Modelling of frictional unilateral contact in automotive differentials

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Multibody simulation techniques are widely used in automotive engineering for the dynamic analysis of both vehicle dynamics and engine dynamics. Current trend in the industry addresses the global modelling of the full vehicle including not only the suspension and the engine but also the various components of the drive train.

An accurate dynamic model of the type C TORSEN differential has been developed in a previous work [1] and has been validated by comparisons with experimental results. The model is based on the nonlinear finite element method for flexible multibody systems described in Ref. [2] and available in the software SAMCEF/MECANO. This method allows the modelling of complex mechanical systems composed of rigid and flexible bodies, kinematic joints and force elements.

The type C TORSEN differential is mainly composed of an epicyclic gear train and thrust washers. The axial force produced by the helical mesh leads to contact between the lateral circular faces of toothed wheels and the various thrust washers. The friction generated between these two bodies is at the origin of the locking effects, specific to the operation of TORSEN differentials.

In this work, several frictional contact conditions have been considered and compared to model the contacts between gear wheels and thrust washers. Firstly, a contact between a rigid body (gear wheel) and a flexible body (thrust washer) has been used. The nodes of the flexible body are projected on the rigid surface and an associate distance sensor is created. The kinematic constraint is only active when the bodies are in contact. An augmented Lagrange method or a penalty method can be used.

Although this flexible-rigid contact formulation has allowed to validate globally the differential model, several drawbacks have been identified. When the differential changes from one working mode to another one, the axial displacement of gear pairs is very quick and produces impact phenomena which force the Newmark-type integration scheme to use very small time steps and sometimes leads to convergence problems.

In order to avoid these problems and to reduce the high computational time due to these numerous configuration parameters of the meshing of the flexible body, two contact models defined between two rigid bodies have been implemented in SAMCEF/MECANO. The first formalism is based on a restitution coefficient to account for the kinetic energy loss during the impact [3]. The second rigid-rigid contact model considers the thin oil film between parts and the inherent damping or sticking behaviour. This last formulation is issued from the Navier-Stokes equation and also includes a Lagrange multiplier or a penalty method. For these three models, a regularization tolerance is used for the friction coefficient to avoid discontinuities when the sign of the sliding velocity changes.

References

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