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A Semi Active Suspension System for Motorbikes

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ABSTRACT – Our long-term goal is to develop a fully adaptive suspension system for motorbikes. Depending on the driving position in a (race) route the system will automatically adjust the spring rate and damping ratio. Through changes of the prestressing of the springs on the front and rare suspension a geometrical altering could be reached in some limit.

The tuning regarding the spring rate and damping ratio at front and rare wheel of a motorbike is always a compromise. On an even road the rate could be set harder to reach more transparency; on an uneven road then rather reverse. This is just an example for shortly explaining the complexity of the problematic nature.

The setting parameters of our systems will be useful for more and more popular driving training in a race route. A hobby biker will be supplied with a practical basis setup for his motorbike.

Based on the data that we have found out by our test driving we create a protocol for the particular race route. This is optimized for the tuning in each racing stages.

In the first phase of our development the biker has to set the optimized and uncompromisingly adjusted parameters, which is stored in a database, manually during the driving (semi active). The adjustable spring and damper unit would be realized for this purpose in the first phase. A corresponding control system using rapid prototyping control dSPACE would be developed too.

In the second, upgrading phase the suspension system adapts automatically to the preselected driving style such as sporty, comfortable, luggage or pillion ride. The route database supplies the setting parameters for spring and damper elements based on the actual position of the motorbike located by GPS.

We will further develop the system in the third phase so that this could work as an autarkic one. This requires sensors and observers that provide the setting parameters for self adjusting the suspension on the basis of road roughness.

The measurement data from the tree phases extend the dataset for course, road states and the suspension setting parameters accordingly. For public roads the maps of navigation systems could be supplemented through such information.

It is to expect that the database, which we have established for a certain motorbike used by testing, could be transformed to other different types of motorbikes.

INTRODUCTION

The damping of a motorbike is always a compromise between handling and stability on one hand, comfort and transparency on the other hand. The problem is that this compromise covers a wide speed range and variety of road surfaces. Therefore, the potential of the chassis is in most situations not fully exploited.

A suspension, which is for example set up hard on flat surface for good tire feedback, leads by poor surface to a decrease of the road contact and grip. Similarly, a handy motorcycle at high speed has a tendency to nervous reactions in a slower speed area due to the lack of stabilizing forces of the wheels. Not just the speed and the road surface but also the driving state of the motorcycle play an important role, such as acceleration, braking, cornering input and output.

These conflicts can be resolved, in which we adapt a specific setting for each speed range, every road surface and any vehicle state. This means that while driving the chassis adapts to each situation independently, and that in gentle manner so that the balance of the motorcycle is not disturbed. Examples of possible settings are listed in table 1.

Damping settings

	Fahrzustände	Curve			Straight	
Grip	Road surface	Brake	Constant speed	Acceleration	Brake	Acceleration
Good	Even	-1	-1	-1	-2	-2
	Bump	+1	+2	+2	+1	+2
	Longitudinal rill	0	0	0	-1	-1
	Rough unevenness	+1	+1	+2	+1	+2
Moderate	Even	+1	+1	+1	-1	-1
	Bump	+2	+2	+2	+2	+2
	Longitudinal rill	+1	+1	+1	0	0
	Rough unevenness	+2	+2	+2	+2	+2

-2 : Hard, 0 : Medium, +2 : Soft

Table 1: Damper settings related to the rod grip and road surface

SYSTEM PARAMETERS AND REQUIREMENT

The behaviour of a motorcycle depends mainly on weight, location of the centre of gravity, vehicle geometry, tyres and suspension work. From the above parameters, responsible for a good or a bad driving behavior the damping work is the factor that is easiest to change. The most of sporty motorcycles are already deliverd from the factory with adjustable dampers, which greatly simplifies a modification to a mechatronic system.

For adapting to the different rider weights and to take another opportunity to influence the driving behavior, the vehicle geometry will be adjustable by an adjustable spring preload of both dampers which affects the vehicle ground clearance. 3 parameters are made variable for the rear and the front suspension:

• compression damping
• expansion damping
• spring preload

The parameter compression and rebound define the damping behaviour of the shock absorber. The parameter spring preload determines the height of the motorcycle on the road for the front and rear part of the motorbike. We can influence the castor which affects the maniability by setting a different altitude for the front and rear part of the motorcycle. By a symmetric raising or lowering of the chassis the air resistance as well as the stability and the handiness will be adapted to the driving situation.

The adjustable damping and spring preload system would be realized by using shock absorbers from the Firma Öhlins. The limitation of the shock absorbers lets the adjustable damping work up to 25% and height on the bike up to 30 mm.

In order to determine the speed with which the system settings shall be adapted, the motorcycle was driven on a winding course. The speed relative to the time and the associated motorcycle position were recorded using GPS, as showed in table 2.

	Minimum duration	Maximum duration
straight	1,5s	5s
Curve	2s	5s
Brake	1,5s	4s
Acceleration	1,5s	3s

Table 2: duration of various drive states

It can be read out all the events that might require a change in the damper settings. We see that the shortest time duration between two events takes 0.2s. It should be noted that there is overlaps, as we brake into a curve and again accelerate out of it. Regarding these values a maximum of 0.2 s for a setting change for such extremely winding routes is considered as appropriate. But since only a certain amount of bandwidth from the entire spectrum is relevant, a maximum response time of 0.5s for the entire spectrum is sufficient.

THE SYSTEM AND COMPONENTS

Figure 3 describes the system for controlling the vehicle height. In this sub-system a hydraulic pump controls two spring preload cylinder through electrovalves. The feedback is done by the stroke sensors. These sensors measure the position of the spring preload cylinder, which remains constant during the ride.

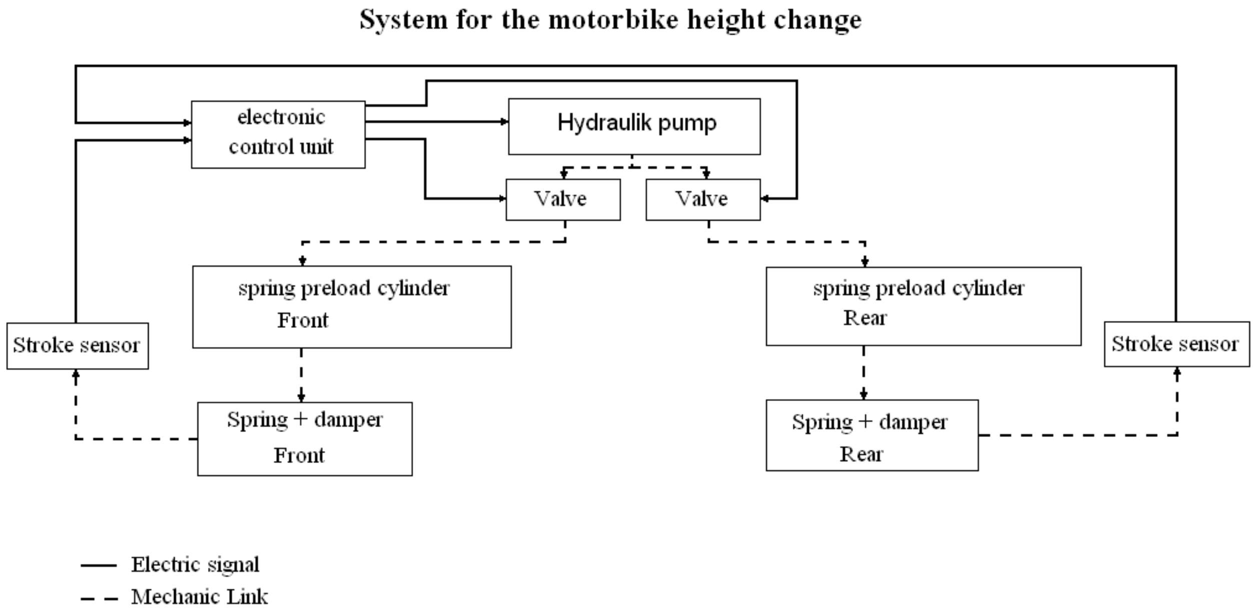

Figure 3: Adjustment of the spring preload through hydraulik pump

Figure 4 shows both sub-systems in a chart. The electronic control unit device sends impulses to the power output stage, then to the stepping motor. These stepping motors regulate the compression and expansion damping work.

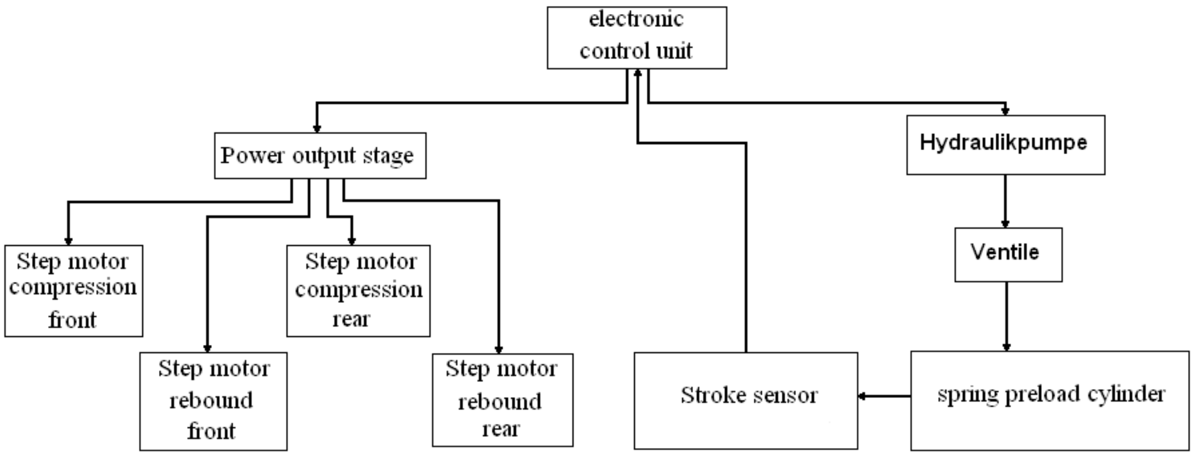

Figure 4: System description for compression, rebound and preload adjustement

The electronic control unit used is a rapid control prototyping system from the company dSPACE, the MicroAutoBox (MAB). The MAB is small enough to be integrated in the motorcycle and uses 12V power supplier. The control algorithm would be developed and modelled firstly in Simulink and then exported to the MAB via Real-Time Workshop, both from the MathWorks. In the Simulink model the stepping motors, the hydraulic pump and the electrovalves would be controlled and the spring preload cylinder position would be read through the stroke sensor. Setting changes are triggert by a manual switch located on the handlebar.

In Figure 5 the compression stepping motor with gear located at the reservoir of the damper and the expansion stepping motor at the bottom, the spring preload cylinder is sitting above the spring but without the stroke sensor mounted.

Figure 5: Front shock absorber modified

CONCLUSIONS AND FUTURE RESEARCH

The system has now reached the first stage with manual setting change. A Prototyping for the further development would be established. In the second, upgrading phase the suspension system will automatically adapt to the preselected driving style such as sporty, comfortable, luggage or pillion ride. The route database will supply the setting parameters for spring and damper elements based on the actual position of the motorbike located by GPS. We will further develop the system in the third phase so that this could work as an autarkic one. This requires sensors and observers that provide the setting parameters for self adjusting the suspension on the basis of road roughness. The measurement data from the three phases extend the dataset for course, road states and the suspension setting parameters accordingly. For public roads the maps of navigation systems could be supplemented through such information.

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