SIMULATION STUDY ON THE HYDRAULIC JACKING SYSTEM FOR LIAOHAI2 PLATFORM

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ABSTRACT

A dynamic model of the Hydraulic Jacking System for LIAO HAI 2 Platform is developed by means of power bond graphs. Dynamic response and performance of the system are simulated on a computer. Based on the simulation results, some precaution methods are put forward to prevent the working cylinders from bulging that had happened before.

KEY WORDS: Power flow modeling; Power bond graphs; GUSTO Hydraulic jacking system; Bulging

1. INTRODUCTION

Hydraulic systems are widely used for jack-up unit to lift the oil platform or its legs. The GUSTO jacking system used in LIAOHAI2 oil platform is a typical one. The cylinder of this system has been enlarged up to 10mm in radial direction in 1995. It was repaired in Dalian Maritime University Shipping Technical Co.LTD. in 1997 and 1.3 million *yuan* cost. In order to predict the system performance, analyze the reasons caused the bulging and further to main it work well, a project (Liaoning Province key project in industry technology A970531232) was made in September 1997 by Liaoning Province Scientific and Technological Committee. The problem studied in this paper is one part of the project.

2. SYSTEM DESCRIPTION

Fig.1 illustrates the system to be studied. The system consists of the following components:

·LP Triple pump "Hydro-Meca" PF2BC 3085/3085/106H. Capacity 2×118; 1×8 l/min.

· Motor "Leroy Somer" 280M-2 BACY N=45KW(61 HP) n=1450rpm.

·HP "Gury/Poclain" L4 H 10 12.5 Capacity 4×16.7 l/min.

·v18 Check-valve "Rexroth" NW30 Nr.:301 916

·v19,v20 "Rexroth" NW20 Nr.:301 914

·v21 Check-valve "Gestra" Rk44-NW50-ND10/16

·v24/v30 Solenoid operated 4-wayvalve "Rexroth" H-4WEH-22-E-3X/10A W220-50-N-S2-B1.0

·v25/v39 Solenoid operated pressure control valve "Rexroth" DBW 30 A2-30/315U-W220-50-N-Z4.Adjusted at 24.0MPa.

·v26/v34 Solenoid operated pressure control valve "Rexroth" DBW30B2-30/100YU-W220-50-N-Z4.Adjusted at 7.0MPa.

·v27/v33 Solenoid operated pressure control valve "Rexroth" DBW 10 B2-20/315 U-W220-50-N-Z4.Adjusted at 29.0MPa.

·v28,v35,v36,v37 Solenoid operated pressure control valve "Rexroth" DB3U 10H2-20/315U-W220-50-N-Z4.Adjusted at 20.0/32.0MPa.

·v32 Pilot operated check valve "Rexroth" SL 30 P20

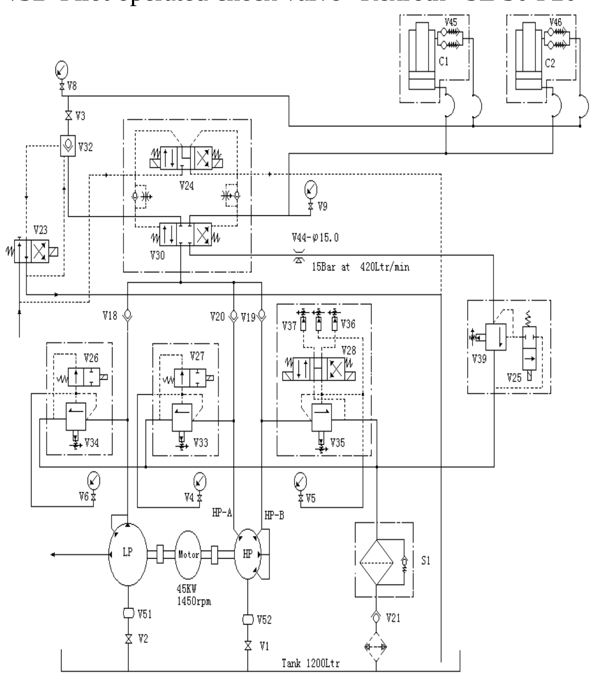


Fig. 1 The hydraulic jacking system

·v44 Orifice ϕ15 mm. Pressure 1.5MPa at 420l/min.
·v45/v46 Built in 2x hose-damage protection "Hawe" LB4C-160.
·v51 Compensator "Willbrandt" 4904 Yellow NW80-ND1
·v52Flexmaster "Aeroquip" GM 10009060.DIN2632
·C1/C2 Double acting jacking cylinder "Hydraudyne"
  Piston 450 mm
  Piston rod 220 mm
  Stroke 1130 mm
  Working pressure 32.0 MPa
·S1 Filter "Hydac" RFP 660 F 10 B1.1

3. DYNAMIC MODELLING

(1) Power Bond Graph

The bond graph model for the system .has been discussed in reference[1], but the model can not be solved correctly, so new models for the same system but difference working process are developed (see Fig.2 and Fig.3).

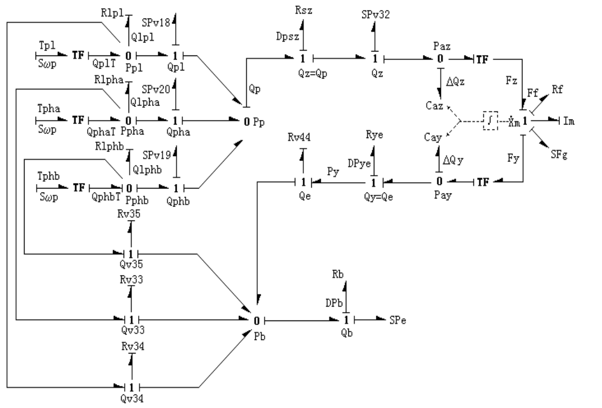


Fig. 2 Bond graph for platform lifting

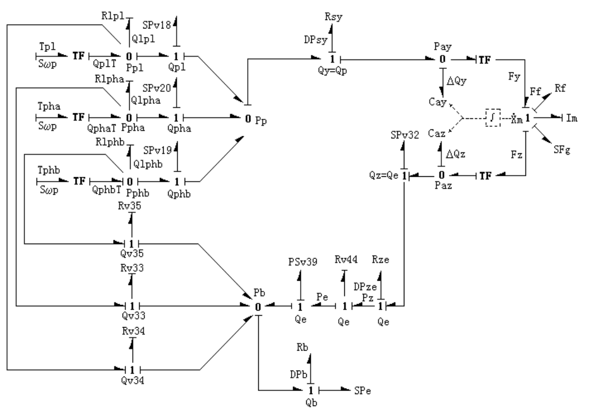


Fig. 3 Bond graph for platform lowering

(2) Dynamic Model

According to the power flow directions and the causality showing in the bondgraph, the power state equations are written as the following:

Source

Sùp =constant
SPv18 =constant
SPv20 =constant
SPv19 =constant
SPv32 =constant
Spv39 =constant(down)
Spe =constant
SFg =Im·

TF

Vpha Tpha =Vpha·Ppha
QphaT =Vpha·Sωp
Vphb Tphb =Vphb·Pphb
QphbT =Vphb·Sωp
Vpl Tpl =Vpl·Ppl
QplT =Vpl·Sωp
Ay Fy =Pay·Ay
Qay =Xmd·Ay
AZ Fz =Paz·Az
Qaz =Xmd·Az

R effect

Rlpl Qlpl =1/Rlpl·Ppl
Rlpha Qlpha =1/Rlpha·Ppha
Rlphb Qlphb =1/Rlphb·Pphb
Rv35 Qv35 =QphbT-Qlphb Sv28F
Qv35 =0.0
Sv28LT & Pphb<PSv35L
Qv35 = QphbT-Qlphb
Sv28LT & Pphb≥PSv35L
Qv35 =0.0
Sv28RT & Pphb<PphbH
Qv35 = QphbT-Qlphb Sv28F or
Sv28RT & Pphb≥PSv35H
Rv33 Qv33 =QphaT-Qlpha Sv27F
Qv33 =0.0
Sv27T & Ppha<PSv33
Qv33 =QphaT-Qlpha
Sv27T & Ppha≥PSv33
Rv34 Qv34 =QplT-Qlpl Sv26F
Qv34 =0.0
Sv26T & Ppl<PSv34
Qv34 =QplT-Qlpl
Sv26T & Ppl≥PSv34
Rsy DPsy =Qy· Rsy (DOWN)
Rsz DPsz =Qz· Rsz (UP)
Rye DPye =Qe· Rye (UP)
Rze DPze =Qe· Rze (DOWN)
Rf Ff =SIGN(Fu,Xmd)+Kf·Xmd
Rv44 Qe =(Py-Pe)/Rv44 (UP)
Qe =(Pz-Pe)/Rv44
(Pz>Psv39&Pp>0.0)

Qe =0.0
(PZ<PSv39 or Pp<0.0)
(DOWN)
Rb Dpb =Qb·Rb

C effect Cay Pay $=1/Cy\int \Delta Qy+Pay0$

Caz Paz $=1/Cz\int \Delta Qz+Paz0$

I effect Im Xmd $=1/Im\int Fm+0.0$

0 junction

Ppl Qpl =QplT-Qv34-Qlpl
Ppha Qpha =QphaT-Qv33-Qlpha
Pphb Qphb =QphbT-Qv35-Qlphb
Pay ÄQy =Qy-Qay (DOWN)
=Qay-Qe (UP)
Paz ÄQz =Qaz-Qe (DOWN)
=Qz-Qaz (UP)
Pb Qb =Qv34+Qv33+Qv35

1junction

Qpl Ppl =SPv34+Pb Sv26F
Ppl =Pp-SPv18 Sv26T
Qpha Ppha =SPv33+Pb Sv27F
Ppha =Pp-SPv20 Sv27T
Qphb Pphb =SPv35+Pb Sv28F
Pphb =Pp-SPv19
Sv28LT or Sv28RT
Qv35 ΔPv35 =SPv35 Sv28F
ΔPv35 =Ppha-PSv35L Sv28LT
ΔPv35 =Pphb-PSv35H Sv28RT
Qv33 ΔPv33 =SPv33 Sv27F
Pv33 =Ppha-PSv33 Sv27T
Qv34 Pv34 =SPv34 Sv26F
Pv34 =Ppl-PSv34 Sv26T
Qsy Pp =Pay-Dpsy (DOWN)
Qsz Pp =Paz-DPsz-SPv32 (UP)
Qe Pz =Paz-Dpze-SPv32
(DOWN)
Qe Py =Pay-DpyeUP)
Xmd Fm =Fz-Fy-Ff-SFg-SFe
(UP)
=SFg-Fz+Fy-Ff+Sfe
(DOWN)
Qb Pb =ΔPb+Spe

Auxiliary equtions

Cay =(Vy0+Ay·Xm)/Bo (DOWN)
Cay =(Vy0-Ay·Xm)/Bo (UP)
Caz =(Vz0-Az·Xm)/Bo (DOWN)
Caz =(Vz0+Az·Xm)/Bo (UP)
Xm $=\int Xmd+0.0$

4. SIMULATION AND DISCUSSION

(1) Simulation of the Happened Malfunction Condition

Fig.4 illustrates the pressure fluctuation in the cylinder due to inclination as the platform lowered down with full load. Before 12s, no oil is supplied. The pressure is nearly constant during 12s-25s with normal load and constant oil flow supplied. However the pressure varies sharply with the abnormal additional load exerted at 25s due to platform's inclination . It is the fluctuant huge pressure that causes the cylinder bulging.

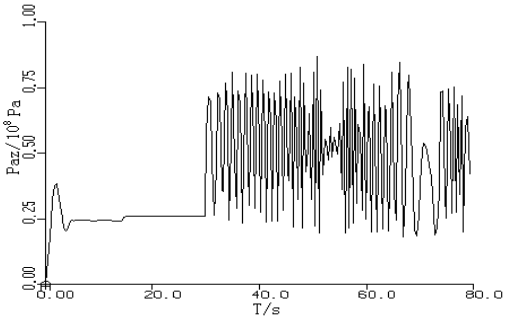
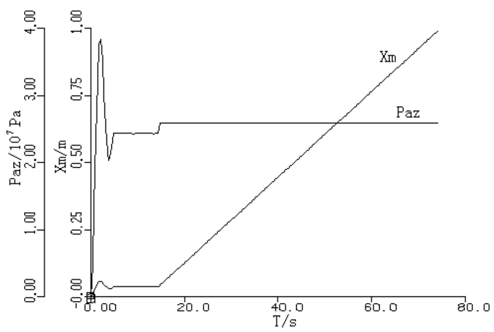


Fig. 4 System response to additional load (Paz)

(2) Simulation Analysis on Lowering Processes with Heavy Load

The high pressure in Z side of the cylinder and the displacement of the piston are showed in fig.5 while the platform is lowered with full load but v23,v39 and v44 set abnormal. Different working conditions and results are showed on table 1.



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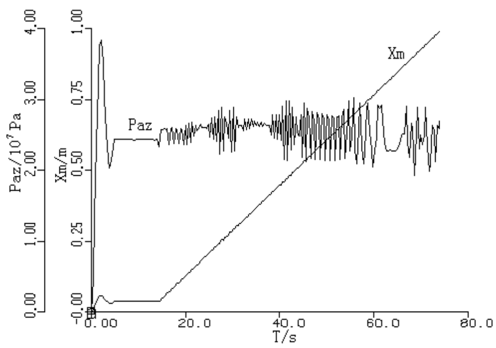

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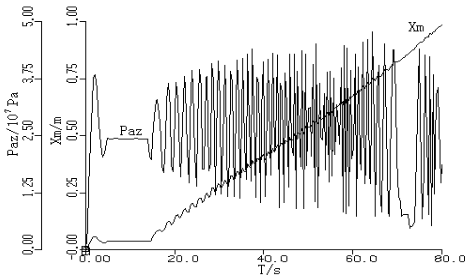

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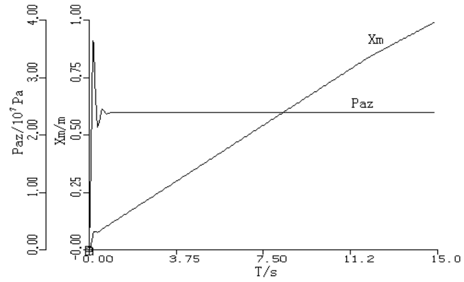

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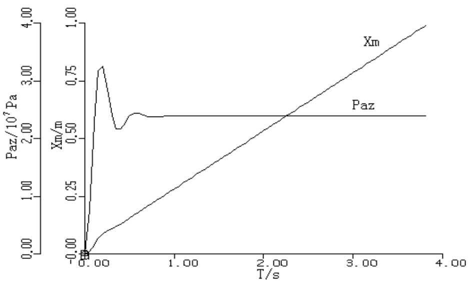

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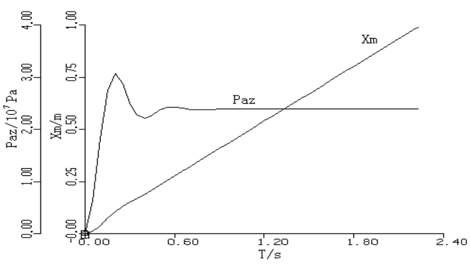

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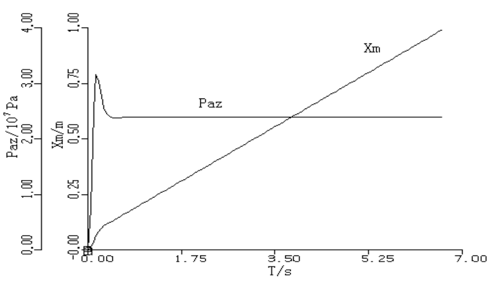

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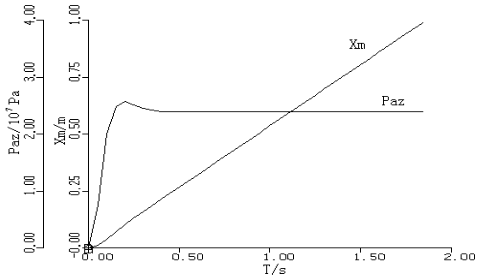

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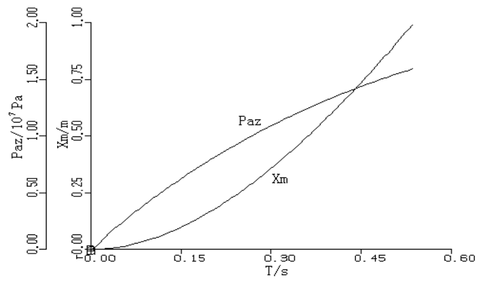

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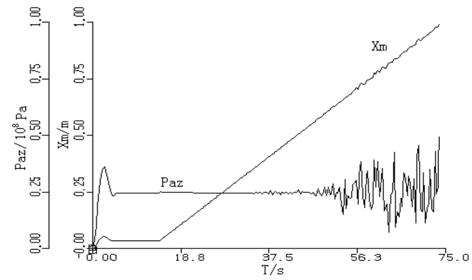

j

Fig. 5 System performance with v23, v39 and v44 set in different states or values(lowering platform with full load)

Table 1 comparison of different working conditions

conditions No:	v39 Set value Mpa	v23 state	v44 set value 10^8 Pa/ (m^3/s)	oil supply start T1/S	oil Supply stop T2/S	used time T/S	Step (S)	caused results
5- a	24.0	t	2.142	12.0	74.06	62.06	0.035	N
5- b	20.0	t	2.142	12.0	73.92	61.92	0.035	C PS
5- c	10.0	t	2.142	12.0	80.11	68.11	0.035	S PS
5- d	20.0	f	2.142		14.80	14.80	0.005	F
5- e	10.0	f	2.142		3.815	3.815	0.005	FQ
5- f	0.0	f	2.142		2.230	2.230	0.005	FQ
5- g	20.0	f	1.0		6.610	6.610	0.005	FQ
5- h	10.0	f	1.0		1.840	1.840	0.005	FQ
5- i	0.0	t	0.2		0.535	0.535	0.0005	FQ
5- j	24.0	t	0.2	12.0	78.16	78.16	0.035	C PS

Where, t—normal state

f—failure state

C—creeping

S—shaking

FQ—falling down quickly

N—working normal

PS—pressure surge in the cylinder

Fig.5-a shows the normal working condition with oil supplied at 12s. Before 12s, there is a weak wave in pressure locus and a small displacement of piston. This is caused by putting on load suddenly and results in oil compression. From fig.5-b to fig.5-c, we can see clearly that if the adjustment pressure of v39 were set too low, the platform would creep down and shake off and the pressure in the cylinder of z-side would surge up and down. In the event of v23 failure, the platform would fall down quickly (see Fig.5-d). If the v23 malfunction took place and v39 adjustment pressure were set too low, dangerous situations would occur (see Fig5-e to Fig5-i). The platform would fall down. If v44 adjustment pressure were set too low, even if v23 and v39 worked in good condition, the platform would creep down and pressure in the cylinder would be fluctuant (see fig.5-j).

5. CONCLUTIONS

According to the simulation results, we can draw some conclusions as the following:

Valve 23, valve 39 and valve 44 play a significant role in the system safety operation. Valve23 should be kept in good condition. It is the key component to prevent plaform falling down. The security and reliability of the system are dependent directly on valve 23, valve39 and valve44 and due attention should be paid to them. The adjustment pressure of valve39 and the orifice of valve44 should regulate according to maintenance instructions and can not change them ad arbitrium.

It is the high pressure surge in the cylinder that results in cylinder bulging and the surge is caused by uneven load due to inclination of the platform or non-synchronization of the 4 power units.

6. GENERAL CRITERIA FOR SYMBOLS

- Upper case English letters are used generally for system variables and coefficients, each being reserved for particular quantities.
- Subscripts are lower case letters or numbers, each reserved for a particular significance.

A. Parameters (coefficients and variables)

A— area
B— bulk modulus of oil
D—difference
F— force
I— inertia
K— general symbol for coefficient
P— pressure
Q—volumetric flowrate; general flowrate variable
R— resistance or resistive effect
S— source; constant or independent variable
T— torque
TF—direct power transformation
V— volume
X— linear displacement

B. Suffixes (all lower case)

a—actuator (cylinder)
c—fluid compliance (compressibility)
e—exhaust
f—friction
k—spring, mechanical compliance
l—leakage
m—linear motion inertia (mass)
r— relief valve
s— supply (port)
t— time
u—coulomb friction
v— valve

- The capital letter T after variables capitalized by Q denotes theoretical flowrate, for example, QplT stands for theoretical volumetric flowrate of the lower pressure pump. The capital letter T or F after logical variables capitalize by "Sv" denotes the solenoid valve is on or off.

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