FORTÉ
Predicting Knock in IC Engines

Knocking in spark-ignition (SI) engines is an undesired combustion phenomenon that limits how efficiently an engine can operate, produces noise and can result in severe engine damage. Knock typically results from auto ignition of the unburned gas in front of a spark-ignited flame front (see Figure 1), disrupting normal flame propagation across the cylinder. For downsized and boosted SI engines, knock represents a constraint on performance and efficiency since it inhibits the uses of more advanced spark timings, higher compression ratios and/or higher boost pressures.

As uncontrolled autoignition is the root cause of knock, accurate modeling of both autoignition and flame propagation in the cylinder is critical to successful prediction of knock. Recent improvements made in the accuracy of fuel models now enable predictive simulations of the impact of operating conditions and fuel type on autoignition. These fuel models require advanced solution techniques to handle the chemistry detail robustly when coupled to CFD. FORTÉ makes use of proven CHEMKIN-PRO solver technology that can handle the detail. In FORTÉ, detailed kinetics with 100s of species and 1000s of reactions can be utilized while maintaining practical Time-to-Solution.

Setting Up a Knock Case in FORTÉ

The first step to predicting knock in an engine is to use an appropriate fuel mechanism with autoignition chemistry. FORTÉ comes with mechanisms for predicting knock in SI gasoline engines. FORTÉ uses a state-of-the-art flame propagation model using the G-equation to track the flame without requiring mesh refinement in the flame region. Autoignition events in the simulation are monitored by virtual sensors defined in the FORTÉ CFD model, and then analyzed with signal processing techniques that mimic experimental setups during solution visualization (Figure 1).

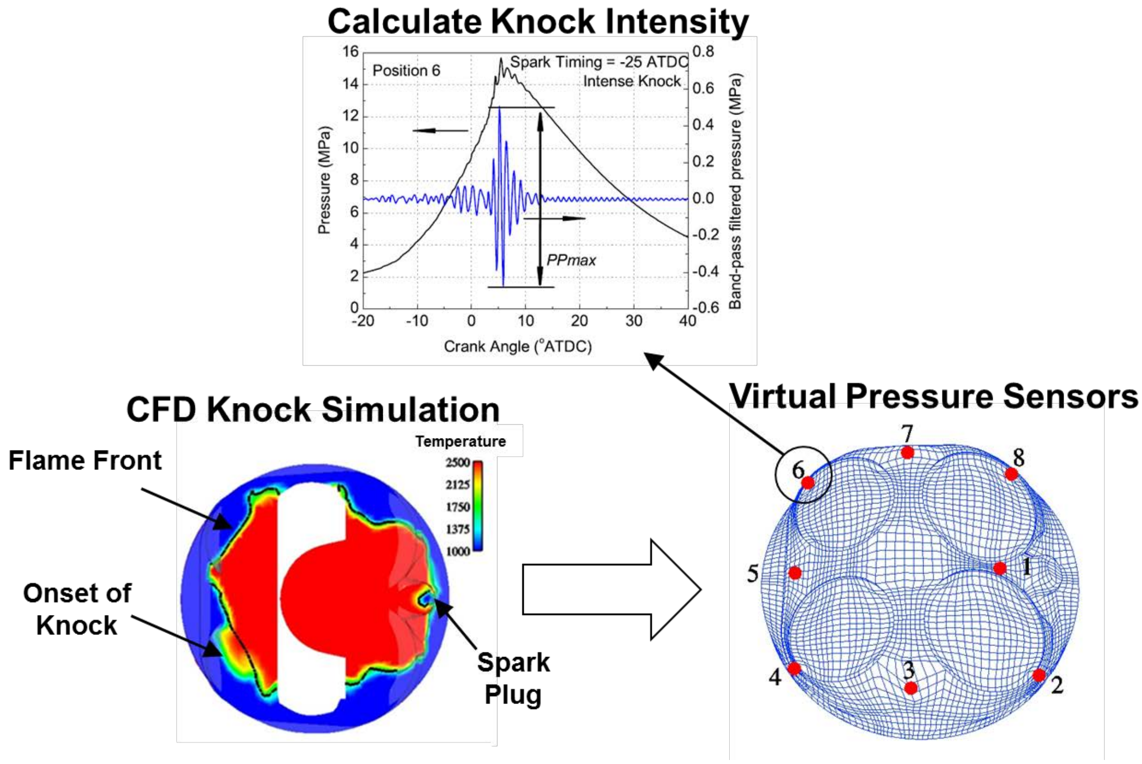

Figure 1. Knock Intensity CFD Simulations with FORTE CFD.

Results

The pressure signals recorded by the monitors can be post-processed in the FORTÉ Visualizer with a High Band Pass filter (Figure 2). This removes the low frequency portion of the pressure trace allowing visualization of the peak-to-peak pressure amplitude of the pressure fluctuations. FORTÉ also calculates the Knock Intensity Index to allow comparison of the knock severity across design or operating condition changes. An example of such a parameter sweep provided in Figure 3 shows significant knocking can occur with advances in the spark timing beyond -20 BTDC.

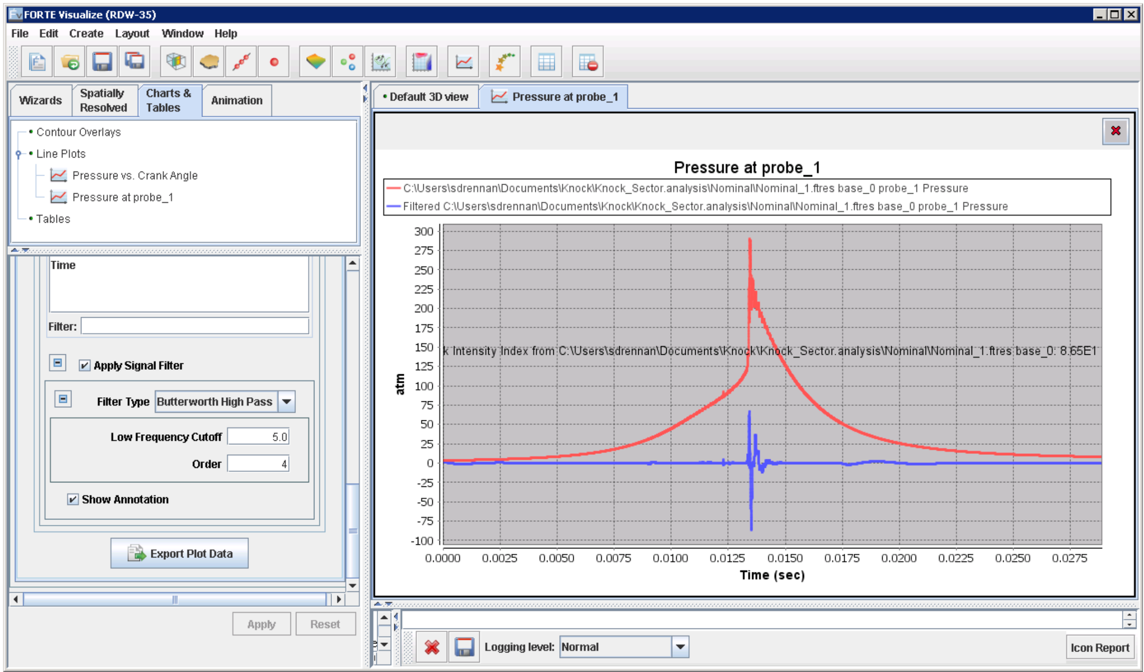

Figure 2. FORTE Visualizer showing average cylinder pressure (red) and High Pass filtered pressure for Knock Intensity calculation.

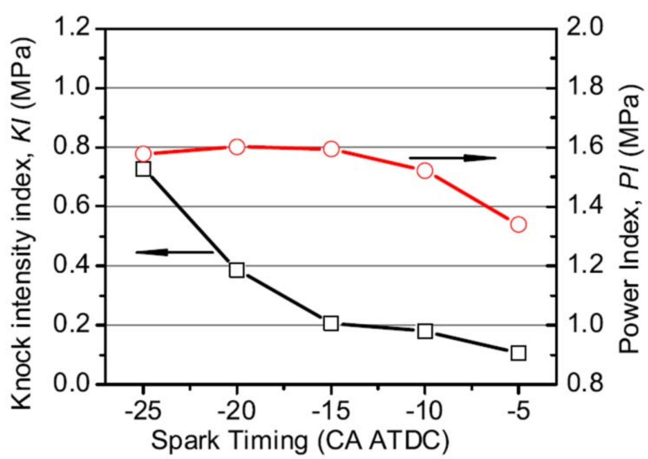

Figure 3. Effect of spark timing on Knock Intensity.[1]

[1]Liang, L., Reitz, R.D. Iyer, C.O. and Yi, J., "Modeling Knock in Spark-Ignition Engines Using a G-equation Combustion Model Incorporating Detailed Chemical Kinetics," SAE 2007-01-0165