Polymer Services Group

Innovation, Application, Evaluation

How Do Plastic Parts Fail?

Plastics parts fail simply by pulling them apart --- they <u>always</u> fail as a result of tension. Whether the part is in flexure, torsion, shear, or even compression, failure always is the result of tensile effects on the polymer molecules --- they are simply being pulled apart as a result of the applied load.

Polymers exist as a jumbled mass of long molecular chains --- not unlike a plateful of uncut spaghetti. The points at which the spaghetti strands contact each other are “sticky”, similar to the resistance caused by side-branches or secondary attractive forces between molecules. Also, because of their long lengths, many of the molecules are entangled, amongst themselves and with other molecules.

As one begins to pull on one or more of the molecules, there is an interaction with the others --- pull on one and the others will tend to move. Some of the short molecules or those with less entanglement will slip and move more easily, while others will begin to tighten and restrict movement. When extension or deformation occurs, there is some alignment in the direction of the force. This alignment or orientation causes the molecules to come closer together and results in a lessening of the free volume. This phenomenon is commonly viewed as “necking” or yielding in a test specimen, when the center of the specimen begins to “thin” as a result of extensional alignment.

Slippage releases the stress on those molecules that can actually move (as well as those that it might have been “pulling” on), but that slippage correspondingly increases the load on those entangled or restrained chains that cannot relieve the stress. As a result, with further extension, a disproportionately high load is carried by fewer entangled molecules. Ultimately, these chains begin to break. The locations of these breaks as well as chain ends that have previously pulled out of the mass, collect as a “space” or “defect” in the plastic part. With further extension or the application of more stress, the defect begins to extend perpendicular to the direction of the load, breaking adjacent chains one-by-one, until the part fractures.

The strength of a polymer is a function of the material’s ability to deform with a high resistance to defect extension --- an intrinsic property of a material known as fracture toughness.

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