

Gear Pair Enhancements with SIMPACK Version 8904

Several new functionalities are available with the SIMPACK Gear Pair module in SIMPACK version 8904. Not only has the visualization and handling of bevel gears and force arrows been vastly improved but major new functionalities (e.g. tooth profile and flank modifications, easy modelling of non-parallel axes, etc.) have been added.

HISTORY

Initially developed for Formula 1 high performance engines back in 2003 (by Lutz Mauer, an executive board member of SIMPACK AG), the SIMPACK Gear Pair functionality has since been used in a large variety of industrial sectors, e.g. automotive, wind, rail, shipping, aerospace, concrete mills, material handling, etc.

GENERAL

In SIMPACK, a large variety of elements are available for the simulation of torque converters. Depending upon the task at hand, elements of various level of detail may be used for achieving the optimum balance between solver speed and accuracy. For example, simple one-dimensional elements may be used for torsional analyses whereas gearbox elements (e.g. planetary gear stage) may be used for more detailed analyses when reaction moments on the housing are required. For simulations where individual tooth contact forces are required, the SIMPACK Gear Pair force element, FE 225, may be used. This element enables the additional analyses of the meshing forces and moments, shaft bending, bearing

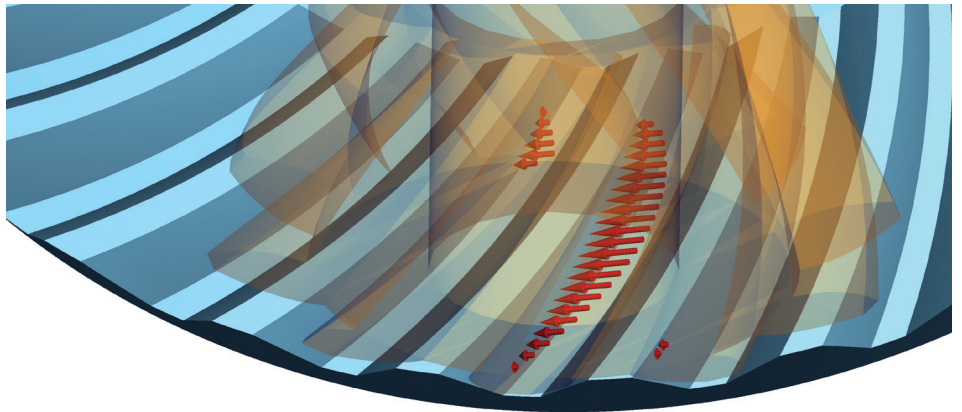


Fig. 1: Bevel gear with crowning

forces, and a host of other pertinent analyses (Fig. 2).

The gear pair FE 225 is an analytical element, and therefore, extremely fast simulation times can be achieved. Graphical primitives are subsequently used for the force calculations. This results in accurate animation of the gear tooth contacts and play.

The element includes the following functionality [1, 2]:

- Involute spur, helical and bevel gears
- Internal and external gears
- Profile Shift
- Backlash and friction
- Single and multiple tooth contact (internal excitations due to tooth meshing)
- Dynamically changing gear pair center distance and backlash (particularly important for floating suns (Fig. 3) and elastically mounted shafts)

The major gear pair enhancements with version 8904 are:

- Rack and pinion gearing
- Bevel gear primitive
- Tooth modification
- Flank modification
- Shuttling forces
- Easy slicing for non-parallel gear wheels and gear wheels with flank modification
- Easy handling of output values and animation of contact forces

GEAR PAIR PRIMITIVES MAJOR ENHANCEMENTS

With bevel gears, a new parameter, the "Rim thickness", has been added for a more realistic graphical representation (Fig. 4).

For all gear pair types, tooth and flank modification has been added. The modifications are primarily used for smoothing the non-linear internal excitations due to the continually changing number of teeth in contact. The following modification types have been added:

- Tip (Fig. 5)
- Root
- Circular
- Left and Right Side
- Lead Crowning (Fig. 6)
- Lead Angular
- Bias (Twist)
- Input Function Array

All modification types can be input for the right and left flanks or for both together.

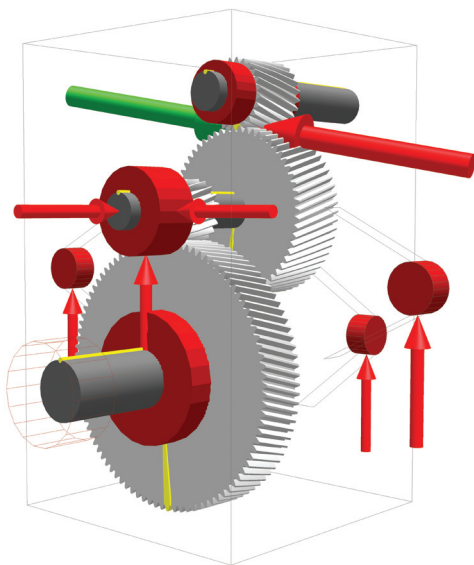


Fig. 2: Gear box with Gear Pair forces and other resultant forces

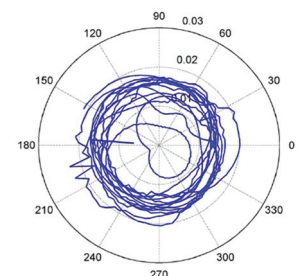


Fig. 3: Motion of floating sun within a planetary stage (© IMM, TU Dresden)

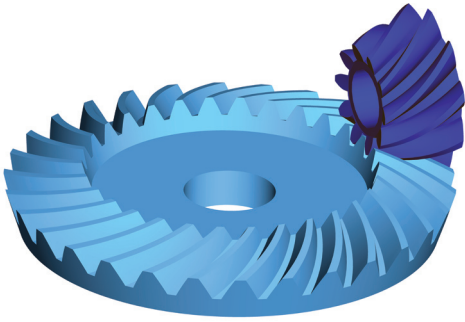


Fig. 4: Bevel gear primitives

GEAR PAIR FORCE ELEMENT MAJOR ENHANCEMENTS

For simulating gear pairs with non-parallel axes, "slicing" of the gear wheels is necessary [3]. Previous to version 8904, extra gear wheel primitives and force elements had to be used for this purpose. This functionality is now achieved by setting single parameter (i.e. "Number of slices") within the gear pair force element. The handling of the offset angles for helical gears is now fully automatic. Slicing is also necessary if flank modification is used. Shuttling forces, i.e. the axial displacement of the contact forces, has now been implemented. In the case of helical gears, this will result in an additional tilt moment. The graphical representation of rack gears has been available for a long time now. With



Fig. 5: Tip profile modification

version 8904, the calculation of the rack and pinion forces has also been implemented (Fig. 7).

With version 8904, the user can now easily switch on and off, and choose between, various output value types. This enables easier handling and a more efficient use of data storage space. The different types of output are described below.

GEAR PAIR DATA CHECK

In order to check the input parameters and initial conditions of the gear pairs within a model, a user can perform a "Test Call". This will result in a list being generated for

each gear pair consisting of important input parameters and calculated data. Information such as the theoretical center distance, radial offset, axial offset, transverse contact ratio, overlap ratio, and total contact ratio will now be readily available.

GEAR PAIR OUTPUT VALUES

By way of parameterization, a user can choose for which gear pairs the "Basic Output Values" will be generated. These values include such data as the relative

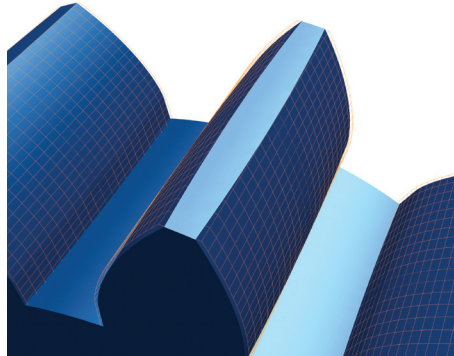


Fig. 6: Crowning, left and right flank

angles and angular velocities, "total normal contact stiffness" and the "dynamic transmission error".

Similarly, a user can also choose which "Advanced Output Values" are to be saved (Fig. 8). These values are primarily used for analyzing the coupling forces of the gear pairs, either for the sum of all teeth in contact or the individual tooth-pair contacts. In addition the "Advanced Output Values" enable easy animation of the force arrows in the PostProcessor (Fig. 9).

After an integration run is complete a user can subsequently choose which output values to generate. Re-running the time integration is not necessary. Only re-performing "measurements" is required.

CONCLUSION

SIMPACK version 8904 represents a major milestone in the development of the gear

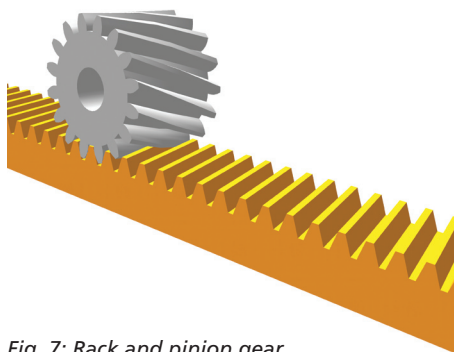


Fig. 7: Rack and pinion gear

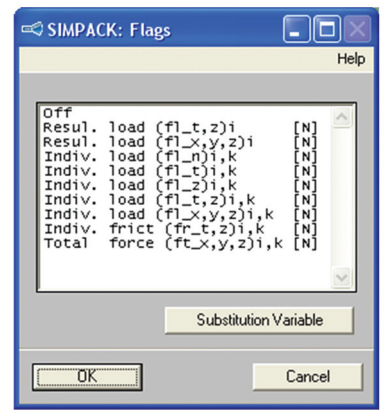


Fig. 8: User choice for advanced output values

pair module. New functionalities such as tooth and flank modification and automatic slicing and force arrow visualization, enable not only easier and faster model generation but also improved accuracy and quicker analyses. Although a significant development step has been achieved, the demanding and varied applications of the gear pair element will continue to result in further, more advanced requirements. The development of the gear pair element does not have one static functionality goal, after which the development can be seen as being completed, but rather a continually

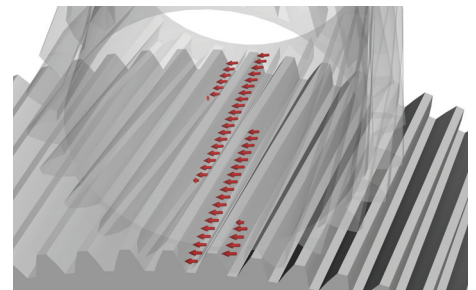


Fig. 9: Animation arrows of normal loads "Indiv. load (fl_n) i,k"

advancing goal to which subsequent further SIMPACK development will ensure that the gear pair element can accompany industrial users long into the future.

REFERENCES

[1] L. Mauer, 'GearWheels in SIMPACK', SIMPACK News, July 2004
 [2] L. Mauer, 'Modeling and Simulation of Drive Line Gears', SIMPACK News, July 2005
 [3] E. Pflieger, 'Simulation of the Dynamic Behaviour of Nose Suspension Drives for Rail Vehicles Using SIMPACK-GearWheel', SIMPACK User Meeting 2006
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