Thermal Stability of PLA Preforms

Background

Since temperature is an important parameter in terms of affecting a packaging article's ability to retain and hold its shape and integrity during shipping and storage, various PLA preforms were subjected to the following temperature and storage scenarios for simulation to help understand heat distortion effects:

1. To a temperature of 66°C (150°F), without load, in order to determine how the heat would affect the shape of a single preform
2. To simulate load deformation when multiple preforms would be stored in a large volume container, weights were added to the top of a specified number of preforms while in the oven.
3. A larger-scale simulation was also performed using a 55 gallon fiber storage drum to try and simulate real-life load conditions preforms may see in a shipping/storage environment.

Discussion

For a non-load scenario, single preforms were stood upright in the oven for thermal exposure.

To simulate a load, weights were placed on top of the preforms. 22 preforms (this was counted based on a hand full taken and used) were placed into a cylindrical jig. The diameter of the container was approximately seven inches. Since each preform weighs 23 g, approximately 500 g was the weight of 22 preforms. Estimating that a gaylord or container is about 4-5 feet in height, then based on a 7" diameter tube that is 4-5 feet in height the amount of weight used was calculated to be approximately 7.6 kg.

For the above simulations, a Thermotron laboratory oven was used. The oven test consisted of subjecting the preforms to elevated temperatures. The temperature program took the preforms from 30°C to 66°C, using a heating rate of 2°C/min and then holding the preforms for an hour at the 66°C temperature. After, the samples were cooled and then taken out for observation. To understand how the preforms would hold up, the samples were tested at couple of other temperatures.

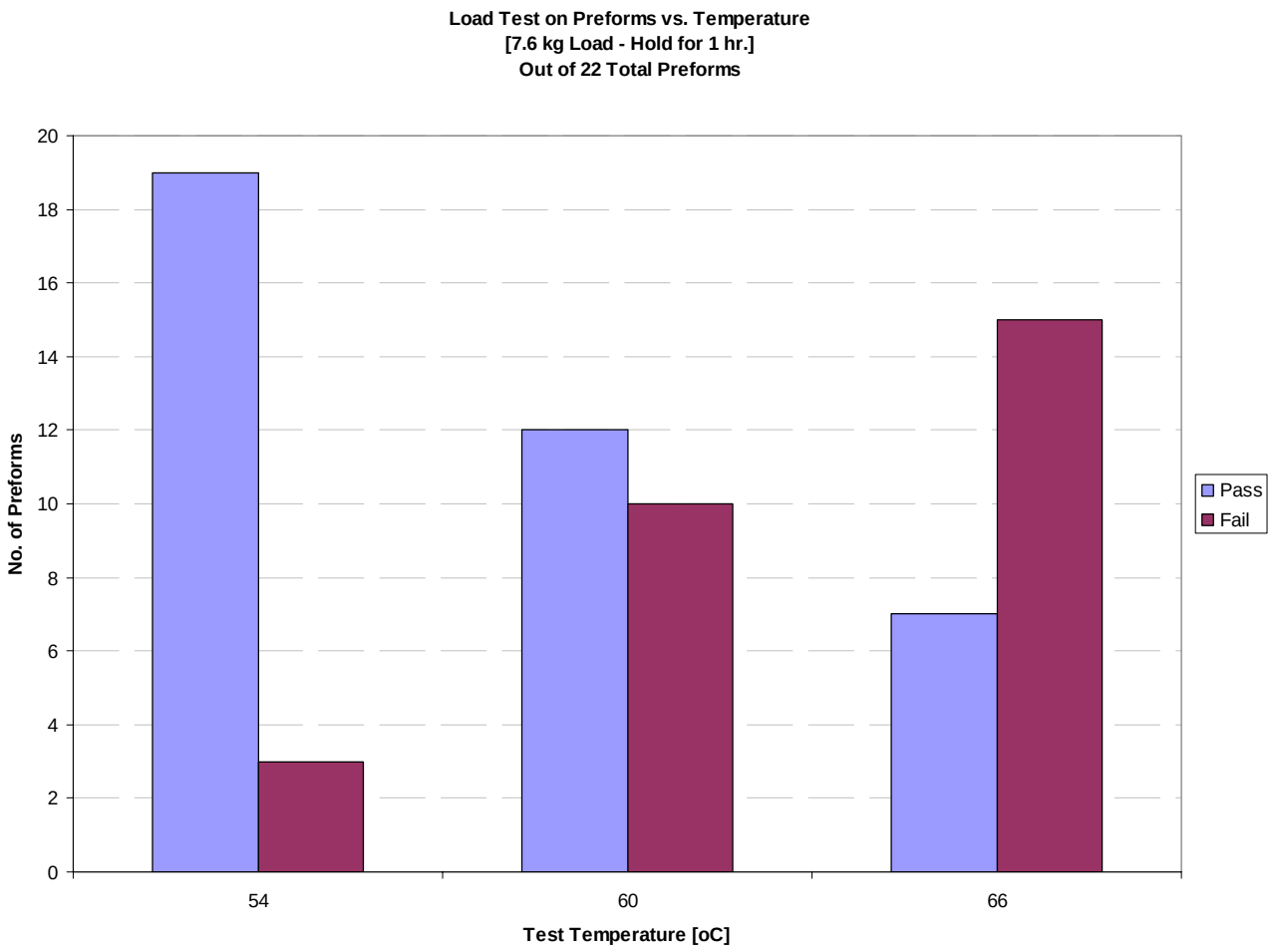
For the larger scale simulation, PLA and PET preform temperature stability was compared using a barrel oven heater. Approximately 85 lbs. of PLA preforms were poured into a fiber drum and placed in the oven at 50°C, along with 85 lbs. of PET performs placed in a separate fiber drum. The performs remained at this temperature for approximately 48 hours. After 48 hours, the performs were evaluated for heat deformation. After being evaluated, the performs were returned to the oven at 55°C. This procedure (a 5°C increase in temperature after 48 hours) was followed until the performs began to show significant heat distortion.

Summary

The data indicates that preform shrinkage at 66°C is minimal on freestanding preforms, without load. Higher temperatures were not run.

However, load tests on preforms showed deformation occurring. Chart 1 illustrates the number of preforms that deformed as a function of temperature. Temperatures were increased from 30°C to three different temperatures at a 2°C/minute heating rate and then held at the final temperature for an hour with a 7.6 kg load on the preforms. The data indicates that the majority of the deformation starts to occur in the 50-60°C temperature range. This temperature region corresponds to PLA's glass transition temperature (Tg), which is 55-60°C. The Tg is a thermal transition event in which the amorphous chain mobility starts to significantly increase. At Tg, the plastic material changes from a glassy, rigid state to a more mobile, rubbery state. In general, this is how many thermoplastic materials respond when their Tg is approached. This physical property change not only occurs in preforms, but also other plastic, amorphous-type articles.

Chart 1 – Thermotron oven test on PLA preforms with load simulation



For the larger scale storage simulation, the PLA preform deformation results are similar to the Thermotron oven laboratory results. After 48 hours, the PLA and the PET performs were heat stable at both 50°C and 55°C. However, the PET preforms were also stable at 60, 65, and 70°C. The PET preforms began to fail at about 75°C, with about 2% failing - primarily around the threaded area of the preform. At about 80°C, 60 lbs. of the PET preforms were bad, and 25 lbs. were considered still good.

The PLA preforms began to significantly fail at about 60°C. At this temperature, the total weight of the fiber drum was 85 lbs. and 35 lbs. of the performs were found to have failed – a 41% failure rate. No significant preform deformation was noted at 55°C. A qualitative evaluation revealed performs at the bottom of the drum were affected the most by heat distortion. Deformation was mostly around the threaded area. The threaded area became deformed and was no longer a perfect circle. The perform height diminished by 2 to 3 mm on some samples. At 65°C for 48 hours, all the PLA performs failed.