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MODELING AND SIMULATION OF A MULTI-DOMAIN DYNAMIC SYSTEM

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Summary: *Wheel loader Z-bar system is a complex hydomechanical system with an electronic controller. Therefore the new approach of Physical modeling in MATLAB & Simulink software was used in this case. In this method the hydraulic, mechanical and electrical parts were modeled by assembling blocks which represent an elementary parts of the real system. This model could be directly simulated to achieve the system dynamic behavior.*

1. Introduction

Modern technical systems are usually very complex. Hence the modeling design of such systems is very difficult and time consuming. The problem grows if there are interactions of several different fields of physics. One possible way is using of a physical modeling method. This method deals with representation of physical objects instead of differential equations and includes signals with physical units. Therefore the interaction between elements inside the system is handled the same way as in a real system.

2. Model of a wheel loader lifting system

The lifting system of the wheel loader (Fig. 1) is a complex kinematic mechanism. An accurate mathematical model is needed for both dynamical analysis and design of control algorithm.

Fig.1: Wheel loader

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The model was developed by using the MALTAB & Simulink simulation tools with modules for Physical modeling. The basic module is Simscape which includes fundamental elements from electrical, mechanical and hydraulic domain. SimMechanics provides extensive capabilities for modeling of kinematic systems by connecting bodies and joints in 3D space. The last used module was SimHydraulics with libraries of more complex hydraulic elements.

Z-Bar (Fig. 2) is the most used type of lifting systems for the earth-moving machines. The main components of a Z-Bar are the lift arm, the cylinders, the lever, and the bucket. It is necessary for the modeling to divide this system into two parts.

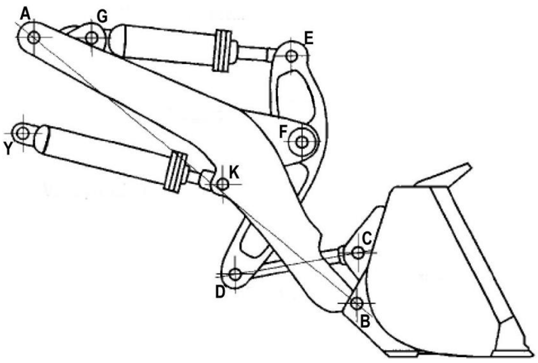

Fig. 2: Z-bar of the wheel loader

2.1. Modeling of the mechanical part

The first part consists of mechanical components which describe complete kinematics of the lifting system and it was modeled in SimMechanics (Fig. 3). The model is composed of rotational and translational joints and bodies. Each body carries information about weight and inertia of one solid in the Z-Bar system and includes connection points to the other solids. The program automatically computes a dynamic equations from the specified kinematics. The dynamic equations are necessary for the following simulation of the system.

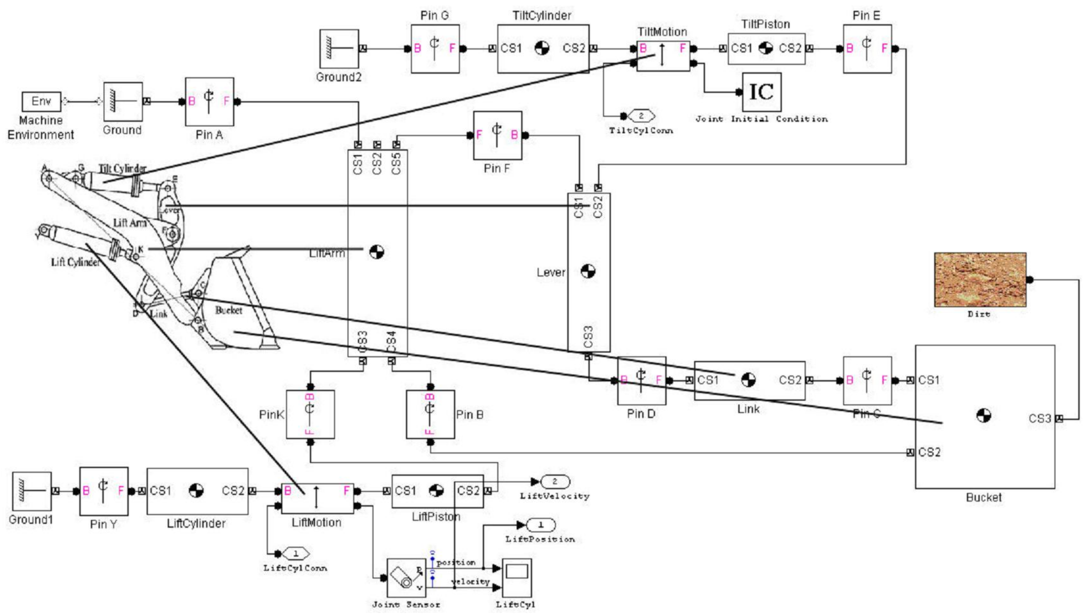

Fig. 3: Mechanical model of the wheel loader lifting system

SimMechanics also includes a simple visualization which shows the motion of the mechanical system during simulation (Fig. 4).

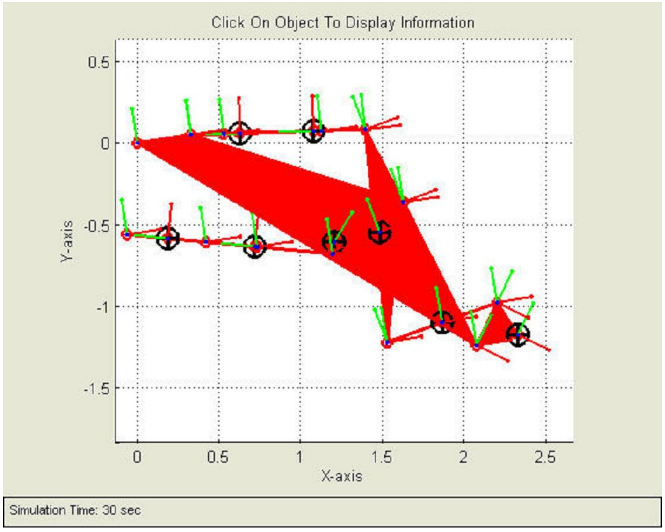

Fig. 4: Simple visualization of the mechanical model

2.2. Modeling of the hydraulic part

A controlled electro-hydraulic system is the second part of the mechanism (Fig. 5) and it was developed in Simscape and SimHydraulics. The controller is connected with a four-way directional valve for changing the fluid direction and with the pump for regulation of flow rate to a cylinder. The hydraulic cylinder is a hydro-mechanical converter which moves with the Z-Bar.

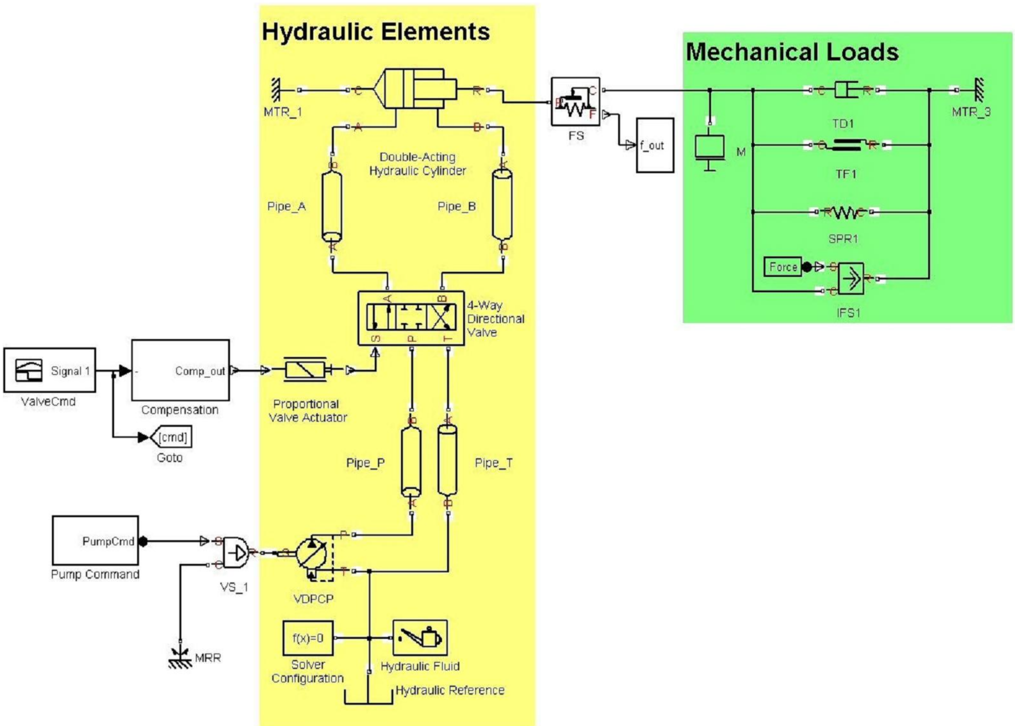

Fig. 5: Hydraulic model with the simplified mechanical part

2.3. Complete model and simulation results

The connection between the mechanical and the hydraulic part of the model is simply made by a signal with information about position of the piston (Fig. 6). This connection is made by bidirectional interaction line which works as the connection of these parts in real world.

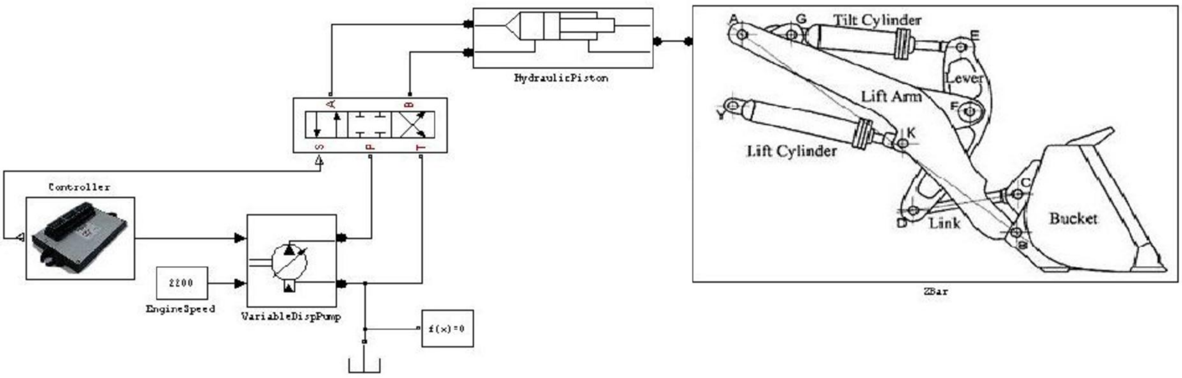

Fig. 6: Interaction between the mechanical and the electro-hydraulic part

Then it was possible to provide simulation of complete system. The simulation results show the movement of the Z-bar system with mechanical load (Fig. 7).

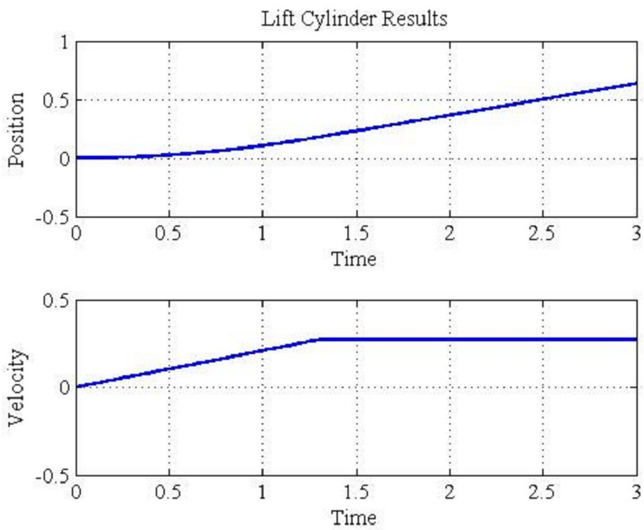

Fig. 7: Simulation results of the lift cylinder position and velocity

3. Conclusions

The wheel loader lifting system represents the multi-domain technical system. It is necessary for the satisfactory modeling design to deal with interaction between the mechanical part and the electro-hydraulic part. Although the physical modeling technique isn't wide spread yet it shows the significant advantages for the modeling such systems.

References

Prabhu, S., Wendlandt, J., Glass, J. & Egel, T. (2007) Multi-Domain Modeling and Simulation of an Electro-Hydraulic Implement System, sources of The MathWorks, Inc.