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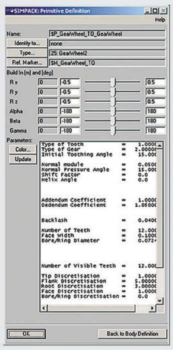
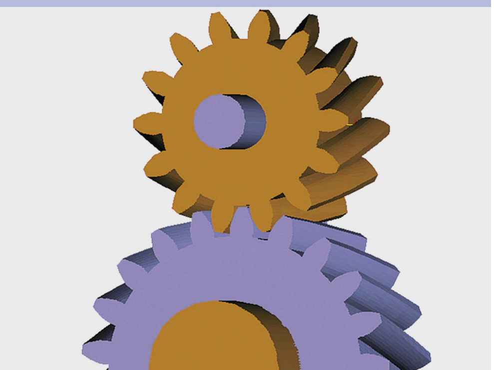
Gearwheels in SIMPACK



GUI for the definition of the geometrical gearwheel parameters



Helical gearwheels

Gearwheels have now become an integral part of modern internal combustion engines and gearboxes, and therefore the ability to incorporate them into a multi-body system has become essential for the simulation engineer. The module SIMPACK Engine offers a Force Element to accurately simulate Gearwheel pairs by considering the forces and moments generated in meshing gears; the resulting overall transfer stiffness is calculated by adding the individual stiffness at each contacting tooth. The Force Element models involute gear geometry and consider the effect of multi-tooth contact, as well as backlash and changes in direction of the gear rotation.

This new Force Element was designed to be easily configurable whilst offering a high level of technical performance, incorporating the characteristics inherent in the modelling of gears. Along with the contact mechanics within the meshing gears, the effects of changes to the relative position of the gear axes are an important feature within this element. The Gearwheel can be used to model spur tooth and helical involute gearing for multi-tooth contact, and to include the effects of backlash and gear rotation direction changes.

GRAPHICAL PRIMITIVES

The Gearwheel geometry is created from the respective graphical Primitive and is defined via the standard Gearwheel parameters; number of teeth, normal module, pressure angle, helix angle, addendum and dedendum coefficients, along with addendum modification coefficient and backlash. The amount of detail shown in the visualisation of the Gearwheels can be modified by defining the number of points used to describe the tooth flank, tip and root. However, changes to the graphical representation do not affect the accuracy of the force calculation.

INPUT PARAMETERS

The Gearwheel Force Element uses various different parameters to describe the geometrical relationship of the wheels to each other, as well as the physical and material properties of the Gearwheels. The parameters describing the geometrical form include:

- A reference angle for the tooth position.
- The face width of the meshing teeth.

The parameters describing the physical and material properties include:

- The mean Young's modulus of both wheels.
- The gearwheel form factor. This is used for the calculation of the weakening of the tooth, when compared to a gearwheel of complete cross-section.
- The normal damping coefficient of meshing.
- The coefficient of friction used for the calculation of the tangential forces induced from the meshing gears.
- The parabolic function used to describe the normal stiffness, from the minimum to the maximum value, as the contact point progresses over the tooth.

The parameter tip relief is used to smooth the running of the Gearwheels. The tip relief reduces the large changes in normal stiffness, which can occur for multi-tooth contact when gear teeth pairs commence and cease meshing.

INPUT VARIABLES

The Gearwheel Force Element is connected to two Body Fixed Markers, which are located on the rotational axis of the Gearwheels, and should be located at the centre point of the Gearwheel's width. The parameters automatically provided by SIMPACK are as follows:

- The angle of the reference Marker of both gear Bodies.
- The angular velocity of both gear Bodies.

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- The relative axial displacement of the gear Bodies to each other.
- The relative radial displacement of the Body Fixed Reference Frames.

Due to radial or axial displacement of the wheels, it is possible for the wheels to come out of meshing. If the nominal tooth backlash reduces, due to a reduction in the axial displacement, it is possible for both tooth flanks of the meshing teeth to come into contact. As an initial condition, the Gearwheel axes should be parallel. If the gear angle for all gear pairs are set to zero in the initial position, the simulation will begin without forces applied as the gear pairs are located in the centre of the backlash position.
The force law for the calculation of the nominal force is calculated linearly or non-linearly as a function of the penetration of the involute tooth profile. The tangential force, during meshing, is calculated from a Coulombic force law, with the friction coefficient given by the user.
For the calculation of the resulting meshing stiffness, the contact ratio of the involute gearing is considered. The contact ratio is dependent on the current Gearwheel axial displacement. Up to five tooth pairs can be in contact at any one time.

OUTPUT VALUES

The output values for the *External Gear* Force Element are the effective forces and moments applied at each wheel. The force and moments can also be output in Reference Frames, which do not rotate with the Gearwheels. In addition to other internal measurements which include Gearwheel angle, stiffness, force and position, it is possible to return the current meshing condition concerning the type of flank contact.

PARTICULAR FEATURES OF THE FORCE ELEMENT

The analytical calculation of the Gearwheel contact geometry reduces the need to search for the individual contact points, and therefore leads to very efficient calculation performance. At the start of the time integration, the meshing tooth pairs are all located at the centre of the tooth backlash position, ensuring no transient effects are present. The separate input of the initial tooth angle allows, for each Gearwheel level, the required meshing. For chains of Gearwheels, the phase relationship of the dependent Gearwheels is calculated from the initial tooth angle input of one of the Gearwheels. The tooth force pulsation, resulting from multi-tooth contact and the tooth stiffness function, can be reset to zero from two Force parameters.

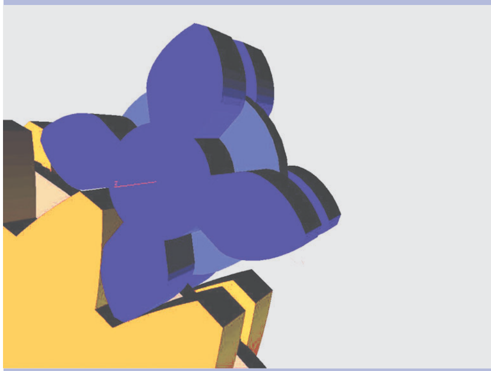
FUTURE DEVELOPMENTS

An important aspect considered when the Gearwheel Force Element was implemented was to easily allow the future realisation of new features. Further planned developments to the Gearwheel are as follows:

- Internal Gearwheel functionality.
- Implementation of straight and helical bevel gears.
- Calculation of the nominal tooth stiffness, dependent upon the number of teeth, the x-gear pair shift factors and the shape factor.
- Implementation of non axially aligned gears, for use on flexible shafts.

SUMMARY

The SIMPACK Gearwheel is an easily configurable Force Element, and allows the data to be entered easily and efficiently. The calculation of the tooth forces considers all of the geometric features of the involute tooth. The optimised calculation algorithm used for the tooth forces means a simulation containing gearboxes with a large number of gears can be performed, whereby the phase difference of the meshing tooth pairs is accurately modelled.



Spur gearwheels

Automatically created primitive for Gear element