Characterizing Foam Hinged Lid Containers Utilizing Dynamic Mechanical Analysis (DMA)

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Abstract:

Dynamic mechanical analysis was proven an effective tool in characterizing open cell foams like polyurethanes, and closed cell polyolefin foams.[1, 2, 3]

The foam hinged lid container market continues to grow as more people order takeout. Products from various manufacturers appear and feel the same or equivalent, but the performance is noticed by customers and the end user. Traditional test methods, like differential scanning calorimetry (DSC) and fourier transform infrared spectroscopy (FTIR), and even gel permeation chromatography (GPC) show that the products are similar or equivalent. Mechanical testing by tensile and compression show equivalent performance at room temperature.

Figure 1. Typical Foam Hinged Carryout Container

Many general plastic testing methods do not measure the affects from processing nor slight changes in morphology[4]. A more sensitive mechanical test is required.

Dynamic mechanical analysis (DMA) using three point bending can measure the difference that goes down to the cellular level, struts and cell walls. DMA also covers the entire temperature range, from cold salads to hot stir fried Chinese takeout.

Introduction:

Several manufactures make foam hinged lid containers and the products appear and even feel to be equivalent, but the performance varies, Figure 1.

Many foam hinged lid containers undergo failure, resulting in customer complaints and/or even loosing customers altogether. DMA can predict the product performance in many cases.

For example; take out food in New York City. Before the rush, vendors stockpile the orders and stack the foam hinged lid containers. However, some products fail and the stacks fall over, what a mess. You just lost a customer (one) and all their associates (ten more).

The other vendor's foam hinged lid container held up to the heat, force, and creep. But why? What made their product better? Resin? Additives? Process?

Experimental:

The dynamic mechanical properties were measured using a Rheometric Scientific RSA II Solids Analyzer equipped with a three point bending fixture, Figure 2.

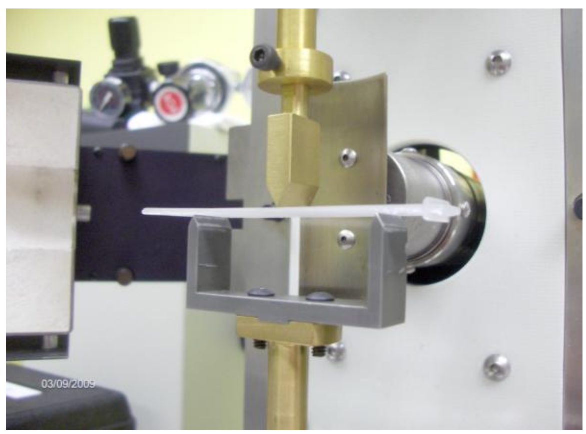

Figure 2. DMA Three Point Bending Fixture with Sample

The test method was a temperature ramp with a heating rate of 2.5ºC per minute, a strain of 1%, and a frequency of 3.14 radians per second. Sample size was 10 mm by 60 mm and the thickness measure prior to testing.

Samples were from 4 major companies that produce foam hinged containers. We refereed to these companies as Samples A, B, C, and D. The corporate names are to remain safely anonymous.

Results and Discussion:

We looked at foam hinged lid containers from several manufacturers to compare the performance. Room temperature studies showed the modulus (stiffness) was different. This means the feel and rigidity can be ranked.

The measured properties include storage modulus (E' the elastic portion) loss modulus (E" the viscous portion) and tan-δ (E"/E' the damping ratio). These properties are measured as a function of temperature and provide an effective way to predict the foam hinged lid container performance.

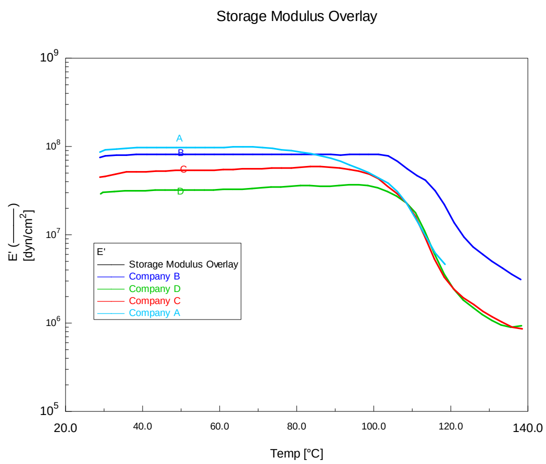

Figure 3. Storage Modulus, E', Elastic Portion

The storage modulus in Figure 3 had differences even from room temperature. This confirms earlier findings that the samples felt different. Three of the samples, A, C, and D, appear to merge together around 109ºC, Figure 4. Sample B was shifted 10ºC higher, and had a step transition in the storage modulus at 113ºC.

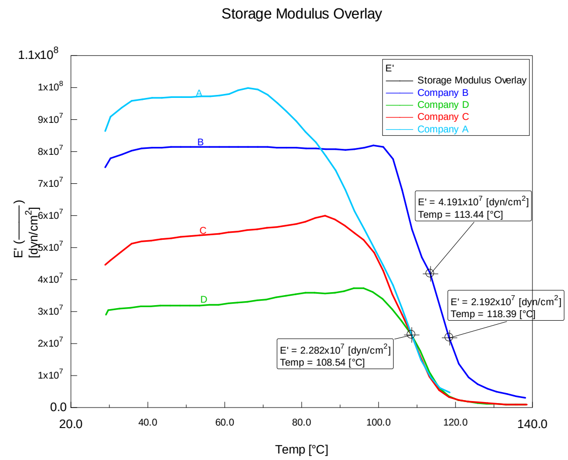

Figure 4. Storage Modulus, E', Linear Scale

The loss modulus curves, Figure 5, had dirrerent shapes, slope to the peak, and peak height. Samples A and D had broad peak shapes and a gradual slope to the peak indicating the foam materials are moving gradually, creep, and start moving at lower temperatures.

Sample A is the stiffest and Sample D the softest, neither one will perform at high temperature. Both will fail when stacked with food product.

Samples B and C had higher slope values, but B had the 10ºC advantage.

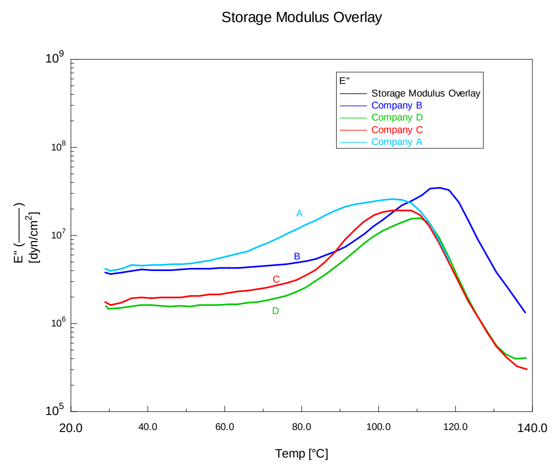

Figure 5. Loss Modulus, E", Viscous Portion

The tan-delta curves had different peak heights and temperature values, Figure 6. The general rule for product stability is as the tan-delta peak area decreases the product stability increases. This explains why products with broad tan-delta curves are less stable then products with sharp curves.

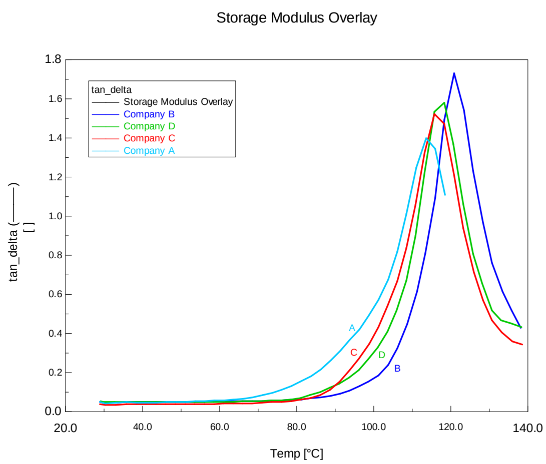

Figure 6. Tan-delta (E"/E')

Another part of the tan-delta curve that's important is the slope and baseline (temperature) intercept.

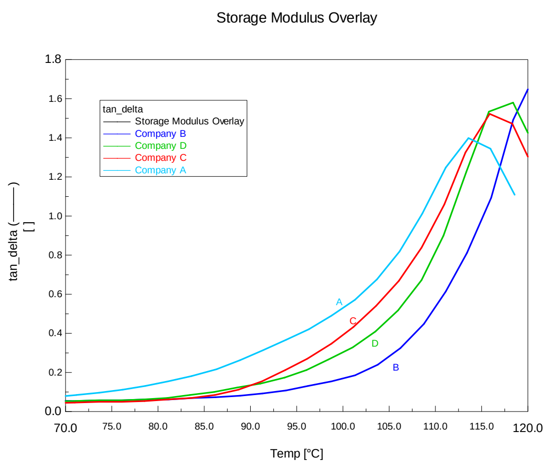

Figure 7. Tan-delta (E"/E'), Expanded Region

The curves in Figure 7, show the tan-delta peak temperature varies, 113ºC, 115ºC, 118ºC, 121ºC, the product stability is ranked as Sample B being the highest, and Sample A as the lowest. The stability order is B, D, C, and A.

Conclusion:

The temperature ramp program measured significant differences in the rheology curves and are related to the final product usage temperature. A 30-minute test can measure the foam hinged lid container performance from room temperature up to the failure temperature.

The areas of interest are from the storage modulus (E') that relate to the "feel" or "stiffness" of the foam hinged lid containers. The loss modulus and tan-delta provides valuable information about the temperature stability based on peak shape, slope and area.

The overall ranking from the products was B being the best, most preferred feel, stiffness, and thermal stability. Second was Sample C having a "good feel" and stiffness. The loss modulus appeared to have a stronger influence then the tan-delta curve.
Third was Sample D, softer feel, but still a good performer for thermal stability.
Last was Sample A. This product had high stiffness, but poor thermal properties.

References:

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