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Modelling Flexible Bodies at High Revolution Speeds

A further method for modelling flexible bodies at high revolution speeds has been implemented in SIMPACK FEMBS version 8804. Engine simulations recently have shown that centrifugal forces at a high revolution speed can have a significant influence on the dynamic behaviour of the crank train. Durability calculations based upon SIMPACK results make great demands on both the accurate representation of the inertia forces and the accuracy of the bearing forces that act, for example, on the crankshaft.

The current representation of centrifugal forces in flexible bodies is established in FEMBS, based on the reduced model. This approach for straight structures such as camshafts, driveshafts is accurate. However, the reduced representation of inertia forces for spatial flexible bodies, such as crankshafts with crank angles unequal to 180 or 90 degrees, cannot always be accurately represented at high revolution speeds using this approach.

The new method improves the accuracy of centrifugal forces in flexible bodies in SIMPACK by using the capabilities of the finite element code. Inertia forces due to rotations are established prior to the reduction step based upon the full-size finite element model. In general this is done by defining three unit load cases for the reduction step in the FE-input deck. These load cases represent the inertia forces due to the angular velocities of the body about the three axes, and three mixed load cases that represent spatial rotations. In nearly all cases, the rotation is primarily about a single axis and the definition of the corresponding single load case will be sufficient. During the reduction of the finite element model, the additional inertia loads are projected in the co-ordinates of the reduced finite element model and finally the reduced load vectors are written to the flexible body input file, which is read-in in FEMBS. This technique is currently available in SIMPACK's finite element interface to NASTRAN and soon will also be available for ANSYS and ABAQUS.

This representation of centrifugal forces is unit scaled in FEMBS and imported via an SID file into the multi-body system. The format of the SID file has not been changed. In SIMPACK, the additional loads are scaled with the current values of angular velocity. This new representation of the dynamic behaviour of inertia forces in SIMPACK, demonstrated by the deflections at the bearings of a camshaft, is outstanding when compared with the results of corresponding finite element analyses.

The rotation induced stresses have also been checked. Although the deformations at the attachment points correlate well with the results from finite element analyses, the previous extensions of SIMPACK's FE-interface were not sufficient to compute the stresses accurately over the entire flexible body. For the component mode synthesis, the accuracy could be improved by increasing the number of dynamic degrees of freedom in the reduction step. However, this raises the question about the essential number of dynamic degrees of freedom.

A workable solution is the concept of residual flexibility; this is available in NASTRAN. This additional residual deformation vector augments the deformation of the reduced finite element model to represent exactly the deformation generated by the load cases; in this case the deformation due to the centrifugal forces.

In NASTRAN, the residual vectors calculation is performed if the parameter RESVEC is defined in the input deck, additionally to the load cases.

Both the reduction of load vectors and the concept of residual flexibility enable the calculation of deformation and stresses in SIMPACK LOADS. The results match almost exactly those from finite element analyses. (fig. 1)

The model database on the website will soon be extended with an example for the common FE-codes including NASTRAN, ANSYS and ABAQUS.

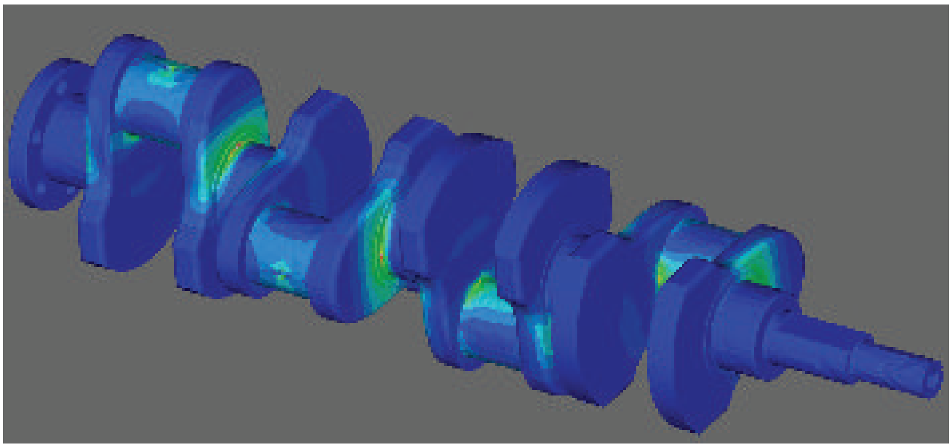

Fig. 1: Mises`stresses of a crankshaft at a high revolution speed calculated with NASTRAN. SIMPACK`s LOADS interface combination with NASTRAN and FEMAT exactly produces the same result.