Maplesoft
Engineering
Solutions

Advanced Hydraulic System Design by Maplesoft

Introducing the MapleSim Hydraulics Library from Modelon

Introduction

The MapleSim Hydraulics Library® from Modelon lets engineers seamlessly incorporate highly complex hydraulic components into multidomain models in MapleSim's advanced system-level modeling and simulation environment. The library contains over 200 enhanced hydraulic components for modeling hydraulic systems including cylinders, directional control valves, lines, pumps, restrictions, sensors, volumes and fluids. Based on Modelica®, an open, object-oriented system-level modeling language, all components are easy to reuse and extend.

The partnership between Maplesoft and Modelon was a natural fit. Maplesoft introduced MapleSim, its advanced system-level modeling and simulation tool, in 2008. In its first release, MapleSim contained a basic Hydraulics library, which allowed engineers to model basic hydraulic systems to incorporate variables such as flow rates and pressures into a system model. However, as MapleSim gained popularity, the company received many requests for a more comprehensive hydraulics library. Enter Modelon. Since 2005, Modelon has been focused on providing superior Modelica libraries. To date, Modelon has deployed more Modelica-based commercial libraries than any other company in the world. This partnership between Maplesoft and Modelon resulted in a library of state-of-the-art hydraulic components, suitable for use in many applications, including aerospace, automotive, heavy machinery and robotics.

The Benefits of the MapleSim Hydraulics Library from Modelon

The MapleSim Hydraulics Library from Modelon enables engineers to:

- Accelerate the design and development process by eliminating the need to design hydraulic components from scratch
- Use ready-made validated hydraulics models based on years of industry experience
- Customize and extend hydraulic components
- Take advantage of advanced numerical solvers
- Optimize code generation
- Easily integrate hydraulic components into multidomain systems
- Quickly model non-standard configurations and component designs

Using the MapleSim Hydraulics Library from Modelon

With MapleSim's advanced multidomain modeling capabilities, engineers are able to easily connect components from the MapleSim Hydraulics Library from Modelon with other subsystems within the model. MapleSim includes libraries for over 500 components from different domains and comes equipped with many basic component libraries including 1-D Mechanical, Electrical, Hydraulics, Magnetic, Multibody, Signal Blocks and Thermal. MapleSim's built-in Hydraulics library allows the user to model basic hydraulic systems; however, the MapleSim Hydraulics Library from Modelon is a much more comprehensive add-on package, allowing the user to model highly complex hydraulic systems. Other add-on libraries for MapleSim include Batteries, Drivelines, Tires and Pneumatics, among others. Using MapleSim, the user simply drags and drops multiple components from different libraries directly into the workspace to build a dynamic multidomain model.

The components in the MapleSim Hydraulics Library from Modelon use standard ISO hydraulic schematic icons. This allows users new to MapleSim to quickly identify hydraulic components. The standard hydraulic symbols are shown in **Figure 1**.

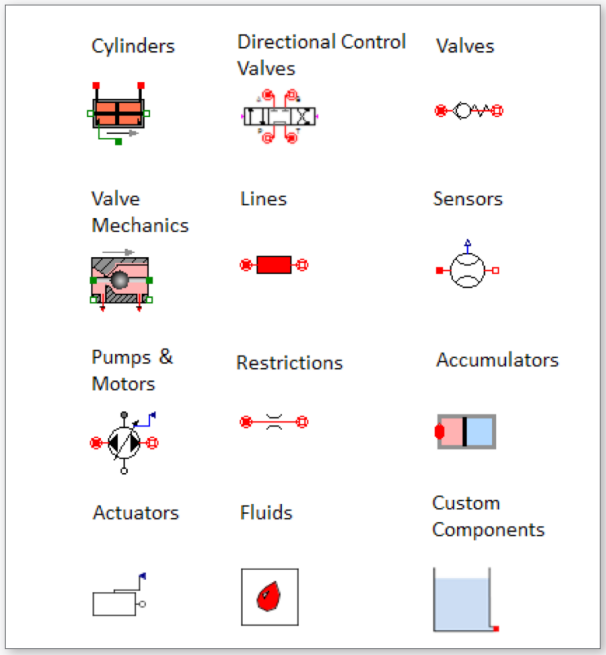

Figure 1. Standard Hydraulic Symbols

By simply double-clicking on any hydraulic component, the engineer can drill down to see the basic building blocks of the component, as shown in **Figure 2**. With this feature, users can easily visualize how components work and quickly understand how to extend their own custom components by simply adding to or modifying the component. The hydraulic components contain all of the underlying mathematical equations and physics relationships to describe their dynamics, useful for advanced analysis, parameter optimization and visualization in Maple, Maplesoft's advanced computation engine.

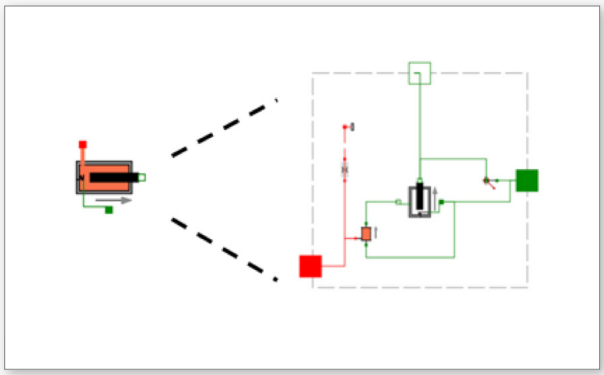

Figure 2. Basic Building Blocks of a Plunger Cylinder

The MapleSim Hydraulics Library from Modelon was designed to model advanced hydraulics, such as hydrostatic drives or actuation systems. Using advanced components from the MapleSim Hydraulics Library from Modelon, an engineer can model and simulate complex hydraulic scenarios occurring in the real-world. MapleSim allows temperature offsets in which different parts of the hydraulic system may operate under different temperatures. It also allows higher-order effects, such as internal and external leakage and compressibility. This allows an engineer for example, to counteract cavitation effects, attenuate fluid compressibility and predict and correct power losses due to fluid leakage.

The MapleSim Hydraulics Library from Modelon contains a large range of commercially available hydraulic fluids, including Skydrol® and Mobil™, as well as theoretical models of hydraulic fluids. The engineer can easily view the descriptions of these fluids, such as temperature and pressure dependent qualities. The user also has an option to create their own hydraulic fluid using fluid characteristics from tabulated data.

Since hydraulic models are inherently numerically complex, MapleSim includes several advanced numerical solvers, shown in **Figure 3**. These solvers, for instance, allow the engineer to scale numbers to be closer in magnitude to each other, simplifying the computations and allowing the models to execute more rapidly. Using Maple as the underlying computation engine, complex equations are simplified, redundancies are eliminated and mathematical calculations are optimized.

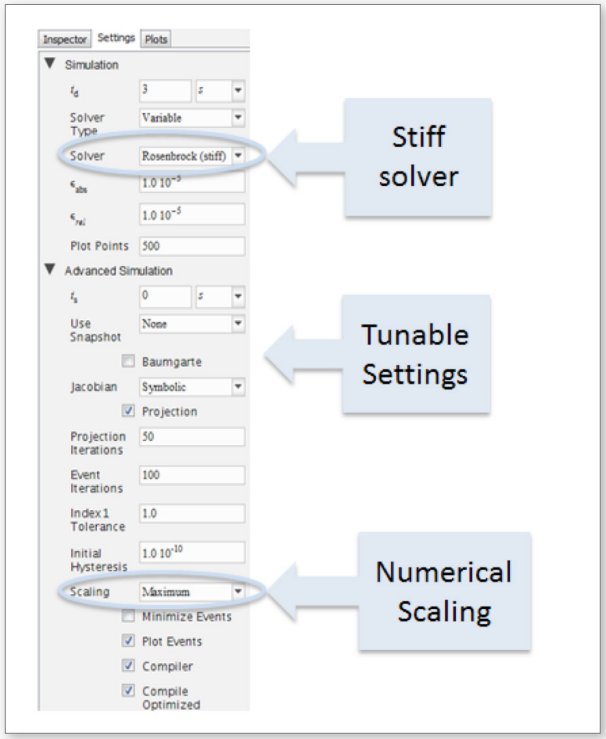

Figure 3. MapleSim's Advanced Numerical Solvers

The MapleSim Hydraulics Library from Modelon also includes a comprehensive Tutorial for the Hydraulics Library®. Prepared by Modelon, this document encompasses various aspects of hydraulic systems, from basic principles of hydraulics to detailed descriptions of the mathematical models of advanced systems.

Once hydraulic components have been incorporated into a multidomain model within MapleSim, the entire system can be analyzed and optimized through MapleSim's seamless integration with Maple. Maple provides additional visualization routines, interactive tools and a rich technical documentation environment.

The system equations can be extracted from the model and manipulated to perform inverse kinematics, inverse dynamics or sensitivity analyses. This seamless integration with Maple ensures that MapleSim produces efficient simulations providing greater insight into the system's behavior.

The code generation tools in MapleSim apply symbolic optimization techniques to generate simulation code from the models, including those with custom components. The royalty-free code can then be incorporated into popular real-time toolchains and other applications, including Simulink® and FMI-compatible tools.

Examples from MapleSim's Model Gallery Using the MapleSim Hydraulics Library from Modelon

Multidomain models in MapleSim are created by dragging and dropping components from various component libraries into the workspace. With MapleSim's easy-to-use interface, an engineer can visually connect the components together to create an accurate multidomain model of a complex system. Following are two examples of models developed using various components from MapleSim's component libraries, showcasing components from the MapleSim Hydraulics Library from Modelon.

Excavator Example

Figure 4 shows an example of a multidomain model of an excavator. The excavator is modeled using components from the MapleSim Hydraulics Library from Modelon, as well as MapleSim's built-in libraries for Multibody, Signal Blocks and 1-D Mechanical components. The main sections of the excavator are modeled using multibody components with revolute joints providing the rotational movement between the bucket, stick, boom and cab. The sections are driven by hydraulic actuation from two identical hydraulic cylinders, modeled from the MapleSim Hydraulics Library from Modelon.

By double-clicking on either of the hydraulic components, the user can drill down to see its basic building blocks. Illustrated in **Figure 5**, the building blocks include a flow source, pressure relief valve, differential cylinder, prop valve and a counter-balance valve.

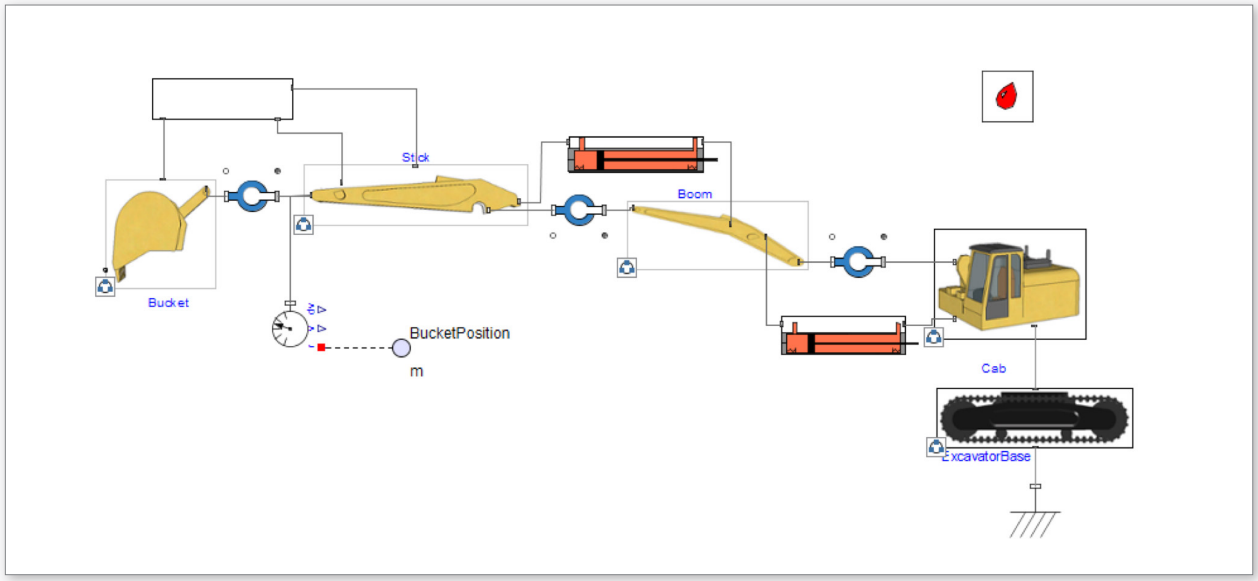

Figure 4. MapleSim Model of Excavator

A counter-balance valve is necessary to counteract the effects of cavitation. Cavitation occurs when the demand for the volume of fluid required by any part of the hydraulic circuit exceeds the supply. This imbalance causes the absolute pressure to fall below the vapor pressure of the hydraulic fluid, resulting in the formation of vapor bubbles within the fluid. These vapor bubbles can implode when compressed. Cavitation causes metal erosion, and in extreme circumstances, results in major mechanical failure.

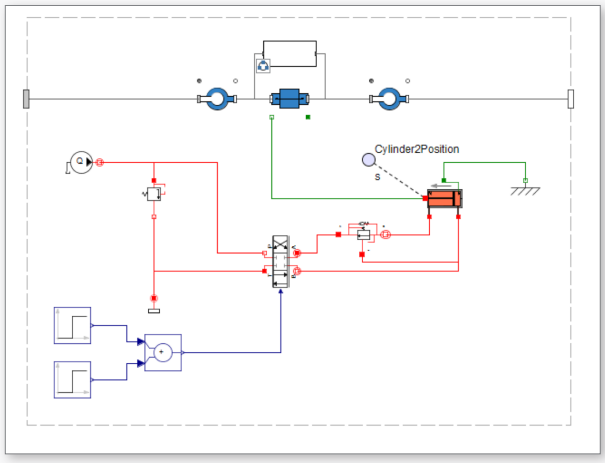

Figure 5. The Building Blocks of a Hydraulic Component in the Excavator Model

However, the use of a counter-balance valve ensures that the cavitation effects are attenuated.

An animation of the trajectory of the excavator's bucket, which is controlled by the extension and retraction of the hydraulic cylinders, can be observed in the Model Gallery.

Forklift Example

Figure 6 shows an example of a multidomain model of a forklift. The forklift is modeled using components from the MapleSim Hydraulics Library from Modelon, the add-on Tire library and the built-in Multibody library. The forklift components include realistic tires, a multibody chassis with a suspension mechanism, a multibody lifting mechanism and the hydraulic cylinder. A PI controller controls the hydraulic cylinder which controls the lifting action of the forks.

By double-clicking on the hydraulic component, the engineer can drill down to see its basic building blocks. Illustrated in **Figure 7**, the building blocks include a flow source, pressure relief valve, differential cylinder and a servo valve. The engineer can click on the differential cylinder to vary its parameters. These parameters include the effects of external leakage and friction, the piston mass and the spring and damping constants.

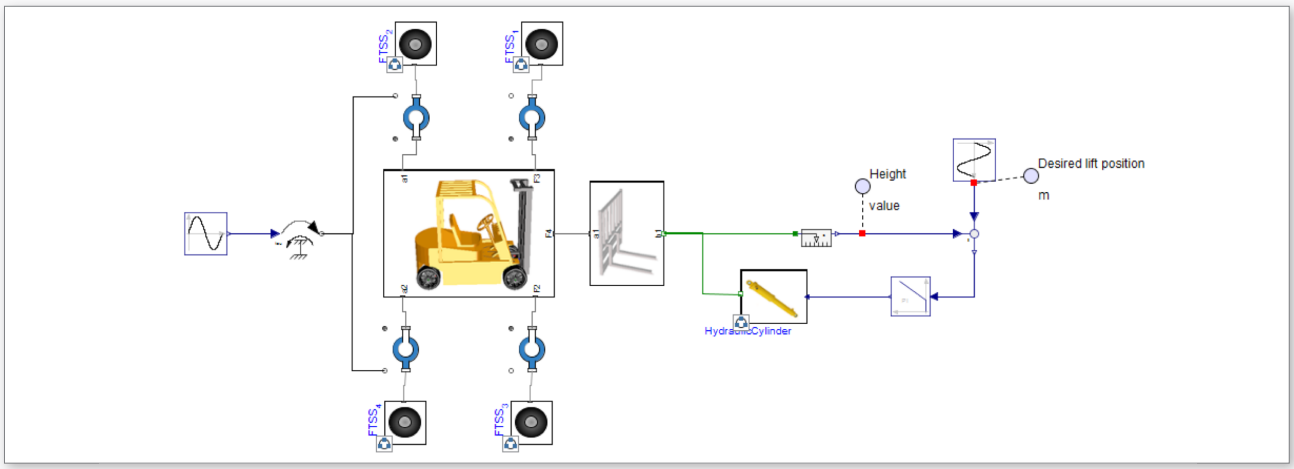

Figure 6. MapleSim Model of Forklift

In the Model Gallery, the animation of the forklift, moving forward and backward with the forks being lifted and lowered using the hydraulic cylinder, can be observed. This motion is similar to the desired motion of offloading or loading a pallet.

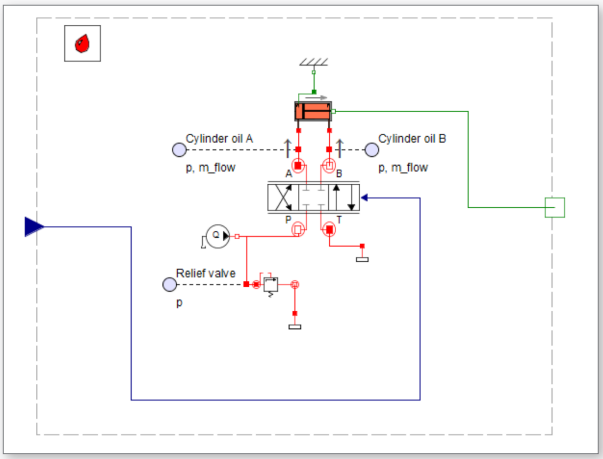

Figure 7. The Building Blocks of the Hydraulic Component in the Forklift Model

Summary

The MapleSim Hydraulics Library from Modelon is a comprehensive hydraulics library for modeling and simulation. It was created to provide engineers a powerful tool to model realistic multidomain models containing complex hydraulic systems. With over 200 enhanced hydraulic components, the MapleSim Hydraulics Library from Modelon allows engineers to seamlessly incorporate highly complex hydraulic components into multidomain models. By eliminating the need to design hydraulic components from scratch, the design and development process is accelerated. With MapleSim's intuitive interface, the user simply drags and drops multiple components from different libraries directly into the workspace and visually connects the components to build models. These models can then be run in MapleSim's advanced simulation environment, allowing users to take advantage of advanced numerical solvers and optimized code generation. MapleSim's seamless integration with Maple ensures that the accurate and efficient simulations provide the engineer with greater insight into the system's behavior, critical in the design of complex multidomain systems.

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