Flexible Beams in Dymola

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This article is based on the master thesis "Efficient Modeling of a Flexible Beam in Dymola using Coupled Substructures in a Floating Frame of Reference formulation" written at LTH, Division of Mechanics, in cooperation with Modelon AB. The thesis has been written with the purpose to create a flexible beam model in the simulation software Dymola.

Ever since Isaac Newton laid the foundation for classical mechanics, it has been possible to describe the physical world around us with mathematical laws. Simple problems can be solved through hand-calculations on paper, but with increased complexity hand calculations becomes too time consuming. In today's modern industry, along side the advancement of the computational age, the development of computer based physical modeling becomes a requirement for companies in order to solve complex mechanical problems.

Introduction

Dymola is a simulation software with special focus on large system models, e.g. vehicles or aeroplanes. Large mechanical systems put high demands on required computational power. To maintain short simulation times, implementation of efficient model components reduces required computational power at the same time as the models are capable of describing the physical behaviour sufficiently.

Currently Dymola only supports modeling of rigid bodies. In many cases this is sufficient to get an understanding of the system behaviour. However, in applications where large loads and vibrations occur it is required to include flexible bodies in the system. The flexible components can, in comparison to rigid ones, describe deformation caused by applied loads and therefore provide important information concerning the system behaviour.

Beam model

A beam is by definition a structural element that is capable of withstanding load primarily by bending but also by torsion and elongation. They are characterized by their length, cross section geometry and material properties. Beams are widely used in mechanical applications, e.g. vehicle chassis and drive-lines, but also within the industry of civil engineering, e.g. structural components in buildings and bridges. There are several different mathematical theories in which beams are described, some are more advanced than others, and the model presented in this thesis is based on the simplistic and well proven, Euler-Bernoulli beam theory.

A theoretical beam model was established by embedding the Euler-Bernoulli beam theory in a Floating Frame of Reference formulation combined with the Craig-Bampton reduction method. The theoretical model was implemented as a flexible beam library in Dymola.

The result is a beam model that can describe elongation, torsion and bending deformation both in static and dynamic loading cases. For those who are not familiar with these terms, consider a forklift with a hanging object on the fork, the fork can be considered as a beam. The object's mass will apply a force to the fork due to gravitation, the fork will bend if the object's mass is large enough, i.e. the fork is subjected to a static load case. On the other hand if the object starts to bounce then the fork would start to vibrate which can be considered as a dynamic load case.

The beam model in Dymola shows good response and accuracy, in comparison to the theory, when subjected to a static load case. When dynamic load cases are considered the response is not as accurate but sufficient enough to describe a realistic behaviour. Results from the validation process shows that the beam model is able to connect with other components in Dymola, which enables the beam to be a part in larger system models.

Conclusion

A flexible beam library has been implemented in Dymola. The models has shown promising results through the validation process where it has been tested for both static and dynamic load cases. Before the beam model can be presented as a commercial library in Dymola, further testing should be conducted in order to identify sources of error. The deviation in accuracy during dynamic load should be investigated. Tests of the beam model in larger applications, e.g. wheel suspension, should be performed in order to further evaluate the compatibility with the mechanical library in Dymola.

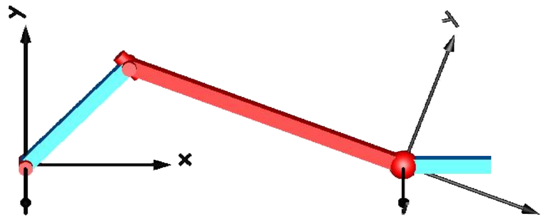

Figure 1: *Flexible beam component(red) connected with rigid components(blue) in a piston and crankshaft mechanism.*

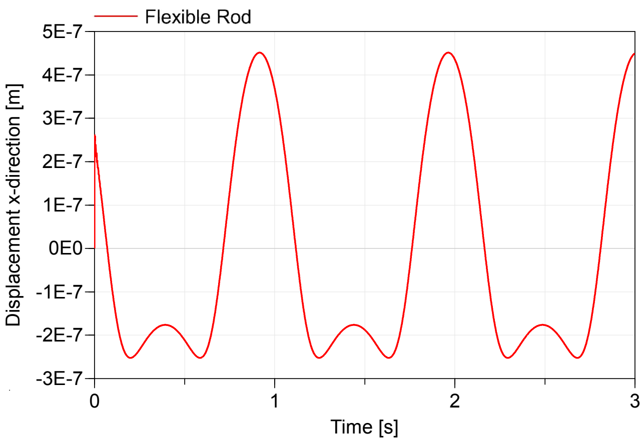

Figure 2: *Displacement in x-direction as a function of time of the flexible beam in Fig.2, displacement is measured in the coordinate system attached at the beams right end.*