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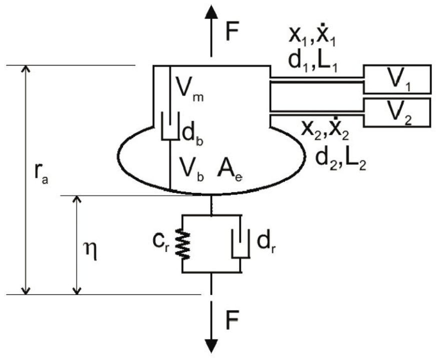
Air –Springs in SIMPACK



Scheme of the non-linear air spring type 82 together with two additional volumes and the according parameters

In modern automotive and railway vehicles, more and more of the conventional springs are being re–placed by air–springs. Although for the vehicle designer this is more technically challenging, they offer considerable dynamic advantages. SIMPACK 8.5 was the first version to offer this spring type and this article will explain more about the different elements and their uses.

WHY USE AIR-SPRINGS?

Engineers, when designing a chassis, are looking to achieve the highest passenger comfort by reducing the vibrations felt by the passengers, whatever the vehicle loading. For railway vehicles, designers are looking to achieve an eigenfrequency of approximately one Hz vertically, which, when using steel springs, causes problems as eigenfrequencies vary with vehicle loads. The major advantage of air-springs is that, whatever the loading, the eigenfrequencies remain almost constant. Air-springs have now become the standard for regional trains, which have very different laden and unladen weights.

A further advantage of air-springs is when the air is divided between the air-spring bellow and an additional volume. If the air-spring bellow and the additional volume are then connected via a orifice pipe, then the air flow is restricted, creating a damping effect. In contrast to oil dampers, there is no parasitic friction, which can lead to a reduction in passenger comfort.

With vehicle chassis, the four air-springs, which support the vehicle, are typically connected to each other (two- or three-point supports) and to a pressure regulator. The regulator ensures the initial level is constant, whatever the vehicle loading, and also that the level remains constant when the vehicle is moving, particularly important when travelling over a crest or through a trough.

What are the air-spring modelling approaches in SIMPACK?

LINEAR AIR-SPRING ELEMENT 83

This element calculates the stiffness and damping linearly, with the vertical stiffness calculated from the polytropic equation, which relates the volume changes, due to the spring deflection and the pressure change. This equation is automatically linearised before the calculation, so that the appropriate properties are applied whatever the initial loading or spring deflection. Laterally and longitudinally, the element is both linearly stiff and linearly damped. It is also possible to add linear rubber mounts vertically. The user enters physical parameters for the bellow volume and the effective area with the damping entered as a constant.

NON-LINEAR SPRING ELEMENT 82

Different to the linear force element, the polytropic equation is used here in its non-linear form, and therefore takes into consideration the large spring deflections. This element allows up to two additional volumes to be defined, along with either a linear or non-linear rubber element, connected in series. If the additional volumes are defined, then the non-linear damping will be calculated from the air friction produced between the bellow and the additional volumes. Because the non-linear damping has second order characteristics, the damping effect vanishes, if numerical linearisation is applied. All parameters can be entered as physical parameters, with the exception of the longitudinal and lateral stiffnesses and damping coefficients, which are entered as constants.

Both these elements are largely suitable for the simplified modelling of air-spring systems, where the pressure equalisation and level control are not important. The limi-

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tation of both of these elements is that, they cannot be coupled together or used with a level controller.

THE AIR-SPRING SYSTEM

The most detailed modelling of air-spring systems in SIMPACK is offered via the control elements 152 and 153 (licensed with Control, Automotive+ or Wheel/Rail). These elements, used together, allow air-spring systems to be coupled together as well as allowing multiple additional volumes to be added. They can also be used to create systems with a level or external pressure controller.

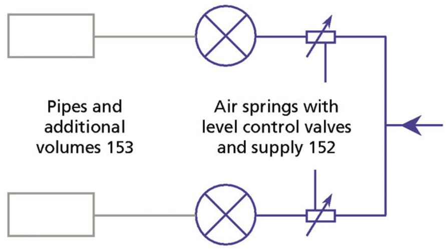
Control element 152 is similar to force element 82, in that the force is calculated from the spring deflection using the non-linear polytropic equation. This element, however does not generate a force, but transfers the force value to the actuator control element 110, which then applies the force between the coupling markers. This actuator also supplies the kinematic measurements to the air-spring element. Users, who want the same force to be applied at different actuators, can also connect up more than one actuator to each air-spring element.

Element 152 can be linked up with a level controller, with the position resulting either from the actuator or from an external control-sensor element. If the level moves away from the required value, the internal pressure will be adjusted, at a rate proportional to the difference from the required level, so the system moves back to the correct state. A maximum level deviation value before fully opening and a position delay for the level deviation can be entered as parameters. In addition a time constant for the rate of change of pressure and a non-return valve can be defined. The fill and drain of the element can also be determined by an external control loop, instead of via the level sensor.

The control element 153, pipe dynamics, is used to connect air-spring elements together or to add additional volumes. The element is a pipe with non-linear, as well as time dependent pipe friction characteristics. Either both ends of this element can be connected to control elements 152, or one can be defined directly as an additional volume. The user can also define multiple additional volumes, which are attached in series.

USES

The properties and behaviour of an air-spring are very different to those of a standard spring-damper. The differences, which have been listed in this article, relate to the spring stiffness due to the force loading, the non-linear damping from the pipe friction and the pressure equalisation between the air-springs, as well as the position-level control. The representation of air-springs with standard spring-damper elements means a lot of the important characteristics are not sufficiently portrayed. The SIMPACK air-spring elements improve therefore, the modelling detail and allow the user's data to be easily incorporated into a SIMPACK model.



Part of a typical air spring system with level control