Horizontal vs. Vertical Dilatometers

One of the most baffling aspects of selecting a dilatometer is making the choice between a horizontal and vertical unit. Frequently it is cited that the choice is purely a personal preference. In reality, there are substantial differences between the two configurations, each being better suited for a particular task than the other. This note attempts to highlight some of these differences and to give a rule of thumb for rational selection.

TA Instruments produces both types of dilatometers, and to start with, neither system is better than the other, except with respect to certain specific applications.

Horizontal Configuration

These instruments have a cantilevered horizontal tube protruding into a horizontal furnace cavity. The pushrod is also cantilevered parallel with the axis of the tube. The sample (cylindrical or rectangular slab) rests on the bottom inside face of the tube, on a cradle or holder, which then rests on the tube. Most frequently the top half of the tube is cut away to make the changing of the sample easy. The end of the tube is closed off either rigidly (such as when the base is actually fused to the tube) or with a plate trapped in grooves. The sample is then slid up against it and held in place by tacking force of the pushrod from the other end. It is clear that the pushrod must exert a reasonable force on the sample to overcome the friction between it and the tube. For a trapped end plate, this pressure must also be sufficient to also keep the plate pressed against the far side of the groove and do not allow it to move at all. Normally this requires a fair amount of force, which in most cases for rigid solids matters little. In one specific application, however, this aspect becomes a major weakness of this configuration. Samples that soften, shrink, or sinter will shorten rather than expand when heated. If the pushrod force is low to prevent indentation into the end of the sample, then it may not be enough to overcome the friction and the sample will not slide to keep the other end pressed against the end plate. As it shrinks a gap may develop between it and the plate. This is totally unpermissible, as the dilatometer just lost track of the process. The end result can even look believable and smooth, but totally wrong. In some dilatometers that use flat leaf spring suspensions for the pushrod, this problem is even further aggravated by the minimal force exerted by the spring. These "frictionless" suspensions refer to the absence of friction in the suspension of the pushrod and not the friction of the sample. For these reasons, it is not advisable to choose a horizontal system for shrinkage or sintering work.

A major advantage of the horizontal configuration is its superior thermal uniformity. A horizontal furnace is not subject to convection parallel with the sample, and can be made a lot more symmetrical than a vertical one. For long samples, a horizontal system is a must to ensure reasonable thermal uniformity.

A commonly encountered problem with a hotizontal design is the sagging of the pushrod and eventually the sample holder tube. This is caused by slow creep of the cantilevered section under its own, and the samples' weight. Fused silica exhibits it the least while alumina, especially if regularly used above 1500 ^{o}C, will do it extensively. The first sign is a droopy pushrod tip and later a quite discernable downward arching of the tube. Eventually it may even interfere with proper insertion into the furnace cavity. The process is very slow and therefore it has no detrimental short term effects (no single test will be affected)

Vertical Configuration

In this form, the furnace is either a tube furnace or a pot furnace (bottom of chamber is blanked) and the dilatometer is inserted into it vertically.

This design is obviously not subject to the sag problem, although their pushrods sometimes slowly buckle with extensive high temperature use. Counterbalancing reduces this tendency to some extent, but it seems to be a problem present above 1600 ^{o} C use. Vertical creep of the tube, although present, is not a factor up to 1700°C.

Constructions employing a trapped bottom plate (similar to the trapped end plate in horizontal devices) becomes a plus. The plate is always held in place by gravity and at the same time, it is readily replaceable if damaged or corroded by a sample.

A major advantage of vertical dilatometers over horizontal ones is realized when sintering or softening of samples are studied. All problems noted for the horizontal device disappear as the sample is held against the bottom plate by gravity, so it can never shrink away from it. These processes also necessitate long pushrod travels, as 10-30% shrinkage is not unusual. Leaf spring suspensions lose their value in the vertical mode and can not accommodate long travels either. More successful vertical designs employ some form of linear bearings to hold the pushrod in line and a static counterbalance by weights to reduce the tip pressure on the sample.

Vertical furnace cavities are always subject to convection and have a less uniform hot zone than horizontal ones. For this reason, it is customary to reduce sample length and even to use multiple thermocouples alongside. Sometimes, the rising heat tends to warm up the dilatometer head causing a drift, but this can be eliminated using a downward gas purge that is introduced through the head and judicious use of water cooling at critical locations. Due to having the sample stand up on one end, loading stability, and tracking is often better in a vertical device.

A unique variation on the same theme is the upside-down design where the furnace is on the top and the dilatometer is inserted from below. At first, this seems to possess a number of advantages, such as no heat flow into the head, etc., but upon closer examination, they become insignificant compared to the balancing act one must do to have the sample centered on top of the pushrod and held in place against the end plate. Because a substantial force is exerted by the pushrod to press the sample upward against the end plate, all of the advantages for softening or sintering studies that conventional vertical units offer largely, disappear. This is a clever solution to a non-problem.

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