

# Self-Locking MRF Latches & Dampers

G.Magnac<sup>1</sup>, F.Claeyssen<sup>1</sup>, K.Vial<sup>1</sup>, R.Le Letty<sup>1</sup>, O.Sosnicki<sup>1</sup>, C.Benoit<sup>1</sup>

<sup>1</sup> Cedrat Technologies S.A., Meylan, France, [www.cedrat.com](http://www.cedrat.com)

Email: [actuator@cedrat.com](mailto:actuator@cedrat.com)

**Abstract.** MRF actuators are new electromechanical components using Magneto Rheological Fluids (MRF). When submitted to a high enough magnetic field, MRF switch from a liquid to a near solid body. New developed MRF actuators were developed in order to reach three aims: to offer a blocking force at rest which can be strongly reduced by applying a current, to provide an electrically-controllable resistive force over a stroke of 30 mm, to perform the control of the force in a very short time, typically in a few milliseconds. Thus, these MRF actuators can be used for two main applications: damper and latch - lock. Experiments on two versions of the actuator (a single piston rod and a feed through output axis) allow to get a blocking force around 100N, which is more than 10 times the actuator weight (its mass is 700gr). The required current and electric power required to cancel the blocking force are only 1.6A and 4W. The paper further presents the design and the electromechanical properties of the Self-breaking MRF Actuators for dampers & latches and new results on the control of these actuators.

## 1. Introduction

The MRF actuators are new electromechanical components using Magneto Rheological Fluids (MRF) [1]. These smart fluids are characterized by their ability to change their rheological properties versus applied magnetic field. With sufficient field, they can switch from a liquid to an almost solid body. This effect is reversible. It operates in few milliseconds. This effect can be used to create controllable damper, smart shock absorber or brakes. Most of MRF actuators (see for ex [2]) offer a controllable breaking force but do not offer a blocking force at rest for self-locking operations.

## 2. Aim

The purpose of the new developed MRF actuators is to reach three aims:

- to offer a blocking force at rest, which can be nullified by applying a current,
- to provide an electrically- controllable resistive force over a stroke of 30 mm, with as less as possible moving parts, offering high reliability,
- to perform the control of the force in a very short time, typically in a few ms.

A fourth aim could be added for the actuators presented in this paper. They were designed, in term of blocking force and free force to be in the range of human capability and therefore be easily manipulated.

### 3. Applications

The MRF actuators have two main applications, damper and latch-lock. In some cases, the two applications can be combined to provide a smooth lock or unlock operation. An other application for some embedded instruments for example is the adaptative suspension function. The aim of such kind of suspension is to manage shocks with much better efficiency than passive hydraulic dampers. Yet another application is, combined with non controllable linear actuators as pneumatic cylinders for example, to create a fully controllable, high stroke and low cost actuators.

The self-locking feature has been obtained in the presented actuators thanks to a particular magnetic circuit, designed with FLUX software [2] and using knowledge acquired [3] on MRF fluid magnetic and rheological properties.

The first application, the optimized damping, needs to control the energy dissipation during the piston movement. The device provides dissipated energy control in real time thanks to the current control. In a few milliseconds, the energy dissipation can be increased by 500%. A maximum damping can be maintained without power supply and so the fail safe operating can be guaranteed in several applications. Vibrations damping and shocks absorption can be optimized thanks to a closed loop. The second main application is the locking in position. The current control allows blocking the load in any positions along the stroke. The MRF actuator acts therefore as a linear electro-mechanical break without moving parts. Whatever the piston rod position, if the motion force is lower than the maximal force damping (@0A), the control of the current allows to get the rod locked.

### 4. MRF actuators

Two mechanical architectures of the device are presented:

- an actuator with a single rod piston, the device allows to damp a movement versus the frame
- an actuator with a double rod piston which allows to transmit the movement through the actuator, which operates in series with the motion line.

Both devices operate in flow mode with a twin tube structure.

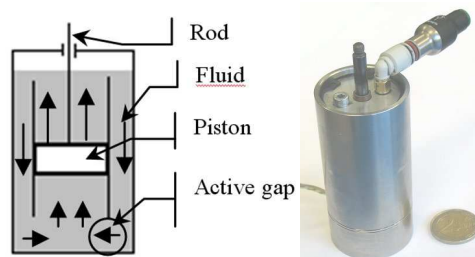


Fig. 1: Twin tube structure & Actuator

The following reasons led to the choice of the twin tube structure:

- Decoupling fluidic aspect and magnetic aspect.
- Non mobile coil, simplifying wires path and increasing reliability
- Immobile fluid gap, avoiding geometric deformations during the rod displacement
- Fast, easy and efficient replacement of the fluid gap parts, for easy customization to meet customers requirements

The magnetic field in the fluid gap is controlled from 0 T to 0.8 T, thanks to a 0.38 cm<sup>3</sup> permanent magnet and a coil. The coil resistance is 1.4 Ohms with an inductance close to 36mH, this leads to an electrical time constant of 25ms. The 132DG Lord MR fluid was employed.

Single rod and double rod solutions are using mostly the same structure. Thus, same behaviors between both actuators could be expected. The main difference is that single rod actuator needs a specific component, a moss fixed in one chamber, to solve the volume variation problem. Volume variation is due to the rod movement, entering or coming out of the actuator.

### 5. Damper performances

A first test campaign has been performed to assess the technologies versus the theoretical expectations. First generation of prototypes reveals cavitation effects (Fig 2) during pulling movement.

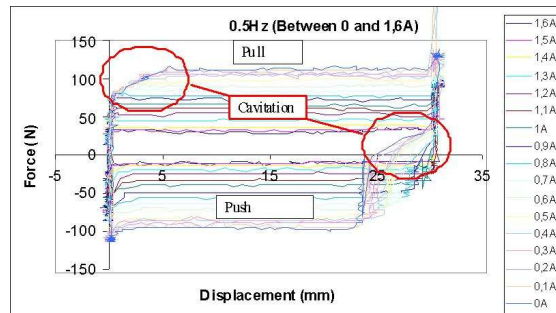


Fig. 2: Performances with cavitation

This limitation was met only with the single rod actuators. Cavitation is due to pressure drop in the MRF below the saturation vacuum pressure. This pressure drop appeared only in the single rod actuator because of the volume compensation.

Indeed, as in every hydraulic damper, the piston movement creates a pressure difference between its both sides. Because of the moss fixed in one chamber of the actuator, the pressure in this chamber reacts as if it was filled with a compressible fluid, whereas the other chamber is filled only with MRF, an incompressible fluid. Consequently, during pulling, there is a very low level of pressure increase in the compressible chamber, and there is an high pressure decrease in the other chamber. As soon as the pressure falls under the saturation vacuum pressure, the MR fluid evaporates and the cavitation appears.

To solve this limitation, specific solutions have been implemented and tested to be validated. To avoid cavitation issue, the single rod actuators was filled up with a pressure of 4 bars before being tested again. The results show that the cavitation is suppressed and performances become similar in both pulling or pushing operations.

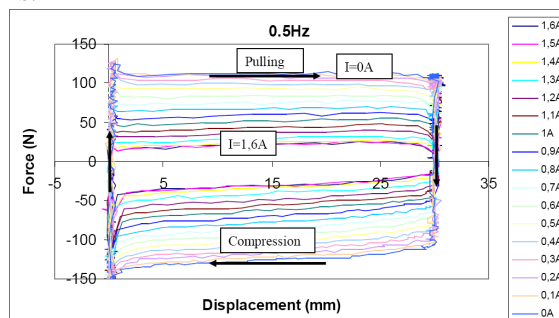


Fig. 3: Performances without cavitation

The damper with the double rod piston (fig 4), does not need moss because it has no volume variation (excepted thermal expansion, which is negligible in this case). It presents roughly the same performances as the former prototype

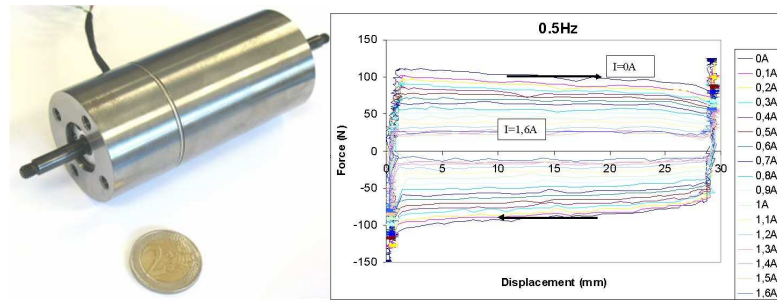


Fig.4: Damper with a double piston rod and its performances as damper

## 6. Latch performances

When the device is used in a latch, the rod is locked without power consumption. The moving parts are locked as long as the force applied through the load on the latch does not exceed the maximal locking force (around 100N for these prototypes). However, after experiment, latching shows limitations as slow loss of position (fig 5).

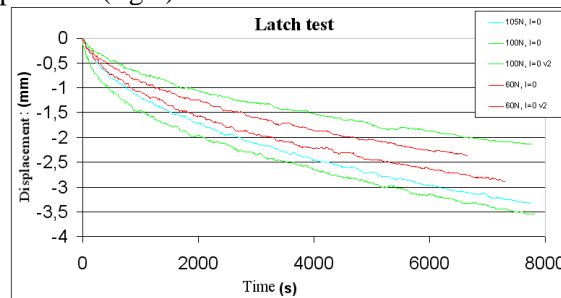


Fig. 5: Displacement vs time locking

## 7. Conclusion

As targeted, both developed MRF actuators offer blocking at rest, electrically controllable resistive force and fast control. They operate in all orientations and in both directions (pulling & pushing) with same performances. Several physical limits were solved like the cavitations, the sealing and the volume variation when the rod goes in the damper.

A test campaign has been performed to assess the technologies versus the theoretical expectations. Force versus displacement at different currents, shows the achievement: locking at rest, controllable forces, pulling & pushing operations with similar properties for both actuators.

## 8. Acknowledgements

The authors thank M.Csukai (OSEO) and M.Amiet (DGA) for supporting these works via OSEO.

- [1] J.D.Carlson, et al Magnetorheological and electrorheological fluid highlight 2006, Actuator Conf Proc, pp 2 35-239
- [2] <http://www.cedrat-groupe.com/en/software-solutions/flux.html>
- [3] Magnac, 2006, Characterisation of magneto-rheological fluids for actuators applications, Actuator 2006, Bremen,