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MOTORCYCLE ENGINE CRANKCASE ANALYSIS

Being a long time enthusiast for all things with two wheels, it was a blast to have an opportunity to work with Norton Motorcycles on the development of their next-generation bike. Their challenge was to validate the structural behavior of their new aluminum engine block which was designed from the ground up to have the classic Norton look along with state-of-the-art weight and performance characteristics. The analysis model was fairly complex with extensive use of my full grab bag of modeling tricks and tweaks. However, the real challenge was calculating the various load sets. Along with the main crankshaft power stroke, inertia forces from the main crankshaft and balance-shaft must be considered, and of course, the traction torque of the chain. As the engine is cycled from full power to full RPM, various peak forces are encounted in different regions of the motor drivetrain. I wish I could take credit for figuring this stuff out but my engineering hat is off to the team at Norton Motorcycles. They were able to supply me with detailed calculations for all major load cases along with "lessons" on how motorcycle engines really work and why the HP versus RPM curve flattens out and starts to decrease when a certain RPM level is exceeded. This collaborative project is on track and with some luck, a new breed of Nortons should be seen on the streets in the near future.

Modeling Notes: The finite element model was meshed using SolidWorks parasolid geometry provided by Norton Motorcycles. The solid portions of the model reflect the exact geometry of the prototype crankcase. The crankcase shaft, balance shaft and transmission shafts were modeled using beam elements. The bearings of these shafts were modeled using plate elements that are connected via gap elements (nonlinear elements that can bear compressive loads but not tensile loads) to the solid FEA model. This arrangement allows the shaft loads to be distributed onto the crankcase bearing seats in a uniform "bearing-like" manner. That is, only compressive forces normal to the crankcase bearing seat are applied. The bearings and shafts were considered somewhat rigid. This is a reasonable assumption given that the bearings and shafts are steel and the crankcase is aluminum. Complete contact behavior was simulated between all bearing surfaces and all corresponding crankcase surfaces.

The parting line mechanical behavior was enforced using gap elements to simulate the contact behavior between the two halves of the crankcase. The crankcase parting line bolts were also pretensioned in the analysis procedure. A nominal bolt pretension force was used. This was estimated to be reasonable given the diameter of the bolt and the resulting stresses within the aluminum crankcase under this bolt preload. This bolt preload should be refined if subsequent work is pursued. However, for this initial analysis work, it provides a reasonable engineering approximation of the bolt/crankcase behavior.

NX Nastran V3.0 was used for all analysis work with FEMAP V9.0.1 as the pre- and post-processor.

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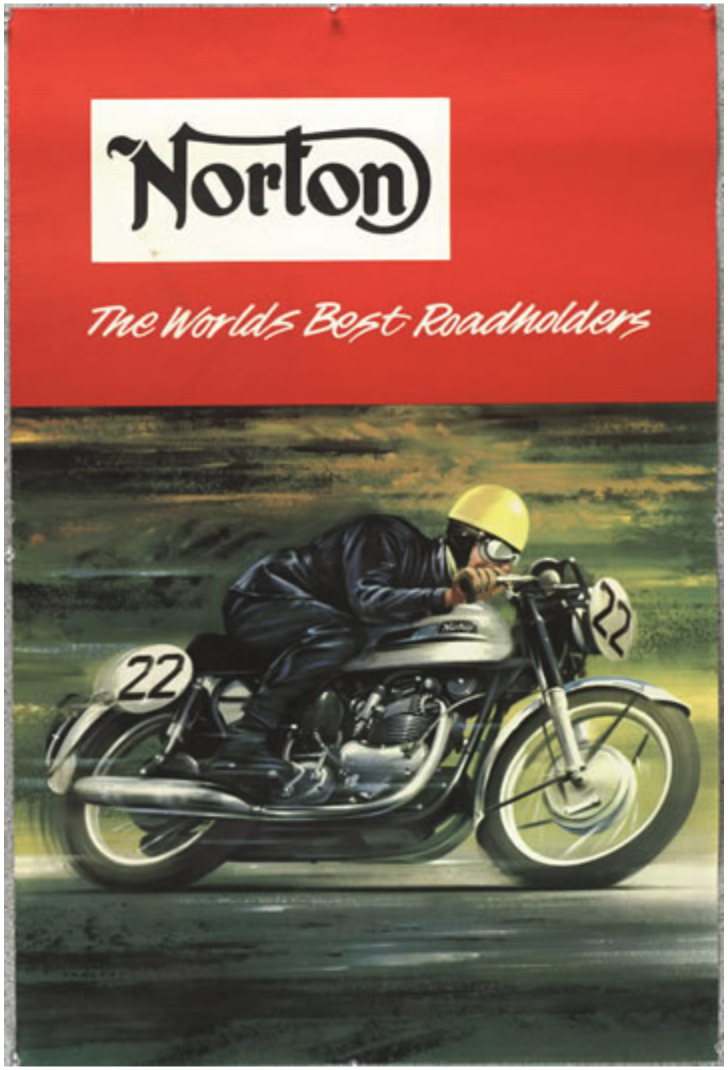

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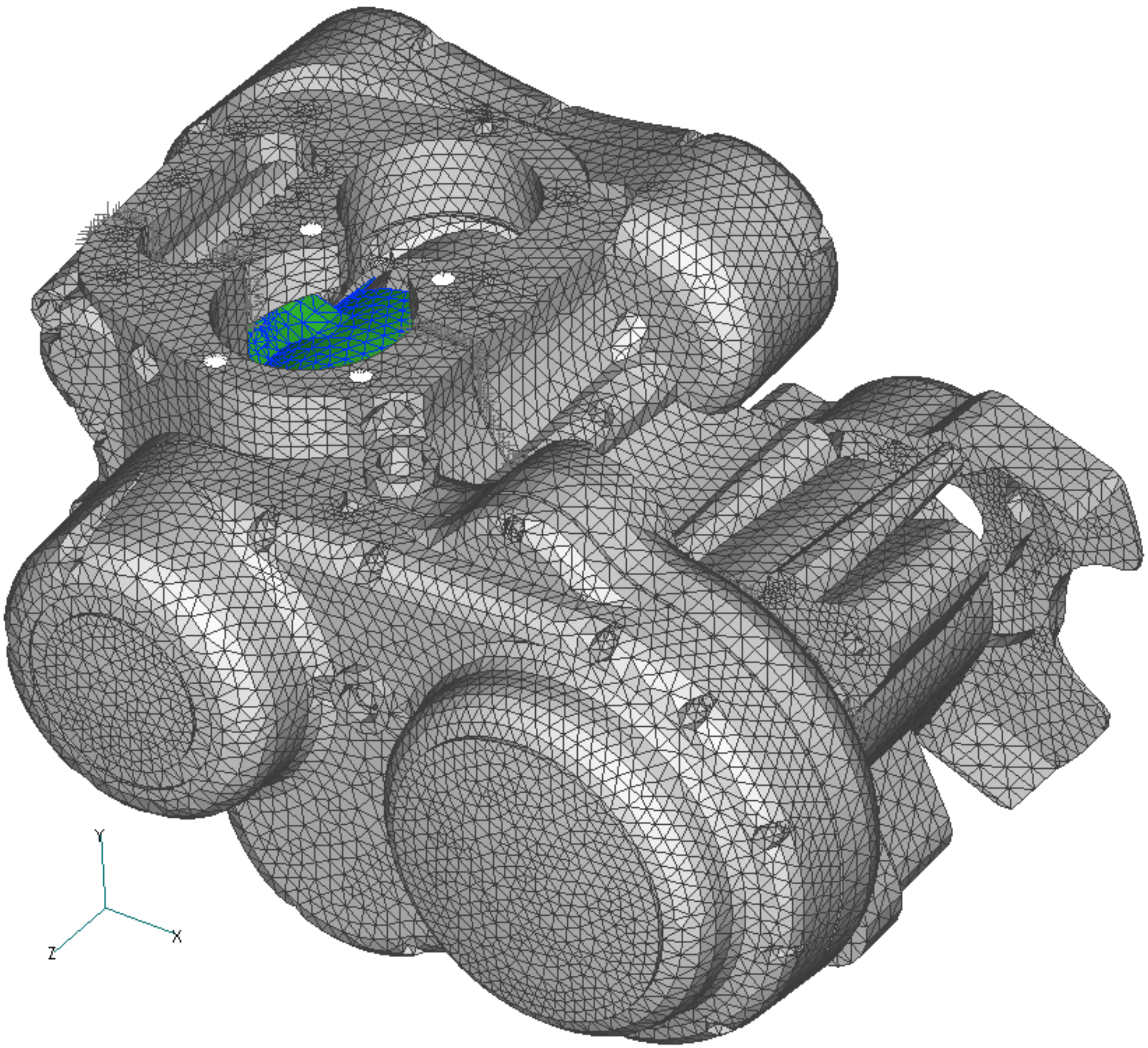

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Norton Motorcycles engine crankcase FEA model. The model has 270,000 nodes and 144,000 elements. Nonlinear gap elements are used to enforce the crankcase parting line behavior and to apply loads evenly along the bearing journals (not shown in this view).

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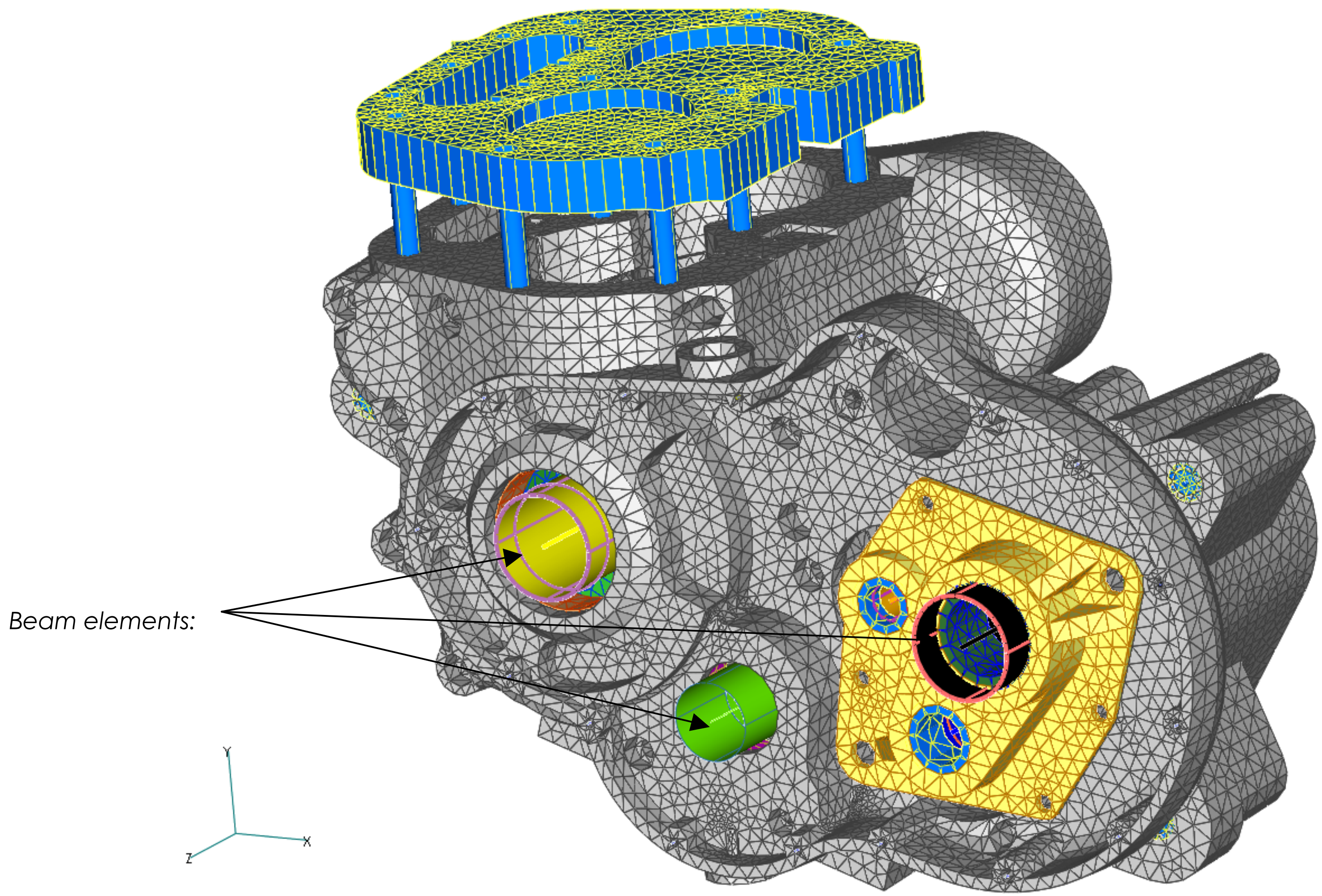

This interior view of the crankcase model shows an outline of the beam elements used to idealize the crankshaft, balance shaft, lay shaft and transmission shaft. Although it is difficult to show on this graphic, the loads are applied to the beam elements which then distribute the forces onto the bearing seats of the crankcase structure through a network of plate and gap elements (not shown). Note: gap elements are nonlinear elements that can carry compressive loads but no tensile loads. They are very useful for modeling contact interfaces that bear compressive forces but no tensile loads normal to the interface (e.g. like bearings or parting line seals).

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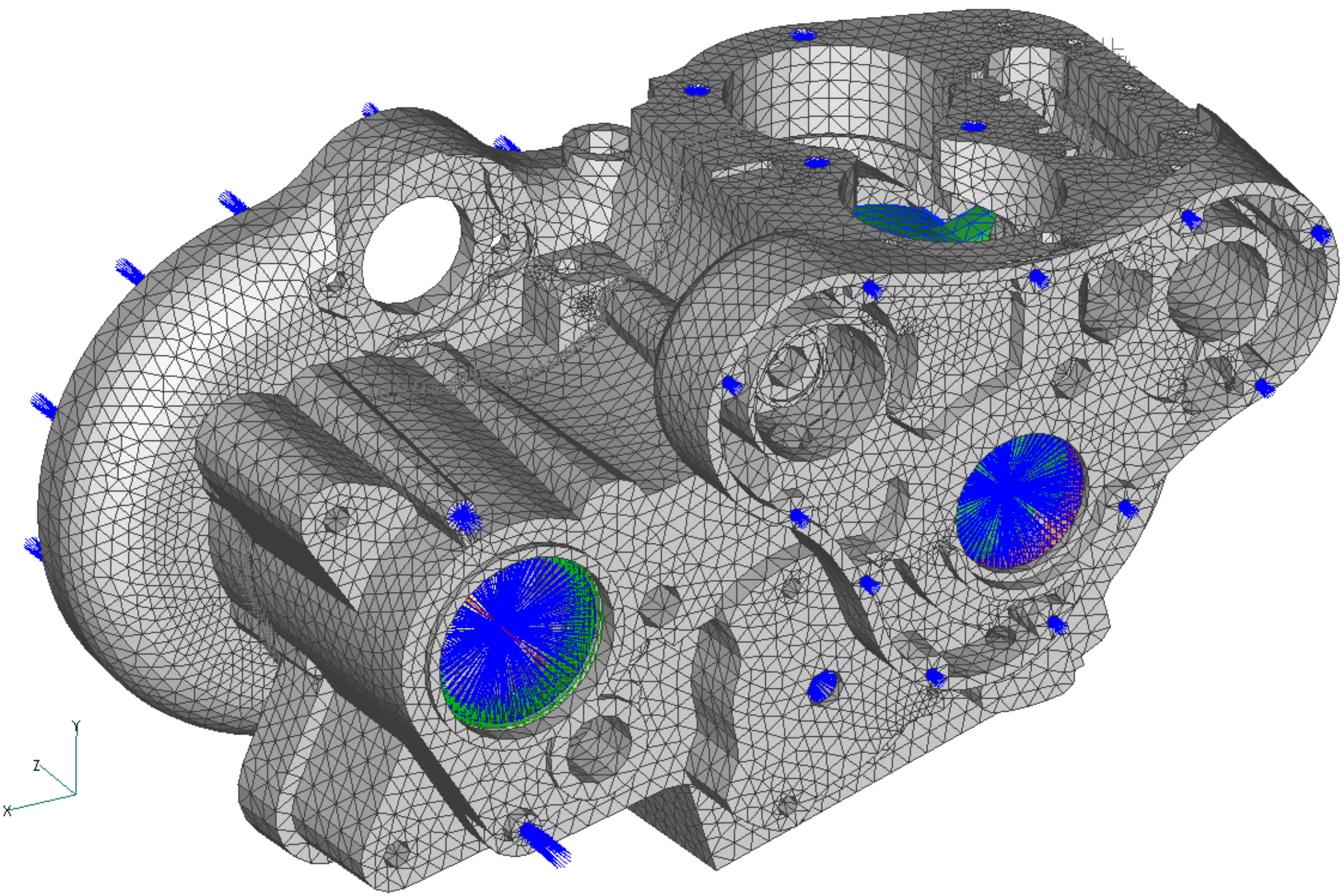

The connection technology used on this FEA model consists of a blend of rigid links, plate, beam and gap elements. The crankcase covers were joined to the main cast structure via beam elements (simulated bolts) and rigid links. The rigid links are shown in blue in the above graphic. They act as the “glue” between the beam elements and the 10-node tetrahedral elements used to construct the crankcase model. Effectively we have a rigid steel structure inserted into the elastically soft aluminum crankcase. This is a reasonable assumption for steel bolts threaded or inserted into the structure.

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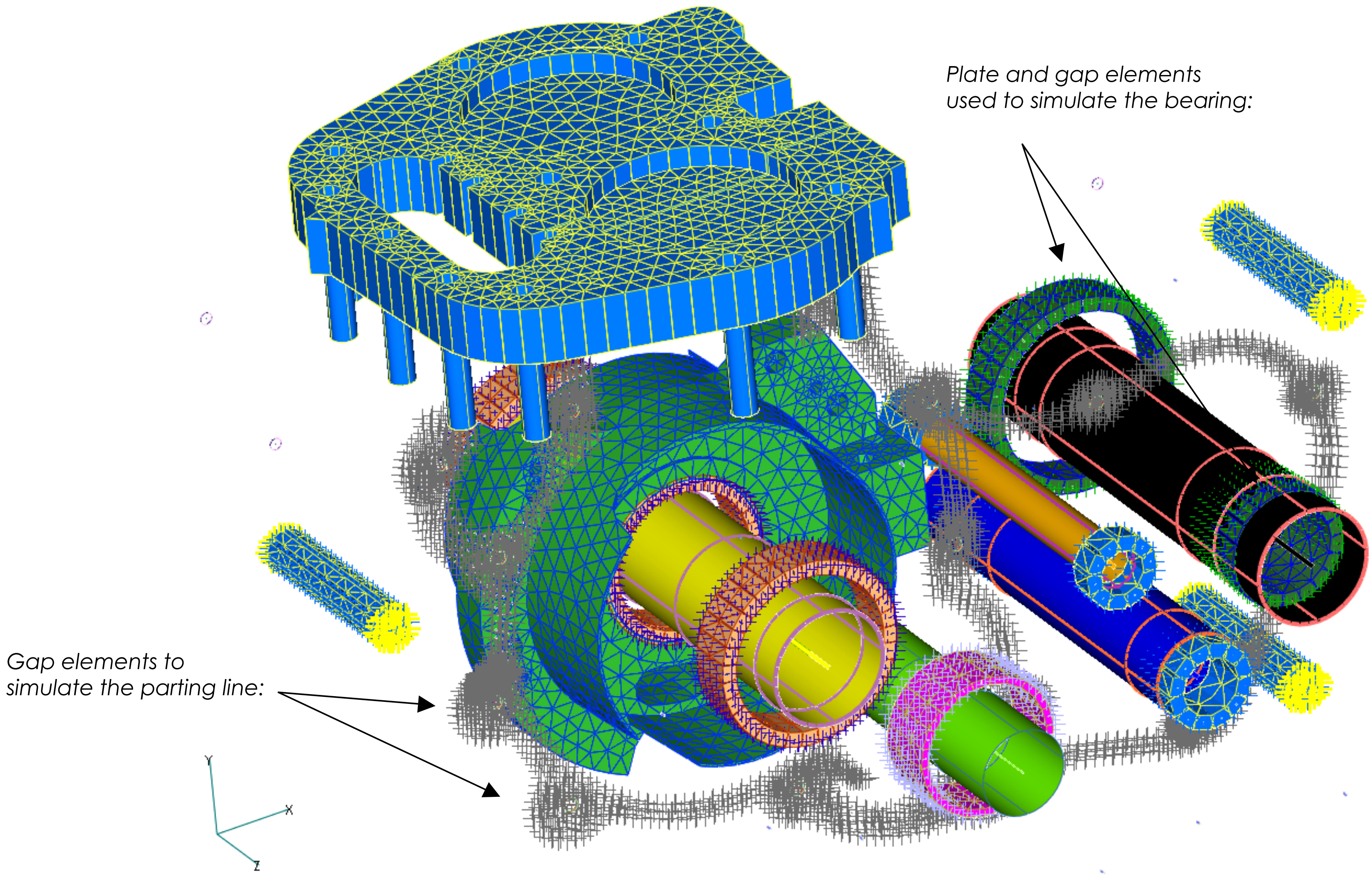

A view of the model structure without the crankcase FEA parts. Gap elements (nonlinear elements) were used to prevent interpenetration between the two crankcase halves yet allow it to pull apart if the load case induces such action. The simulated bearing seats with their gap elements (fuzzy lines) are also shown in the above graphic.

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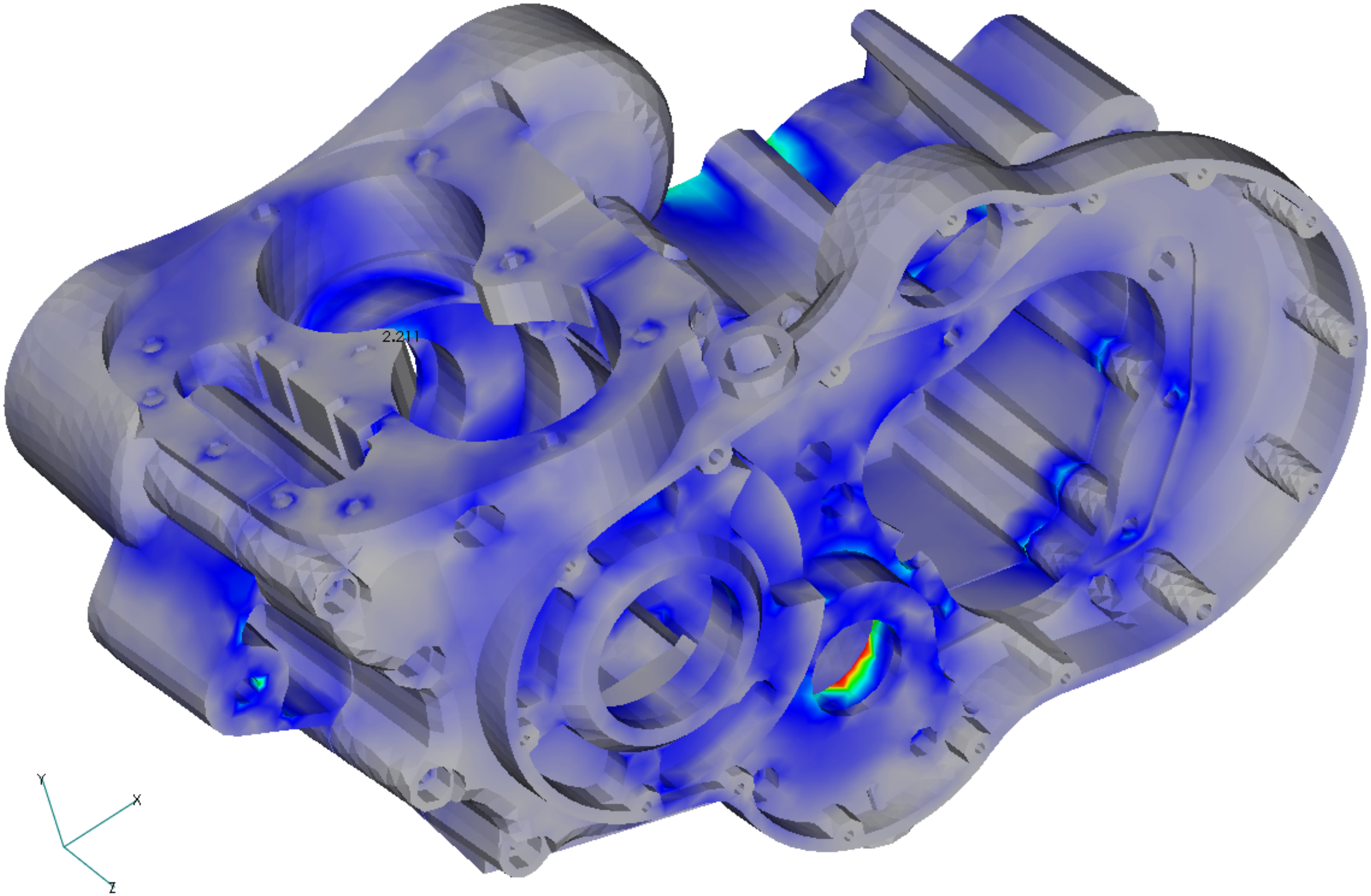

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An example of the stresses that can developed within the crankcase under load.

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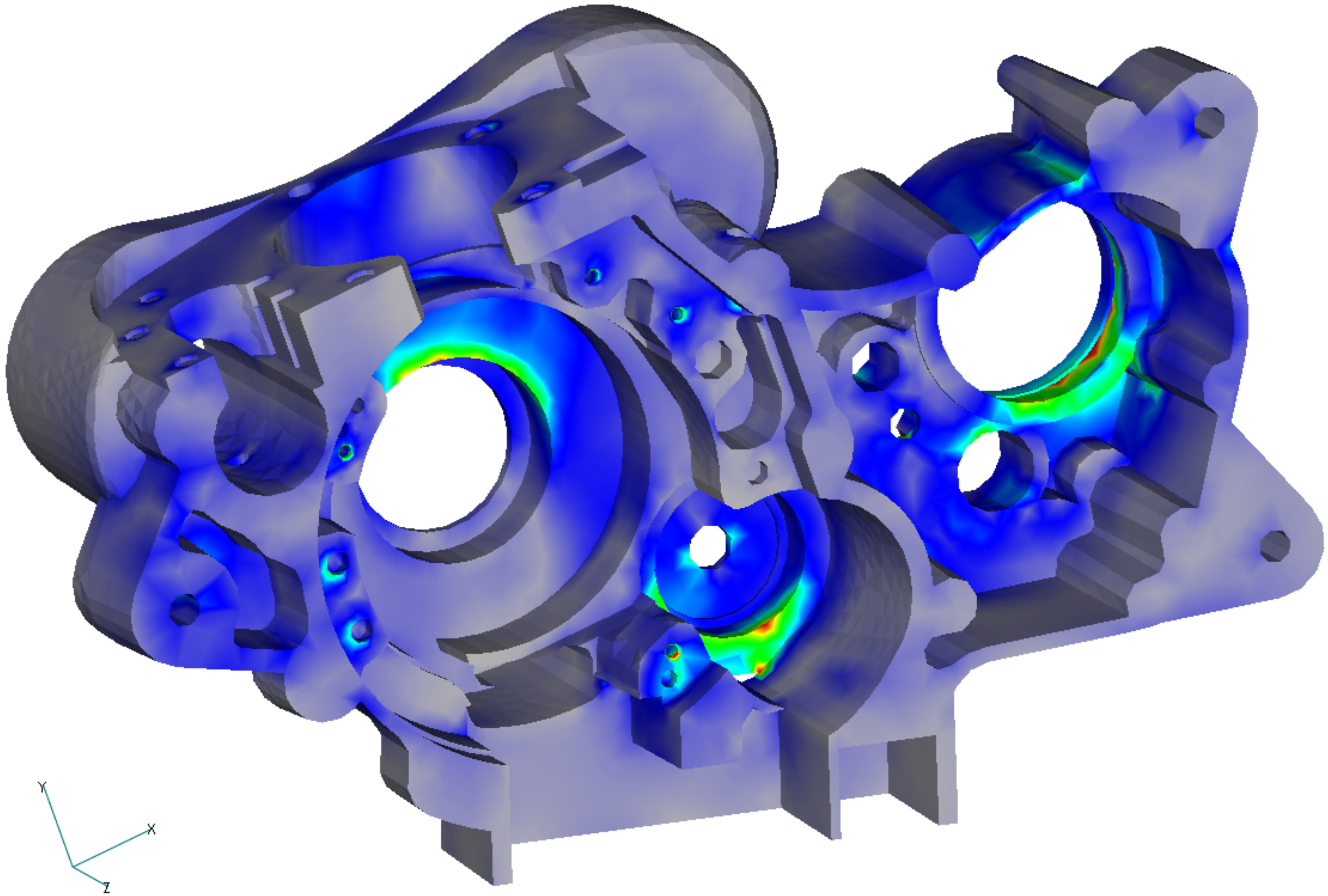

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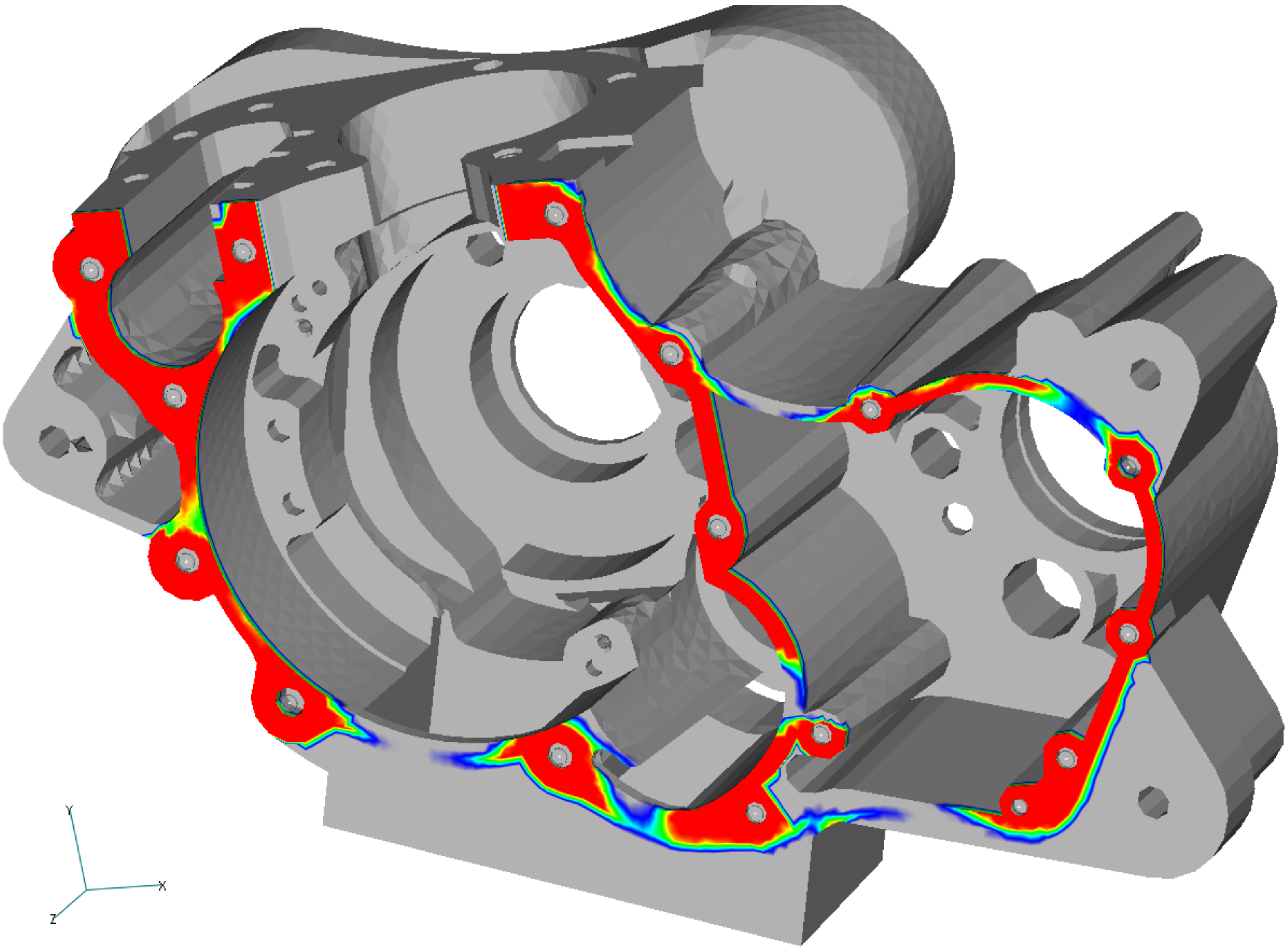

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This slide shows the parting line interface force under the Wide Open Throttle (WOT) load case with the Left Side (LS) piston firing. This slide is rather unique since the gap element forces are contoured over the 10-node tetrahedral elements allowing an accurate display of the contact behavior between the two faces of the crankcase.