Design of Safe, Reliable and Efficient Electro-Hydraulic Systems for Subsea Applications

Wagner Mattos / Alexandre Orth, Bosch Rexroth
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Topics

- The Company
- The Motivation
- The Application
- The Concept
- Further Research
We are the Drive & Control Company

Bosch Rexroth: Part of Bosch-Group

| Bosch-Group                          | • 70.6 billion euros in sales  
<table>
<thead>
<tr>
<th></th>
<th>• 374,778 associates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility Solutions</td>
<td></td>
</tr>
<tr>
<td>• One of the world’s largest suppliers of automotive technology</td>
<td>59% share of sales</td>
</tr>
<tr>
<td>Industrial Technology</td>
<td></td>
</tr>
<tr>
<td>• Leading in drive and control technology, packaging, and process technology</td>
<td></td>
</tr>
<tr>
<td>Energy and Building Technology</td>
<td></td>
</tr>
<tr>
<td>• Leading manufacturer of security technology</td>
<td>41% share of sales</td>
</tr>
<tr>
<td>• Global market leader of energy-efficient heating products and hot-water solutions</td>
<td></td>
</tr>
<tr>
<td>Consumer Goods</td>
<td></td>
</tr>
<tr>
<td>• Leading supplier of power tools and accessories</td>
<td></td>
</tr>
<tr>
<td>• Leading supplier of household appliances</td>
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</table>

Original excerpt Presentation of the Bosch Group | C/CCB; C/CCD | April 2016
We are the Drive & Control Company

Marine & Offshore: Our World
Bosch Rexroth experience with subsea applications

World see depth landscape: 2/3 underwater!!!

- 72% of the worlds surface is covered with water
- About 88% of the ocean is deeper than 1.000 m
- Deepest part of the ocean is in a depth of 10.911 m* (with 1.100 bar)

Source: http://www.ginkgomaps.com/de/ri1w_xx_weltkarte_satbmngtb08_jr_0_a4.pdf
http://de.wikipedia.org/wiki/Erde

* Deepest part of the ocean is Mariana Trench, see red dot
Market sees Subsea as major trend in offshore

Verbatim’s of key stakeholders:

Statoil* - Subsea Factory:
“We are taking subsea longer, deeper and colder … aim to develop the elements required for a subsea factory by 2020.”

Petrobras** - Subsea Prod.:
“Future Perspective: 2030 the production is subsea”
“Pre-Salt fields require new innovative solutions”

DNV GL*** – All Subsea:
“The question for the subsea sector therefore is not whether it will grow, but rather by how much”

➤ The future is subsea...

Source: *Statoil – The Subsea Factory ** Pretobras – Presentation of Mr. Camerini at IEPUC (BR)
*** DNV GL – All Subsea White Paper
Bosch Rexroth experience with subsea applications

Subsea Hydraulic Cylinder

- Rod seals pressure compensated
- Special wiper ring
- Main seal not in contact with seawater
- High-strength bolts protected with cover and seals in order to avoid water penetration

Pressure Compensation:

- Sea water
- Hydraulic oil reservoir
- Spring force 1 bar
- Work pressure

Special (Double) Sealing:

- 23 Control manifolds
- 27 Cylinder axes
- 7 Hydraulic motors
Bosch Rexroth experience with subsea applications

Subsea Hydraulic Power Unit (HPU)
Bosch Rexroth experience with subsea applications

Electro-Hydraulics Controls adapted for Subsea

- Encapsulated manifold, oil filled and pressure compensated
- Sea water resistant seal for cover
- Air has to be vented completely
- Specially developed on-off and prop. valves with modified solenoids, pole tubes and terminal strips
- Sub sea electrical connector
Subsea Technology @ Bosch Rexroth

Topics

The Company

The Motivation

The Application

The Concept

Further Research
Application Subsea Trees & Manifolds

Subsea oil & gas: what that means?

Consequences

- High external pressures (> 300 bar)
- Long distances (> 300 Km)
- Higher weights (big vessels)
- Wave movements (big marine currents)
- Remote control (full automation)
- Corrosive environment
- Explosive atmosphere
- Long service time (30a)


26/10/2016 | Dr. Alexandre Orth (DC-IA/SDM14-Lo) | Marine & Offshore | Project Subsea | © Bosch Rexroth AG 2016. All rights reserved, also regarding any disposal, exploitation, reproduction, editing, distribution, as well as in the event of applications for industrial property rights.
Application Subsea Trees & Manifolds

Subsea equipment landscape

- The main function of the subsea process valve to produce oil or gas:

  - Control volume flow
  - Controlled oil flow
  - Oil flow

<table>
<thead>
<tr>
<th>Energy supply</th>
<th>Transform energy</th>
<th>Control actuated energy</th>
<th>Realize actuation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>Mechanical, Electrical</td>
<td>Mechanical, Hydraulic, Pneumatic</td>
<td>Mechanical, Electrical</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auxiliary energy</td>
<td></td>
<td>Auxilliary energy for actuation control</td>
<td></td>
</tr>
</tbody>
</table>
### Application Subsea Trees & Manifolds

#### Key Requirements & Available Competencies

<table>
<thead>
<tr>
<th>Oil &amp; Gas Production</th>
<th>Offshore Application</th>
<th>Water Depth (&gt; 3,000 m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Process industry (continuous flow)</td>
<td>• Huge dimensions</td>
<td>• High pressures</td>
</tr>
<tr>
<td>• High productivity</td>
<td>• Corrosive environment</td>
<td>• Long distances</td>
</tr>
<tr>
<td>• High availability</td>
<td>• Wave movements</td>
<td>• Low visibility</td>
</tr>
<tr>
<td>• Explosive atmosphere</td>
<td>• Snow crust</td>
<td>• Remote control only (no manual)</td>
</tr>
<tr>
<td>• Earth quake safe</td>
<td>• Ecological system (mussels...)</td>
<td>• New technologies (unknown effects)</td>
</tr>
</tbody>
</table>

Testing Methods | Subsea Experience | Condition Monitoring

**Functional Safety**
- Corporate Research

**Reliability Engineering**
- Bosch Engineering System
- System Availability
Topics

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Self-Contained Hydraulic Actuator - Industry

- Self-contained electro-hydraulic servo axis: suitable for Subsea?

Adjustable mounting

Hydraulic cylinder

IndraDyn servomotor

IndraDrive frequency converter to control the drive

Control block with integrated pump

Optional with:
- Installed digital valve to control pressure or positioning by drive stand stills (with Safety Functions)

Suitable for SAFETY ON BOARD
Force in Gate Valve (Fail-Safe Close):

\[ F_{at} = F_{\text{hydraulic}} - F_{\text{spring}} + F_{\text{sea}} - F_{\text{ingate}} - F_{\text{drag}} - f_f \]
Subsea Technology @ Bosch Rexroth

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Subsea Fluid Study

Types of hydraulic fluids

<table>
<thead>
<tr>
<th>Environment</th>
<th>Industry fluids</th>
<th>Subsea fluids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Water free</td>
<td>Water free</td>
</tr>
<tr>
<td>Organic</td>
<td>Mineral oil</td>
<td>Ester</td>
</tr>
<tr>
<td>Manufactures</td>
<td>M</td>
<td>X</td>
</tr>
<tr>
<td>Type</td>
<td>M1</td>
<td>P1</td>
</tr>
</tbody>
</table>

All these fluids are environmental friendly and approved for application in subsea conditions!
Subsea Fluid Study

Approach based on API 17F / ISO 13628-6

- Theoretical analysis
- Chemical analysis
- Tribological test
- Metals compatibility test
- Sealings compatibility test

Application in prototypes + validation program
We never give up until the right solution is found

Further Information:
www.boschrexroth.com/SUBSEA
www.boschrexroth.com.BR

Thank you for your attention!
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Would you like any additional information? You will find example of applications, systems and components at: www.boschrexroth.com/SUBSEA