Janne Ojala
TAMROCK OY
Technology Center / Research
P.O. BOX 100
FIN-33311 TAMPERE
FINLAND

tel. +358-31-2414067
fax. +358-31-2414333
email. jo@tamrock.fi

1996 INTERNATIONAL ADAMS USER CONFERENCE: **VIRTUAL PROTOTYPING OF A TAMROCK DRILLING BOOM**

1 INTRODUCTION

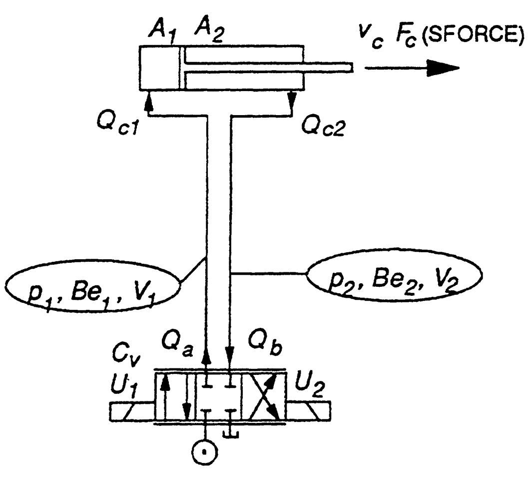
The purpose of using simulation techniques in the design of moving boom structures is to lower the costs of the whole design process. The problem in simulating the behaviour of boom structures has been the integration of different engineering design fields, such as the boom mechanics, hydraulics and electronics. A hydromechanical boom is a complex system, which consists of various mechanical, hydraulic and electronic components. In addition some parts of the boom have to modelled as flexible structures to quarantee sufficient correlation to the real system.

TAMROCK has been using ADAMS since early 1995. Simulation models of a TAMROCK drilling boom have been made. Depending on boom version, there are different hydraulic and control systems in the boom. Several hydraulic systems have been modelled. The digital boom control system has also been modelled. The model has been verified by comparing the simulation results to measured data. The correlation between simulated and measured results has been good. TAMROCK has used the simulation model as a tool in design of boom hydraulics.

The principles used in the modelling of boom hydraulics and control systems are described in this paper. The verification of the simulation model is presented briefly.

2 PRINCIPLES OF HYDRAULIC SYSTEM MODEL

A simple hydraulic system is presented in figure 1. Principles used in the modelling of hydraulic systems are shown in figure 1.



$$F_c = p_1 A_1 - p_2 A_2 - F_\mu$$

$$\dot{p}_1 = \frac{Be_1}{V_1}(Q_a - Q_{c1})$$

$$Q_a = C_v \cdot U_1 \sqrt{|\Delta p|} \cdot sign(\Delta p)$$

$$Q_{c1} = A_1 v_c$$

Figure 1. A simple hydraulic system and equations describing it.

The symbols used in figure 1 are explained below.

A_1 , A_2	cylinder areas
Be_1 , Be_2	effective bulk modulus of volumes V1 and V2
C_v	an empirical constant obtained from the valve manufacturers catalogues
F_c	the net force of the cylinder
$F\mu$	total friction force
p_1 , p_2	pressures in volumes V1 and V2
Q_a ,Q_b	flows through the directional valve
Q_{c1} ,Q_{c2}	flows in and out of the cylinder
U_1 ,U_2	feedback voltages
V_1 , V_2	hydraulic volumes
v_c	velocity of cylinder

Hydraulic systems in drilling boom are naturally more complicated than the one shown in figure 1. Typically a drilling boom hydraulic circuit consists of a proportional control valve, counterbalance valves and the actuator, usually a hydraulic cylinder. Hydraulic components are connected with hoses.

3 PRINCIPLES OF CONTROL SYSTEM MODEL

TAMROCK DATA-series drilling booms are fully automated. Principles used in the modelling of DATA- booms control systems are presented in figure 2.

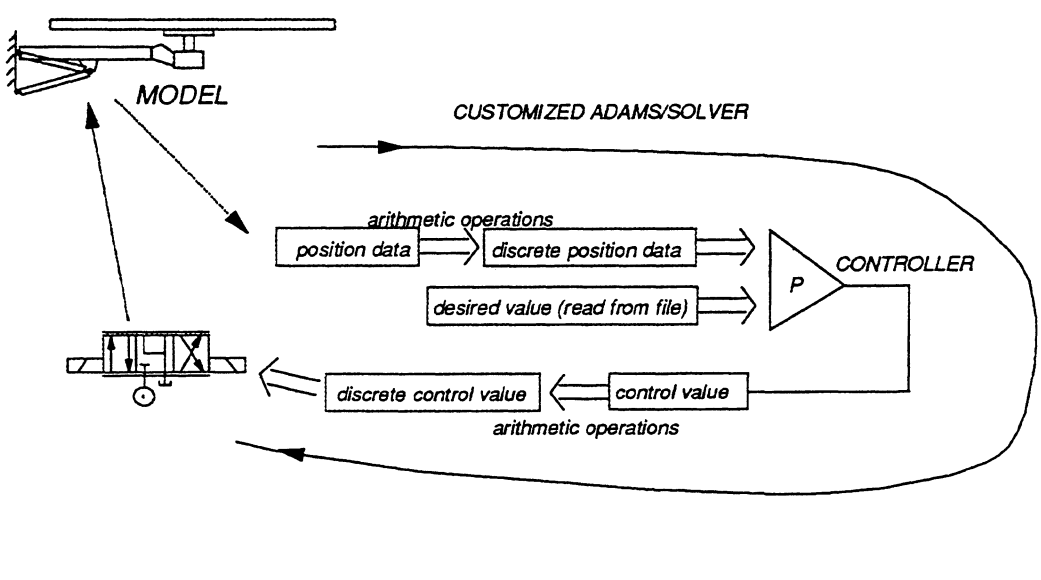


Figure 2. Principles used in the modelling of DATA-booms control system

A position or an angle transducer is modelled in every joint by using ADAMS displacement or angle functions. The continuous displacement/angle data got from the transducers is modified into discrete form by doing some arithmetic operations. The control algorithm compares the 'measured' data and the desired value read from file and creates a control value. The control value in then modified into discrete form. The model solution is carried out by a customized ADAMS/Solver. During model solution the control frequency is taken on note by subroutine *reqsub*. Subroutine *varsub* then returns the discrete control value to the control valve.

4 THE SIMULATION MODEL

The TAMROCK drilling boom simulation model is presented in figure 3.

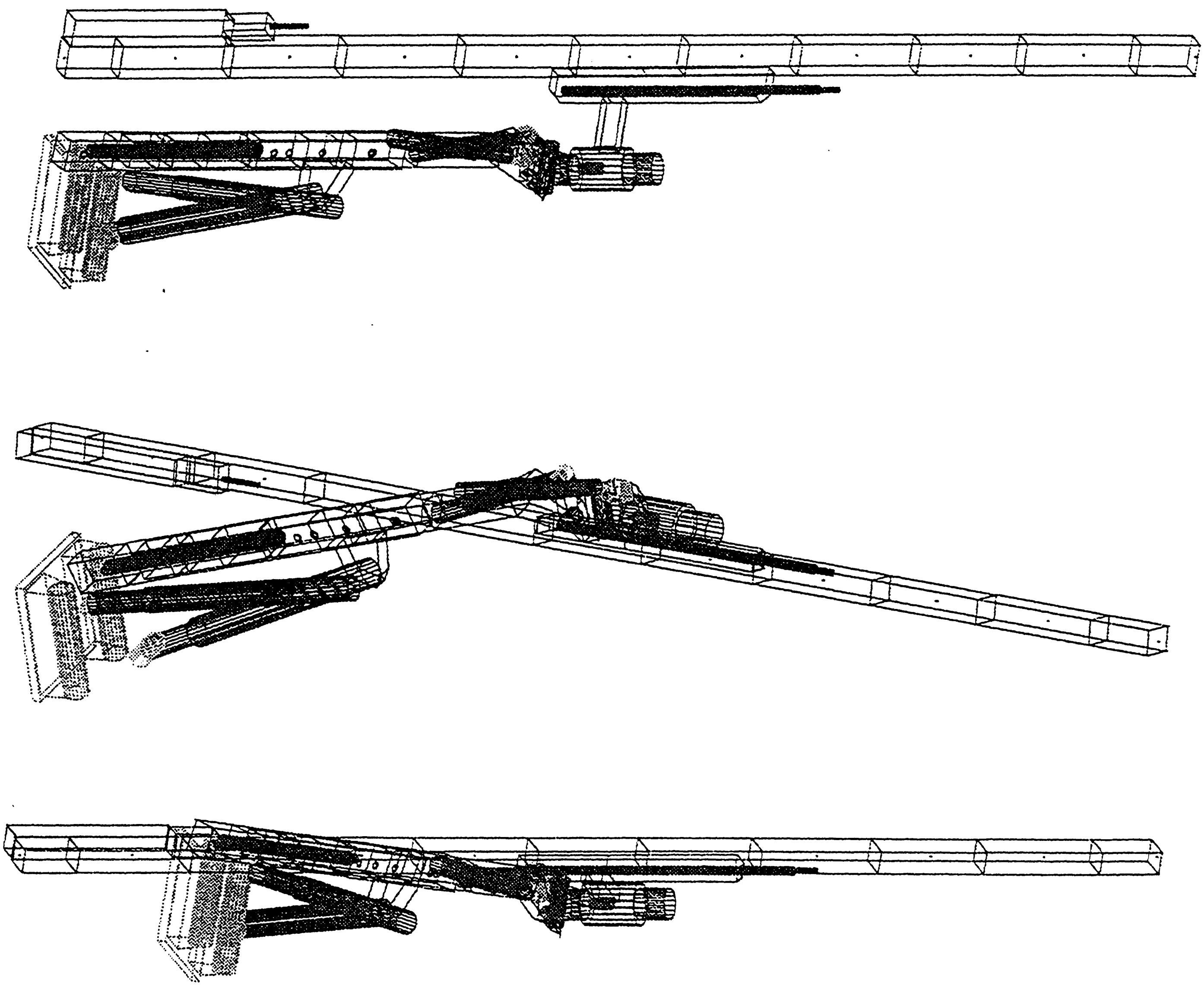


Figure 3. The simulation model

Seven hydraulic actuators and circuits have been modelled by writing the equations describing the boom hydraulic system in the model. Hydraulic flexibility has also been modelled. Flexible steel structures have been modelled by using the ADAMS/FEA- module. Digital control system of the boom has been modelled by using the ADAMS/Solver subroutines.

5 EXPERIMENTAL VERIFICATION

The simulation model has been verified by comparing some simulation results to measurement data. Some of the verification results are presented in figures 4...9.

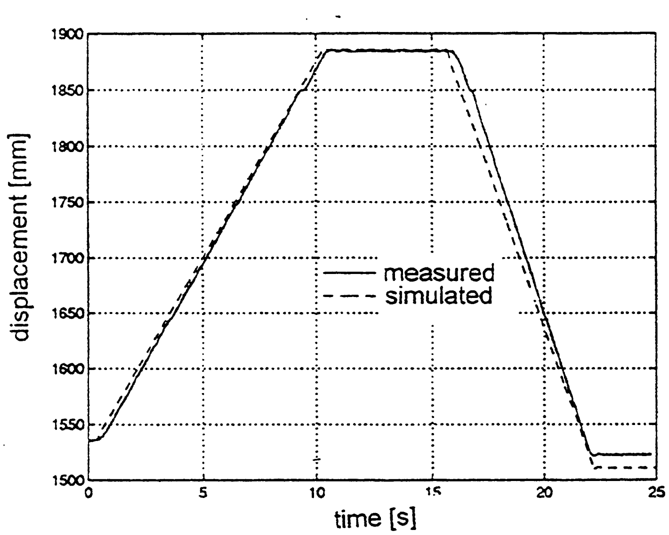


Figure 4. Boom lift cylinder, displacement

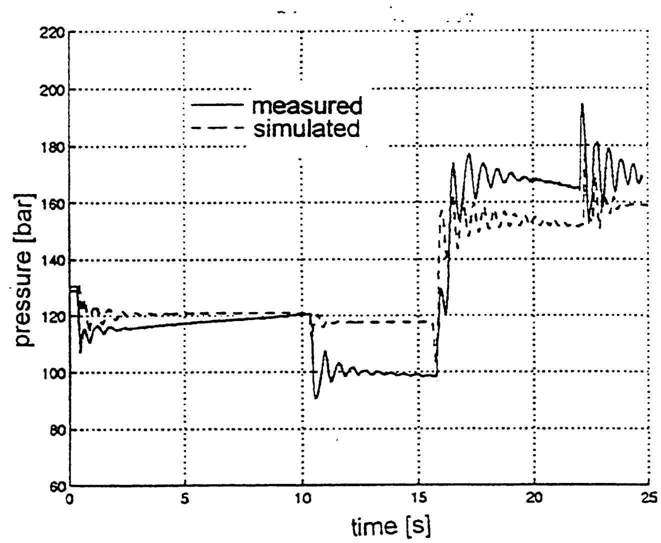


Figure 5. Boom lift cylinder, piston side pressure

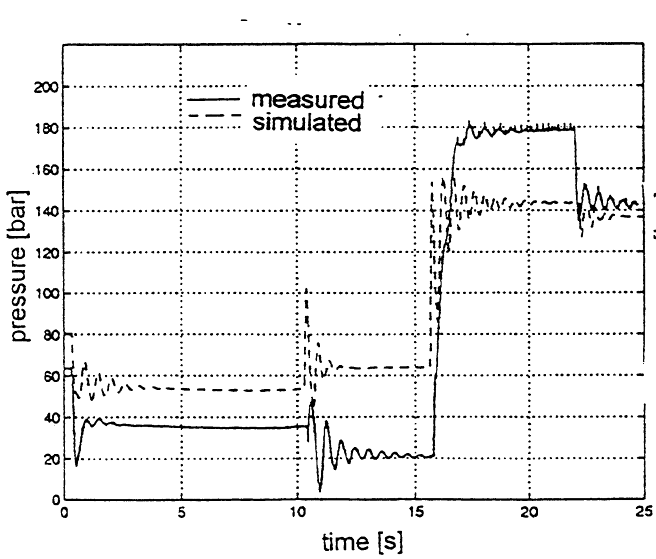


Figure 6. Boom lift cylinder, piston rod side pressure

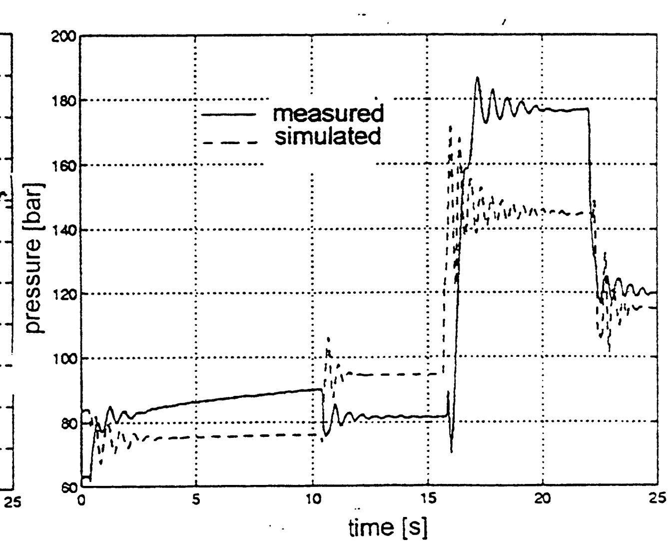


Figure 7. Boom lift cylinder, 3rd chamber pressure

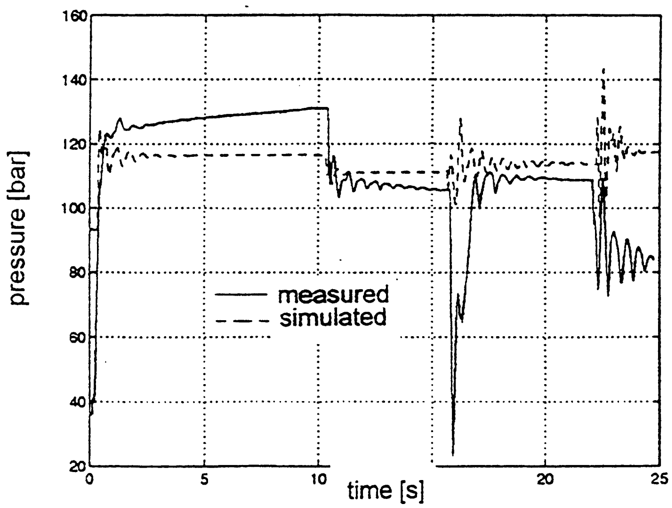


Figure 8. Feed tilt cylinder, piston side pressure

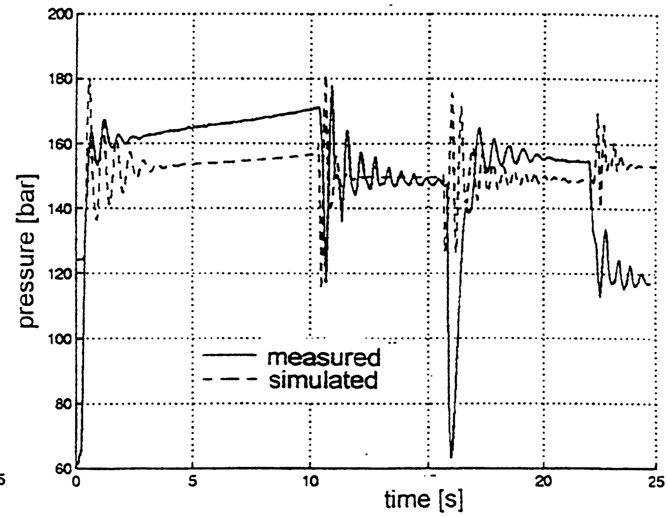


Figure 9. Feed tilt cylinder, piston rod side pressure

Also the technique of modelling the boom control system has been verified experimentally. The correlation between measured and simulated data has been good.

6 USING THE SIMULATION MODEL

So far TAMROCK has used the simulation model as a design tool for the boom hydraulic system design. The model has proved to be a useful tool in comparing different boom hydraulic control systems and afterwards different control valves. ADAMS simulations have given important and useful information for our engineers. There has also been some minor details in the hydraulic system, on which some research has been carried out. The results achieved have been satisfying.

In the future the area where ADAMS is used will expand to the boom control system design and the boom mechanics design. That means, for example, structural design and fatigue life prediction and analysis. To make our products even more reliable will be one of our goals in the future and virtual prototyping with ADAMS will be an important engineering tool.