Example of Hydraulic Brake
Hydraulics

- Generation of forces and motion using hydraulic fluids
- Hydraulic fluid used as medium for power transmission
- Application areas
  - Marine
  - Mining
  - Aircraft
Hydraulic Cylinder and Piston

Cut-away View

Section View

Sealing Components
Rod Seal
Chrome Plated Rod
Air bleed
Wearband
Piston seal
Rod cartridge
Wearband
Piston
Rod seal
Rod wiper
Hydraulic Force Transmission
<table>
<thead>
<tr>
<th></th>
<th>Electricity</th>
<th>Hydraulics</th>
<th>Pneumatics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Leakage</strong></td>
<td></td>
<td>Contamination</td>
<td>No disadvantages apart from energy loss</td>
</tr>
<tr>
<td><strong>Environmental influences</strong></td>
<td>Risk of explosion in certain areas, insensitive to temperature.</td>
<td>Sensitive in case of temperature fluctuation, risk of fire in case of leakage.</td>
<td>Explosion-proof, insensitive to temperature.</td>
</tr>
<tr>
<td><strong>Energy storage</strong></td>
<td>Difficult, only in small quantities using batteries.</td>
<td>Limited, with the help of gases.</td>
<td>Easy</td>
</tr>
<tr>
<td><strong>Energy transmission</strong></td>
<td>Unlimited with power loss.</td>
<td>Up to 100 m, flow rate ( v = 2 - 6 \text{ m/s} ), signal speed up to 1000 m/s.</td>
<td>Up to 1000 m, flow rate ( v = 20 - 40 \text{ m/s} ), signal speed 20 - 40 m/s.</td>
</tr>
<tr>
<td><strong>Operating speed</strong></td>
<td>( v = 0.5 \text{ m/s} )</td>
<td>( v = 1.5 \text{ m/s} )</td>
<td></td>
</tr>
<tr>
<td><strong>Power supply costs</strong></td>
<td>Low</td>
<td>High</td>
<td>Very high</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Linear motion</strong></td>
<td>Difficult and expensive, small forces, speed regulation only possible at great cost</td>
<td>Simple using cylinders, good speed control, very large forces.</td>
<td>Simple using cylinders, limited forces, speed extremely, load-dependent.</td>
</tr>
<tr>
<td><strong>Rotary motion</strong></td>
<td>Simple and powerful.</td>
<td>Simple, high turning moment, low speed.</td>
<td>Simple, inefficient, high speed.</td>
</tr>
<tr>
<td><strong>Positioning accuracy</strong></td>
<td>Precision to ±1 ( \mu \text{m} ) and easier to achieve</td>
<td>Precision of up to ±1 ( \mu \text{m} ) can be achieved depending on expenditure.</td>
<td>Without load change precision of 1/10 mm possible.</td>
</tr>
<tr>
<td><strong>Stability</strong></td>
<td>Very good values can be achieved using mechanical links.</td>
<td>High, since oil is almost incompressible, in addition, the pressure level is considerably higher than for pneumatics.</td>
<td>Low, air is compressible.</td>
</tr>
<tr>
<td><strong>Forces</strong></td>
<td>Not overloadable. Poor efficiency due to downstream mechanical elements. Very high forces can be realized.</td>
<td>Protected against overload, with high system pressure of up to 600 bar, very large forces can be generated ( F &lt; 3000 \text{ kN} ).</td>
<td>Protected against overload, forces limited by pneumatic pressure and cylinder diameter ( F &lt; 30 \text{ kN} ) at 6 bar.</td>
</tr>
</tbody>
</table>
Laminar Vs Turbulent Flow

- Laminar flow fluid moves through pipe in ordered cylindrical layers
- In turbulent flow the fluid ceases to flow in ordered layers and form eddies

Reynolds Number

\[ \text{Re} = \frac{v \cdot d}{\nu} \]

- \( v \): flow velocity (m/s)
- \( d \): Pipe diameter (m)
- \( \nu \): Kinematic viscosity (m\(^2\)s\(^{-1}\))

Laminar flow: \( \text{Re} < 2300 \)
Turbulent flow: \( \text{Re} < 2300 \)
Components of Hydraulic System

- Pumps
- Valves
- Accumulators
- Actuators
- Reservoir
Pumps

- A hydraulic pump is a mechanical source of power
  - Converts mechanical power into hydraulic energy (hydrostatic energy i.e., flow, pressure)

- Types of Pumps
  - Vane pump
  - Gear Pump
  - Axial Piston Pump
Vane Pump
Gear Pump

External Gear Pump

Internal Gear Pump
Axial Piston Pump
Symbolic Representation of Pump

**Hydraulic pumps with fixed displacement**

- with one flow direction
- with two flow directions

**Hydraulic motors with fixed displacement**

- with single direction of rotation
- with two directions of rotation
Valves

- To change flow direction (Direction Control)
- To change flow rate (Flow Control)
- Change fluid pressure (Pressure Control)

Simplest example of valve is your basin tap

What does that do among above three?
Direction Control (DC) Valve

Check Valve
Direction Control (DC) Valve

Pilot Operated Valve
Direction Control Valve

- Spool can be placed
  - Manually
  - Mechanically
  - Pilot pressure
  - Electrical solenoid
Symbolic Representation of Valves

- **Number of ports**
  - **Number of switching positions**

- **2/2-way valve**
  - Port designations:
    - P: pressure port
    - T: return port
    - A: power ports
    - L: leakage oil

- **3/2-way valve**
  - Port designations:
    - P: pressure port
    - T: return port
    - A: power ports
    - L: leakage oil

- **4/2-way valve**
  - Port designations:
    - P: pressure port
    - T: return port
    - A: power ports
    - L: leakage oil

- **4/3-way valve**
Direction Control Valve

Two-Way Valve
Direction Control Valve

Four-Way Valve

PRESSURE TO "B"
"A" TO TANK

PRESSURE TO "A"
"B" TO TANK
Manually Actuated 4/3 Valve
Air Pilot Actuated 4/3 Way Valve

Air introduced through this passage pushes against the piston which shifts the spool to the right.

Centering washers.

Springs push against centering washers to center the spool when no air is applied.

Pistons seal the air chamber from the hydraulic chamber.
Solenoid Actuated DC Valve
**Flow Control Valve**

- Used to reduce the speed of cylinder or rpm of motor
- Functions
  - Flow control
  - Flow regulating

<table>
<thead>
<tr>
<th>Needle restrictor</th>
<th>Increase in velocity, high friction owing to long throttling path</th>
<th>Considerable owing to high friction</th>
<th>Excessive cross-sectional enlargement with a short adjustment travel, unfavourable ratio area to control surface</th>
<th>Economical, simple design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circumferential restrictor</td>
<td>As above</td>
<td>As above, but lower than for the needle restrictor</td>
<td>Steadier cross-sectional enlargement, even ratio area to control surface, total adjustment travel only 90°.</td>
<td>Economical, simple design, more complicated than the needle restrictor</td>
</tr>
</tbody>
</table>

Festo
<table>
<thead>
<tr>
<th>Restrictor Type</th>
<th>Function</th>
<th>Gap</th>
<th>Note</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal restrictor</td>
<td>As above</td>
<td></td>
<td>As above, however sensitive adjustment owing to long adjustment travel</td>
<td>Festo</td>
</tr>
<tr>
<td>Gap restrictor</td>
<td>Main part: increase in velocity, low friction, short throttling path</td>
<td>Low</td>
<td>Unfavourable, even cross-sectional enlargement, adjustment travel of $180^\circ$</td>
<td>Economical</td>
</tr>
<tr>
<td>Gap restrictor with helix</td>
<td>Increase in velocity, maximum friction</td>
<td>Independent</td>
<td>Sensitive, even cross-sectional enlargement, adjustment travel of $360^\circ$</td>
<td>Expensive to produce helix</td>
</tr>
</tbody>
</table>
Flow Control Valve
Pressure Relief Valve
Linear Hydraulic Cylinders

(a) SCHEMATIC REPRESENTATION

(b) SYMBOLIC REPRESENTATION
Hydraulic Circuit Design

- Single acting cylinder

Two position three way manually controlled dc valve

- Single acting cylinder

- Pressure relief

- Pump

- Strainer

- Reservoir
Hydraulic Circuit Design

- Double acting cylinder

Three position four way manually controlled dc valve
Hydraulic Circuit Design

- Regenerative Circuit
Drilling Machine Example

- Spring centered position: Rapid Advance
- Left envelope: Slow feed
- Right envelope: Retracts piston