

# Custom Transient Finite Element for the Modelling of Ultrasonic Testing Methods for Downhole Well Integrity

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The transient spectral element method (SEM) can be understood as a specific high-order finite element method that is particularly accurate and fast with a low memory footprint, hence enabling 3D ultrasonic testing simulations on a standard PC. However, particular care must be taken in its settings when seeking both practicality and performance. In comparison, fast semi-analytical simulation using ray tracing is easily accessible to nondestructive testing (NDT) experts, through the CIVA simulation software. Although this approximate model effectively deals with a wide range of industrial applications, it reaches its limits in certain cases, particularly at relatively low frequencies involving resonance phenomena. To deal with these challenging inspection configurations, CEA-List is working on dedicated finite element models in the CIVA framework to meet specific needs in a compromise between efficiency and accuracy.

The case study considered in partnership with SLB perfectly illustrates the benefits of developing such a modelling approach. In this application, SLB checks the integrity of oil well casings using ultrasonic resonance methods at very low frequencies to control the interface between the casing and cement. The accurate reproduction of this type of process by simulation requires the consideration of complex phenomena that can be handled by finite element modelling with sufficient accuracy.

The development strategy of dedicated hybrid finite element applications adopted by CEA-List is presented in broad outline. Cross-model comparisons on a reference configuration of pristine cases will be presented, highlighting the effective limits of standard CIVA ray models. The contribution offered by the new hybrid finite element approach is then discussed. We will discuss the evolutions of model functionalities to handle geometries that differ from the canonical case (interface defects, loss of thickness in arbitrary geometries, etc.) from the perspective of a digital twin of this control.