The BMW integral rear axle, a new rear axle construction for the BMW 850i

A new rear axle was developed for the BMW coupé in order to meet all the special demands made on a sports car.

In detail, the demands are:

- effective anti-squat and anti-dive control

- camber adapted to reduce strain on tyres at high speeds

- balanced elasto-kinematics required to obtain a good roll steer characteristic and load reversal reactions

- compact construction to provide more room to install large fuel tanks and catalytic converters

Construction features

The task definition resulted in the design of a "multi-dimensional" suspension. This design solution has four control arms for each wheel. A new fifth integral control arm is added to provide a functional link for two control arms. BMW has long taken advantage of "multi-dimensional" suspension with the well-known precision-arm rear axle or the double-joint spring strut front axle in the 5 Series and the 7 Series
[1].

Two lower wishbones and one upper wishbone link the wheel carrier to the rear axle support which is mounted in elastic bearings on the body and is sometimes called a "bogie". It supports the rubber-mounted final drive and, as in the 5 Series and 7 Series, there is double acoustic insulation.

A longitudinal track control arm connects the wheel carrier directly to the body. It supports all the longitudinal forces and its rubber mounts provide "longitudinal suspension". The integral control arm is a vertically mounted strut which does not connect the wheel carrier to the chassis but is a new "intermediate link" connecting the longitudinal control arm to the upper wishbone.

The coil spring and the shock absorber are mounted adjacently on the rear wishbone. Due to the carefully selected moving shape of the spring with its minimum compression and rebound deflection angles, it is low enough for the longitudinal body carriers not to be offset [2].

Anti-squat and anti-dive control

To obtain an effective anti-squat and anti-dive control (i.e. the suppression of movements about the transverse axis of the vehicle), high-performance cars in particular must have the wheel carrier pivot or pole located in front of the wheel and above the wheel centre (viewed from the side) when the spring compresses and rebounds. For reasons of space, the front bearing of the longitudinal control arm is placed in front of the wheel but below the wheel centre. If the wheel carrier were to pivot about this bearing, nosediving could be compensated but not squatting. In fact it is possible from a design point of view to shift the pole to the desired position by mounting two longitudinal control arms one above the other. However, the disadvantages of this configuration would be the space required by the upper longitudinal control arm and the negative effect on the elasto-kinematic characteristic. This is described below.

However, at this point, the first advantage of the vertical strut, i.e. the integral control arm, which was mentioned previously [3] becomes obvious.

The strut transfers moments acting on the wheel carrier, especially braking moments, through the upper wishbone to the longitudinal control arm. The strut hinging point on the longitudinal control arm has a lower velocity during compression and rebound than the hinging point of the wheel carrier on the longitudinal control arm. This (lower) velocity is transferred to the strut hinging point on the upper wishbone. Since the distance between the wheel carrier bearing on the upper wishbone to the pivot is relatively long, the wheel carrier viewed from the side has a greater velocity than the strut in the range in which the strut itself operates. During compression and rebound, the wheel carrier than turns more slowly than the longitudinal control arm. When viewing the vehicle in its longitudinal axis, the pole is located further to the front and above the wheel centre, which is required to obtain efficient anti-squat control. The exact position can be adjusted by selecting the strut hinging points on the longitudinal control arm or on the upper wishbone accordingly.

Longitudinal elasticity

The wishbones absorb no longitudinal force and they are mounted in very rigid bearings in the rear axle support. When elastic longitudinal movements occur, e.g. when braking, the support effect of the vertical strut causes the wheel carrier to shift backwards [4].

The elastic spiral, i.e. the twisting movement of the wheel-controlling parts about the wheel axis, caused by braking moments are largely suppressed, despite the fact that the softness of the longitudinal suspension is freely selectable. On conventional axle designs, a soft longitudinal suspension is very limited [5].

If longitudinal control arms (or A-frame arms) are fitted one above the other to absorb braking moments, the longitudinal suspension is divided to the two arms, i.e. the longitudinal elasticity of each arm must be double the resulting longitudinal elasticity on the wheel. During braking, however, the lower arm is subjected to a high tension load while the upper arm receives a high pressure load. The resulting effect is counteracting shifts in the wheel carrier and considerable spiral angles, also causing the arm bearings to shift. This results in toe-in alterations and undesirable steering effects. For this reason, the control arms were not mounted in elastic bearings and the longitudinal suspension function was moved to the rubber mounts of the rear axle supports. The disadvantage here is, however, that when a longitudinal force acts on one side, which is usually caused by a difference in roll resistance, the entire rear axle support tilts, with the result that both wheels steer and interfere with directional stability [6].

With the new BMW integral rear axle, the suspension of each wheel is designed for full longitudinal suspension. The rubber mounts of the rear axle support ("the bogie") only act as acoustic insulation. The longitudinal forces on the wheel have almost no effect on the rear axle support. Any longitudinal force acting on one side is compensated by the wheel suspension on that side. There is no tilting of the rear axle support and the opposite wheel is not affected.

Elasto-kinematics

Elasto-kinematics is the design of the axle arms, the rigidity of the rubber mounts and the interaction of the components concerned.

Tension and pressure forces are caused in the wishbones through the support of longitudinal forces on the longitudinal control arm next to the wheel contact point. Although they are very rigid, the wishbone bearings and also the rear axle support still have a certain flexibility [7].

When braking, the lower front arm is subjected to tension forces, while the rear arm is subjected to pressure forces. The inevitable elasticity then causes the front wishbone to extend and the rear wishbone to shorten. At the same time the longitudinal control arm, which is mounted in a soft bearing to support longitudinal suspension, yields and the wheel carrier moves back together with the wishbone hinging points. By selecting the correct incidence or "sweep" of the wishbones to counteract the vehicle transverse movements, the wheel carrier is made to move only in a longitudinal direction, thus avoiding track error and disturbing steering effects. The lateral forces are transferred through the three wishbones to the rear axle support and through its rubber mounts to the body. By correctly dimensioning all the rubber mounts and components involved, a neutral steering behaviour of the entire wheel suspension is achieved.

Load reversal

Due to the large drive torque and the short wheelbase compared with the saloon, special importance was given to a smooth behaviour under load reversal conditions. A major contribution to this is the complex way the longitudinal arm is linked to the body, making it independent of the rear axle support [8].

At high lateral acceleration and the resulting side tilt of the vehicle, the wishbones of the wheels on the inside of the bend (rebounded) and on the outside of the bend (compressed) are distinctly skew to the body. If a load reversal occurs (sudden removal of drive torque), the rear axle support swivels back to its balanced position due to the resilience of the rubber mounts compressed by torque. At the same time, it pulls the hinging point of the upper wishbone with it in a horizontal direction, and the hinging point of the front lower wishbone is displaced relative to the car by the distance fv and the rear lower wishbone is raised by the corresponding distance fh. Due to the wishbone tilt, the displacements fv and fh also cause a lateral displacement in the hinging points of the wheel carrier by the distances fv′ and fh′, resulting in understeer in both wheels. These steering angles occur at almost the same time as the removal of drive torque. Therefore, the general tendency of all cars to turn too far into the bend because of dynamic relief in the rear axle when a load reversal takes place is compensated as it occurs.

However, this effect can only be achieved because the suspension of the longitudinal control arm is independent of the rear axle support and prevents the wheel carrier from twisting and converting the displacements fv' and fh' into definite steering angle corrections.

On straights, the wishbones are almost horizontal to the road and the steering effect caused by load reversal in bends as described above does not occur.

Summary

The new BMW integral rear axle has a multi-dimensional five-arm suspension with three wishbones, one longitudinal control arm and a fifth control arm, the integral arm, which is a new type of "intermediate link" between one wishbone and the longitudinal control arm. The wishbones are mounted on the rubber mounts of the rear axle support, and the longitudinal control arm is attached directly to the body in a soft rubber mount. There is double acoustic insulation of the final drive to the body. The wheel suspension provides anti-squat and anti-dive control and a soft longitudinal suspension for each wheel without requiring the help of the rear axle support bearing which would otherwise cause mutual disturbance between the two rear wheels.

By distributing the arm bearings onto the rear axle support and the body, it was possible to remove the negative effects of load reversal and one-sided longitudinal forces on handling, thus preventing roll and increasing steering precision.

Explanatory graphics

[1] Axle construction schematic **(Fig. A89/30)**

[2] Schematic of five-arm wheel suspension **(Fig. A89/31)**

[3] Function of anti-squat and anti-dive control **(Fig. A89/32)**

[4] Effect of longitudinal elasticity in the BMW integral rear axle suspension **(Fig. A89/33)**

[5] Effect of braking moment on conventional wheel suspensions **(Fig. A89/34)**

[6] Effect of one-sided longitudinal forces on different wheel suspensions **(Fig. A89/35)**

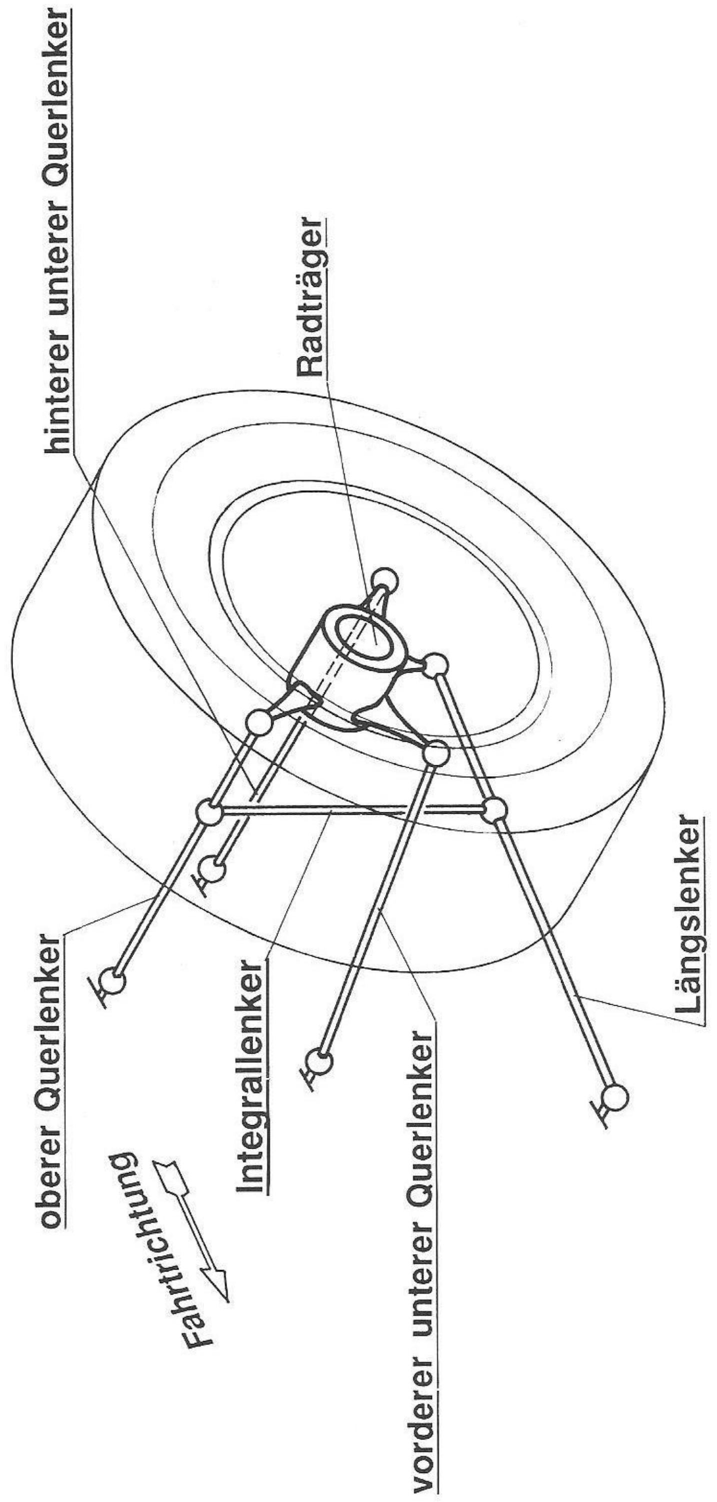
[7] Distribution of forces on wheel-controlling parts of the BMW integral axle when the brakes are applied **(Fig. A89/36)**

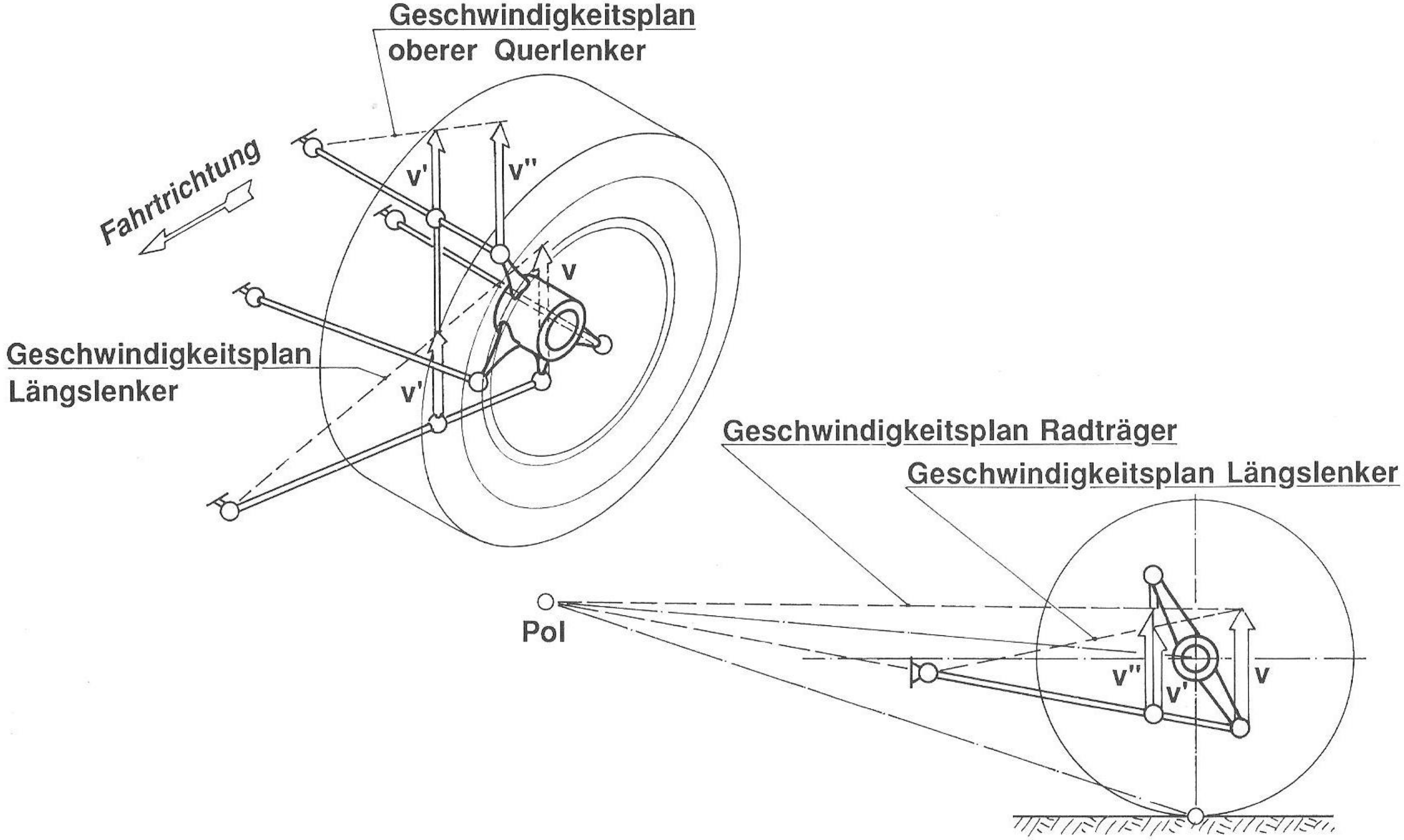
[8] Processes occurring in the BMW integral axle when the load is suddenly reversed **(Fig. A89/37)**

BMW Integralachse
Komponenten

A 89/30

Schemabild



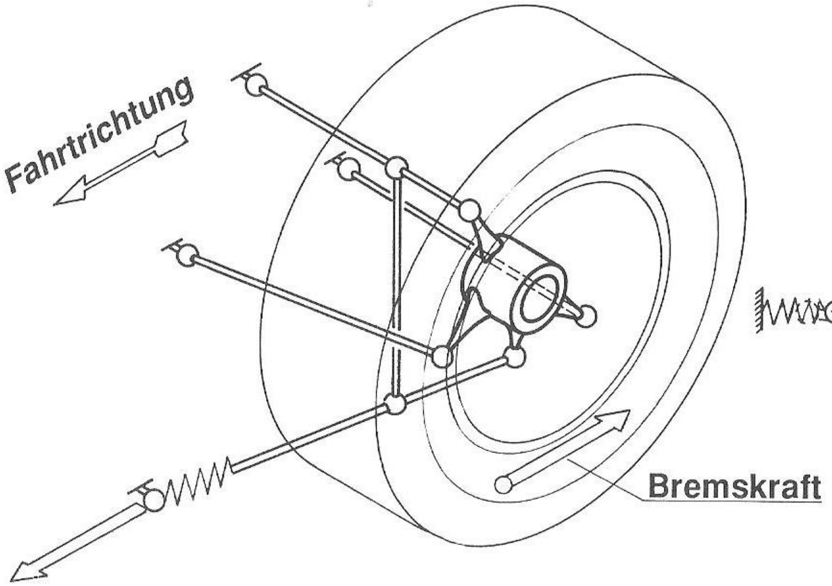


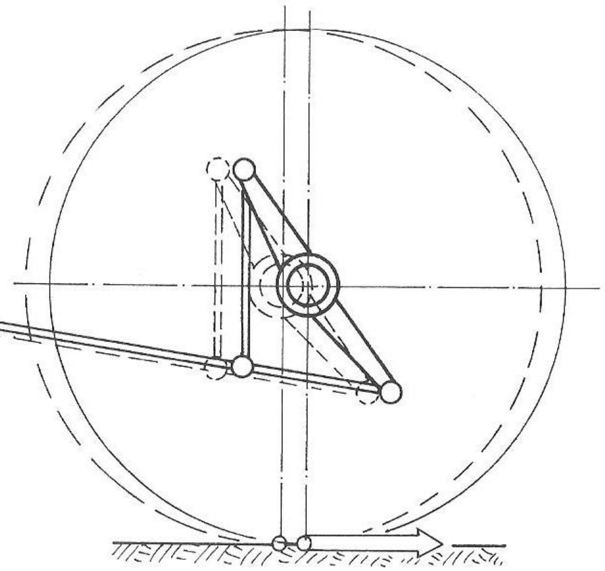
BMW AG Presse

BMW Integralachse

Funktionsweise des Anfahr- und Bremsnickausgleichs

A 89/31





Längskräfte werden nur vom Längslenker übertragen, daher weiche Längsfederung möglich

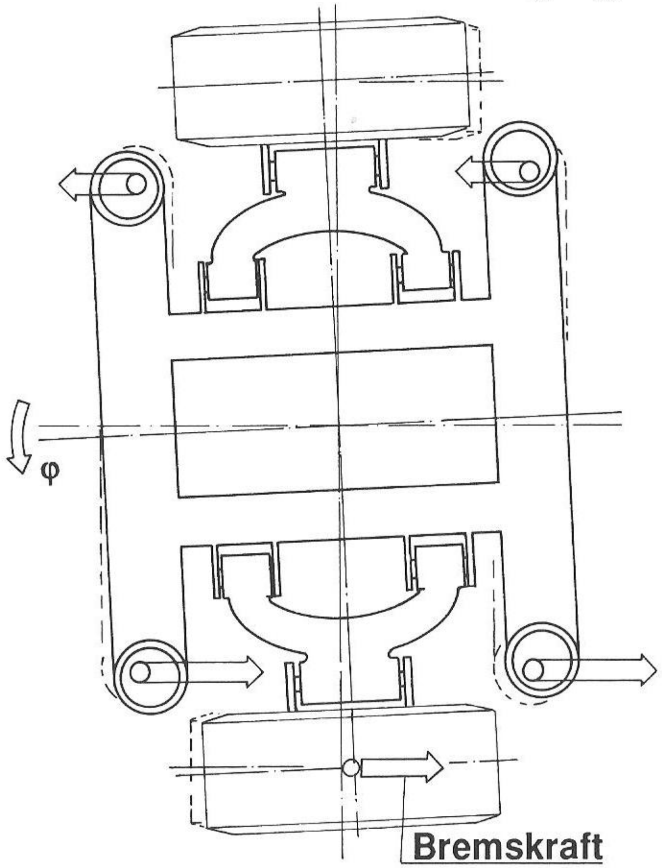
Parallelführung des Radträgers bei Bremsung (kein Aufziehen)

BMW AG Presse

BMW Integralachse

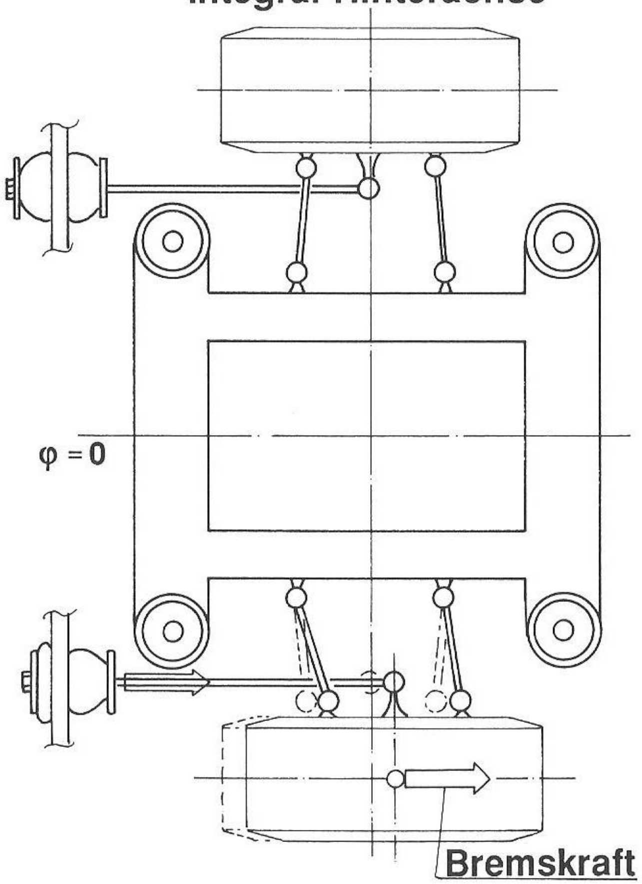
Beeinflussung konventioneller Radaufhängungen durch das Bremsmoment

Konventionelle Radaufhängung



Bei einseitiger Bremskraft Schiefstellung des Hinterachsträgers und Lenken der ganzen Achse

Integral-Hinterachse



Keine Schiefstellung des Hinterachsträgers
Keine Beeinflussung des anderen Rades

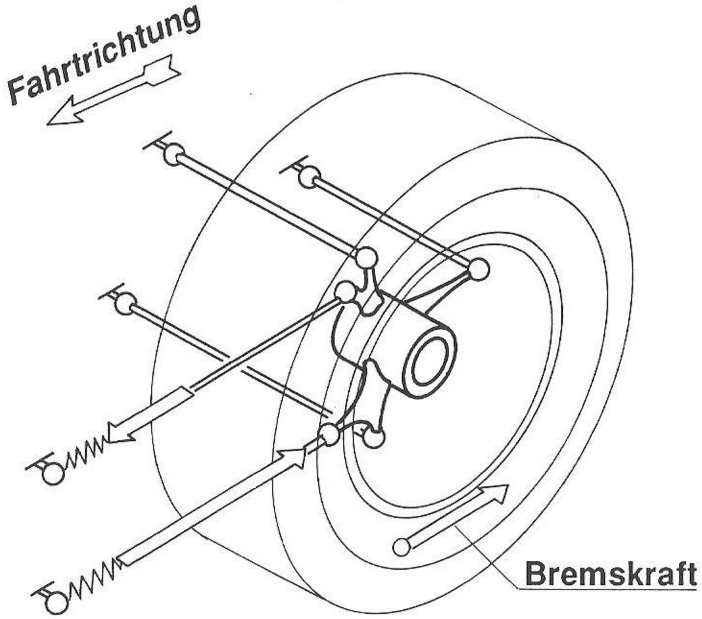
A 89/33

BMW AG Presse

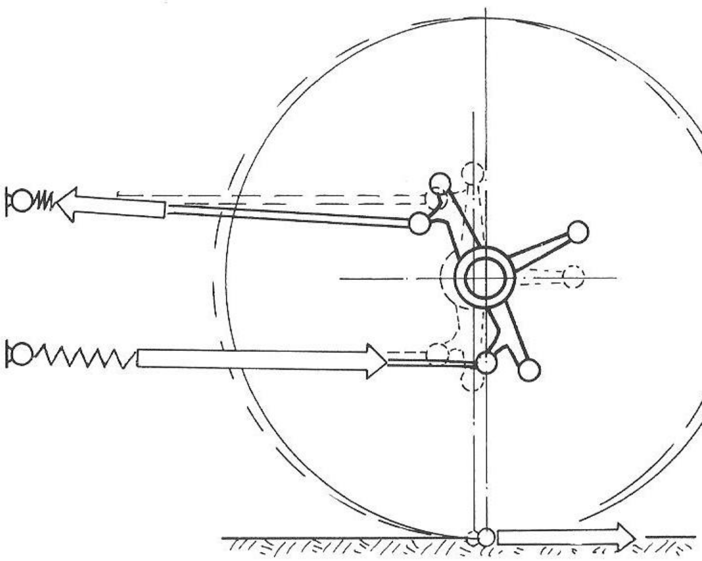
BMW Integralachse

Situation bei einseitig wirkender Längskraft

A 89/34



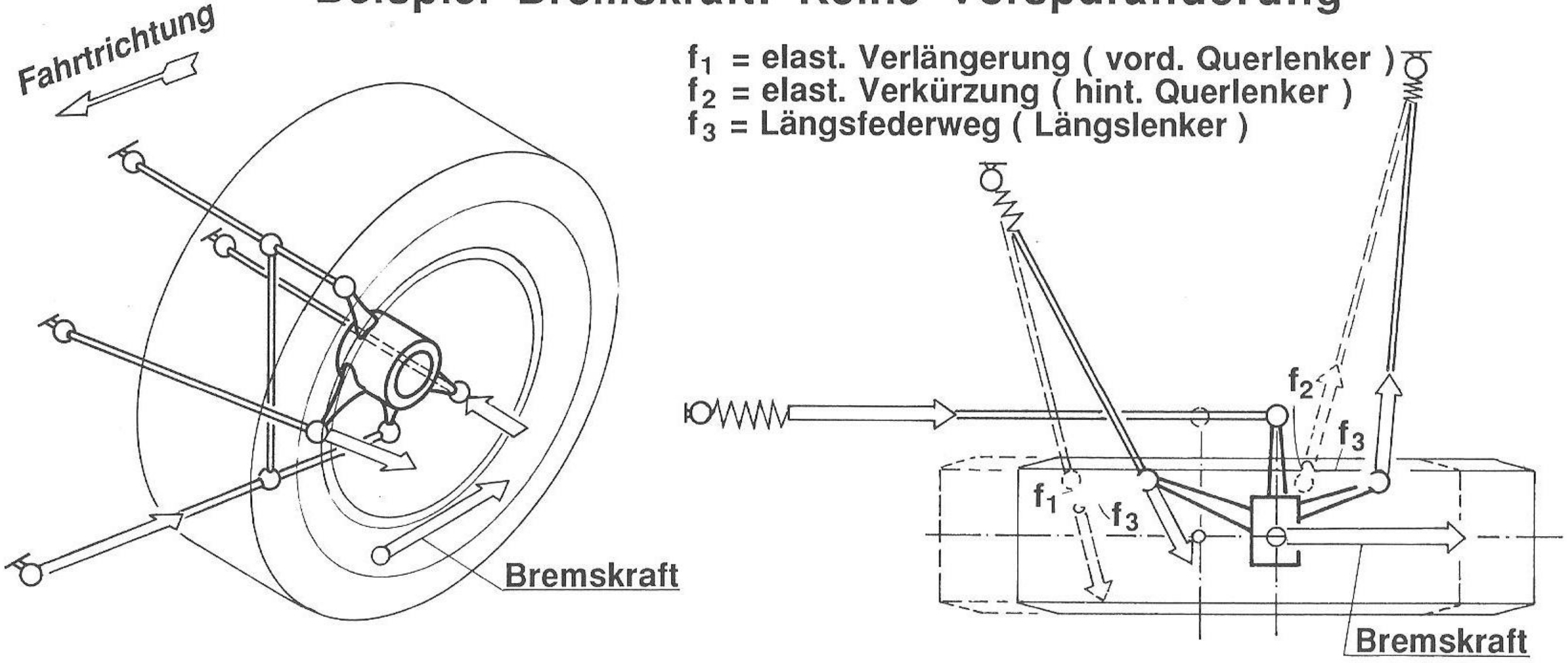
Hohe Kräfte in entgegengesetzter Richtung



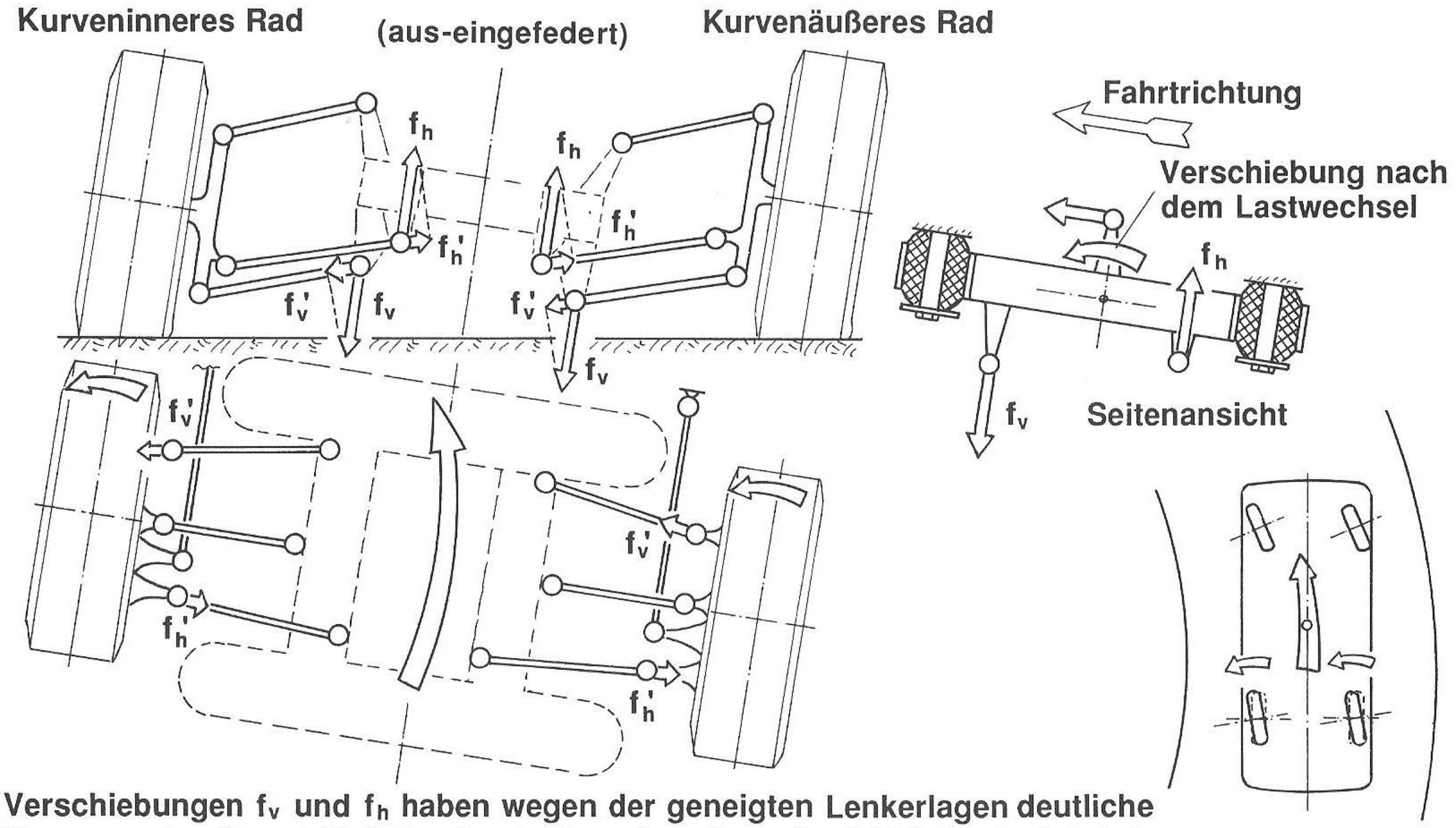
Starker Aufziehwinkel des Radträgers

Folge: Starke Vorspuränderung

Beispiel Bremskraft: Keine Vorspuränderung



Federraten der Querlenker und ihre Pfeilungswinkel sind auf die Federrate des Längslenkers so abgestimmt, daß Parallelführung des Rades erfolgt



Verschiebungen f_v und f_h haben wegen der geneigten Lenkerlagen deutliche Komponenten f_v' und f_h' in Lenkerrichtung (s. obere Ansicht). Lenkwinkel der Hinterräder wirken nach dem Lastwechsel einem übersteuernden Eindrehen des Fahrzeugs entgegen (unten links u. rechts)

BMW AG Presse

BMW Integralachse

Lastwechselreaktionen

A 89/36