HydraForce Axle/Cabin Suspension Solutions
Smooth Ride for Off-Highway Vehicles

Comfort, Productivity, Profit

Off-highway vehicles operate in demanding conditions but operators don’t have to take a beating. There are many strategies available to smooth the ride. Suspension and damping isn’t just about operator comfort: it’s about productivity and profit. New regulations for daily permissible vibration exposure limits can shorten work time and impact productivity. Let HydraForce apply our years of experience on a custom-designed system for your vehicle.

Suspension Systems:
- Increase operator comfort
- Increase controllability
- Improve traction
- Allow faster transport speeds
- Improve roll stability
- Optimize axle positioning
- Increase tire service life

Traditional Systems

Traditional suspension systems isolate the axle and frame using leaf or coil springs. These springs absorb energy from abrupt changes in terrain elevation. They also help keep the wheels in contact with the ground, improving traction. Pneumatic or hydraulic shock absorbers provide damping to reduce system oscillation. Spring suspension systems are typically unable to modulate their response and can be susceptible to resonants that may cause bouncing or amplify variations in terrain.

Hydro-Pneumatic Suspension Systems

Hydro-pneumatic systems replace steel springs and mechanical shock-absorbers with a hydraulic cylinder coupled to a gas-charged accumulator. Displacing fluid into an accumulator compresses its gas charge to absorb energy. Hydrostatic fluid transmits energy from the wheel/axle to the accumulator. Orificing in the system restricts fluid flow to provide damping.

Cylinder mounted suspension manifold and accumulator components of a distributed hydro-pneumatic suspension system.

For detailed information and specifications, visit www.hydraforce.com or contact your local HydraForce representative at www.hydraforce.com/distribrs/world.htm

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Three Types
There are three basic classifications of hydro-pneumatic suspension systems. Each system provides a solution with differing degrees of sophistication. Following are examples of the three approaches using a basic design for illustration. There are many components and possible circuit configurations at our disposal to provide you with a proprietary system optimized to your vehicle's unique requirements.

Passive Systems
Passive systems provide the basic functionality of suspension with fixed damping. This is a cost-optimized solution that can be tuned to your vehicle's unique dynamics. Passive systems can include level control with position feedback from a stroke sensor.

- Valves SV1 and SVCL1 provide level control to allow full travel of the cylinder under any load condition.
  - SV1 activates to lower the system.
  - SVCL1 activates to raise the system.
  - SVCL1 is a multi-function valve that provides check-isolated signal to a load-sensing hydraulic supply.
- Both valves are poppet-style for load holding.
- Stroke sensor relays cylinder position to the control unit.
- Relief valve RV1 protects the cylinder and accumulator from pressure spikes.
- ORF1 and ORF2 provide fixed flow restriction for damping.
- ACC1 provides spring force.
Semi-active Systems

Semi-active systems can vary the accumulator pre-load to change spring rate. Feedback through position sensors and pressure transducers allows a system like this to respond well to varying terrain, speed, and load conditions.

- Valves SV1, 2 and SVCL1, 2 provide level control and variable accumulator pre-load.
  - SV1/SVCL1 modulate piston-side pressure/pre-load in ACC1 with fixed damping through ORF1
  - SV2/SVCL2 modulate rod-side pressure/pre-load in ACC2 with fixed damping through ORF2
  - SVCL1, 2 are multi-function valves that provide check-isolated signal to a load-sensing hydraulic supply.
- All valves are poppet-style for load holding.
- Stroke sensor relays cylinder position to the control unit.
- Pressure transducers PT1, 2 provide feedback to the control unit.
- Relief valve RV1 protects the cylinder and accumulators from pressure spikes.

Semi-active system provides variable spring-rate suspension with fixed damping and level control.
Active Systems

Active systems vary fluid restriction to change damping characteristics. These systems use proportional flow control valves between cylinder and accumulator. In addition, acceleration sensors and more sophisticated logic can improve response to changing conditions and speeds. This system can achieve a damping profile following the sky-hook principle.

- Valves SV1, 2 and SVCL1, 2 provide level control and variable accumulator pre-load.
  - SV1/SVCL1 modulate piston-side pressure/pre-load in ACC1.
  - SP1 provides variable damping to the piston-side accumulator.
  - SV2/SVCL2 modulate rod-side pressure/pre-load in ACC2.
  - SP2 provides variable damping to the rod-side accumulator.
  - SVCL1, 2 are multi-function valves that provide check-isolated signal to a load-sensing hydraulic supply.
- SV1, 2 and SVCL1, 2 are poppet-style valves for load holding.
- Stroke sensor relays cylinder position to the control unit.
- Pressure transducers PT1, 2 provide feedback to the control unit.
- Relief valve RV1 protects the cylinder and accumulators from pressure spikes.

Some very costly active systems employ fast-acting servo valves to control large flow volumes without using an accumulator for spring response. This technology is only used in applications where cost is not a high concern.

**SUSPENSION SOLUTIONS:**

**REDUCED VIBRATION**
**Roll Stabilization**

Cross-connecting suspension cylinders on opposite sides of the vehicle can provide roll stabilization. When cornering, centrifugal forces tend to roll the chassis about its center of mass. Cross-connected cylinders can transfer outboard force to the inboard cylinder leveling the chassis. This can eliminate the traditional sway-bar, simplifying the system.

- The circuit features a flow path between opposite cylinders.
- Orifices ORF1-4 restrict flow for damping.
- Accumulator ACC1, 2 provide spring force.
- Valve SV1 reverses the flow path connecting left rod to right piston and right rod to left piston. This switches the roll-stabilization feature on/off.

**Advantages**

Advantages of the hydro-pneumatic suspension over spring suspension include:

- Level control
- Variable spring-rate possible
- Variable damping
- Control system with feedback
- Dynamic response
- Compact system with fewer/smaller components

**Possible Applications of Hydro-Pneumatic Suspension**

- Cabin suspension – isolate cabin from chassis
- Axle suspension – isolate chassis from axle
- Independent suspension – isolate each wheel from chassis
- Seat suspension – isolate the operator’s seat from the cabin/chassis
- Load/boom/head suspension – isolate vehicle load or operating components

**Challenges**

High development cost and time have been barriers to adoption of hydro-pneumatic suspension technology. HydraForce’s expertise in compact hydraulic system design, space-saving multi-function valves, and proportional pressure controls allow us to develop a custom cost-optimized solution based on available components in much less time. And our enhanced plating/corrosion resistance package gives you the freedom to locate suspension components anywhere on the vehicle without exposure concerns.

**Ride control** is a rough road for all off-highway mobile equipment, but there are many opportunities to develop a custom system approach that elevates your vehicle above the competition. HydraForce is here to smooth the way.

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