Steady-state dynamic analysis of a tire substructure

This example illustrates the use of the substructuring capability in Abaqus to create a substructure from a tire under inflation and footprint loading.

Use of tire substructures is often seen in vehicle dynamic analyses where substantial cost savings are made using substructures instead of the whole tire model. Since tires behave very nonlinearly, it is essential that the change in response due to preloads is built into the substructure. Here the substructure must be generated in a preloaded state. Some special considerations for creating substructures with preloads involving contact are also discussed.

This page discusses:

Products: Abaqus/Standard

Problem description and model definition

A description of the tire model used is given in Symmetric results transfer for a static tire analysis. In this problem inflation and fooptrint preloads are applied in a series of general analysis steps identical to Symmetric results transfer for a static tire analysis. Symmetric model generation and symmetric results transfer are used to exploit the symmetric nature of the structure and loading. Nodes in the bead area are tied to the rigid body representing the rim.

The substructure's retained nodes include the rim node and the road node that is the reference node of the rigid body representing the road surface. To enhance the dynamic response of the substructure, these interfacial degrees of freedom are augmented with generalized degrees of freedom associated with the first 20 fixed interface eigenmodes. Depending on the nature of the loading, it may be necessary to increase the number of generalized degrees of freedom to cover a sufficient range of frequencies. The extra cost incurred due to the addition of the extra frequency extraction step is offset by the enhanced dynamic response of the substructure.

Loading

An inflation load of 200 kPa is applied in the axisymmetric half-tire model contained in substructtire_axi_half.inp. This is followed by a footprint load of 1650 N applied to the three-dimensional half-tire model given in substructtire_symmetric.inp; and, subsequently, results are transferred to the full tire model with the complete footprint load of 3300 N. All of these steps are run with the NLGEOM=YES parameter, so all preload effects including stress stiffening are taken into account when the substructure is generated.

To enhance the dynamic response of the substructure, several restrained eigenmodes are included as generalized degrees of freedom. These restrained eigenmodes are obtained from an eigenfrequency extraction step with all the retained degrees of freedom restrained. In this example the first 20 eigenmodes are computed. With one road node with six degrees of freedom, one rim node with six degrees of freedom, and 20 generalized degrees of freedom, the substructure has 32 degrees of freedom.

At the usage level the steady-state response of the substructure to harmonic footprint loading is analyzed over a range of frequencies from 40 to 130 Hz. Structural damping is applied in the material definitions of the finite element model to obtain finite displacements at the resonant frequencies. The generated condensed structural damping operator is used to apply damping in the substructure usage analysis.

Results and discussion

The results for the frequency sweep are shown in Figure 1, which compares the magnitude of the vertical displacement at the road node of the substructure to the response of the entire tire model. The substructure captures all resonances in the original finite element tire model. The baseline results for the finite element tire model were calculated using the direct and mode based steady-state dynamic solvers. The same two solvers were used to calculate the substructure response. To improve accuracy of the mode-based analysis the modal subspace was augmented with a residual mode. Results for the finite element tire model obtained using the mode-based steady-state dynamic analysis and results for the model using the substructure have the same level of accuracy. That was expected because dynamic substructures are modal reductions of the finite element models.

Input files

substructtire_axi_half.inp

Axisymmetric model, inflation analysis.

substructtire_symmetric.inp

Partial three-dimensional model, footprint analysis.

substructtire_full.inp

Full three-dimensional model, final equilibrium analysis.

substructtire_generate.inp

Substructure generation analysis.

substructtire_subuse_ssd.inp

Usage level model with steady-state dynamics analysis.

substructtire_femodel_ssd.inp

Steady-state dynamic analysis of the original finite element model of the tire.

Figures

Figure 1. Vertical response of the road node due to unit vertical harmonic load.