Servo Direct drive for Hydraulic Machines

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Servo Direct Drive for Hydraulic Machines

What is Servo Direct Drive hydraulic?

Servo direct drive is a new method of controlling the motion (speed and position) and pressure of a hydraulic machine using a hydraulic pump(s) connected directly to servo motor as the method of control.

Because the servo motor has the ability to provide high torque at low RPM’s, the machine can provide high tonnage at nearly any speed.

Servo direct drive eliminates the need for most hydraulic valves in the system.
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- Large Servo Motor
- Fixed displacement hydraulic pump
- Control system
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Conventional Hydraulic drive

- Direct Drive
- Many valves to control motion and pressure
- Speed/Pressure control through valves, variable pumps.
- Motors always turning
- Elaborate safety circuits to protect man/machine
Servo Direct Drive Characteristics:

- Servo motors directly coupled to pumps
- Pumps may be “ganged”
- Elimination of swiveling in pumps as servo motors control the motion and pump volume
- Elimination of almost all valves
- Pressure controlled with transducers/motor control system.
- Positional control with encoders
- Automatic parallelism control
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Parts of a typical Servo Direct Drive system

- Linear Encoder in Ram or cylinder
- Blocking valve
- Pressure Transducer
- S120 drive system
- Rotary encoder
- Servo motor
- Hydraulic pump

Block diagram of the servo pump with SINAMICS S120
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DCC-Application / PID-Technology: controller reaction
Speed and pressure traces

Example trace of a set pressure step inputs

Controller works in positive and negative directions (turning pump backwards to diminish pressure)

Overshoot can be diminished / eliminated

![Graph showing speed and pressure traces](image-url)
First Advantage of Servo Direct Drive is:

Energy Efficiency:

Lower power consumption by the Machine to produce the same Amount of forming.

Lower power consumption to Remove heat from the hydraulic Oil.

Only generates the pressure required to carry out the movement.
Energy Cycle

- As ram is falling, speed is controlled by servo motor through regenerative braking.
- Power gained is stored in capacitors of the drive system and used for lifting.
- Power can also be used for generating pressure in the pressing cycle.
- Decompression of the system is accomplished through regenerative braking.
- Power is used for lifting.
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Example of energy efficiency using Servo Direct Drive vs conventional direct drive with proportional control

Two 800 Ton presses running identical products

<table>
<thead>
<tr>
<th></th>
<th>Press 1 Direct drive</th>
<th>Press 2 (Servo direct drive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of measurements</td>
<td>23.10.12</td>
<td>28.10.12</td>
</tr>
<tr>
<td>Period [min]</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Stroke rate [1/min]</td>
<td>28,5</td>
<td>40</td>
</tr>
<tr>
<td>Parts produced [-]</td>
<td>850</td>
<td>1200</td>
</tr>
<tr>
<td>Peak Power [kW]</td>
<td>265</td>
<td>225</td>
</tr>
<tr>
<td>cos φ (average)</td>
<td>0,65</td>
<td>0,93</td>
</tr>
<tr>
<td>Energy consumption total [kWh]</td>
<td>95</td>
<td>84</td>
</tr>
<tr>
<td>Energy consumption/part [Wh/part]</td>
<td>111</td>
<td>70</td>
</tr>
<tr>
<td>Average oil temperature [°C]</td>
<td>57</td>
<td>41</td>
</tr>
</tbody>
</table>

36.9 % less energy/part

SOP: November 2012
Counter: 11.648.797 strokes 16.01.2014
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Observations:

- Average oil temperature approx. 41°C
- 50% less demand for cooling water
- Motor temperature 56 / 75°C
- No indication of wear in oil samples
- Standard press 95 kW
- Servo Press 84 kW

Comparison of Energy Consumption:

- 30 minute running time
- Standard press in red
- Servo-press green
- Standard press at 28 SPM
- Servo press at 40 SPM
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2\textsuperscript{nd} advantage of Servo Direct drive:

Faster decompression of cylinder resulting in:

\begin{itemize}
  \item Less dwell time at bottom
  \item Less hot contact time of tool
  \item Faster cycle time
\end{itemize}
Lower Dwell time at BDC

- Pressing cycle Servo motors turn pump to make pressure
- NC controller finds accurate Bottom dead center position
- Servo motor stops in position
- Pump then acts like a motor turning servo motor backwards to release compression of oil and frame stretch
- Faster decompression than with traditional poppet valves
- Servo opening of filling valve
- Lifting of the ram by separate servo motor.
- Reduction of dwell
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3rd advantage to Servo direct drive
Very High Dynamic Response

- Servo motors have high torque capability
- NC control systems have fast update speeds
- Servo direct drive has a very high dynamic response
- Allows updating of speed and positioning in very quick increments
- Allowed the construction of a high speed preforming press
- Servo pumps adjust the closed position of the press
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Hydraulic Preforming machine

- Up to 250 Strokes/minute
- Synchronized servo electric manipulator
- Preforming tapered air foil product
- Servo pumps add oil to circuit to close distance between moving rams
- Servo pumps remove oil between moving rams to open distance between rams
- Thickness changes occur in .12 seconds
- Tapers and features are able to be programmed into the run
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4th Advantage of Servo Direct Drive
Very great ability to synchronize axes

- Because pumps are directly connected to cylinders each cylinder position can be carefully controlled.
- One cylinder is selected to be the master
- All other cylinders are selected to be slaves
- Positional transducers detect the position of one cylinder or axis to another
- The slaves speed up or slow down to keep the relationship between the master axis and it’s position.
- Can be used for auto parallelism control across ram
- Can be used for multi-axis presses
- Can be synchronized between Electro-mechanical and hydraulic axes
**Challenge: Off-center loading or shifting loading**

- Precise forging requires close guidance of moving rams
- High levels of off-center loading creates high guide/gib pressure
- Servo direct drive can control off center or shifting load center by using master/slave sequence.
- High accuracy with very little change in ram speed. (High dynamic compensation)
- Guides for the ram are theoretically not necessary, but practically can be greatly reduced.
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Example: Multi axis Horizontal Forging Press

- 18 pressing axes
- 12 servo auxiliary axes
- Total Pressing power approx. 32,000 M-Tons
- Rams weigh in excess of 120 tons each
- Positioning capability over 60 inch stroke approx. 0.015”
- Synchronization of axes within 0.015”
- Practically no power consumption when the rams are not physically moving.
Example: Flexible multi-axis press

- 315 Ton vertical ram
- (2)- 200 ton side rams
- Ability to add extra axes.
- Main ram for clamping/forming
- Side rams synchronized
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- Heated workpiece is loaded into the die
- Main ram closes, forms workpiece and makes clamping pressure.
- Clamping pressure can be programmed and held with servo motor
- Side rams can be synchronized through pressure or position.
- Synchronization through pressure balances load across tooling.
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Example: Servo direct drive ejection system

- Synchronized to the position of the ram
- Responsiveness of servo motor/pump reduces or eliminates recoil
- Accurate stopping positions for top and bottom
- Fully programmable for speed and timing
Example: Servo Direct drive for a 1000 Ton Press

- 4 large servo motors
- 8 fixed displacement axial piston hydraulic pumps
- Only small blocking valves to prevent motion when press stopped
- No large manifold blocks
- Ram motion synchronized to a drawing cushion
- Drawing cushion uses Servo direct drive to hold constant force
- Power generated by cushion is used to make press force
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Some applications where Servo direct drive is being used today

- Forging presses
- Stamping presses
- Die Casting machines
- Fine blanking presses
- Plastic injection molding presses
- Elevators
- Glass presses
Advantages of Servo Direct drive:
- Lower power consumption
- Quick decompression/lower contact time
- High dynamic response/accuracy
- Programmable motion
- Ability to synchronize with other axes
- Scalable to any size
- Less complicated hydraulic circuit
- Inherently safe
- Less stringent oil quality requirements
- Smaller reservoir size

Disadvantages of Servo direct drive:
- New technology/training of technicians
- Higher upfront cost
Questions?

Thank You

Mike Gill