Technical Abstract No. 2:

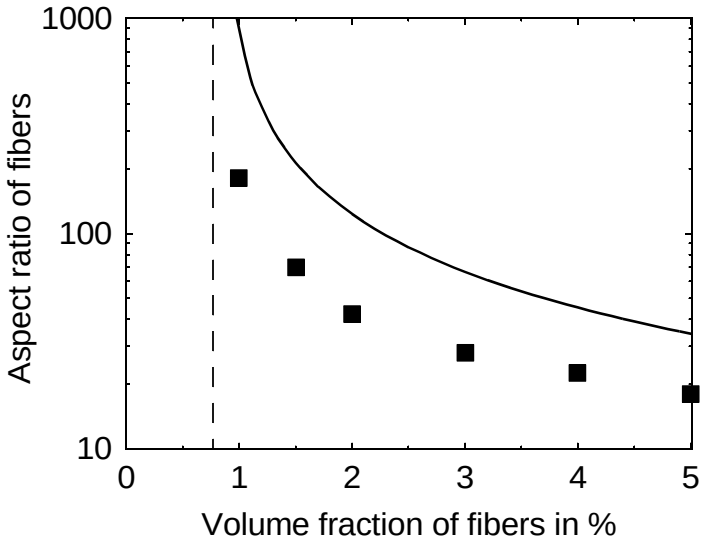
How Can One Match the

Thermal Expansion of Steels and Polymers?

In many demanding applications, including aviation, aerospace, and the automobile industry, one is interested in lowering the mismatch between the thermal expansion of metals and polymer-based composite materials. Typically, organic polymers have a linear thermal expansion α of about 10^{-4} K^{-1}, metals about 10^{-5} K^{-1}. As a result, a temperature change of 100 K (by driving from Alaska to the Death Valley) leads to a relative size mismatch of about 1 %; therefore one needs to use some additional fixation tools to keep metal and polymer parts together. A relevant example is the fixation of an automobile bumper on the car's body where, on a base of 2 m, the unconstrained size mismatch reaches 2 cm as the temperature changes by a hundred degrees.

Many fibers have a very low or even negative thermal expansion in the fiber direction. Therefore, one is interested in putting short fibers into a polymer in order to obtain a material with a lower effective thermal expansion. The goal is, for instance, to match the longitudinal thermal expansion of a polymer-based composite with that of Aluminum. For this, we consider a composite of perfectly aligned, randomly situated carbon fibers and carry out numerical predictions of the effective thermal expansion coefficients. Here our interest is in relatively small fiber volume fractions, where the composite can still maintain the attractive mechanical, impact, insulation, and other properties of unfilled organic polymers. The figure shows the aspect ratio required to match the two thermal expansions at a given fiber volume fraction, once estimated with the industry-standard Halpin-Tsai equation, once accurately modeled by *Palmyra*.*

One can see that the Halpin-Tsai equation considerably underestimates the technological potential of short carbon fiber reinforced polymers, leading one to the wrong perspective about the attainability of maximal performance. **In fact, modeling with *Palmyra* reveals that ordinary short carbon fibers are potentially completely sufficient to reach the desired result**.



Car bumpers with thermal expansion coefficients matching those of the metal chassis allow to safe on expensive fixations.

*) Ref: *A. A. Gusev*, Macromolecules 34(9), 3081 (2001).

A. A. Gusev, J. J. M. Slot, Advanced Engineering Materials 3(6), 427 (2001).