SME Mining Conference
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Technical Presentation

“VARIABLE SPEED DIRECT HYDRAULIC DRIVE (DHD) APPLICATIONS AND ITS RECENT TECHNICAL DEVELOPMENTS FOR THE MINING AND BULK MATERIAL HANDLING INDUSTRY”

Presented By
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AGENDA

- Alternatives of LSHT Drives
- The Concept of DHD (Direct Hydraulic Drive)
- Principle of Operation for DHD
- Continuous Technical Development of DHD
- Comparison of Various Drives, Performance, Efficiency, Service life
- Distinct Features and benefits of DHD
- Applications in Mining & Material handling
- Conclusion
Alternatives of Variable Speed Drives

- AC Supply
  - Frequency Control
    - AC Electrical motor
    - DC Electrical motor
  - Fluid Coupling
    - Electrical motor
  - Gearbox
    - Hydraulic Motor
      - Insulated power unit
        - Variable displacement pump
      - L-shape Power unit
        - Variable displacement pump
    - Electrical Motor
  - Driven shaft
    - Gearbox
      - Hydraulic Motor
        - Insulated power unit
          - Variable displacement pump
        - L-shape Power unit
          - Variable displacement pump
      - Electrical Motor
        - AC Supply
Variable Speed Drives Alternatives

1. DC drives with variable speed inverter and gear reducers
2. AC drives with variable speed control unit and gear reducers
3. Direct Hydraulic drives
4. Hydraulic Drive with gear reducers
The Direct Hydraulic Drive consists of:

1. LSHT hydraulic motor
2. Power unit
3. Pipes / flexible hoses
4. Electrical controls
Open Loop & Closed Loop Circuit
1957-Prototype L.S.H.T.

1994-L.S.H.T. Motor
Variable displacement pump - function

- The pump displacement is dictated by an electrical signal.
- The pump flow is controlled by the angle of the swash plate.
Operating Principle

\[ F_T = F_R \times \tan \alpha \]
\[ T = F_T \times R \]

- \( F_R = \text{Piston force} \)
- \( F_N = \text{Normal force} \)
- \( F_T = \text{Tangential force} \)
- \( T = \text{Torque} \)

Cam ring
Cam roller
Pistons
Cylinder block with shrink disc coupling or splines
Oil inlet and outlet
Hydraulic power unit

The power unit supplies fluid to the motor. It is a closed loop hydraulic system.

The hydraulic power unit consists of:

- Electric motor, fixed speed
- Variable displacement pump
- Stainless steel tank
- Air or water/oil cooler
- Filters & Gauges
- Sound insulated cabinet
- Control / Monitoring Box
Continuous development of DHD

- 1960: 130 RPM, 110000 Ft-Lbf
- 1983-1991: 130 RPM, 1000000 Ft-Lbf
- 1994: 400 RPM, 51000 Ft-Lbf
- 1996: Control system, 2002
  - 320 RPM, 206,500 Ft-Lbf
- 2005
  - 100 RPM, 206,500 Ft-Lbf
- 2012: 1,500,000 Ft-Lbf

SME Mining Conference, Denver, CO, USA-Feb 2015 by Ashok Amin, Bosch Rexroth Corporation
Increased Power density by modernization of products
 Technologies from 1991 to 2012 - Increased Power density

- **VIKING 84-ser**
  - In production year: 1972
  - Relative weight: 100%
  - Power density: 0.3 KW/Kg

- **MARATHON MA141**
  - In production year: 1983
  - Relative weight: 57%
  - Power density: 0.4 KW/Kg

- **COMPACT CA140**
  - In production year: 1994
  - Relative weight: 20%
  - Power density: 2.5 KW/Kg

- **Availability and Performance**
  - **L_{100ah} = 20 000 h**
  - **T = 25 000 Nm**
  - **n = 25 rpm**
Technologies from 1991 to 2012 - Increased Power density

MB1150/1600
4.3 Ton

MB2400
6.0 Ton

MB3200
8.0 Ton

MB4000
9.8 Ton

CBM2000
4.1 Ton

CBM3000
5.0 Ton

CBM4000
5.8 Ton

CBM5000
6.7 Ton

CBM6000
7.5 Ton
Technologies from yesterday to today
Increased Power density

Yesterday to today
Comparison of Variable Speed Drives
DC Drives performance

Electric motor with gearbox
VFAC Drives performance

Torque %

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200

Start up - 2 sec

Overload - seconds

Limitations for continuous operation

Overload 1 min/10 min

Forced cooling

Continuous operating range

Ex 1

Ex 2

Speed Hz
Continuous output torque – VFD drive

Dimensioning point of VFD
Example: 70 x 0.9 = 63%

Continuous operation
Speed range 0-100 %

Installed nominal power
VFD
Losses in a 3-stage gearbox

Example; at 50% load and fixed speed

- Total losses = 100%
- 80% of losses at rated load
- 50% output load of rated load (fs=2.0)
Overall efficiency VFD drive

Efficiency Drive Chain:  
Converter  At Rated Data: 97-98%  At Operating Data (50% of rated): 96-97%  
Electrical motor: 95-96%  94-95%  
Gearbox 3-stage planetary, helical: 91-96%  87-93% (depends of gearbox,  
84-90%  79-86%  
Additional Power consumption:  
Cooling & lubrication gearbox: 98-99%  
Forced cooling electrical motor: 98-99%  
Cooling Converter: 99%  
Cooling Converter room: 97-98%  
Summary: 73-82%  
Losses caused by harmonic distortion:  
Electrical motor, cables, electrical filters, transformer 95-99%?  
Overall efficiency: 70-82%
Overall Efficiency

Hydraulic motor + planetary gearbox versus Direct Hydraulic Drive

High speed motor + planetary gear
\[ \eta_{\text{total motor}} = 93\% \]
\[ \eta_{\text{total gear}} = 91\% \text{ (3-stage at rated data)} \]
\[ \eta_{\text{total}} = 85\% \text{ (at rated data for gearbox)} \]

Medium speed motor + planetary gear
\[ \eta_{\text{total motor}} = 93\% \]
\[ \eta_{\text{total gear}} = 97\% \text{ (1-stage at rated data)} \]
\[ \eta_{\text{total}} = 90\% \text{ (at rated data for gearbox)} \]

Hydraulic Direct Drive
\[ \eta_{\text{total motor}} = 95-96\% \]
Service life
Bearing rated life according to ISO 281

1962: Basic rating life, L_{10h}: Operating conditions has not been taken into account

1977: Adjusted rating life, L_{10ah}: Lubrication conditions has been taken into account

2000: Modified rating life, L_{10aah}: Lubrication conditions, fatigue limit and contamination has been taken into account. (SKF use this theory since 1989).
Service life of a Gearbox

The service life depends on:

- Type of application
- Service factor
- Thermal rating of gearbox
- Oil temperature and viscosity
- Cleanliness of oil
- Water content in oil
- Wear
Service life of a Hydraulic Drive

The service life depends on:

- Torque/pressure and speed
- Oil temperature and viscosity
- Cleanliness of oil
- Water content in oil
- Wear
Comparison of service life

- Service life of LSHT motors are based on $L_{10ah}$ or $L_{10aah}$
- Service life of gearboxes are normally based on $L_{10}$
- The gearbox $L_{10}$ and Hägglunds $L_{10aah}$ cannot be compared to each other as reduction factors according to ISO 281 not are used in the gearbox $L_{10}$ calculation
Features of Direct Hydraulic Drive

Versatile mounting, *Possibilities to optimize the machine design*

- Torque arm mounted motor
- Bracket mounted motor
- Flange mounted motors with splines

With shrink disc coupling.
With flange adapter.
With splines.
With stub shaft.

Low radial load on driven shaft.
High radial load \((Fr)\) on driven shaft.
Through hole for cooling of driven machine.

Torque arm mounted motor
Bracket mounted motor
Flange mounted motors with splines
Features of Direct Hydraulic Drive

Low Moment of Inertia for the Drive

A hydraulic direct drive has less than 1 % of the moment of inertia on an equivalent Electro-mechanical drive.
Calculation example; Hydraulic Direct Drive

Torque generated by the LSHT hydraulic motor:
\[ T = 18.3 \times \frac{2\pi \times 1470}{60 \times 0.083} = 462 \text{ Nm (driven shaft)} \]

Torque generated by the Moment of Inertia of the hydraulic motor is only 0.7% of the hydraulic motor rated torque (70000 Nm).

The supplementary stresses caused by the Moment of Inertia of the drive motor are 813 times higher for an Electrical motor with a gearbox compared to a Hydraulic Direct Drive!
Features of Direct Hydraulic Drive

**Soft start**

- Step less Acceleration and Deceleration
- Soft start, reducing the stresses on the driven equipments
Features of Direct Hydraulic Drive

**Accurate torque response**

- The Hydraulic Drive can operate at nearly constant torque throughout the speed range.
- The Hydraulic Drive can accurately limit the maximum torque of the system.
Features of Direct Hydraulic Drive

**Shock load protection**

- The low inertia ensures that the maximum torque is not exceeded.
- Peak loads are limited by the fast acting pressure limitation in the system.

![Graph showing torque and pressure over time](image.png)
Features of Direct Hydraulic Drive

Four Quadrant drive

- Driving reverse
- Driving forward
- Braking reverse
- Braking forward

Maximum torque available
Maximum speed available
Installed power

Speed
Torque

Features of Direct Hydraulic Drive

- Four Quadrant drive
- Driving reverse
- Driving forward
- Braking reverse
- Braking forward

Maximum torque available
Maximum speed available
Installed power

Speed
Torque
Load sharing

- The hydraulic motors are supplied from a common hydraulic system
- Load is balanced by fluid pressure
- Multiple pumps or motors provides flexible combination.
Features of Direct Hydraulic Drive

Weight reduction

- The Hydraulic motor has much less weight than an equivalent Electro-mechanical drive solution
- The power pack can be installed remotely from the motor
- Less weight of the drive means reduced stress on the boom
Features of Direct Hydraulic Drive

Unlimited starts & stops without any problems.
Features of Direct Hydraulic Drive

Space saving & Simple to install
Features of Direct Hydraulic Drive

Reduced electrical load

- Stops & starts can be achieved without effecting E motor status
- Each E motor starts in turn in an unloaded condition (pumps at zero)
- Modular Concept – Use of LT Motors in place of HT
- Great flexibility - reduced starting current requirement
Drive Log Data for DHD

Shows how long time a **preset** parameter have been within two limit values

**Selectable log channel readings:**
- Speed
- Pressure
- E-motor power
- Temperature
- Speed set point
- System internal signals (stroke current, error signal etc.)
## Drive Log from Control Box

### Alarm Drive 1

<table>
<thead>
<tr>
<th>Drive No.</th>
<th>Timestamp</th>
<th>Alarm Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>000211 07:38</td>
<td>MAX TEMP</td>
</tr>
<tr>
<td>2</td>
<td>000211 07:38</td>
<td>SUCTION LINE</td>
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<tr>
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<td>000211 07:38</td>
<td>CHARGE PRESSURE</td>
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<td>4</td>
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<tr>
<td>5</td>
<td>000128 14:06</td>
<td>CHARGE PRESSURE</td>
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<td>6</td>
<td>000128 14:06</td>
<td>MIN OIL LEVEL</td>
</tr>
<tr>
<td>7</td>
<td>000126 13:39</td>
<td>CHARGE PRESSURE</td>
</tr>
<tr>
<td>8</td>
<td>000126 13:39</td>
<td>MAX TEMP</td>
</tr>
<tr>
<td>9</td>
<td>000126 13:39</td>
<td>MIN OIL LEVEL</td>
</tr>
<tr>
<td>10</td>
<td>000126 13:39</td>
<td>SUCTION LINE</td>
</tr>
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### Alarm Drive 2

<table>
<thead>
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<th>Timestamp</th>
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<tbody>
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<td>MIN OIL LEVEL</td>
</tr>
<tr>
<td>6</td>
<td>991214 10:57</td>
<td>MAX TEMP</td>
</tr>
<tr>
<td>7</td>
<td>991214 10:57</td>
<td>MIN OIL LEVEL</td>
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<tr>
<td>8</td>
<td>991214 07:48</td>
<td>MAX TEMP</td>
</tr>
<tr>
<td>9</td>
<td>991214 07:48</td>
<td>MIN OIL LEVEL</td>
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<tr>
<td>10</td>
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<td>0</td>
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<tr>
<td>1</td>
<td>000211 07:38</td>
<td>RETURN FILTER</td>
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<tr>
<td>2</td>
<td>000211 07:38</td>
<td>DRAIN FILTER</td>
</tr>
<tr>
<td>3</td>
<td>000211 07:38</td>
<td>LOW OIL LEVEL</td>
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</table>
Remote Logging & Monitoring System
Early Warning Prediction

Customer

Control Box

Pressures

Temperature

Speed
Self Contained-TADS Torque Arm Drive Systems
For Low speed Low power Below 125 HP
Torque Arm Drive System for Feeders
Self Contained Complete drive
100,000 Ft-Lbf, 75 Hp, 0-8 RPM
Typical apron feeder & Two roll crusher installation
Applications for DHD, BWR

- Long travel Drive
- Bucket Wheel Drive
- Boom Conveyor
- Slewing Drive
- Long travel Drive
Slewing Drive for BWR Drives
Power PLANT Coal blending  Conveyor Drives
Screw Feeder Drive, for Bulk Material Handling
Belt Feeder – Collahausi Chile

Motor: 2 x CB 840
Power: 2 x 104 kW
Scrubber Drum drives 800 hp, 0-11 rpm
4400 TPH Limestone washing dirt
2 ROLL CRUSHER, Direct Drive

2 X LSHT DHD, 4 X 600 HP, 0 -27 RPM
4400 TPH.
Bucket Wheel Drive

Before
(Electro-Mech. Drive)

After
(Direct Hydraulic Drive)
Conveyor Drive Drive upto 3500 kW
Long Travel Drive for BWR
Before
(Electro-Mechanical Drive)
After
(Direct Hydraulic Drive)
Conclusion

- Today’s demanding mining industry can benefit from this Direct Hydraulic Drive DHD for following:

1. Apply the long term experience from Mining and material handling plants, ports and many industrial sectors like Pulp & Paper, Cement, Chemical, Rubber and so on
2. Improve reliability & productivity
3. Reduce down time, maintenance & life cycle cost.
4. Provide more flexibility for future expansion
Where can we apply DHD?

- Conveyor & Feeder Drives
- Bucket Wheel Reclaimers
- Bucket Wheel Excavators
  - Low speed crushers
- Wagon Tipplers & Side Arm Charger
  - Drum & Kiln Drives
- Ball Mill Drives & Inching Drives
- Roller Mills & Pulverizers
  - Surface Miners
  - Thickeners
- Slewing
Thank You!

Questions?

I will be also available throughout this conference and Exhibit hall area