HRB – Hydrostatic Regenerative Braking System
The Hydraulic Hybrid Drive from Bosch Rexroth

and

Hydrostatic Fan Drive in Vehicles

Mauro Silva – DCBR/Mobil Sales
Within The Bosch Group

Bosch Group
Revenue: 38,2 Bill. euros
Associates on Jan. 1, 2010: 270,687

Automobile Technology

Industrial Technology

Consumer Goods and Building Services Eng.

Bosch Rexroth
Drive and Control Techn.
Revenue: 4,146 Bill. Euros
Associates 2009: 34,225

Packaging Technology

Solar Energy
The Workshop

HRB and Fan Drive
HRB and Fan Drive
### Comparison E-Hybrid vs. HRB

#### Energy density
- **Battery**: 10 - 100 Wh/kg
- **Ultracaps**: 1 - 10 Wh/kg
- **Hydr. Accumulator**: 0.2 - 5 Wh/kg

#### Power density
- **Battery**: 10 - 300 W/kg
- **Ultracaps**: 200 - 4000 W/kg
- **Hydr. Accumulator**: 2000 – 300 000 W/kg (Depends on diameter of opening)

- **High energy density**
- **High specific power density**
Storage Loading Speed vs. Brake Energy

**Refuse Truck**
25 to, 10 km/h, 1,5 m/s²

Only the **hydraulic accumulator** is sufficient fast to absorb the complete breaking energy.

**Delivery Vehicle**
7 to, 30 km/h, 2,5 m/s²

The **hydraulic accumulator** is suitable and the **lithium battery** can largely recover the braking energy.

**Passenger Car**
1,5 to, 50 km/h, 2 m/s²

The **Lithium Battery** fits well, however the **lead battery** is never sufficient to recover a part of the braking energy.

---

Hydraulic Bladder Accumulator, Lithium Battery, Lead Battery and **real Breaking Energy**
System Components:

- **P/M** Pump/Motor Unit
- **C** Clutch
- **SHP** High Pressure Accumulator
- **G** Gearbox
- **V** Valveblock
- **HCU** Hybrid Control Unit
| Parallel – HRB System |

APU (A4VSO)  
210 ccm; Pmax: 250 kW; Tmax: 1100 Nm

HRB-Gearboxratio:  
3.21; 2.2; 1.5

Accumulator:  
2 x 32 l, pmax: 325 bar, ca. 550 kJ/0.15 kWh

Weight HRB:  
500 kg

HRB operation range  
0…50 km/h
Driver activates HRB by button or lever
acceleration pedal is released HRB engages & disengages engine
Axial Piston Unit (APU) charges accumulator
Braking torque is controlled by APU’s displacement.
acceleration pedal is pushed
Accelerating with the HRB

accumulator discharges via Axial Piston Unit (APU)
Drive torque is controlled by APU’s displacement and supplemented by engine if necessary.
HRB disengages when accumulator is discharged
Test vehicles in 2009 / 2010

- MAN TGM (Germany)
- MAN TGS (Germany)
- Crane Carrier LET2 (USA)

Quelle Grafiken: media.daimler.com; MAN MediaCenter
Benefits of HRB – confirmed in Practical Tests

- Actual test confirms fuel savings of up to 25% and lower emissions
- Reduction in brake wear app. 50%
- High power density of the hydraulic accumulator
- Great cost advantage (Hydraulic vs. Electric) at the same fuel efficiency
- Long lifetime, high level of ruggedness (HRB-System lifetime = vehicle lifetime)
- Well known maintenance and servicing requirements
- The HRB-System consist of Million-fold tested components
- Simple, reliable operation means high driver acceptance
- No deceleration during shifting → Increased drive comfort

HRB from Bosch Rexroth tested by the Independent German Automobile Association

During the test runs, performed under daily refuse truck conditions, the hybrid drive HRB from Bosch Rexroth shows an fuel savings between 13-28% and a significant break wear reduction. The HRB system shows the highest potential with short distances between stops and a slight uphill grade because it is then possible to drive the vehicle via the hybrid drive.
Carsten Mielke, Head of Department for Transport in Kassel, Germany:

“Our refuse collection vehicles consume clearly less diesel fuel than vehicles without HRB. Over an entire route we are seeing savings from 15 to 18 percent. This is enough to justify the acquisition of additional vehicles with the hydraulic hybrid.”

First customer feedback:

| History |
|---|---|
| 06 / 2008 | started with the first prototype testings in Berlin and New York |
| 09 / 2008 | presentation on IAA commercial vehicle 2008 |
| 03 / 2009 | availability of HRB for further prototype vehicles |
| 08 / 2010 | final TÜV (German technical inspection agency) certification |
| 10 / 2010 | over 15 vehicles in 4 countries on the streets |
| 10 / 2010 | start of series production |
HRB and Fan Drive
Fan Drive Applications

Applications

- Mobil Cranes
- Buses
- Wheel Loader
- Carrier Trucks
- Dumper
- Locomotives
- Excavators
- Harvester
Fan Drive control systems

Control systems

**Hydrostatic fan drives**

- **hydro - mechanical control**
  - constant system
    - External gear pump
    - External gear motor
    - Thermal relief valve
    - Priority valve
  - variable displ. system
    - Axial piston pump
    - Axial piston motor
    - Thermal relief valve

- **electro - hydraulic control**
  - constant system
    - External gear pump
    - External gear motor
    - Electronics
    - Temperature sensors
  - variable displ. system
    - Axial piston pump
    - Axial piston motor
    - Electronics
    - Temperatur sensors
Fan Drive control systems
Fan Drive control systems

- Direct linkage between fan speed and engine speed
- 3-step linkage between fan speed and engine speed
- Fan speed is independent of the engine speed
- Stepless variable fan speed from minimum to maximum
- Additional power supplied at lower engine speed

### Diesel Engine Speed [rpm]

- Limited fan power at lower engine speed
- Limited fan power at lower engine speed
- Limited fan power at lower engine speed

### Fan Speed Diagram

- Fan speed is independent of the engine speed
- Stepless variable fan speed from minimum to maximum
- Additional power supplied at lower engine speed
Hydromechanical Control / Constant System

Advantages of the system:

- radiator can be positioned independently of the engine
- short overall length of the gear pump
- good price/performance ratio
- infinitely variable fan speed, from minimum to maximum, if permitted by oil flow from the external gear pump
- low weight

External gear pump
AZPF
Size 4 ... 28 cc

External gear motor
AZMF
Size 8 ... 28 cc

Priority valve LPS
Thermo relief valve MHDBDT
Hydromechanical Control / Variable System

Advantages of the system:

- radiator can be positioned independently of the engine
- infinitely variable fan speed from minimum to maximum
- drive power of the variable displacement pump corresponds with the required fan power
- no throttling losses
- fan speed is largely independent of the engine speed
- lower fuel consumption
Advantages of the system:

- variable fan speed control
- fan speed is largely independent of the engine speed
- direction and weighting of several operating parameters
- minimum throttling losses
- Fail-safe function
- reduced power consumption

External Gear Pump
AZPF
size 8 ... 28 cc

External Gear Motor
AZMF
size 8 ... 28 cc

BODAS Control Unit RC 2-2/2x
PTC - Temperature Sensor for Air / Water
Electroproport. Control / Variable Displacement

Advantages of the system:

- infinitely variable fan speed from minimum to maximum
- fan speed is largely independent of the engine speed
- direction and weighting of several operating parameters
- high control quality
- no throttling losses
- Fail-safe function
- lower fuel consumption
**Summary**

*Hydraulic control* is used in configuration simple systems, i.e. typically for measuring one or two temperatures of fluids.

- fixed pump system or
- Variable displacement system

*Electronic control* permits the configuration of complex systems, covering several gas / fluid temperatures and switching signals.

- fixed pump system or
- Variable displacement system

---

`hydraulic control ➞ simple systems`

`electronic control ➞ complex systems`
Advantages of a hydrostatic fan drive with variable displacement pump:

- stepless variable fan control from minimum to maximum speed
- drive power of variable displacement pump corresponds to the fan capacity required
- no lost energy
- fan speed largely independent of internal combustion engine speed
- position of radiator independent of engine
- compact design
- enhanced fuel economy
- reduction of noise level emission
Option: Fan Function Manifold (FFM)

Features:
- Bi-directional fan rotation
- No shock valves needed
- Option: fan standstill
- Variable oil heat-up function (via controlling ED-pressure setting)
- No anti-cavitation valve
- No pump drain line
- Fail safe mode
- Fixed displacement system
- Usage for fan drive
- Depending Cooling Power
- One Parameter

- Variable displacement system
- Usage for fan drive
- Independent Cooling Power
- Multiple Parameters

- Variable displacement system
- Combined systems
- Independent Cooling Power
- Multiple Parameters
- Closed Loop Control
Thank you!