SUSPENSION GEOMETRY
CONTROL SYSTEMS
SUSPENSION GEOMETRY CONTROL SYSTEM

PRESENTATION CONTENT

- SYSTEMS FOR INDEPENDENT REAR SUSPENSIONS
- SYSTEMS FOR THE COMPOUND CRANK SUSPENSION
- PROPOSALS FOR FRONT SUSPENSIONS
SUSPENSION GEOMETRY CONTROL SYSTEM

DIRECTIONAL BRAKING STABILITY CONTROL SYSTEM 1

HYDRAULIC TRANSMITTED VECTOR

BRAKE FORCE VECTORS

BRAKE FORCE
SUSPENSION GEOMETRY CONTROL SYSTEM

SEMI TRAILING REAR SUSPENSION WITH HYDRAULIC CONTROL ARM BUSHINGS
SYSTEM 2

TOE CHANGE 1.5°
HYDRAULIC BUSHINGS
HYDRAULIC PRESSURE HOSE
CAMBER CHANGE 1.2°
SUSPENSION GEOMETRY CONTROL SYSTEM

HYDRAULIC CONTROL ARM BUSHING
SYSTEM 1 AND 2

PRESSURE HOSE CONNECTION

PRESSURE COMPARTMENT

OUTER SLEEVE

INNER SLEEVE
SUSPENSION GEOMETRY CONTROL SYSTEM

T/J-CAR MULTI LINK SUSPENSION
SYSTEM 2

HYDRAULIC BUSHING
CAMBER CHANGE

HYDRAULIC BUSHING
TOE IN CHANGE
SUSPENSION GEOMETRY CONTROL SYSTEM

SYSTEM 1  J-2400 COMPOUND CRANK SUSPENSION

\( \mu \)-SPLIT BRAKING STABILITY

\( \mu \)-HIGH

\( \mu \)-LOW

YAW VELOCITY REDUCTION EFFECT BY TOE OUT ANGLE OF REAR SUSPENSION

BRAKE FORCE INITIATED YAW VELOCITY

Z-AXIS
SUSPENSION GEOMETRY CONTROL SYSTEM

$\mu$-SPLIT BRAKING STABILITY FOR THE COMPOUND CRANK SUSPENSION

BRAKE SIGNAL

ELECTRICALLY SHIFTED VALVE

DEFLECTION

HYDRAULIC BUSHINGS

DEFLECTION

BRAKE FORCE HIGH

BRAKE FORCE LOW

2400 COMPOUND CRANK SUSPENSION
SUSPENSION GEOMETRY CONTROL SYSTEM

SYSTEM 2 COMPOUND CRANK SUSPENSION
TOE IN CHANGE FOR CORNERING TO RIGHT

HYDRAULIC INITIATED DEFLECTION

0.6°

HYDRAULIC BUSHING

HYDRAULIC BUSHING
SUSPENSION GEOMETRY CONTROL SYSTEM

SYSTEM 2 COMPOUND CRANK SUSPENSION
ELECTRO-HYDRAULIC CONTROL SYSTEM

SUBSTITUTION BY POWER STEERING
EQUIPMENTS DETERMINED

1 ELECTRIC MOTOR  2 HYDRAULIC PUMP  3 PRESSURE ACCUM.  4 RESERVOIR
5 MAGNETIC VALVE  6 HYDRAULIC BUSHINGS  7 ELECTRONIC CONTROL UNIT

BRake SIGNAL
SPEED SIGNAL
STEERING WHEEL ANGLE SIGNAL
OBJECTIVES FOR IMPROVED HANDLING

- IMPROVED STABILITY UNDER BRAKING BY INCREASING TOE IN FOR BOTH WHEELS
- IMPROVED ANTI-LIFT AND THEREFORE INCREASING THE TRACTIVE FORCE
- REDUCED UNDERSTEER BY TURNING THE OUTER WHEEL INTO TOE IN
SUSPENSION GEOMETRY CONTROL SYSTEM

FWD—FRONT SUSPENSION WITH HYDRAULIC BUSHINGS

HYDRAULIC BUSHING
CONTROL ARM
TIE ROD
CONVENTIONAL BUSHING

ACCELERATION
BRAKING CORNERING
SUMMARY
OPEL APS IS DEVELOPING INACTIVE AND ACTIVE SUSPENSION GEOMETRY CONTROL SYSTEMS

- UNDER DEVELOPMENT IS THE COMPOUND CRANK SUSPENSION SYSTEM 1
  EVALUATION WILL START END OF MAY 1987

- ACTIVE GEOMETRY CONTROL SYSTEM 2 LAYOUTS FOR THE NEW OMEGA REAR SUSPENSION HAVE BEEN STARTED.
  AN EVALUATION CAR IS PLANNED FOR OCTOBER 1987

- OPEL APS MAIN STREAM IS GEOMETRY CONTROL
  WE WILL OBSERVE THE 4WS ACTIVITIES OF OUR COMPETITORS
1. Opel APS has invented a suspension Geometry Control System and we would like to inform you about it.

Geometry Control means changing geometry parameters, toe and camber during certain driving conditions. Geometry angle changes are being performed in the range of 0.5° to 1.5° depending on the driving situation for a limited time. As you will learn in this presentation, the main application of the system is the rear suspension. However the front suspension can also be integrated. Please note that Geometry Control is not a system to improve manoeuvrability steering.

2. This is a rear suspension comparison of Geometry Control and 4 wheel steering, Opel and its competitors.

The two Opel systems optimize the suspension geometry with regard to braking stability, total car steer and lateral acceleration.

From literature we know that our competitors improve turning circle in the lower speed range and total car steering at higher speeds. They do nothing to the safety features braking stability and lateral acceleration.

3. During this presentation we will inform you on geometry control systems for the independent rear suspensions, for the compound crank rear suspension and show possibilities for the front suspension.
This chart shows the objectives of our two systems for the independent rear suspension.

Geometry control will reduce deflection oversteer during cornering by steering of the outer wheel into toe in.

The rear wheels will be steered into toe in for improved directional stability during braking.

Lateral acceleration is being increased by active camber change during cornering.

Let us first introduce the inactive system 1, which improves directional braking stability of the Omega independent rear suspension.

Two hydraulic bushings will replace the production control arm bushings. They are installed in opposite directions and connected with a hydraulic line. The larger brake force vector at the outer bushing is hydraulically transmitted to the inner control arm bushing and consequently moving it in the same direction.

This geometry change prohibits the toe out reaction.

This picture shows the new Omega rear suspension equipped with the active geometry control system 2.

Again inner and outer control arm bushings are replaced by hydraulic bushings. The inner bushings are responsible for toe in change, which improves braking stability and total car steer. Improved lateral acceleration is performed by a hydraulic initiated camber change of the outer bushing.

During cornering only toe and camber of the outer wheel geometry is being optimized by giving pressure to the bushings in dependence of the steering wheel angle. During braking pressure is given to both inner bushings turning the wheels into the toe in position.

Driving straight ahead the control arm automatically will adjust back to normal position.
Here we show the design of the hydraulic control arm bushing used in system 1 and 2 for toe and camber changes. The bolt is vulcanized into the bushing. The hydraulic line is connected to the end of this bolt. The outer sleeve is rubber coated at the inside and pressed above the inner sleeve to close the pressure compartment. The bolt is mounted to the underbody bracket. Pressure applied to the bushing will move the outer sleeve and control arm about 10 mm.

Opel APS is developing the multi link rear suspension as an upmarked suspension for improved handling. This picture shows the hydraulic bushings installation for the active system 2. The toe in change bushing is mounted to the end of the diagonal control arm. The camber change bushing replaces the inner control arm bushing.

This chart describes the active geometry control system 2 for the independent rear suspension. The system consists of a hydraulic unit, motor, pump accumulator and reservoir. The electronic control unit receives signals from a speed sensor, brake light switch and from a steering wheel angle sensor. Each hydraulic bushing is controlled by an electromagnetic valve actuated by the control unit.
So far we have reported on our investigations with regard to independent rear suspensions. I will now inform you on inactive and active geometry control of the compound crank suspension.

With the inactive system it is only possible to compensate the brake force initiated yaw velocity, which occurs on $\mu$-split road surfaces. This picture shows a car under $\mu$-split braking conditions with the danger to rotate around the Z-axis. The toe out angle of the compound crank reduces yaw velocity.

Similar to the semi trailing control arm with system 1, the compound crank suspension is equipped with two hydraulic bushings. The bushings are connected by a hydraulic line. A magnetic valve blocks the line between the bushings and only opens up during braking in order to avoid steering effects in other driving conditions.

The brake force on high $\mu$ is transmitted hydraulically to the low $\mu$-side and consequently turning the suspension. The resulting steering effect reduces the yaw velocity.

The same hydraulic bushings arrangement in the compound crank suspension can also be used for active geometry control system 2. With integrated system 2, total car steer, and $\mu$-split stability can be controlled. If under cornering hydraulic pressure is applied to the outer bushing the suspension steers similar to the front suspension wheels, thus improving cornering stability.
This picture shows the active geometry control system 2 for the compound crank suspension. Under cornering the electronic control unit opens the outer bushing magnetic valve.

For η-split conditions a magnetic valve located between the bushings will allow a pressure connection as already described for system 1. Under cornering this valve will not be activated.

Our objectives for applied active geometry control to the front suspension are:

- Improved stability under braking by increasing toe in for both wheels
- Improved anti-lift and therefore increasing the tractive force.
- Reduced understeer by turning the outer wheel into toe in.

Here we show a system for a FWD front suspension. The front control arm bushing is replaced by a hydraulic bushing that allows active movement to in- and outside direction. So toe-in and toe out angle of both wheels can be changed for specific ride conditions.

For improved braking stability both wheels turn into toe-in during braking. Therefore the hydraulic bushing moves to inside direction.

For improved anti-lift with increasing tractive force both wheels turn into toe out during acceleration. Therefore the hydraulic bushing moves to outside direction.

For reduced understeer during cornering, the outer wheel only is turned into toe in. Therefore the hydraulic bushing moves to inside direction.

Electronic and hydraulic equipment required is similar to the rear suspension system 2.
XXX Here we show the first hardware of the system 1 compound crank suspension. You can also see a sectionized hydraulic bushing.

In summary we can say:

Opel APS is developing inactive and active suspension geometry control systems.

- Under development is the compound crank suspension system 1.
  Evaluation will start end of May 1987.

- Active geometry control system 2 layouts for the new Omega rear suspension have been started.
  An evaluation car is planned October 1987.

- Opel APS main stream is geometry control.
  We will observe the 4WS activities of our competitors.

So far we have learned that 4WS systems with manoeuvrability steering require high investments and high product costs. We believe that those efforts are considerable for the expected customer value. Therefore at present Opel APS main stream will be geometry control.