Polymer Services Group
Innovation, Application, Evaluation

PVC Tensile Strength

Simply stated, tensile strength is the useful limit of a material – it is the point at which a product made of the material will break or severely distort.

The tensile strength of a material is measured by pulling on the ends of a specimen of known cross-sectional area (square inches) at a constant rate (inch/minute) and measuring the force (pounds) required to stretch the material to failure. A brittle material, like glass or ceramic, will continue to increase in load or force until the material breaks suddenly. The peak load or load-at-failure divided by the original cross-sectional area of the specimen is the tensile stress-at-failure, or tensile strength of the material. A more ductile material, like copper or steel, will reach a peak load and not break immediately, but continue to extend – although less force is necessary to continue to stretch the material to failure. In this case, the peak load is termed the load-at-yield and represents the yield strength of the material, while the load-at-break is used to determine the tensile stress-at-break, or ultimate tensile strength. Other more ductile materials are capable of reorganizing their microstructure and strengthen with continued stretching or drawing. As a result, the ultimate strength can be greater than the yield strength of the material. In this situation, the higher of the two, yield or break, is considered the "tensile strength" of the material. Knowing these properties of a material, one can design products and realistically determine at what point a product made from the material will break or severely distort in use.

While most materials have very defined tensile properties, the behavior of polymers, or plastics like PVC, is rate dependent. That means that its strength characteristics vary depending on how quickly or slowly the material is deformed – at very high rates of stretching, the material behaves like a brittle glass, while at extremely low rates of extension it has properties more like rubber. In order to compare the tensile properties of two plastic compounds, one cannot merely compare the reported tensile strengths of the materials, but must ensure that they were determined under identical test conditions – using identical specimen geometries at the same deformation rates. For PVC pressure pipe compounds, the standard conditions for establishing tensile strength are stipulated in ASTM D1784. Still, the strengths cannot be used directly to design a product unless the test conditions closely match the use conditions. For example, the tensile strength of rigid PVC, like that used in PVC pipe, is typically reported as 7800-8200 psi – that means that if held at this stress, a product will typically fail in 1 to 5 minutes – about the time it takes to run a typical tensile test. This value of tensile strength is suitable for estimating the failure stress or pressure in a one-minute quick burst test, but the value is unsuitable for determining the failure stress or pressure rating of a pipe. The stress required to cause a PVC pressure pipe to fail in 11.3 years (100,000 hours) in a product made with the same material is about half the tensile strength at 1 to 5 minutes, or 4000 psi – the value of the Hydrostatic Design Basis used for establishing the pressure rating on PVC pipe.

There are several reasons why one would want to determine the Longitudinal Tensile Strength (LTS) of a PVC pressure pipe.

- For those products that are marked UL1285, a minimum LTS of 7000 psi is a requirement for UL compliance, and all UL1285 products should meet or exceed that property.

- All PVC pressure pipe standards require that the PVC 1120 material, from which the pipe is made, satisfy the cell classification requirements of 12454, stipulated in D1784. One of the cell class requirements is a minimum tensile strength of 7000 psi. Testing the LTS of the pipe ensures that the tensile strength of the material used to make the pipe was in compliance with the standard.

- To attain maximum strength, the PVC compound must be adequately processed into a homogeneous melt and formed properly into the pipe configuration by the extruder-die-sizing process. One way to assess proper homogeneity of the mixing process is by determining the LTS of the product.

    - PVC resin begins as a fine powder, to which is added many other liquids, waxes, solids, and dispersions. While these ingredients are mixed in an intensive mixer, similar to a large home blender, the dry blend remains as a mere mixture of components and not a homogeneous composition. Final mixing into a homogeneous mass is performed in the extruder. LTS can establish if adequate blending and homogeneity has been established by at least satisfying the minimum 7000 psi value for tensile strength.

    - Furthermore, the PVC powder particles themselves have to be adequately broken down and melted, often termed fusion, in order to achieve sufficient tensile strength of the compound. LTS can be used to detect inadequate fusion of the PVC compound.

    - To make these assessments, the tensile specimens need to be prepared directly from the pipe wall – flattening or milling/molding the pipe before specimen preparation would add another heat history, further obscuring the likelihood of detecting the aforementioned material deficiencies.

- Ideally, the PVC extrudate exits the die in a shape very close to the final dimensions of the product – very little has to be done to the extrudate to bring it to final product dimensions. However, some manufactures when changing products to different wall thicknesses or diameters, rather than take the time to change extrusion dies due to lost down time, will manipulate the melt by drawing down the extrudate, rapidly elongating the softened plastic, or expanding the diameter just prior to the sizing/cooling sleeve. This technique saves time and money, but freezes in undesirable residual stresses in the pipe wall, and seriously compromising the physical integrity of the product. LTS is one way to determine if post-extrusion drawing or stretching has affected the physical properties of the product.
    - To detect the presence of excessive residual stresses in the product, it is imperative that the tensile specimens be prepared directly from the pipe wall, and not after flattening or milling/molding. These additional heat histories relax residual stresses in the product, negating their detection in the product.

Rich Geoffroy

POLYMER SERVICES GROUP