak values versus the DWI values is shown in Figure 3. The tan δ values plotted are averages of up to four measurements; the DWI values, of up to 30 measurements. The pooled coefficient of variation for the tan d values is ±8.2% compared to ±13% for the ASTM D-3029 DWI test. For these data the correlation curve in Figure 3 is fitted to the equation:

$$y = 0.0197\ x^{0.135}$$

where y = tan δ
and x = Drop Weight Impact

The two dotted line curves represent the upper and lower standard deviation boundaries for the tan δ values. The curve can therefore be used as a rapid and simple screening technique to rank polypropylenes according to relative impact resistance. For example, materials having tan δ values above 0.028 can be expected to have DWI values above 10 joules (7.4 ft. lb.). One additional note - Impact properties are very dependent upon surface imperfections which act as crack initiation sites. They also are influenced by the degree of dispersion of impact modifier in the polymer matrix. It is therefore very important to ensure identical preparation conditions for impact samples used to establish tan delta versus impact resistance correlations.

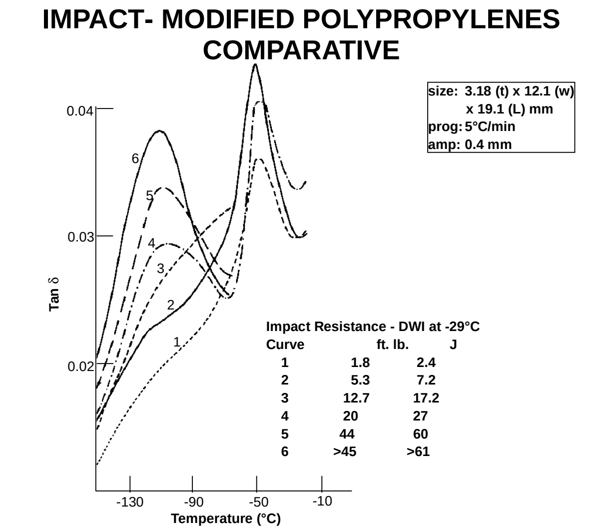

Figure 2

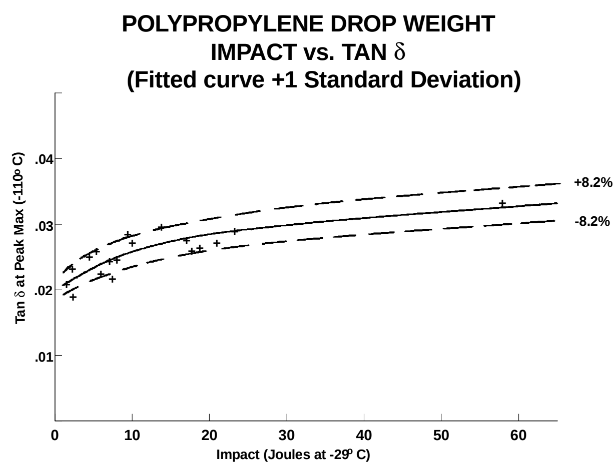

Figure 3

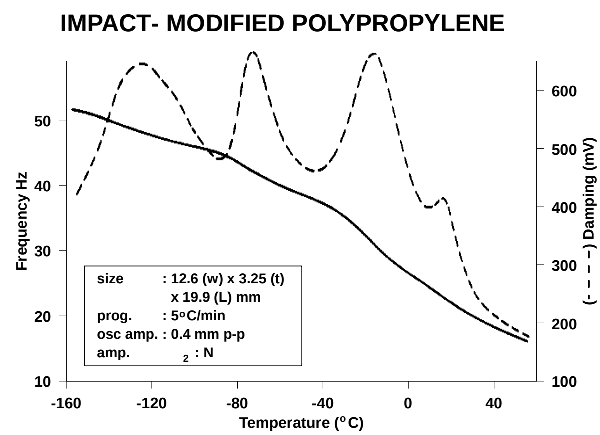

Figure 1

For more information or to place an order, contact:

TA Instruments, Inc., 109 Lukens Drive, New Castle, DE 19720, Telephone: (302) 427-4000, Fax: (302) 427-4001
TA Instruments S.A.R.L., Paris, France, Telephone: 33-1-30489460, Fax: 33-1-30489451
TA Instruments N.V./S.A., Gent, Belgium, Telephone: 32-9-220-79-89, Fax: 32-9-220-83-21
TA Instruments GmbH, Alzenau, Germany, Telephone: 49-6023-30044, Fax: 49-6023-30823
TA Instruments, Ltd., Leatherhead, England, Telephone: 44-1-372-360363, Fax: 44-1-372-360135
TA Instruments Japan K.K., Tokyo, Japan, Telephone: 813-5434-2771, Fax: 813-5434-2770

Internet: http://www.tainst.com

TA Instruments
Thermal Analysis & Rheology
A SUBSIDIARY OF WATERS CORPORATION