# TENITE™ cellulosic plastics

## Stress measurement in parts made of Tenite™ cellulosic plastics

*Plastics made from wood pulp—a renewable resource*

## Stress measurement in parts made of Tenite™ cellulosic plastics

In many instances, failures in performance of plastic parts are caused by stresses induced by improper processing conditions rather than by a fault in the plastic material. A high level of stress often causes brittleness, decorating difficulties, and unsatisfactory dimensional stability in extruded, molded, or thermoformed parts. Fortunately, the level and extent of stress can be measured and processing conditions controlled to minimize or eliminate the difficulty.

## Stresses and strains

The stresses discussed in this report often are referred to as strains, and this is not entirely incorrect. "Stress" refers to a force applied to a body, while "strain" refers to the resultant body deformation. Stress and strain are interdependent. A stress can strain an object, but the object can then exert a stress in attempting to return to its unstrained condition. Stress and strain generally exist simultaneously.

The force applied to compress a molten plastic mass and push it through a nozzle or die stretches and bends the polymer molecules. If the plastic cools too rapidly, the molecules are frozen in their deformed (strained) positions when the plastic hardens. Strained polymer molecules may be compared to stretched springs. They have strong tendencies to return to their unstrained positions, and the forces they exert in attempting to do so constitute stresses within the plastic. Since the stresses arise from freezing strained molecules, they are referred to as "frozen-in" stresses.

When a plastic is cold and hard, it is generally able to withstand its frozen-in stresses; but if it is softened by heat or by the action of a solvent, it yields to its internal stresses and shrinks in one or more dimensions. Shrinkage of a large area frequently causes warpage. Sometimes, small sections on the surface may shrink away from other small sections. This type of shrinkage results in surface roughness and may occur when a coating containing an active solvent is applied to the plastic.

Stresses in a plastic part reduce its toughness and may even cause brittleness. A plastic is tough if its polymer molecules are able to stretch to an appreciable extent without breaking. This ability allows them to absorb the energy of an impact without damage in the same way a rubber pad cushions the recoil of a shotgun. But if processing conditions cause the molecules to be strained to a degree that approaches their maximum extensibility, they can be damaged by a relatively small amount of additional strain. If they are stretched by an impact, they break; and so does the plastic part.

Stresses in plastic parts are divided into two categories: surface and internal. Surface stresses are those within 75 to 100 microns (0.003 to 0.004 in.) from the part's surface; internal stresses may occur throughout the interior.

## Surface stress testing

Surface stresses in a plastic part can be measured by the degree of surface wrinkling, frequently called "orange peel." This appears when the part is wetted for 5 to 10 seconds with an appropriate solvent by either spraying or dipping. Any solvent remaining on the surface after this period should be removed by shaking the part.

A suitable solvent for testing parts made of Tenite™ butyrate or Tenite™ propionate is composed of 50% acetone and 50% butyl acetate; for parts made of Tenite™ acetate, a mixture containing 70% ethylene glycol monoethyl ether acetate[1] and 30% acetone is satisfactory. Both solvent mixtures are available commercially in easy-to-use pressurized cans.

[1] *Available from Eastman as Eastman EM acetate.*

## Internal stress testing

There are two methods commonly used to test for internal stresses, one involves the use of optics and the other, specimen shrinkage when heated. Parts made of transparent formulations are suitable for either method, but opaque parts may be tested only by a heat-shrinkage procedure, which is sometimes referred to as an "unmolding test."

### Optical test

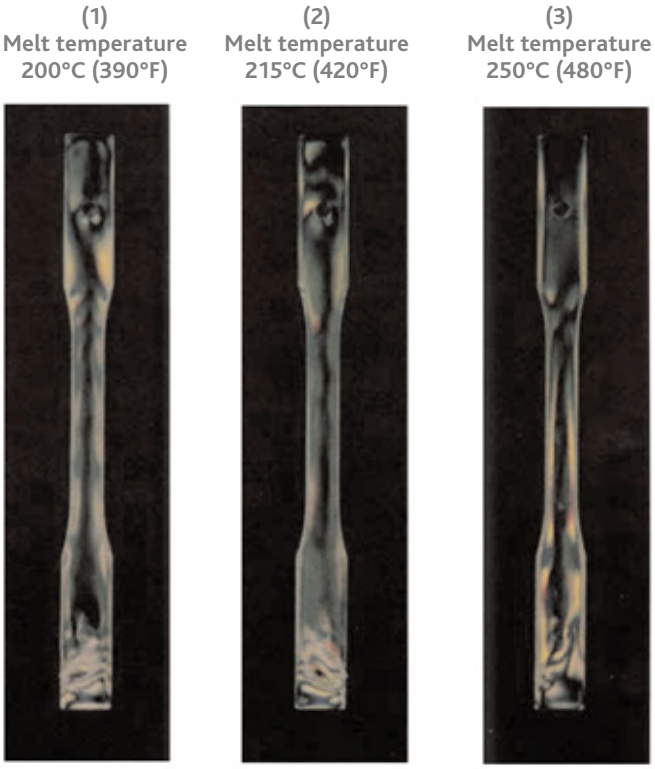
Optical testing for stress is based on birefringence, or double refraction, which is a characteristic of aligned (oriented) and strained molecules. Optical testing requires a transparent specimen.

The instrument used is a polariscope, which consists of a light source and two sheets of light-polarizing material with a space between them for insertion of a specimen. The polarizing sheet nearer the light source is called the polarizer; the other sheet, the analyzer. The polarizer and analyzer are crossed, so the field is dark, and the specimen to be examined is placed between them. When the axis of the specimen forms certain angles with the plane of polarization, stressed areas in the specimen appear as rainbow-like bands of color. The color bands repeat in a regular sequence: yellow-red-blue or yellow-red-green.

The relative magnitudes of stresses are indicated by color sequences, called fringes, and by the frequency with which the fringes repeat. The red-green fringes indicate higher stresses than do the red-blue fringes, and the higher the stresses, the more rapidly the fringes repeat. In the photographs shown in Figure 1, the highest stresses are evident in (1), which was molded too cold. The lowest stresses are seen in (3), which was molded at 250°C (480°F); the stresses in (2) are intermediate.

More detailed information about the distribution of stress can be obtained by use of the polariscope, but the techniques employed are beyond the scope of this technical bulletin. ASTM Method D4093 covers polariscopic testing; details may be obtained from ASTM Section D-20-10-23 on Residual Strain Measurement.

Figure 1 **Stresses in tensile bars molded of Tenite™ acetate 105-29 (reproduced in actual size)**




## Heat-shrinkage tests

Heat-shrinkage tests, also called "unmolding tests," measure the tendency of transparent or opaque specimens to shrink when heated to their softening temperature.

The procedure for the unmolding tests is to measure the specimen, subject it to controlled heating, cool it to room temperature, and remeasure it. Excessive shrinkage, defined later, indicates the presence of potentially troublemaking levels of stress. Large products may be cut into sections to measure internal stresses.

For testing sheet, it is usually necessary to obtain test specimens by cutting the sheet into sections because of size limitations of the test apparatus. Satisfactory test specimens can be obtained by cutting sections 254 mm (10 in.) long by 25.4 mm (1 in.) wide. Testing of specimens taken from different areas and from the machine direction and the transverse direction will indicate whether internal stresses are uniform—or nearly so—throughout the sheet.

## Stress measurement in parts made of Tenite™ cellulosic plastics *(Continued)*

Two tests will be described: one involves oven heating of the specimen; the other specifies oil-bath heating. The oven test is described by ASTM Method D1204 (or ECTS-A-PT-G-PTM-6042, a similar method available from Eastman on request).

To test film or sheeting up to 0.64 mm (0.025 in.) thick, place the 25.4- by 254-mm (1- by 10-in.) specimens in a cardboard (manila) file folder and dust them lightly with talcum powder to prevent sticking. Close the folder and place it in an oven at the appropriate temperature for 20 minutes (see Table 1).

The oil-bath method is described in ASTM Standard D2411 (or ECTS-A-PT-G-PTM-6040, a similar method available from Eastman on request). Either silicone oil or mineral oil can be used for the oil bath, with the specimens supported on a small-mesh wire screen.

In the oven and the oil-bath tests, allow the samples to cool to room temperature and remeasure them.

The proper test temperature varies for different levels of plasticizer, since material with higher plasticizer levels unmold at lower temperatures than ones with less. Table 1 shows desirable test temperatures for various flows of Tenite™ cellulosic plastics.

### Table 1 Test temperatures for Tenite™ cellulosic plastics

| Formula | Plasticizer level, % | Temperature, °C (°F) | | Time, minutes | |
|---|---|---|---|---|---|
| | | Oven | Oil bath | Oven | Oil bath |
| CA 105, 132 | 17–29 | 127 ± 1 (260 ± 2) | 141 ± 1 (285 ± 2) | 20 | 8 |
| | 33–35 | 121 ± 1 (250 ± 2) | 135 ± 1 (275 ± 2) | 20 | 8 |
| | >35 | 116 ± 1 (240 ± 2) | 130 ± 1 (265 ± 2) | 20 | 8 |
| CAB 264, 285, 485, 530, 550, 575, 576 | 3–12 | 127 ± 1 (260 ± 2) | 141 ± 1 (285 ± 2) | 20 | 8 |
| | 13–16 | 121 ± 1 (250 ± 2) | 135 ± 1 (275 ± 2) | 20 | 8 |
| | >16 | 116 ± 1 (240 ± 2) | 130 ± 1 (265 ± 2) | 20 | 8 |
| CAP 307, 358, 380, 381, 385 | 8–18 | 127 ± 1 (260 ± 2) | 141 ± 1 (285 ± 2) | 20 | 8 |
| CAP 360, 371, 375, 376, 377, 382, 383, 384 | 7–16 | 127 ± 1 (260 ± 2) | 141 ± 1 (285 ± 2) | 20 | 8 |

The differences in dimensions before and after testing usually are reported as percent change from original dimensions. Shrinkage values of 5% or less for molded parts and values of 3% or less for extruded or thermoformed parts are considered normal for most applications. Higher values indicate excessive stresses that may cause part failure. Sheeting for offset printing or a part that is to be subjected to reheating generally must have less than 2% shrinkage in the unmolding tests if they are to have satisfactory dimensional stability.

If test results indicate excessive stresses, processing conditions should be varied until stresses have been reduced to an acceptable level, as established by additional testing. This can be accomplished by two methods that may be used singly or together. Either the processing temperature can be raised sufficiently for the molecules to flow past each other freely (rather than stretching or bending), or the formed product can be cooled slowly enough for distorted molecules to have time to return to unstrained positions before the plastic hardens.

EASTMAN

**Eastman Chemical Company**
**Corporate Headquarters**
P.O. Box 431
Kingsport, TN 37662-5280 U.S.A.

Telephone:
U.S.A. and Canada, 800-EASTMAN (800-327-8626)
Other Locations, (1) 423-229-2000
Fax: (1) 423-229-1193

**Eastman Chemical Latin America**
9155 South Dadeland Blvd.
Suite 1116
Miami, FL 33156 U.S.A.

Telephone: (1) 305-671-2800
Fax: (1) 305-671-2805

**Eastman Chemical B.V.**
Fascinatio Boulevard 602-614
2909 VA Capelle aan den IJssel
The Netherlands

Telephone: (31) 10 2402 111
Fax: (31) 10 2402 100

**Eastman (Shanghai) Chemical Commercial Company, Ltd. Jingan Branch**
1206, CITIC Square
No. 1168 Nanjing Road (W)
Shanghai 200041, P.R. China

Telephone: (86) 21 6120-8700
Fax: (86) 21 5213-5255

**Eastman Chemical Japan Ltd.**
MetLife Aoyama Building 5F
2-11-16 Minami Aoyama
Minato-ku, Tokyo 107-0062 Japan

Telephone: (81) 3-3475-9510
Fax: (81) 3-3475-9515

**Eastman Chemical Asia Pacific Pte. Ltd.**
#05-04 Winsland House
3 Killiney Road
Singapore 239519

Telephone: (65) 6831-3100
Fax: (65) 6732-4930

**www.eastman.com**



PP-107C 7/13