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Physical modelling of the effect of fractures on compressional and shear wave velocities

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Ultrasonic measurements were performed on a sample of polyester resin permeated by multiple fractures. The samples were prepared by mixing high doses of catalyst, about 7-10 % with the liquid resin base. The mix was then heated in an oven at 60° C for a period of 1 hour. This operation produced many shrinkage cracks varying in size from 8 mm to 20 mm (Sahouryeh et al., 2002). The produced samples were parallelepiped 50 mm x 50 mm in cross-section with height of 100 mm. Micro-CT scanning of the sample reveals many open fractures with apertures 0.2 – 0.4 mm.

Elastic properties of the fractured samples were derived from ultrasonic measurements using piezo-electric transducers. These measurements give compressional (Vp) and shear (Vs) wave velocities of 2450 and 1190 m/s, respectively, giving Vp/Vs = 2.04. At the same time the velocities in the intact resin are Vp=2460 and Vs=1504 m/s, respectively, with Vp/Vs = 1.63. Thus we see that the fractures have a negligible effect on the Vp (within the measurement error) but a dramatic effect on Vs (about 20%). This contradicts the common understanding that the effects of dry fractures on Vp and Vs are similar in magnitude. Indeed, assuming very roughly that the distribution of fractures is isotropic, we can estimate the cumulative normal fracture compliance from the difference between shear moduli of the intact and fractured resin to be 0.30 GPa^{-1} and fracture density of 0.41. This value can be used to estimate the effective bulk modulus of the fractured material. The corresponding p-wave velocity, Vp = 1860 m/s, is significantly lower that the observed value. The results suggest that an equivalent medium approximation is not applicable in this case, probably due to the fact that the long-wave approximation is inadequate. Indeed the fractures are larger than the wavelength that corresponds to the peak frequencies of the power spectrum of the signal. This suggests a strong influence of diffraction. Furthermore, the diffraction affects the s-wave propagation, while the p-wave propagation is similar to the one in a homogeneous material.