Smart PID Systems made by FLUDICON – A Revolution in Damping Systems

Author: ***Dr.-Ing. Matthias Puff, FLUDICON GmbH, Darmstadt***

FLUDICON GmbH develops, produces and sells variable damping systems based on electrorheological (ER) fluids for a wide range of industrial and automotive applications. With a response time of only a few milliseconds and a very wide adjustable range in force this technology is well suited for semi-active machine suspensions, precise motion control of pneumatic actuators or self-adaptive end-of-stroke damping elements. After introducing the ER technology two examples of applications will be explained in detail: First controlling the movement of a pneumatic actuator in a drilling machine; secondly using the ER technology in machine suspensions for reducing vibrations and isolate the machine from the environment. These examples clarify the benefits of the ER technology. In many applications it is possible to improve the accuracy of a process or reduce the time in production at economic costs. In that way the Smart PID Systems presented by FLUDICON brings a revolution in comparison to existing damping technologies.

What are Smart PID Systems?

The electrorheological (ER) technology offers completely new possibilities at the development of mechatronic systems. By using Smart PID Systems it is possible to increase the efficiencies of many industrial processes, e.g. in manufacturing or assembling of mechanical components, in chemical industries or in the automotive area.

Smart PID Systems consists of at least one adjustable ER damping cylinder and one amplifier with integrated controller (compare fig. 1). For an open loop control it is possible to adapt the damping properties by an electrical remote control. If the application needs a closed loop control measurement elements - e.g. sensors for acceleration, displacement - can be added.

Fig. 1: Components of a Smart PID System

The main advantages by using FLUDICON´s Smart PID Systems are:

Controlling force continuously: There is a wide range between soft and hard damping characteristic.

Dynamics of control: Smart PID Systems only need a few milliseconds to increase the damping force! So it is possible to control processes with high frequencies.

Holding force: At the velocity zero it is possible to clamp or blockade the ER damping cylinder by supplying an electrical field. In that way no other clamp elements are needed. Thereby the behavior is the same like at a friction clutch.

Remote control: Changing the damping characteristic can be done by an electrical signal (e.g. analog or PWM). No further mechanical adjustments are needed.

Efficiency: Smart PID Systems only require a low power consumption (2…20 W) in comparison to other semi-active systems.

Acoustics: There are no throttle effects (no turbulence) inside the ER damping cylinder. In use the system is absolutely noiseless!

Durability: The ER damping cylinder is very robust without any moving valve elements. The electronic components have a fail-safe mode.

Durability of ER fluid: The electrorheological fluid gets no damage by the ER effect!

It is obvious that these properties strongly separate the Smart PID Systems from other damping technologies. In the next chapter the possibilities to use these systems will be shown.

Possibilities with the ER technology

There are many possibilities to use the ER technology in industrial applications. For example:

- damping systems,
- controlling systems,
- positioning systems,
- reducing oscillations at typical frequencies,
- avoid vibrations,
- …

In industrial applications very often there is a need in production or manufacturing to optimize processes. For reaching an optimum cost-benefit ratio this can be done by using intelligent semi-active systems. In fig. 2 the characteristic curves of FLUDICON´s Smart PID System in comparison to a conventional oil brake is shown.

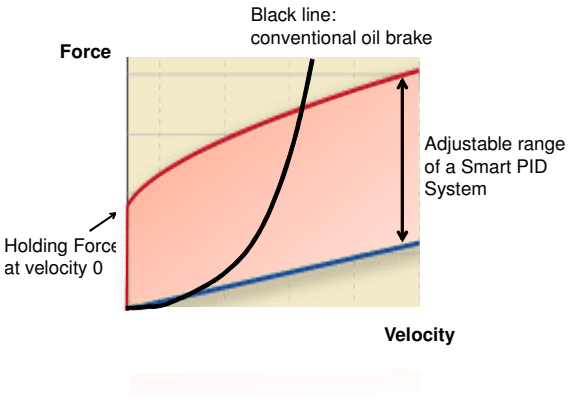

Fig. 2: Characteristic curves of a Smart PID System vs. a conventional oil brake

In the diagram the force is plotted against the velocity. If there is no electrical field applied, the Smart PID System has the behavior of a very soft damper, see blue curve. Now if there is a demand for higher forces the Smart PID System is able to shift the force up to the red curve just by applying a defined voltage. This step in force needs only some milliseconds, that means any kind of mechanic, pneumatic or hydraulic system can be controlled excellently with a Smart PID System. Comparing such a system with a conventional hydraulic oil brake (see black curve in fig. 2) the high flexibility of a Smart PID System becomes clear.

Also in fig. 2 there is another unique feature of a Smart PID System. At the velocity zero it is possible to realize a holding force. That means the movement and the position of any kind of mass can be controlled – a revolution in the world of damping systems.

Controlling pneumatic actuators with 0.1 mm accuracy

Suhner ERdrill is the first drilling machine which uses an ER damper to control the drilling process, see fig. 3. The unit is pneumatically actuated and a Smart PID System is used to control the drilling speed and position.

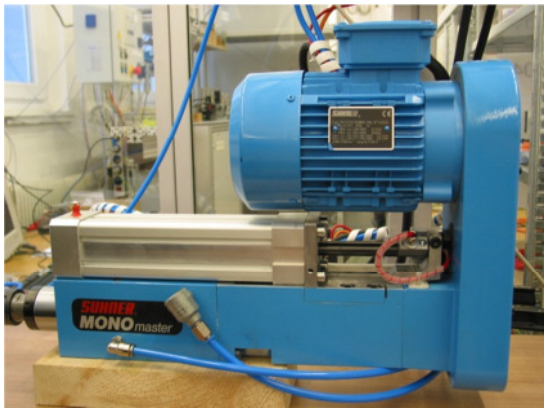

Fig. 3: Suhner ERdrill - A pneumatic actuated drilling machine with integrated Smart PID System from FLUDICON

Before the Suhner ERdrill was invented many mechanical adjustments were necessary to initialize the drilling process:

- oil brake adjustment for choosing the drilling speed,
- choose the end-of-stroke limit,
- choose the drilling depth.

At the new solution these jobs are assumed by the ER damper. Therefore FLUDICON added a classical closed loop PID controller and a sensor for the displacement to the amplifier hardware. The controller uses the signals for position and speed and transmits an electrical signal to the damping device. So it is possible to control the drilling velocity. As soon as the target position is reached the ER damper is turned on maximum performance and the drilling process stops. The Suhner ERdrill is able to do this task with an accuracy of 0.1 mm – an excellent accuracy for pneumatic actuators.

Benefits for customers

The benefits of controlling pneumatics with an ER damper can be summarized in one sentence: By using a Smart PID System it is possible to reach high accuracy and automation (like a CNC system) at economic costs. Further benefits are:

- no mechanical adjustments and so higher flexibility
- speed control (no temperature influence),
- remote control (via signal of a SPS).

Using the response time of 3 ms for controlling dynamic processes

Today in many industrial processes an increased efficiency is reached by higher rotational or translational speed. This causes increased oscillations of the machine which leads to a worse quality in production. Furthermore oscillations into the ground become more. So other processes might be influenced negatively.

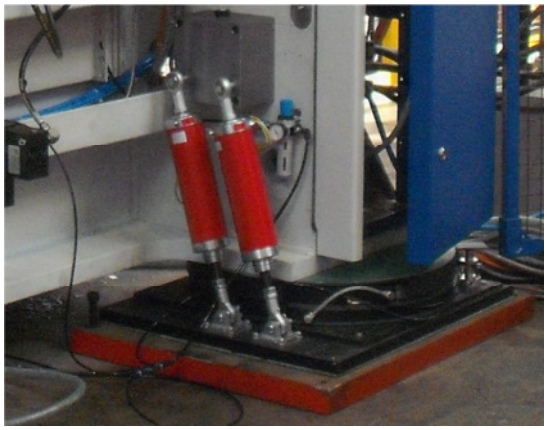

Fig. 4: Machine suspension with air bearings and Smart PID System

In fig. 4 a machine suspension with air bearings and a Smart PID System is shown. The related application is a 40t servo-hydraulic press in the production line. Like described above the aim of the semi-active ER damping concept is to use the damping potential only if it´s necessary. The principle is very simple: If the excitation frequency is equal to the natural frequency of the system the damping rate is increased. Otherwise for over-critical frequencies the damping rate is reduced. In that way an excellent isolation behavior is reached. For detecting the states of the machine sensors for acceleration are used. The described control strategy is explained in detail by figures 5 and 6.

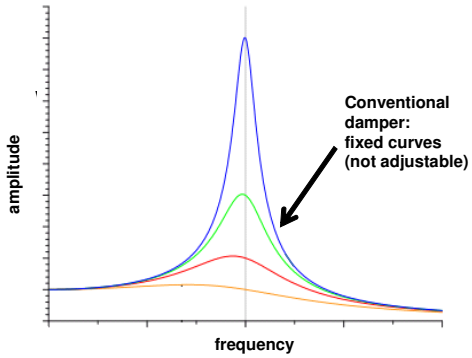

Fig 5: Resonance curves of a 1-mass-oscillator with fixed damping rates

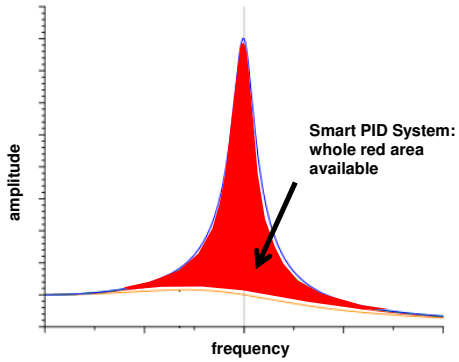

Fig. 6: Resonance curves of a 1-mass-oscillator with semi-active Smart PID System (variable damping rate)

Tuning a conventional suspension system there is always a conflict of aims between providing enough damping rate at the natural frequency and limiting the damping rate for higher frequencies (good isolation behavior). This conflict is shown in fig. 5.

By using a Smart PID System this conflict of aims can completely be solved. In fig. 6 it is shown that the whole red area, that means the range between the lowest and highest damping curve, is available. So an optimum between damping and isolation behavior can be found.

Benefits for customers

Because of the excellent response times FLUDICON´s Smart PID Systems are well suited for applications with high dynamics. Today there doesn´t exist a comparable semi-active damping technology with such a high dynamic.

Also the wide range between soft and hard damping characteristics is a unique feature in the world of industrial dampers.

About the ER technology

Electrorheological fluids belong to the group of Bingham materials and are dispersions consisting of oil (mineral- or silicon oil) and solid polymer particles. The fluid changes its properties from liquid to solid by applying an electrical field. The result is an increased shear stress of the material. In that way it is very easy to adapt the damping properties of a fluid damper system. This effect of changing the fluid properties only last a few milliseconds and works continuously and reversible.

The electrorheological effect

The ER effect will be explained by the simplified graphic of fig. 7. There a pipe with two electrodes for the cases with and without electrical field is shown.

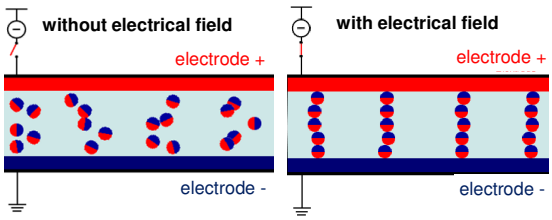

Fig. 7: The electrorheological effect

If the electrical supply is turned off (see fig. 7 left) there is no interaction between the polymer particles and the fluid flow through the pipe. If the electrical supply is turned on a close orientation of the polymer particles becomes visible (see fig. 7 right). This effect is similar to a choked orifice. The result is an increased flow resistance along the pipe.

Looking inside the system

In fig. 8 a sectional view into a Smart PID System is depicted. The system composes of a piston with a defined gap between housing and piston and two chambers with the ER fluid. If the piston is moving and there is no electrical field between housing and piston supplied the fluid just flows through the annular valve. The resultant force is caused by the hydraulic resistance of a laminar fluid flow. This fluid flow can be reduced by supplying an electrical field. Thus the annular valve becomes choked and the result is an increased force.

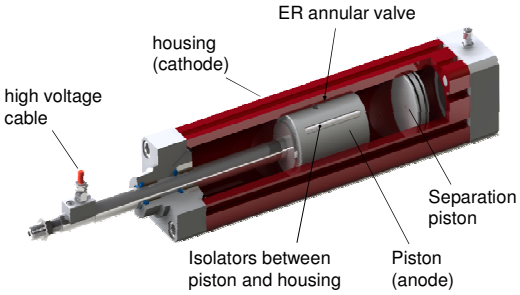

Fig. 8: Inner components of a Smart PID System

A special feature of a Smart PID System is the holding force at the velocity zero by applying an electrical field. With this feature it is possible to exactly control movements of masses or pneumatic actuators.

About FLUDICON and the author

The german company FLUDICON is a spin-off of the Dürr-Schenck Group. It is worldwide innovation leader in electrorheological fluids; this includes the complete R&D knowledge in ER systems – i.e. the development, design and application of any mechanics, hydraulics, electronics and software components. FLUDICON has its own fluid development and production.

The author Dr. Matthias Puff is employed at FLUDICON since 2010. He is responsible for the area of technical sales including the acquisition, application and test of the ER systems. Between 2006 and 2010 he wrote his PhD thesis at the university of Darmstadt, chair of Fluid Systems Technologies. His topic was the development of control strategies for semi-active air spring dampers.

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Matthias Puff