EX172

FLUENT/GT-Power Coupling

The coupled flow in an automotive powertrain system is considered in this example. Traditionally, one-dimensional codes are used to simulate the flow through the components that constitute the powertrain, from the engine through the exhaust. For components that exhibit 3D behavior, FLUENT can be coupled to GT-Power to provide more accurate results for the component level as well as the system level calculation.

Large systems are often analyzed using one dimensional simulation tools to save time and conserve computational resources. GT-Power is a 1D code that is widely used to simulate powertrain systems, representing all system components with 1D models. Certain components, however, like intake and exhaust manifolds, exhibit highly three dimensional behavior and cannot be accurately represented by 1D models. To more accurately represent these components in the powertrain system model, a FLUENT simulation can be coupled to a GT-Power simulation. By coupling the two calculations, engineers can simulate 3D components with FLUENT while simulating the rest of the system using the 1D models available in GT-Power. Throughout the simulation, information is continually passed back and forth between the codes, resulting in more accurate results from the FLUENT (component level) simulation as well as more accurate results from the GT-Power (system level) simulation.

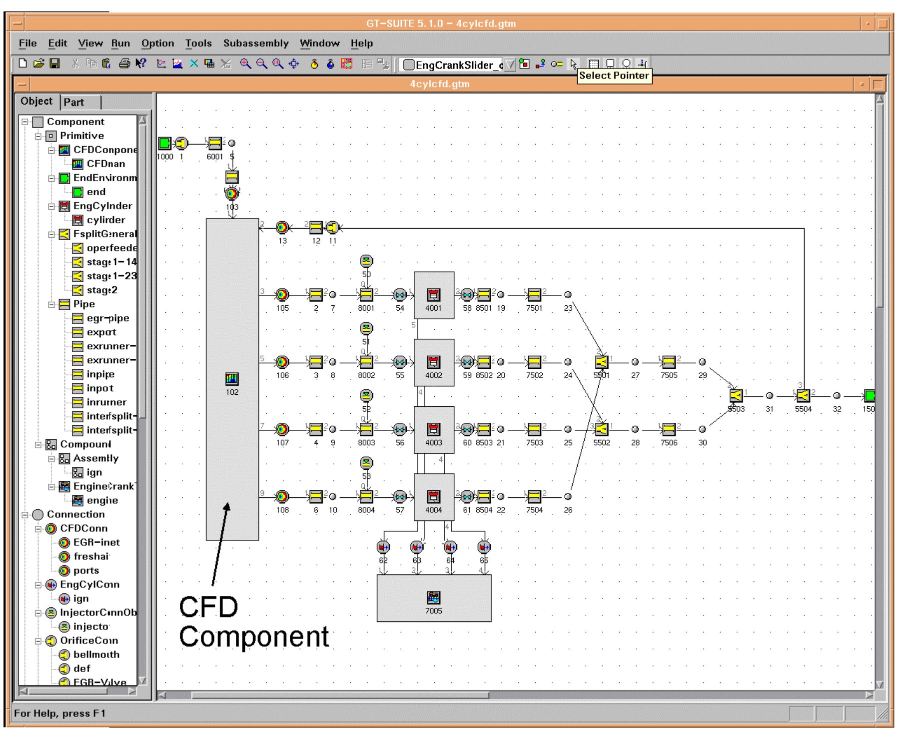

Figure 1: The GT-Power system layout

For this project, the intake manifold and powertrain system of an off-highway vehicle was analyzed. The intake manifold is a part of the powertrain system, which includes the engine, exhaust system and all the piping and tubing that connect these components together, such as the turbocharger and engine cylinders, for example. The performance of the powertrain system is largely dependent on the flow through the intake manifold, since the distribution of air to each cylinder in the engine is governed by the manifold shape and operating characteristics. The primary goal of the project, therefore, was to analyze the flow in the intake manifold and study its effect on the performance of the powertrain system.

First, a GT-Power model of the entire powertrain system was constructed, with all components except the intake manifold represented by 1D models. In GT-Power, the intake manifold is

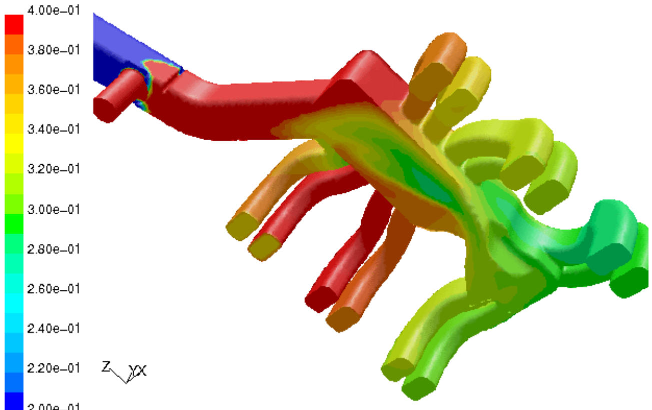

Figure 2: Contours of exhaust gas recirculation (EGR) 1.35 ms from the start of the periodic simulation

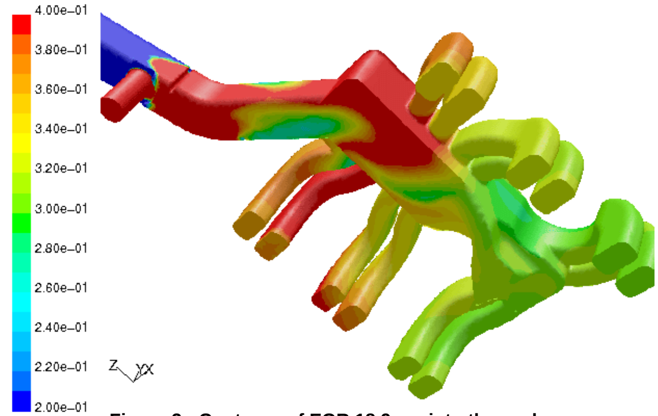

Figure 3 : Contours of EGR 18.9 ms into the cycle

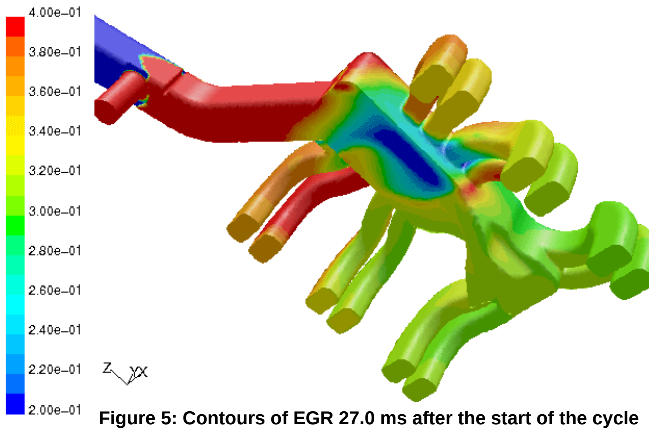

Figure 5: Contours of EGR 27.0 ms after the start of the cycle

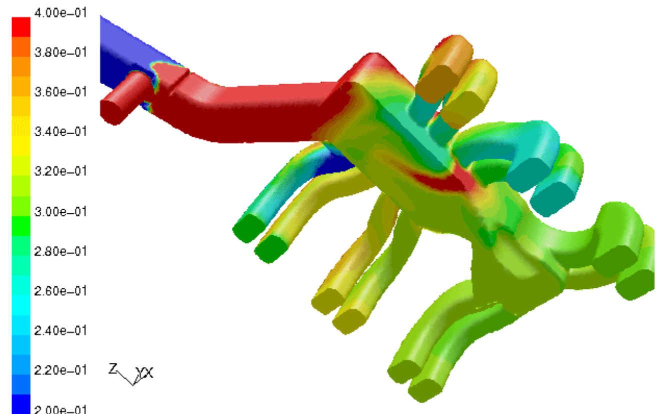

Figure 5: Contours of EGR 50.0 ms after the start of the cycle

represented by a “CFD component” (Figure 1), or more simply, a black box. The links between the CFD component and the adjoining 1D elements are established through “CFD connections.” Each CFD connection represents a coupled boundary between the system level and component level (CFD) domains.

Next, a 3D mesh was created from CAD data of the intake manifold. A transient simulation was set up in FLUENT using this mesh. Rather than prescribing transient boundary conditions a priori, each coupled flow boundary was associated with the corresponding CFD connection in the GT-Power model. From the FLUENT point of view, the GT-Power domain is also regarded as a black box. FLUENT and GT-Power were run simultaneously, and at each time-step, complimentary boundary information was passed between the codes.

Coupled simulations offer improved accuracy on both sides. From the CFD point of view, 1D coupling offers a more accurate representation of the boundary conditions by directly taking into account the system outside of the CFD domain. From the GT-Power point of view, the 3D flow inside the intake manifold is better represented by a multi-dimensional CFD simulation.

In Figures 2-5, contours of exhaust gas re-circulation (EGR) at different times during the simulation are shown: 1.35 ms (Figure 2); 18.9 ms (Figure 3); 27 ms (Figure 4); and 50 ms (Figure 5). It is clear from these figures that representing the complex fluid behavior by a 1D approximation would introduce error into any 1D system level calculation.

Fluent's GT-Power coupling capability allows for more accurate prediction of the transient flow in any component of a powertrain system by accounting for the effect of the domain outside the component. The FLUENT/GT-Power coupling also allows for a more accurate prediction of the system performance by capturing the physics in components that exhibit 3D behavior.

Courtesy of Cummins Inc.

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