2016 NDIA GROUND VEHICLE SYSTEMS ENGINEERING AND TECHNOLOGY SYMPOSIUM
POWER & MOBILITY (P&M) TECHNICAL SESSION
AUGUST 2-4, 2016 - NOVI, MICHIGAN

ADDRESSING THE CHALLENGES OF PROVIDING MOBILITY AND MANEUVERABILITY FOR TACTICAL WHEELED VEHICLES

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ABSTRACT
This paper discusses the semi-active suspension system developed by A.M. General to provide mobility and maneuverability for tactical, wheeled vehicles.

INTRODUCTION

To address the challenges of providing the required mobility over rough terrain and maneuverability at high speed for a 4-wheel Tactical Wheeled Vehicle at up to 22,000 lbs., A.M. General, developed an electrically-controlled, high-pressure hydraulically-actuated semi-active suspension system. This system enables the vehicle to retain extremely rugged 4WD terrain capabilities, while also meeting military and commercial highway stability safety standards. This paper discusses the benefits and capabilities of this suspension architecture as developed for tactical wheeled vehicle platforms.

PROBLEM STATEMENT

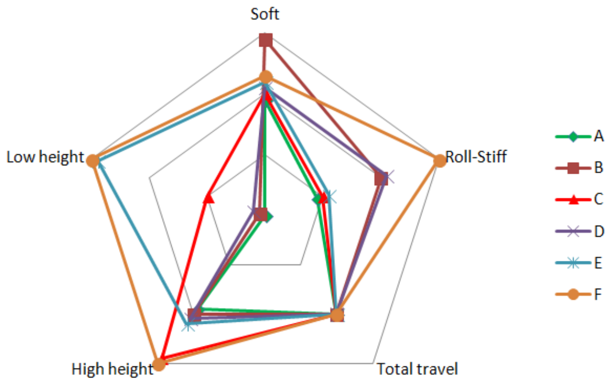
Multiple vehicle programs specified by DoD require offroad capability far exceeding that of commercial on-highway automobiles. In this case, the vehicle type under consideration is a 4-wheeled chassis, with a customer requirement to traverse severe obstacles such as an 18” step, and urban rubble (loose concrete blocks). Customer expectations include capability similar to ORV boulder climbing: ascending grades exceeding 40%, made up of irregular patterns of stone obstacles each of which may exceed 12” step rise. Considering these severe offroad maneuvers, the requirements create a design emphasis on traction. For wheeled vehicles, from a suspension perspective, low-speed and static traction - directly corresponding to normal force at the tire - is achieved on uneven surfaces through low effective wheel spring rates across a high range of motion. Body contact with the ground must also be avoided, which emphasizes a high static ride height (ground clearance). These attributes therefore became included as primary design objectives for the suspension.

Additional, conflicting requirements are specified for multi-purpose vehicles. For this vehicle type, customer requirements also specified on-road handling and evasive maneuvering requirements that *are* similar to commercial automobiles, such as 55mph lane-change stability (meaning: resistance to spin-out and roll-over). A brake-based stability control system is presumed to be included, but because such systems are reactionary in nature, the suspension remains a critical element of stability. From a suspension perspective, dynamic stability on regular surfaces corresponds to front/rear grip distribution and minimizing disturbance of the sprung mass of the vehicle. Overall lateral traction is also relevant, as it is required to achieve the required vehicle displacement for lane-change maneuvers. This vehicle specifies common wheels and tires installed front/rear, based on other design considerations (such as cost and serviceability) which are considered fixed. Its weight distribution is also hugely variable, according to the cargo load. In this case, grip distribution would typically be defined by roll stiffness distribution front/rear, and to a lesser extent, dynamic orientation of each tire resulting from kinematics and compliances of the suspension’s mechanical components. Minimizing disturbance of the sprung mass, summarized by minimizing the body roll angle, is achieved in design by specifying a higher total roll stiffness.

A third conflicting requirement is specified, regarding vehicle overall dimensions (height) during tied-down shipment of the vehicle. This creates the additional design objective for a low overall vehicle height.

A fourth conflicting requirement is specified, regarding water fording capability of 60" depth, while maintaining contact with the bottom. Here, ride height (body height) is emphasized.

Summarized by the figure below, traditional suspension designs do not provide a clear solution for this vehicle.



Type	Description
A	Traditional spring-damper-ARB
B	Spring-damper; disconnectable ARB
C	Spring; damper with pneumatic load assist
D	Spring; electrically variable damper
E	Air spring; damper
F	AMG solution

Figure 1: Design comparison for a given total travel

SOLUTION

A novel suspension design was therefore created, to better address these conflicting requirements. This suspension system utilized a standard double-wishbone assembly at each corner, but with the traditional spring and damper replaced with a specially-designed hydraulic strut containing a unique hydraulic fluid with a high compressibility, which acts as the spring. An electronically-controlled high-pressure hydraulic system including electrically-driven pump, gas pressurized accumulator, and distribution manifold then provides the capability to raise or lower each corner individually by increasing or decreasing the pressure in the strut. Activating hydraulic adjustments during handling maneuvers dynamically modifies the

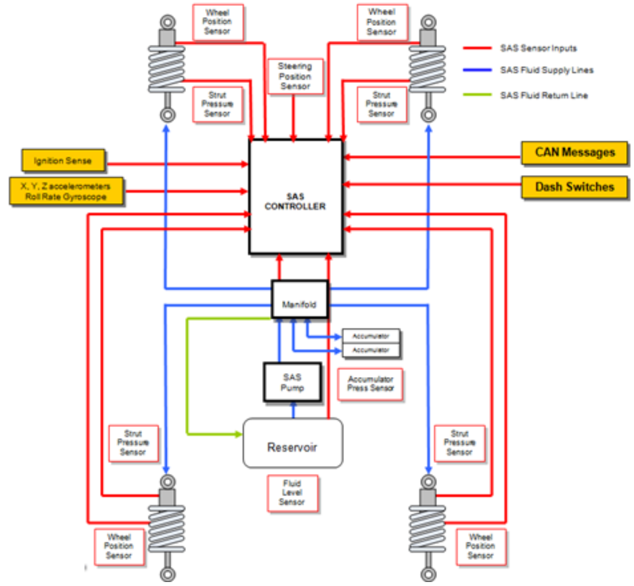


Figure 2: Physical Architecture Diagram

effective roll rate. The system controller utilizes steering wheel angle, strut pressure, and wheel position sensors to provide feedback on the vehicle behavior and then issue commands to the hydraulic system.

FUNCTIONAL ADVANTAGES

The inclusion of a semi-active suspension system enables new vehicle functionalities. This includes terrain-dependant ground clearance, meaning that the vehicle ride height can be automatically raised to a maximum height for water fording, set to a mid-range height for off road ground clearance and blast protection, set to a lower height for high-speed on-road handling, or completely lowered for vehicle service, storage, or transport. When traveling over steep or uneven terrain, the system can halt activity to prevent rollover or disturbing the balance of the vehicle.

The system also enables automatic variation of the vehicle roll stiffness during dynamic maneuvering at higher speeds, which results in improved vehicle stability for increased performance and safety. Similarly, the system can work to reduce pitch during braking. As a demonstration of this performance, when combined with AM General's brake-based electronic stability control system, a test vehicle was able to successfully pass FMVSS 126 [1].

It was discovered that the system provided an additional secondary benefit regarding stationary-vehicle attitude adjustment, for easier occupant egress. This is especially useful for vehicles with heavy armored cockpit doors, where the doors become more

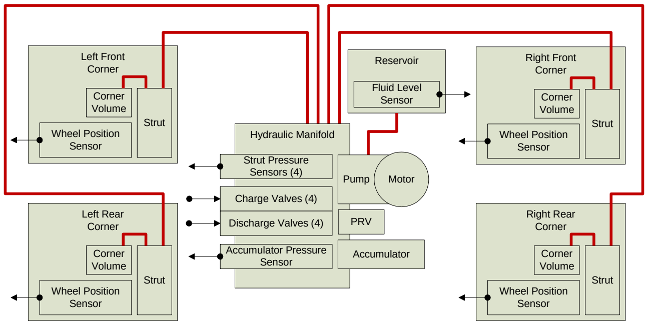


Figure 3: Hydraulic Architecture Diagram

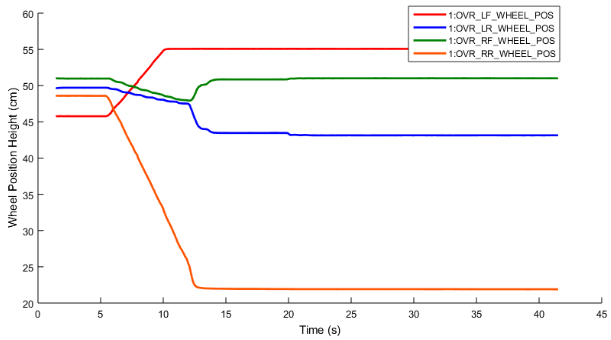


Figure 4: Platform Mode –Wheel Position

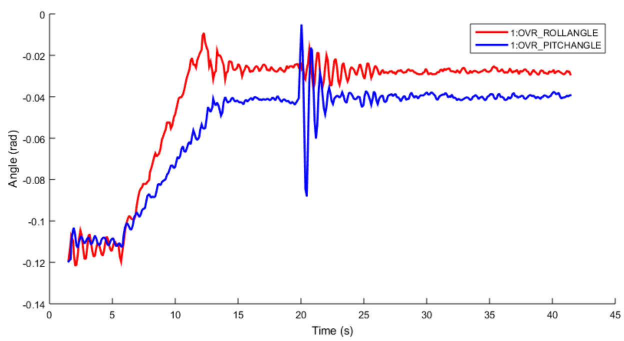


Figure 5: Platform Mode –Roll/Pitch Angle

difficult to open or close when the vehicle is parked on uneven terrain. Through hydraulic actuation of each wheel independently, the cockpit is automatically leveled when the vehicle is parked regardless of the ground profile when the vehicle is parked, and therefore allows the doors to be easily opened or closed. This also avoids the added cost, complexity, and space claim associated with equipping such vehicles with powered door-opening systems.

The driver can command the system through a cockpit-mounted keypad, or the system can operate completely automatically through communication with other vehicle chassis systems which report braking, steering, and powertrain information. The suspension system reports its health and status through the standard vehicle diagnostics interface, and can be manually exercised using the vehicle diagnostics computer for service or maintenance purposes.

CONCLUSION

The conclusions drawn from this project were that by utilizing intelligent electronic control of hydraulically-actuated suspension components, the requirements of both low-speed mobility and high-speed maneuverability can be met for modern tactical wheeled vehicle applications. In addition, suspension systems such as this are applicable to almost all wheeled vehicle types, and can permit the vehicle to meet a wider range of capability than would be possible with traditional passive systems.

REFERENCES

[1] National Highway Traffic Safety Administration, Office of Vehicle Safety Compliance, “TP-126-01”, Laboratory Test Procedure for FMVSS 126, Electronic Stability Control Systems, 2008