DESIGN OF LIFTING OPERATION SYSTEM (HYDRAULIC SYSTEM-SPUD CAN JETTING SYSTEM-LEG MECHANISM) AT LIFTBOAT
CASE STUDY L/B CAMERON CLASS 200

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PROBLEM DEFINITION

a. How to design spud can jetting system to ease spud can extraction from seabed before sail preparation of Liftboat with L/B cameron Class 200 as a case study?
b. How leg mechanism is working during the lifting of Liftboat with L/B cameron Class 200 as a case study?
c. How to design hydraulic system for lifting operation of leg/hull body of Liftboat with L/B cameron Class 200 as a case study?

SCOPE OF RESEARCH

a. Selection type of leg and mechanism system using on it and explanation how it work
b. Piping and Instrument diagram of spud can jetting system
c. Piping and Instrument diagram of hydraulic lifting system
d. The stability of liftboat is not investigated in this thesis
e. Ship strength is not investigated in this thesis

OBJECTIVE

a. Selection type of leg and mechanism system of Liftboat with L/B Cameron Class 200 as a case study
b. Design of spudcan jetting system that technically capable for leg lifting preparation of Liftboat with L/B Cameron Class 200 as a case study
c. Design of hydraulic system that technically capable for hull/leg lifting of Liftboat with L/B Cameron Class 200 as a case study
d. Piping and Instrument diagram of hydraulic lifting system and spud can jetting system
METHODOLOGY

Start

Data Collection

Identification and Problem Statement

Literature Review

L/B Cameron Class 200 General Arrangement Redrawing

Rules/statutory/standard Collection

Design of the systems

Input Parameters

Lifting mechanism

Spud can jetting system

Hydraulic jack-up system
1. Selection of lifting mechanism
2.Selection type of legs
3. Explanation of lifting mechanism

1. Selection of Jetting Pump
2. Spud Can Jetting Pressure
3. Pipe, fitting material & instrument
4. Discharge arrangement

1. Selection of Hydraulic Pump along with other instruments
2. Design of hydraulic system pressure
3. Selection of pipes/hoses, fittings and other supporting instruments

Acceptance: technically/classification/statutory

Yes

Final Design

1. Detail Calculation
2. Detail Drawing (P&ID)
3. Technical Spec

Finish

Conclusions

No
INTRODUCTION TO LIFTBOAT

A liftboat, to differentiate with a conventional jackup drilling rig is defined as a self-elevating, self-propelled vessel equipped with at least one crane and with open deck space that can be used for multiple purposes.
Typical Liftboat Component: *(US Patent US 6,523,491 B1)*

- 14. Aft Leg
- 11. Hull
- 42. Horizontal surface
- 16. Spudcan/pad
- 28. Gantry
- 32. Rudder
- 21. Deck
- 43. Inclined Surface
- 45. Rake
- 13. Leg Stbd
- 30. Propeller
- 26. Boom
- 19. Recess
- 25. Crane Support
- 23. Deck House
- 29. Rigging
- 44. Vertical Surface
- 24. Cab
Typical Liftboat Component: *(US Patent US 6,523,491 B1)*

17. Aft Spudcan/pad  
14. Aft Leg  
11. Hull  
23. Deck House  

26. Boom  
21. Deck  
15. PS Spudcan  
16. SB Spudcan  

34. Upper surface  
22. Support Crane  
12. Portside Leg  
12. Starboard Leg
I. DESIGN OF LIFTING MECHANISM

1. Selection type of lifting mechanism which will be used

There are two popular methods in jacking system:

1. Yoke and Pin Jacking System
   A jacking system using yokes with pins, both operated by hydraulic cylinders, to engage with holes on the legs of the liftboat in order to raise or lower the hull in relation to the legs in the elevated condition or to raise or lower the legs in relation to the hull in the afloat condition. *(ABS Guide For Building and Classing Liftboat 2009, Part.4, Chap.4, Sect. 1, 3.7)*

2. Rack and Pinion Jacking System
   A jacking system using climbing pinions, most commonly driven by electric or hydraulic motors through a jacking gearbox, to engage with racks attached to the legs of the unit in order to raise or lower the hull in relation to the legs in the elevated condition or to raise or lower the legs in relation to the hull in the afloat condition *(ABS Guide For Building and Classing Liftboat 2009, Part.4, Chap.4, Sect. 1, 3.5)*
1. Yoke and Pin Jacking System

Based on US Patent 8,425,155 B2:

- Upper Yoke (no.6)
- Lower Yoke (no.7)
- Locking Pin (no.9, 9’)
- Hydraulic Cylinders (no.8)
- Cylinders for Locking Pin (no.10)
- Leg Holes (no.11A-11J)
- Jack House (no.5)
- Leg (3)

How does it work?

The locking pin (9’) at lower yoke (7) engage to leg hole (11D) by cylinder for locking pin (10), in vice locking versa the locking pin (9) at upper yoke in disengaging position.

So when the load of ship weight of take by the lower yoke (7) then the cylinder (8) push the leg (3) downward.

Now the cylinder is fully extend and ready to engage with leg hole (11G) and prepare to take over the load of ship weight.
2. Rack and Pinion Jacking System

A. Based on US Patent 4,655,640:

- Frame (no.14)
- Upper Cross Member (no.28)
- Upright Side Member (no.24, 26)
- Rack (no.16)
- Pinion (no.56, 58)
- Apart Side Cheek (no.50, 54)
- Means of Shaft (no.60)
- Piston Cylinder (no.64, 66, 68, 70)
- Cross Member (no.84)
- Support Frame (no.18)
- Pivot Joint Establishing Pin (no.84, 86, 92, 94)
- Upper Wheel Support (no.34)

How does it work?

One pair of hydraulic cylinders 64, 66 or 68, 70 are retracted and the other pair is extended. As shown in Fig. Elevational View of Jacking System, the piston cylinders 64, 66 are retracted and piston cylinder 68, 70 on extended position.

To lift up the platform (10), lower pinion is locked by the lock element (100) and upper pinion will be unlocked.

Next, the cylinder 64, 66 are retracted while the upper piston (67, 70) is start to extended.

When lower piston cylinder (64, 66) are retracted they will pull the platform (10) upwardly. The upper wheel support (34) is now being move upwardly by the lift force result by lower piston (64, 66).
B. Based on US Patent 6,652,194 B2:

- Tower (no.40)
- Tubular Column (no.27)
- Rack (no.32)
- Piston Cylinder Unit (no.33)
- Engagement / Disengagement Means (no.35)
- Rack Engagement Member (no.34)
- Pivot Attachment (no.33p)
- Chord (no.26)

How does it work?

There are three pairs of piston cylinder units (33a, 33b, 33c) each leg. To provide continuous linear motion, the piston/cylinder units (33a, 33b, 33c) of each set (31) and the engagement and disengagement of their toothed rack engagement means (34) are phased so it their operation will be displaced in time.
C. Based on GustoMSC Rack and Pinion System

- Teeth pinion
- Motor
- Planetary gearbox
- Tubular Column / Leg
- Rack

**How does it work?**

There are two types of power sources for Fixed Jacking Systems, electric and hydraulic. Both systems have the ability to equalize chord loads within each leg. (Bennet & KeppelFELS, 2005)

This type of jacking system is simple, hydraulic system which have hydraulic motor as actuator that will create rotary motion, then control of rotation will be adjust by planetary gear box, planetary gear box connected to pinion in mechanical connection. Rotary motion in pinion will be change to liner motion by rack teeth attached to the leg.

This type is selected
II. DESIGN OF HYDRAULIC JACK-UP SYSTEM

1. Selection of Hydraulic Pump along with other instruments

1. Hydraulic Motor

<table>
<thead>
<tr>
<th>No</th>
<th>Jacking Condition</th>
<th>Vg (cm³/rev)</th>
<th>Motor Displ. (%)</th>
<th>rpm</th>
<th>Pressure (bar)</th>
<th>Motor Torque (Nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Raising hull</td>
<td>31.06</td>
<td>88.75</td>
<td>200</td>
<td>200</td>
<td>84.82</td>
</tr>
<tr>
<td>2</td>
<td>Raising leg</td>
<td>10.08</td>
<td>28.79</td>
<td>300</td>
<td>100</td>
<td>27.52</td>
</tr>
</tbody>
</table>

Specification:

1. Maker: Danfoss series 40 motor, M35 MV
2. Product type: In-line, axial piston, variable, positive displ
3. Rotation: Clockwise (CW) & counterclockwise (CCW)
4. Displacement: 35 cm³/rev
5. System pressure:
   - Rated pressure: 210 bar
   - Max. pressure: 345 bar
2. Hydraulic Pump

<table>
<thead>
<tr>
<th>No</th>
<th>Jacking Condition</th>
<th>Q req 4 units motor (l/min)</th>
<th>Vg (cm³/rev)</th>
<th>rpm</th>
<th>Pump Displ. (%)</th>
<th>Q supply 4 units motor (l/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Raising hull</td>
<td>27.61</td>
<td>41.21</td>
<td>750</td>
<td>89.79</td>
<td>27.82</td>
</tr>
<tr>
<td>2.</td>
<td>Raising leg</td>
<td>13.44</td>
<td>13.44</td>
<td>1200</td>
<td>29.27</td>
<td>14.51</td>
</tr>
</tbody>
</table>

Specification:

1. Maker: Danfoss series 40 pump, M46 PV
2. Product type: In-line, axial piston, variable, positive displ
3. Rotation: Clockwise (CW) & counterclockwise (CCW)
4. Displacement: 45.9 cm³/rev.
5. System pressure: Rated pressure 345 bar, Max. pressure 385 bar

M46
Single and Tandem Axial Piston Pumps
3. Hydraulic Charge Pump

Total charge flow requirements:

1. Leakage Requirement = 29.5 gpm
2. Loop Flushing Requirement = 24 gpm
3. Fluid Compressibility = 9.09 gpm
4. Auxiliary Function = 5 gpm

Total = 67.6 gpm

Specification:

1. Maker: Danfoss Gear Pump Group 3, SNP3.75
2. Product type: Gear pump, positive displ.
3. Displacement: 74.4 cm³/rev.
4. RPM: Min. Speed 600  
         Max. Speed 2500
5. System pressure: Rated pressure 180 bar  
                     Peak pressure 200 bar
4. Hydraulic Brake

- Torque for brake:
  \[ t = \frac{13889.069}{24} \text{ brake units} \]
  \[ = 579 \text{ Nm} \]

- Brake capacity = 120% x Max. brake torque requirement
  \[ = 120\% \times 578.71 \text{ Nm} \]
  \[ = 694.45 \text{ Nm} \]

**Specification:**

**C-Mount Pressure Override Brakes, Modular Design**

**FEATURES**

- Secondary system for service braking with fail-safe backup
- Standard SAE mounting flanges
- Service brake can be modulated with automotive type master cylinder or hydraulic valve
- Oil cooled option for added capacity
- Nitrile case seals
- Compact modular design
5. Hydraulic Jacking Drive

Jack-up drive requirement:
- For jacking
  Torque = 124253.8 Nm = 1099646.1 in-lbs
  Jacking rate = 44.73 Ton = 49.31 S-Ton
- For holding
  Torque = 149114.01 Nm = 1319659 in-lbs
  Holding rate = 59.65 Ton = 65.75 S-Ton

Specification:
1. Maker: Oerlikon Fairfield
2. Model: S130 Jacking Drive
3. Specification:
   - Jacking
     Max. Torque = 1,300,000.00 in-lbs
     Max. Jack rate = 90.00 S-Ton
   - Holding
     Max. Torque = 2,330,000.00 in-lbs
     Max. Holding = 158.00 S-Ton
1. Selection of Jetting Pump

There are two in jacking system:

1. High Pressure Jetting System
   - Flow rate = 25 m³/h
   - Pressure = 80 bar

*(Stability and Operation of Jackups 1993, Page 280)*
2. Low Pressure Jetting System

- Flow rate = 180 m$^3$/h
- Pressure = 12 bar

References:

1. Seajacks Hydra - Specification Sheet
2. Seajacks Kracken - Specification Sheet
3. Seajacks Leviathan - Specification Sheet
4. Seajacks Zarathan - Specification Sheet

Pump Specification:

1. Maker: Hamworthy
2. Model: CGC 125
3. Head: 140 m (max)
4. Capacity: 200 m$^3$/h (max)
5. Type: Centrifugal Pump
2. Discharge Arrangement at Spud Can

6-12 Nozzles (Stability and Operation of Jackups 1993, Page 279)
3. Selection of pipes, fittings and other supporting instruments

1. High Pressure Jetting System
   • Flow rate = 25 m³/h
   • Pressure = 80 bar
   Main Line: 2 1/2” SCH. 80 diameter pipe is selected (ASTM A 53)

2. Low Pressure Jetting System
   • Flow rate = 180 m³/h
   • Pressure = 12 bar
   Main Line: 6” SCH 40 pipe is selected (ASTM A53 Carbon steel seamless)

3. Standard fitting components: strainer, pressure gauge, etc.
<table>
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<tr>
<th>No</th>
<th>Description</th>
<th>Load (%)</th>
<th>Realization (%)</th>
<th>Progress (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Literature Review</td>
<td>20</td>
<td>100</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>General Arrangement Redrawing</td>
<td>5</td>
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<td>5</td>
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<tr>
<td>3</td>
<td>Lifting Mechanism</td>
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<tr>
<td></td>
<td>a. Selection type of lifting mechanism</td>
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<td>5</td>
</tr>
<tr>
<td></td>
<td>b. Selection type of legs</td>
<td>5</td>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>c. Explanation of lifting mechanism process</td>
<td>10</td>
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<td>10</td>
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<tr>
<td>4</td>
<td>Design of Hydraulic Jack-up System</td>
<td>35</td>
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<tr>
<td></td>
<td>a. Selection of Hydraulic Pump along with other instruments</td>
<td>20</td>
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<td>20</td>
</tr>
<tr>
<td></td>
<td>b. Design of hydraulic system pressure</td>
<td>5</td>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>c. Selection of pipes/hoses, fittings and other supporting instruments</td>
<td>10</td>
<td>100</td>
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</tr>
<tr>
<td>5</td>
<td>Design of Spud Can Jetting System</td>
<td>20</td>
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<td>a. Selection of Jetting Pump</td>
<td>5</td>
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<td></td>
<td>b. Discharge Arrangement at Spud Can</td>
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<td>5</td>
</tr>
<tr>
<td></td>
<td>c. Design of Spud Can Jetting Pressure</td>
<td>5</td>
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<td>5</td>
</tr>
<tr>
<td></td>
<td>d. Selection of pipes, fittings and other supporting instruments</td>
<td>5</td>
<td>100</td>
<td>5</td>
</tr>
</tbody>
</table>

Total (%) = 100
CONCLUSIONS AND SUGGESTIONS

1. Conclusion
   a. Rack and pinion type is used as leg mechanism at L/B Cameron Class design
   b. Spudcan jetting system at L/B Cameron Class design at two pipe ring:
      • High pressure: 80 bar @ 25 m3/h
      • Low pressure: 12 bar @ 180 m3/h
   c. Hydraulic jacking system at L/B Cameron Class design at two operating pressure:
      • Lifting hull: 200 bar @ 88.75% motor disp. and 89.79% pump disp.
      • Lifting leg: 100 bar @ 28.79% motor disp. And 29.27% pump disp.
      With configuration each leg: 2 pumps and 8 motors
   d. Main Component P&ID of hydraulic jacking system are hydraulic pump, hydraulic motor, charge pump and hydraulic brake. Main component P&ID of spudcan jetting are high pressure pump and low pressure pump

2. Suggestion
   a. The research with other type of hydraulic system is possible
   b. For those who interest in gear system, the variety in rack and pinion system make the possibility to be used as a research
   c. Research in geotechnical engineering especially in offshore which has relation to spudcan jetting system is only a few, so to make deeper research in this field consultation to the expert is required.
THANK YOU!