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Editorial

Magneto-Rheological Fluids

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Magneto-rheological fluids, or MRF, have been known for a long time in the technological and scientific community. They have great potential and, as well, have important showstoppers. This combination is always conflicting and may explain why applications of such excellent materials are not yet widespread, despite their market value having already topped the impressive figure of almost 1.5 billion EUR worldwide, and being projected to about 6 billion EUR in 2030.

An MRF is a liquid that can change its rheological state when subjected to a magnetic field. Usually, viscosity is the main objective of such changes; its characteristic may span from values typical of water up to becoming almost solid. Since viscosity is targeted, the main uses concentrate on phenomena wherein this property plays an important role. Therefore, dynamic aspects are mainly considered, with the primary aim to variate the overall viscous damping function to increase the dissipation at the highest level. For instance, controlling viscosity may be essential for vehicle suspensions or other devices dealing with the impact of a system on the ground. Having almost no damping would cause the target structure to vibrate indefinitely, so a certain amount of dissipation capability is necessary. However, it cannot exceed a certain threshold, otherwise, the time response is dramatically affected, in turn determining the system to approach equilibrium in a very long time, virtually infinite. In other words, having infinite damping is almost equivalent, macroscopically, to have infinite local stiffness, as an additional constraint is added. Additionally, dissipation capability depends on velocity, so the damper should be tuned with its current value to attain the best performance.

The potential of such an incredible instrument is hampered by its construction. Usually, a MRF is produced as an oil solution containing small metal particles. The magnetic-forced orientation of such particles hinders the fluid movement. Since metal is heavy, the particles tends to drop down, so that a continuous mixing shall be actuated even though the use of some additives can limit the issue. The drawbacks of this necessity are evident since it would require some external energy devoted to this operation which, in the case of a transport drum, is sometimes generated by a helix constantly mindling the fluid. Luckily, some applications are self-consistent, as the structures that enjoy the presence of the MRF are themselves subjected to continuous oscillations. In the case of cars or bikes, this operation is strictly connected to continuous hits with road irregularities; for this reason, it is not surprising that many patents and several common implementations of magneto-rheological fluids are for road vehicles.

Other major applications of MRF are related to seismic response attenuation, where the need to maximize the energy dissipation is crucial for guaranteeing the device's effectiveness and safeguarding the reference structure. In this case, the system may stand for a long time, silent, without anything to do. However, it should be ready to use at unpredictable moments. Therefore, its state should be preserved at each instant, and an automatic monitoring system is essential. This fact enlarges the costs of implementing such devices, even with the perspective of an exceptional response in danger.

This Special Issue presents two papers that deal with the application of MRF on buildings. The first one [1] is an extensive review of many publications focusing on devices fitted to certain structures. It deals with friction dampers (FD), tuned mass dampers (TMD), and viscous dampers (VD), further classifying them into passive, active, and semi-active systems. The second one is more directed to a specific application and deals with a vibration-suppression system based on MRF-based integrated dissipative bracings [2]. A simulation model is proposed and validated through experimental measures on a dynamically scaled model representative of a five-storey slender building, thus making the article extremely interesting for further investigations.

The other important cluster of papers deals instead with the use of the MRF as a device for enhancing the performance of brake or suspension systems. The first of the series faces the design optimization of a hydrodynamic brake empowered with MRF [3]. The article tries to draft general guidelines for that class of devices. The second one deals with the application of MRF on industrial drive system clutches in continuous operation [4]. In this case, a theoretical design approach is devoted to computing electrical consumption, copper losses, and temperature distribution, parameterized with respect to the number of discs comprising the clutch device. The implementation of MRF systems to enhance the performance of an aircraft landing gear is then approached [5]. Therefore, this paper devotes attention towards aeronautical systems, specifically those that should be effective just once in a flight (or at most two, if take-off is also considered). The focus of the work addresses the pressure losses due to the square of the flow rate, which can be significant for high-speed mechanisms, such as the landing gears at the impact, differently from automotive suspensions, which instead work at relatively low velocities. Finally, an MRF-based semi-active air suspension is proposed to reduce vehicle vibrations and noise fields during motion [6]. It is interesting to remark that the manuscript presents an experimental characterization of the proposed MRF damper, which shows excellent performance with respect to ordinary devices, from both the energy dissipation and interior comfort points of view.

The three other papers of the collection deviate from the traditional concepts expressed above. One of them proposes an integrated concrete mixture charged with ferrous nanoparticles for better controlling the concrete mixture during casting [7]. The introduced methodology proved to be effective in the established aim by implementing an active stiffening control during the manufacturing process. An original issue was considered by the second paper, investigating the induced pressure change within an MRF system following the application of a magnetic field [8]. The correlation between control and observed variables is not linear, increasing for higher values of the input; at the same time, larger currents cause increased heat fluxes, which results in degradation of the coil performance and the magnetic field strength itself. The latest work provides readers with a comprehensive survey on particular applications of MRF, such as flow control devices or valves, [9]. Specifically, after a detailed and systematic review, the paper proposes classification criteria and categorized MRF valves into groups based on architecture similarities and performance envelopes.

The collection of papers in this Special Issue are well-representative of the most common MRF-based systems available in the scientific and technical literature. In turn, based on the wide bibliography represented herein, it can be considered as a starting base from which one can explore the fascinating world of MRF-based devices, which currently continue to exhibit untapped potential and, therefore, are expected to excel in the near future. This step is intimately correlated to the development of technologies, mainly addressed to limit the weights and sizes of their components.

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