

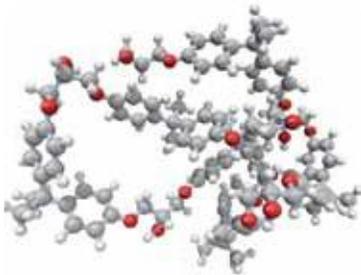
Understanding Mechanical Properties of Epoxies For Modeling, Finite Element Analysis (FEA)

WHAT

Mechanical Properties of Epoxies for FEA

WHY

Understanding the properties of epoxies will help in product selection when using FEA



Crosslinked Epoxy

The unique molecular structure of epoxy allows for a large variety of mechanical properties through varying formulations. Epoxies can range from very soft and flexible to very hard and rigid. Softer materials can relieve stress while harder products are used for their high strength and acoustic properties. The thermosetting nature of epoxies cause them to behave differently than thermoplastics and other engineered materials when stresses are applied. Understanding these properties can help in the selection of the best possible product and aid in the modeling of systems such as finite element analysis (FEA).

Strength

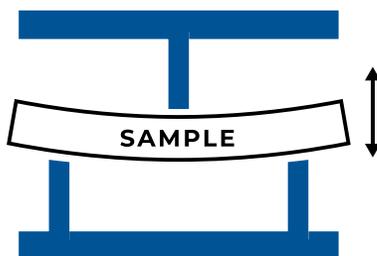
In the majority of applications, the largest stress on an epoxy is shear, not tensile. For this reason we perform two types of shear testing to determine epoxy strength: *lap shear* and *die shear*.

Lap shear is performed by bonding two overlapping aluminum coupons and applying a shear force by pulling the coupons in opposite directions until they fail in a shear mode. The lap shear strength provides a good approximation for strength in structural applications and is reported in units of pounds per square inch (psi).

Die shear strength is typically performed using a probe to push a 2mm x 2mm gold die, adhered to a gold plated kovar substrate. Die shear strength is reported as a force in kilograms (kg) and as a stress in units of pressure (psi). For the bonding of small components such as electronics, this is the preferred test method.

(For further details, see [Epoxy Technology Adhesive Application Guide](#))

Three Point Bend Test Geometry for DMA



Modulus

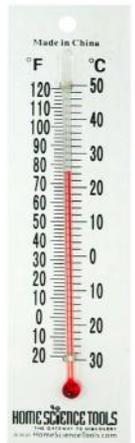
Modulus is an excellent property for judging how rigid or flexible a material may be and is very important in modeling. Epoxies highly cross-linked polymer structure exhibit mainly elastic response to loadings, however there is also a viscous response which causes some plastic deformation. The combination of responses is known as viscoelasticity, which is measured using Dynamic Mechanical Analysis (DMA) and provides a more accurate characterization of the material.

DMA uses a cyclic **Three Point Bend Test** which allows for the viscoelastic response to be seen as a phase shift in the response of the material. The phase shift, reported as $\tan(\delta)$, can also be expressed as the ratio between the loss modulus and the storage modulus. The loss modulus represents the complex or viscous component, while the storage modulus represents the real or elastic response. This allows the storage modulus to act as a good approximation of the Young's Modulus for an epoxy.

(For further details, see [Epoxy Technology Adhesive Application Guide](#))

Temperature

Epoxyes are thermosetting polymers, which causes them to behave quite differently from thermoplastic materials at high temperatures. Unlike thermoplastics, epoxyes will not flow or melt when brought above their glass transition temperature (T_g). Above its T_g , an epoxy becomes softer as evidenced by a decrease in the modulus. However, the cross-linking of the polymer chains causes the material to maintain its shape and adhesion through this transition. Many epoxyes are commonly used well above their T_g with excellent results. Above the T_g , there is an increase in the free volume within the structure which allows for more movement of the polymer chains. The increase in chain movement accounts for the decrease in modulus and an increase in the coefficient of thermal expansion (CTE).



NOTE

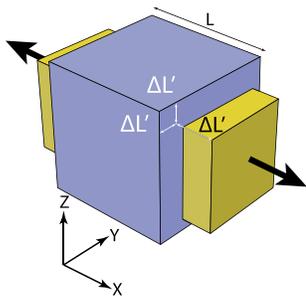
Many times, instinct dictates that a lower CTE value will lead to better resistance of thermal stresses, this is not always the case. While low CTE values indicate less of an expansion in the dimensions of the epoxy with an increase in temperature, it can be impossible to exactly match the CTE of the substrates being bonded. Low CTE materials also tend to be very rigid, so any thermal stresses transferred to the bond line can often lead to de-bonding of the epoxy.

Instead of having a low CTE, the best materials for overcoming thermal stresses usually have a lower modulus. A lower modulus allows the epoxy to absorb stresses caused by temperature changes, even if the epoxy has a high CTE value. This is especially important for larger parts where the forces caused by thermal expansion are proportionately greater.

Hardness

In addition to strength and modulus, another important property is the hardness of an epoxy. Hardness is a useful approximation of the rigidity of an epoxy. Along with the modulus, hardness can provide additional data regarding the compliance of an epoxy.

Hardness is measured using a Shore® Durometer. Higher hardness values indicate a more rigid material, while a lower value, a softer one. There are two scales that are used for measuring hardness; *Shore D* for more rigid materials, while *Shore A* is used for softer products. Each hardness reading can vary from sample to sample and even within the same sample if measured by different operators. This can lead to a variation of approximately ± 5 for most products.



Poisson's Ratio

Another useful mechanical property for modeling systems is Poisson's Ratio. The Poisson's ratio describes the relationship of the change in dimensions of a material in both the axial and transverse direction when a stress is applied. Epoxy Technology does not measure this property, but most epoxyes exhibit a value of approximately 0.3-0.35. For modeling purposes, 0.3 is most commonly used.

CONCLUSION

The above information provides a general guideline for epoxy selection in finite element analysis and can aid in predicting the performance of an adhesive for specific applications. Many times, adhesive performance can be optimized by adjusting cure schedules, application method and surface preparation.

