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Thema: "Dynamic Crankshaft Stress Calculation using a combination of MSS and FEA"

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(Vortrags- / Veröffentlichungsanmeldung liegt vor!)

To save time and expenses in engine development processes, an increasing amount of CAE support is demanded. To achieve this target, the calculations have to be quick on one hand and must deliver reliable results on the other hand.

The increasing power of modern computers leads to the possibility, to support more and more development tasks by simulation. However, it is still necessary to evaluate the efficiency of the different CAE tools and to check carefully which kind of simulation matches the targets best.

Often combinations of different simulation techniques show the best results. A good example is the combination of nonlinear Multibody System Simulation (MSS) with linear Finite Element Analysis (FEA). The dynamics of continuous structures, represented by a large number of degrees of freedom are calculated and reduced, using FEA. The global dynamics of several parts, interacting with each other may be then calculated by MSS, considering all nonlinearities in the coupling locations between the parts and the structural deformation behavior, as eigenvectors from the FEA calculation.

A typical example for this simulation procedure is the interaction between rotating crankshaft and engine block. Beneath the structural deformations of crankshaft and block the influence of the gyroscopic effects, caused by the rotation of crankshaft and flywheel is considered, combining FEA and MSS. The highly nonlinear hydrodynamics of the plain bearings may be taken into consideration using specific subroutines, called by the MSS solver.

For realistic crankshaft stress calculations three main working steps are necessary in general:

First the dynamics of rotating flexible crankshaft and flexible engine block, that are coupled by hydrodynamic journals and the piston-rod assembly has to be predicted accurately. Experiences from applications have been used for enhancements, which provide higher accuracy.

Secondly the broad operating envelope of the engine has to be considered. This means, that a large number of simulations has to be executed. New integration and simulation methods reduce elapsed CPU-time and offer significantly improved usability of the simulation method. However, simplified calculation tools are necessary for a predefinition of the engine working conditions that have to be investigated in detail, using nonlinear MSS. This means that maximum efficiency can only be achieved, combining tools with different degrees of refinement.

Finally the problem of finding stresses and the locations of their concentrations has to be solved. Again the target conflict between limitation of computer resources and results accuracy is the main exercise.

This paper describes the above defined engineering process based on an example of a real engine. For the MSS simulations the ADAMS product line has been used. The general working scope and the hydrodynamic coupling of the plain bearings were developed by FEV Motorentechnik GmbH, Aachen, Germany in cooperation with the RWTH Aachen.

Dynamic Crankshaft Stress Calculation using a combination of MSS and FEA

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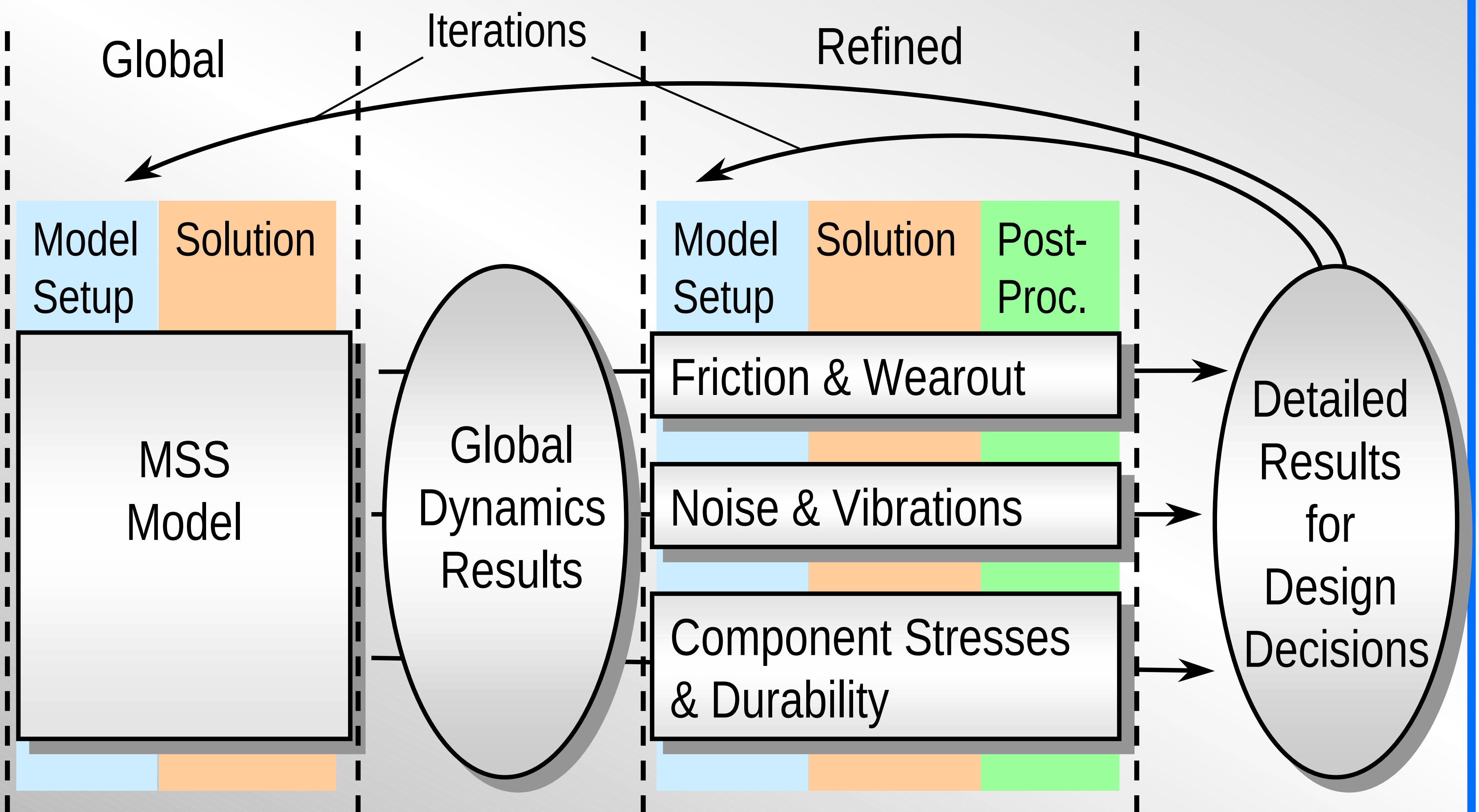
Dynamic Crankshaft Stress Calculation using a combination of MSS and FEA
Introduction: General simulation strategy



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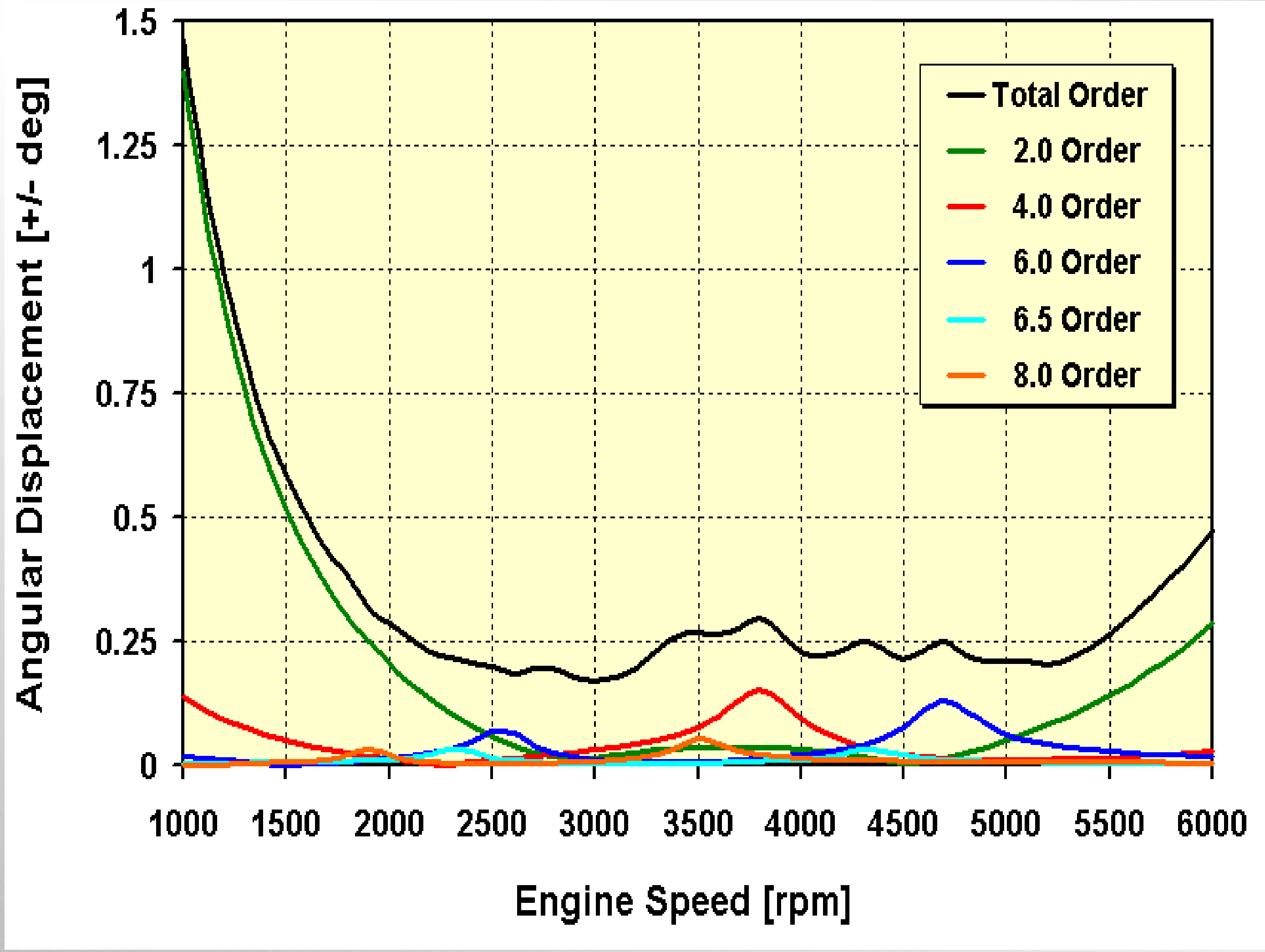
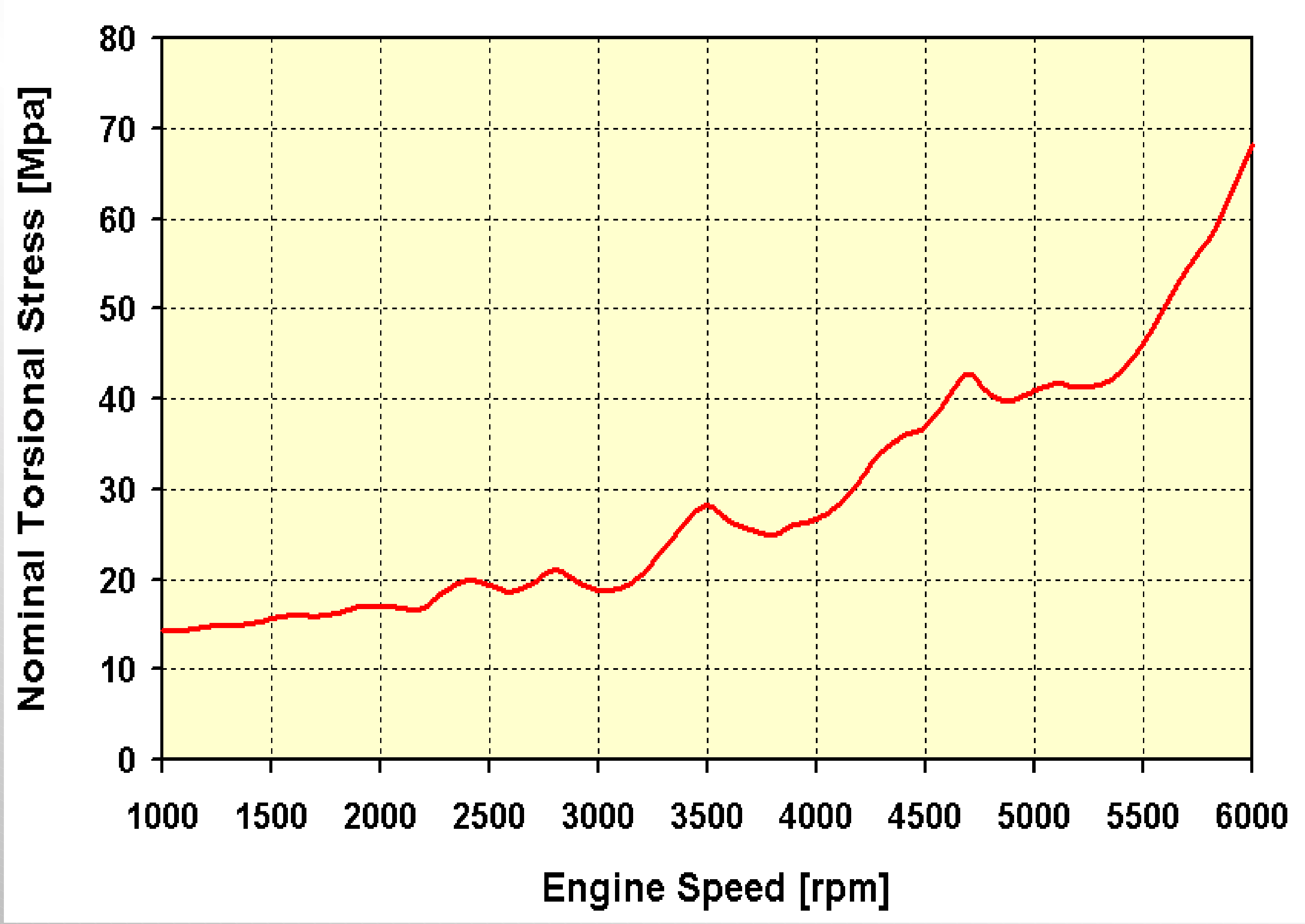
Dynamic Crankshaft Stress Calculation using a combination of MSS and FEA
Traditional Procedure: Angular Displacement at Crankshaft Free End Side



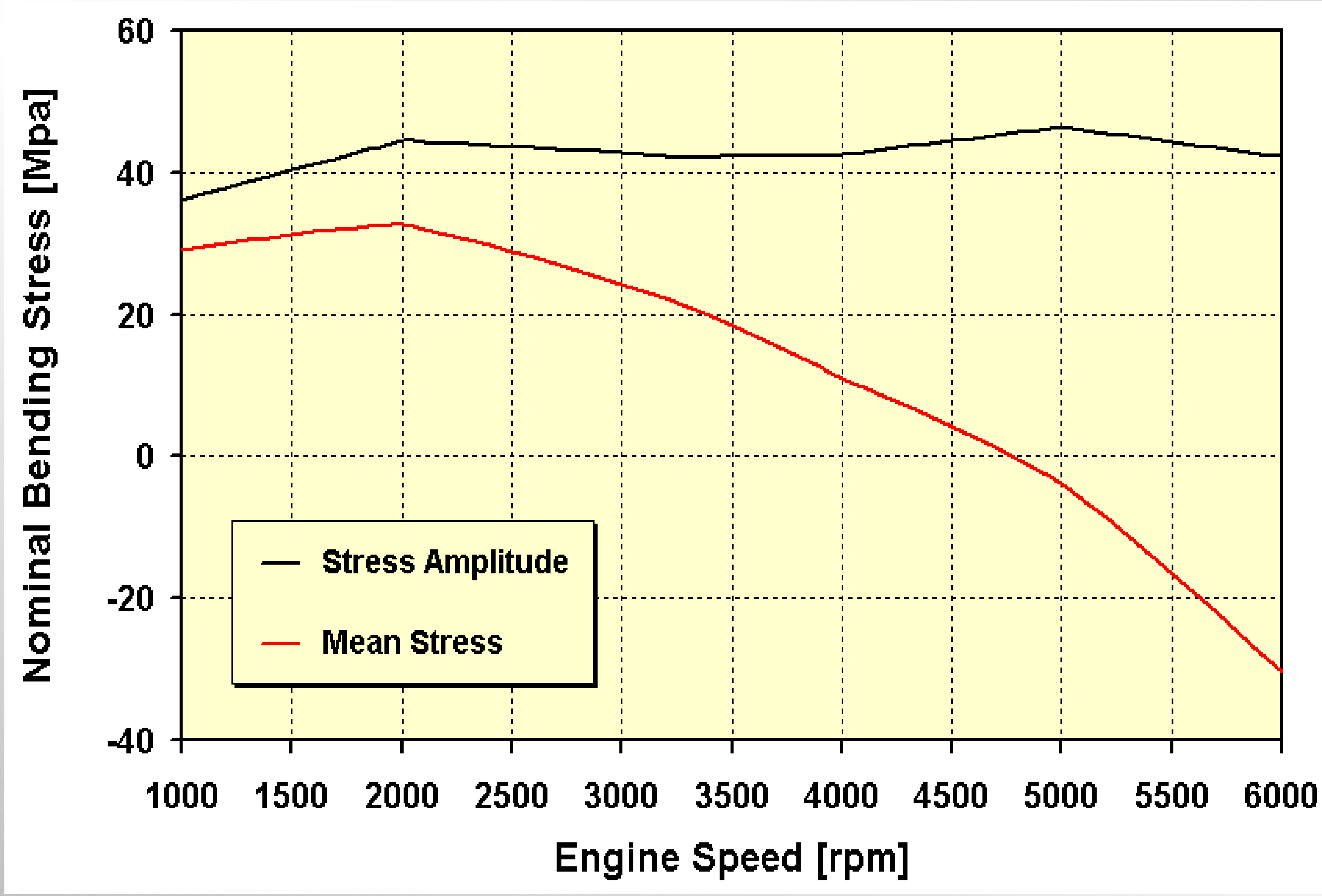
Dynamic Crankshaft Stress Calculation using a combination of MSS and FEA
Traditional Procedure: Nominal Torsional Stress referred to the Crank Pin



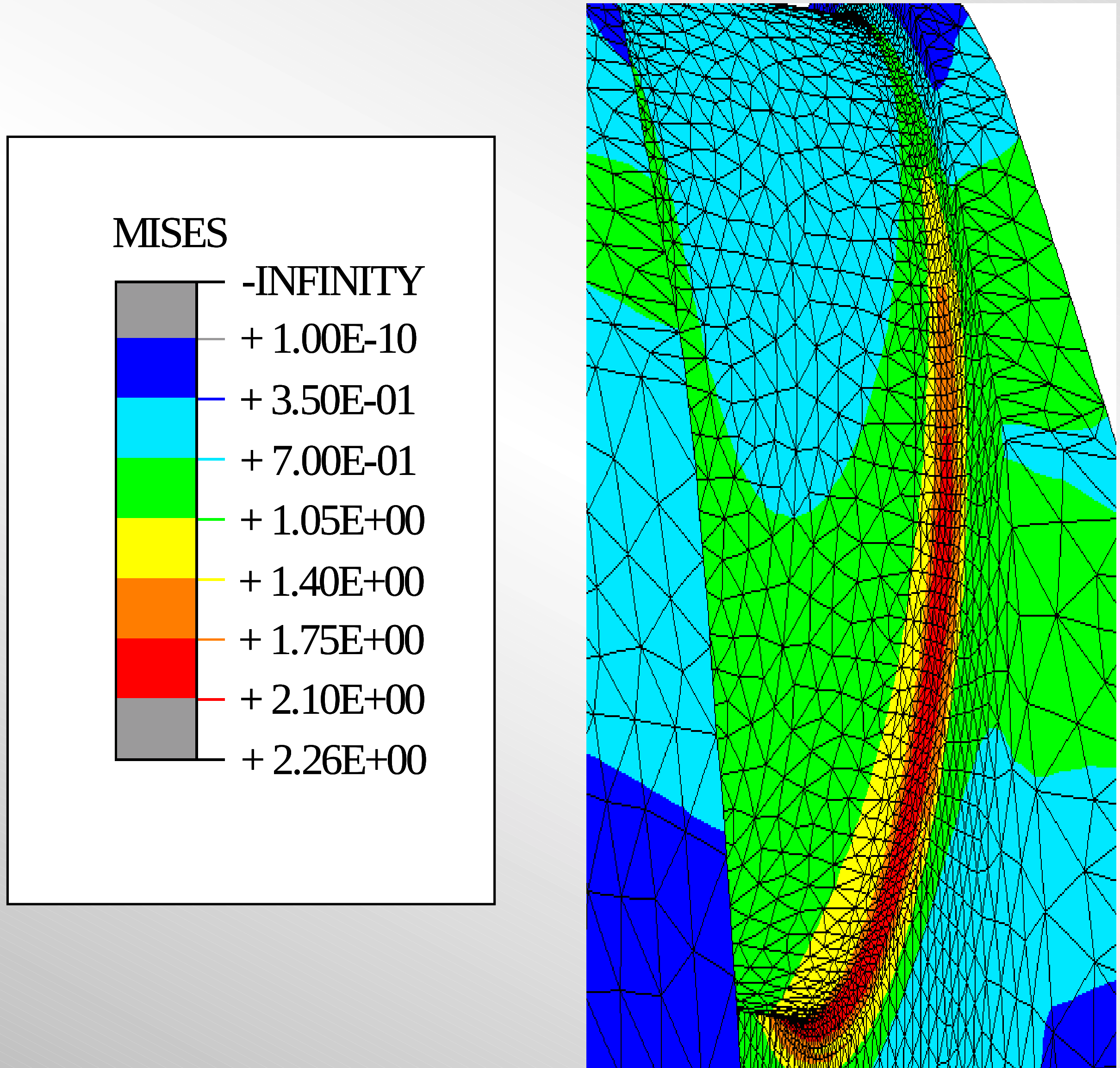
Dynamic Crankshaft Stress Calculation using a combination of MSS and FEA

Traditional Procedure:

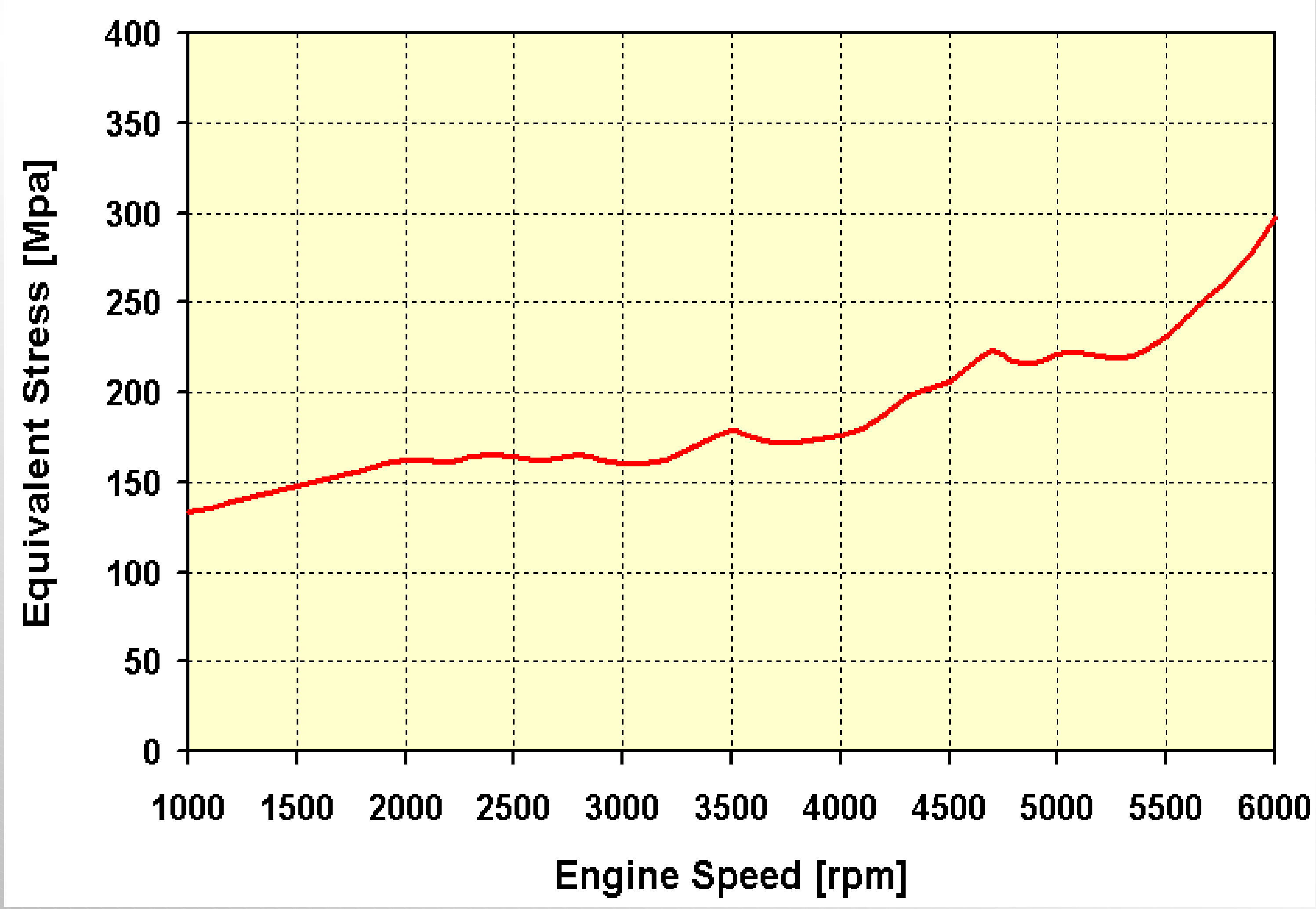
Nominal Bending Stress referred to the Crank Web Area



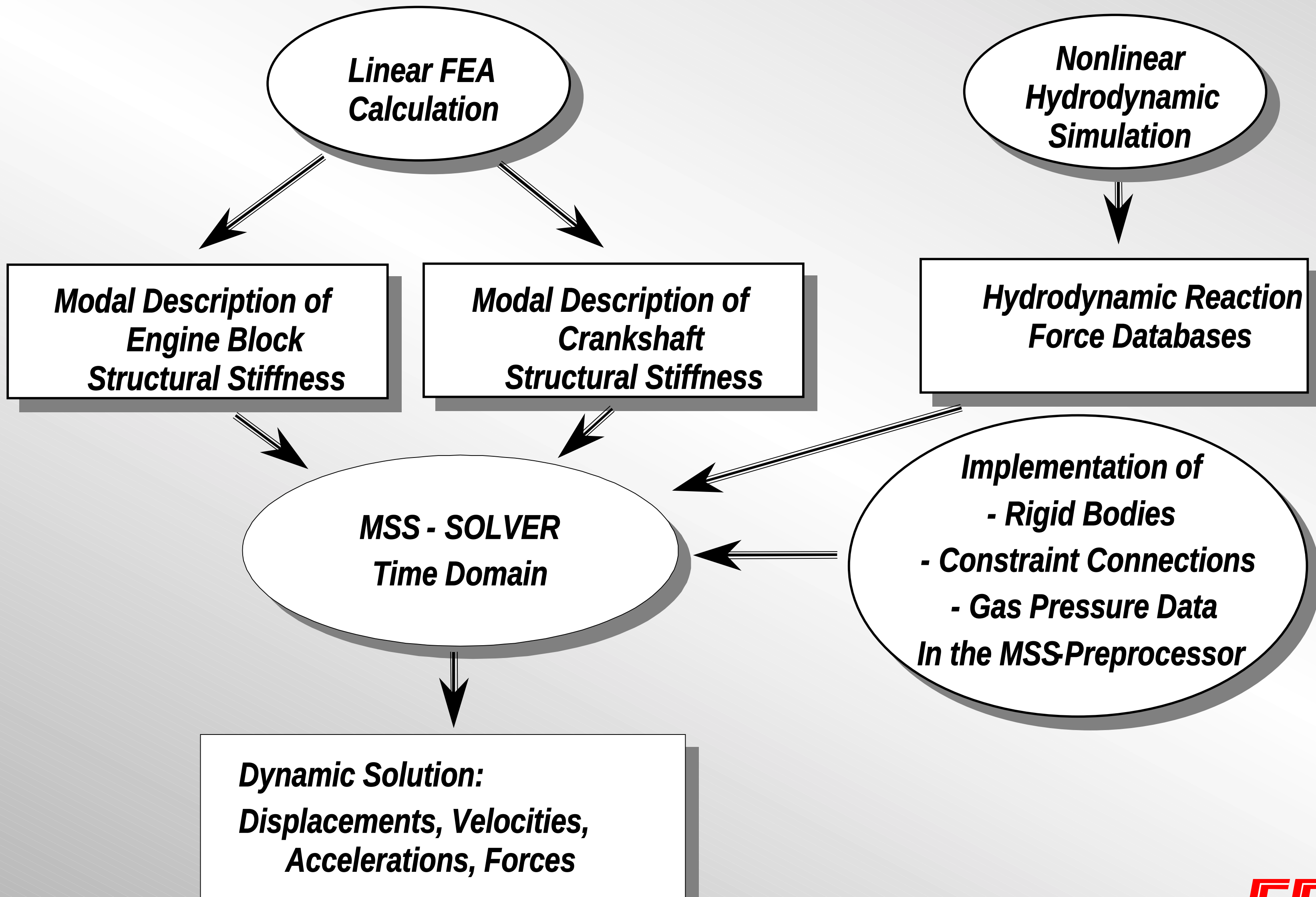
Dynamic Crankshaft Stress Calculation using a combination of MSS and FEA
Traditional Procedure: FE-Analysis of Stress Concentration Factor



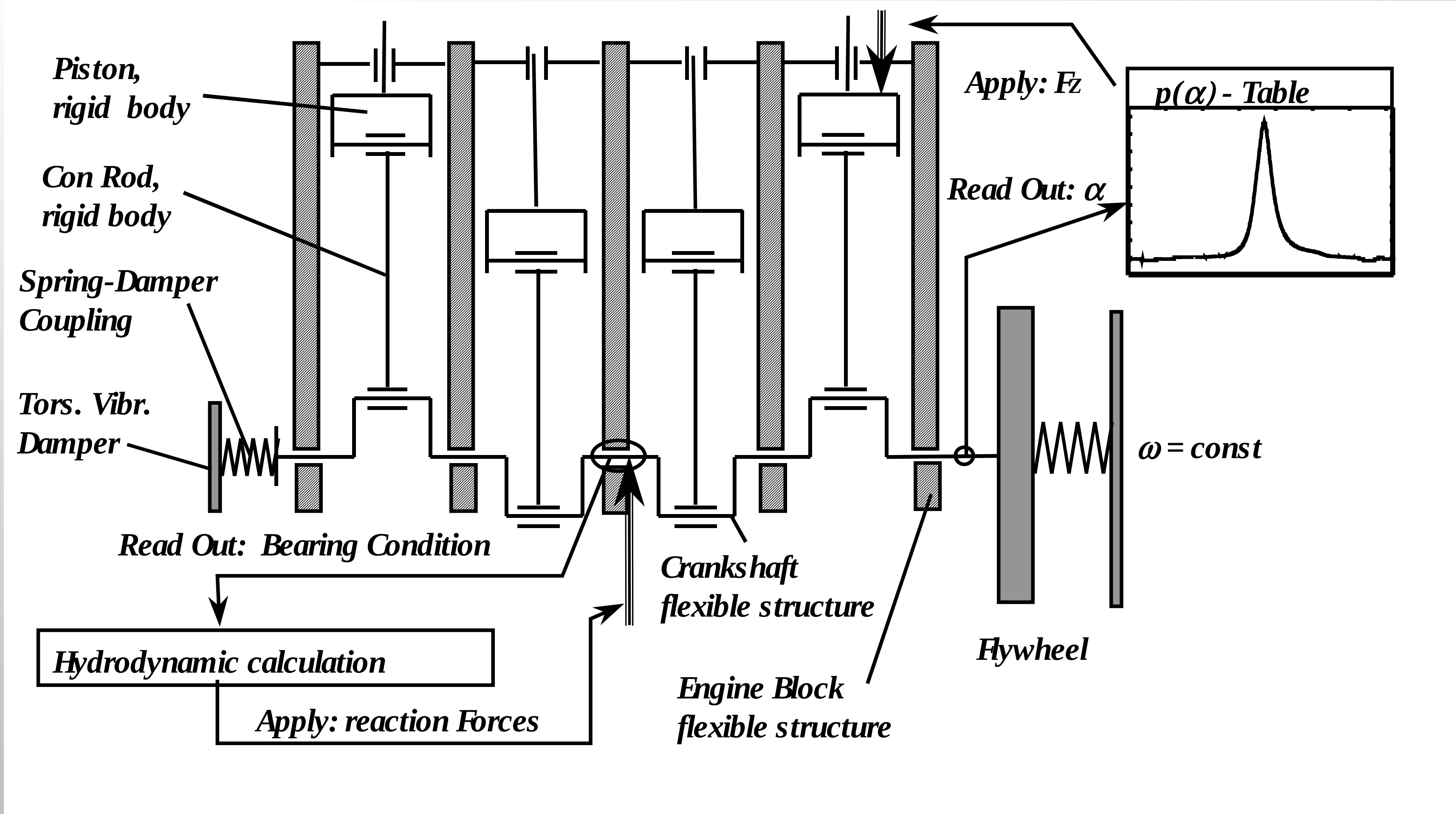
Dynamic Crankshaft Stress Calculation using a combination of MSS and FEA Traditional Procedure: Equivalent Stress at the Crank Pin Fillet Radius



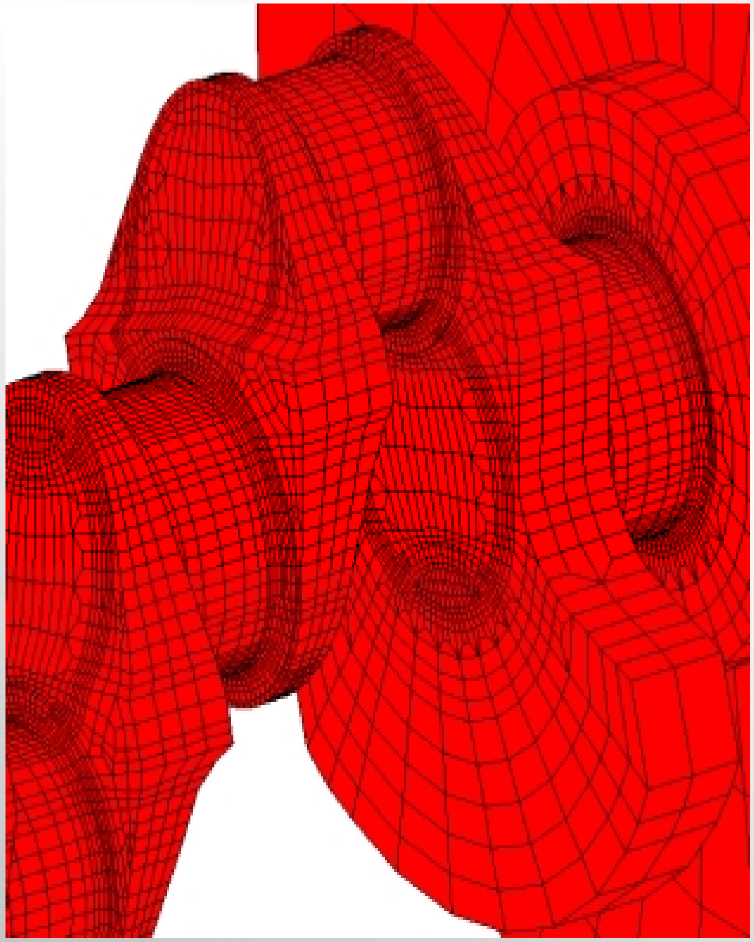
Dynamic Crankshaft Stress Calculation using a combination of MSS and FEA
MSS Simulation: Calculation Path of Crank Train Dynamics

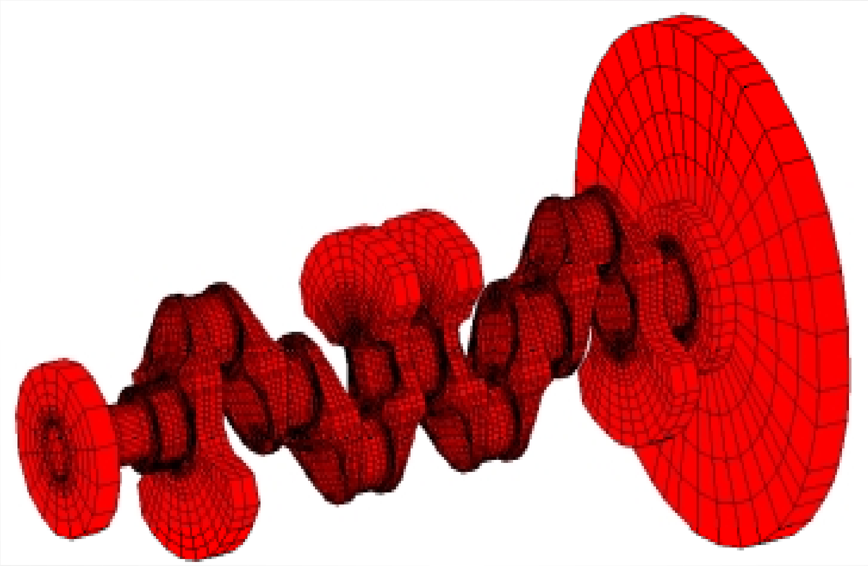


Dynamic Crankshaft Stress Calculation using a combination of MSS and FEA
MSS Simulation: Crank Train Model

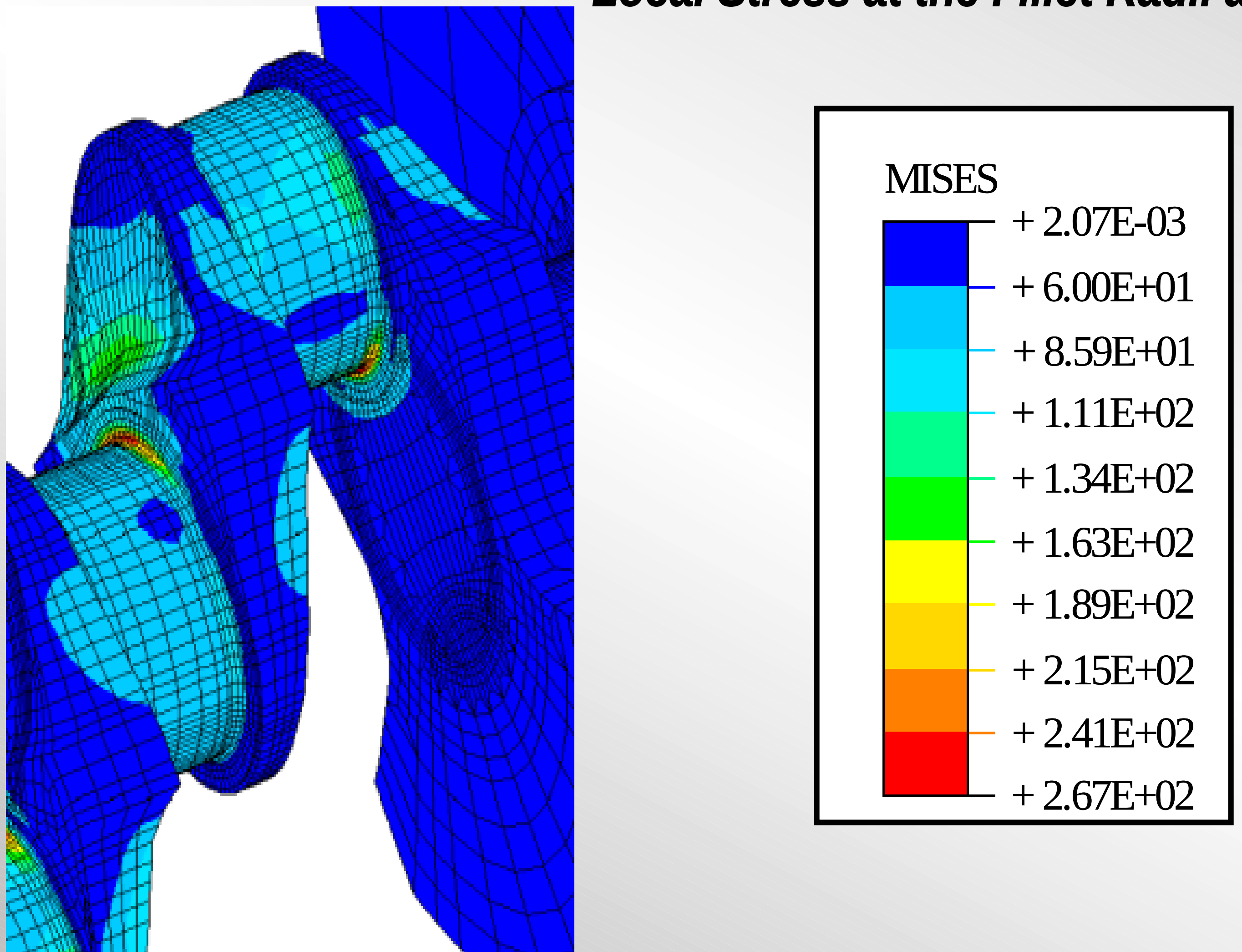


Dynamic Crankshaft Stress Calculation using a combination of MSS and FEA
Recoupling of MSS Results to the FE-Analysis: Refined Crankshaft Model

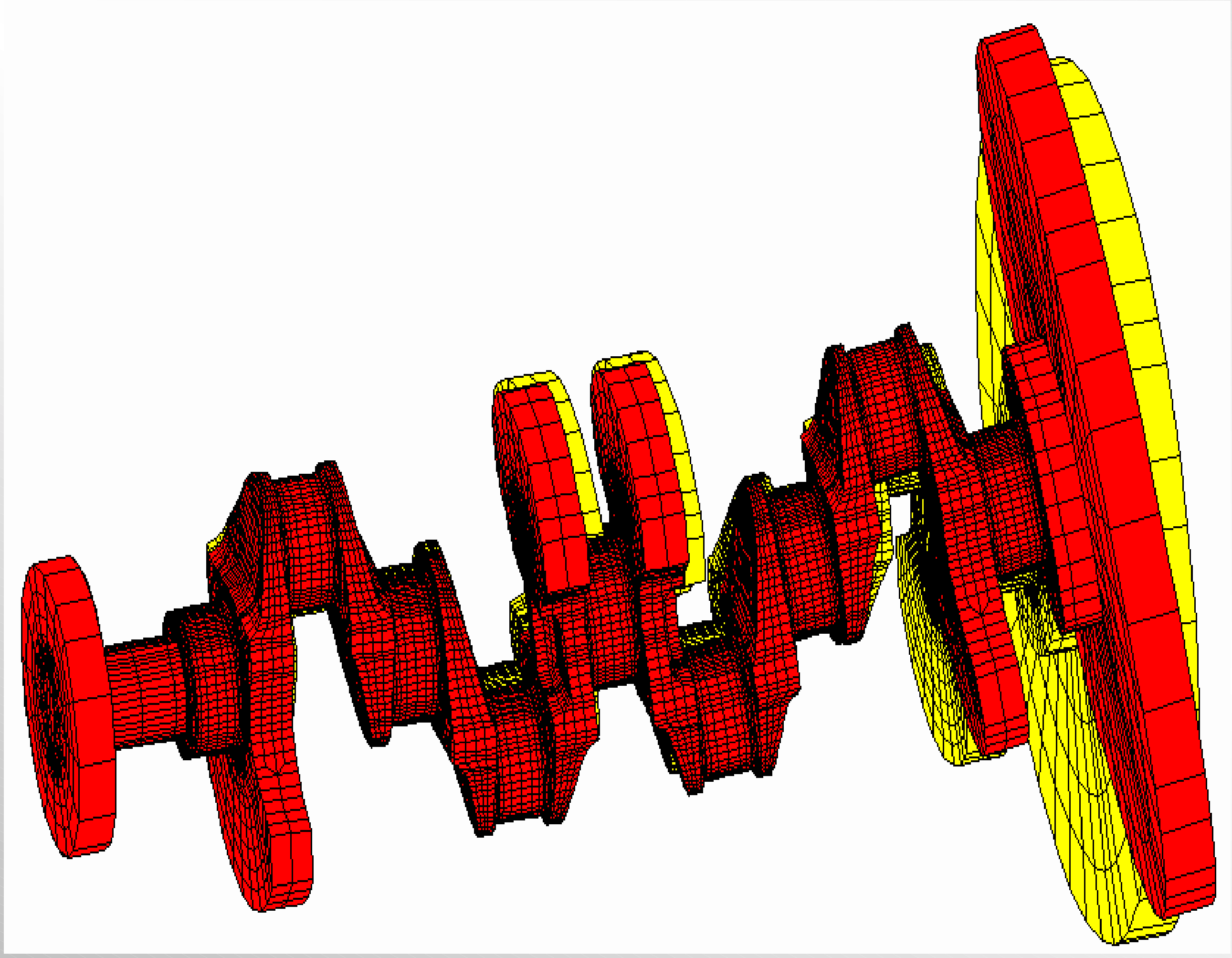




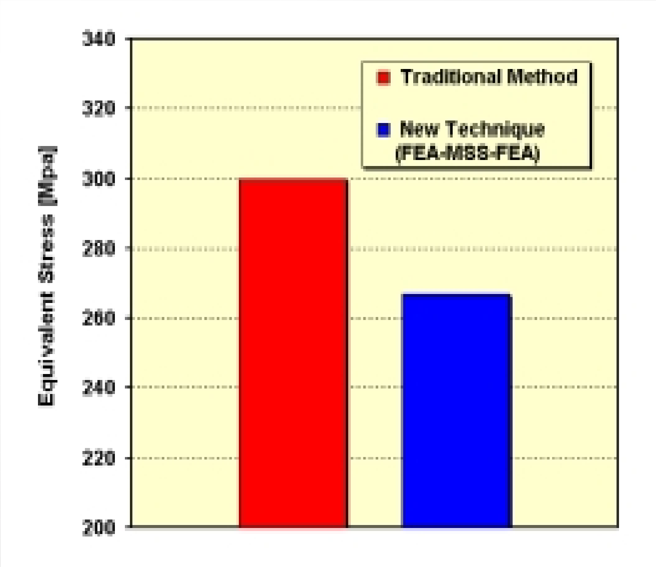
Dynamic Crankshaft Stress Calculation using a combination of MSS and FEA
Recoupling of MSS Results to the FE-Analysis:
Local Stress at the Fillet Radii at 6000 rpm



Dynamic Crankshaft Stress Calculation using a combination of MSS and FEA
Recoupling of MSS Results to the FE-Analysis:
Deformed Shape of the Crankshaft at 6000 rpm



Dynamic Crankshaft Stress Calculation using a combination of MSS and FEA
Comparison between traditional and new calculation method



The additional safety margin detected by the new, more realistic method is about 12% at 6000 rpm, full load.

Dynamic Crankshaft Stress Calculation using a combination of MSS and FEA Summary

- *For crankshaft stress calculations traditional methods based on simple superposition of torsional and bending stresses are state of the art.*
- *New calculation methods are necessary to achieve more accurate results, that allow a design that is nearer to the mechanical limit.*
- *The combination of MSS and FEA methods is the most efficient way of calculating crank train dynamics. The results are boundary conditions for further investigations, not only for stress issues, but also for questions concerning friction and wearout and for NVH.*
- *With the increasing power of modern computers the new techniques will replace the traditional methods.*
- *Further studies are necessary to optimize the interaction of the CAE programs and to validate the new technology.*