Editorial

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Editorial on the need and advantages of nano and smart fluids in the 21st century

Volume 5 Issue 1 - 2023

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Received: March 20, 2023 | **Published:** March 28, 2023

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The improvement of heat transfer by convection is the main object of several works, and to do so, a large number of researchers have carried out a multitude of numerical and experimental tests relating to the description of the phenomena managing convection, the effect of the nature of the systems in which it takes place (especially geometry), and the properties of the fluids involved (physico-chemical properties).

Chronologically, although the ideas for improvement have mainly concerned the geometry of the systems, and the physico-chemical nature of the convective media, the work has only affected the macroscopic or sometimes microscopic order of the process. But with the appearance and rapid development of nanosciences and nanotechnologies during the second half of the 20th century, convection took a large part of this new richness, and took on another aspect of improvement: it is at the nanometric level of the material of the convective medium that recent work has been focused on.

Nanofluids are then one of the fruits of such wealth. Endowed with particular and interesting physico-chemical properties such as their high thermal conductivity, nanofluids offer a heat transfer coefficient unbeatable by others.

Nanofluids synthesized by ultrasound are effective cooling and heat exchange liquids. Thermally conductive nanomaterials greatly increase heat transfer and heat dissipation ability. Sonication is well established in the synthesis and functionalization of thermally conductive nanoparticles as well as in the production of stable and efficient nanofluids for cooling applications.

The thermal conductivity of a material is a measure of its ability to conduct heat. For coolants and heat transfer fluids (also called thermal fluids or thermal oils), high thermal conductivity is desired. Many nanomaterials offer great thermal conductive properties. In order to utilize the superior thermal conductivity of nanomaterials, so-called nanofluids are used as coolants. A nanofluid is a fluid in which particles of nanometric size are suspended in a base fluid such as water, glycol or oil, where they form a colloidal solution. Nanofluids can significantly increase thermal conductivity compared to liquids without nanoparticles or larger particles. The material, size, viscosity, surface charge, and fluid stability of the dispersed nanoparticles significantly affect the thermal performance of nanofluids. Nanofluids are rapidly gaining importance in heat transfer applications because they exhibit superior heat transfer performance compared to conventional base fluids. Ultrasonic dispersion is a very efficient, reliable and well-established technique in the industry to produce nanofluids with high performance heat transfer capabilities.

Nanofluids are a new class of coolants. They consist of a base fluid (eg, water), which serves as a carrier liquid for nanometer-sized particles. Purpose-designed nanoparticles (e.g., nano-sized CuO, alumina titanium dioxide, carbon nanotubes, silica, or metals such as copper or silver nanorods) dispersed in the base fluid can significantly improve the heat transfer capacity of the resulting nanofluid. This makes nanofluids extraordinary high performance coolants. Using specifically engineered nanofluids containing thermally conductive nanoparticles dramatically improves heat transfer and dissipation, for example, 0.1% alumina nanoparticles can increase the critical heat flux of water by up to 70%. The addition of metallic nanoparticles to coolants used in thermal control systems can significantly increase the thermal conductivity of the base fluid. These metallic nanoparticle-fluid composite materials are called nanofluids and their use as coolants can reduce the weight and power requirements of spacecraft thermal control systems.

On the other hand, there is a category of newly invented fluids that is no less important than the first, which is the smart fluids. An intelligent fluid is a fluid that changes its properties when subjected to an electric field or a magnetic field. The best-known smart fluids are those that change their rheological properties, such as viscosity, under the influence of one of these two fields.

These fluids can generally be classified into two categories: electrorheological (ER) fluids and magnetorheological (MR) fluids. An electric field causes a change in the viscosity of ER fluids and a magnetic field causes a similar change in MR1 fluids.

The response of smart fluids to fields is fast (a few milliseconds) and the phenomenon is completely reversible. Several applications have been proposed, such as damping, clutching, vibration reduction and shock absorption. An intelligent fluid is a suspension of solid particles dispersed in an insulating fluid called carrier fluid. The carrier fluid can be, for example, water or oil.

At rest, the particles are suspended inside the carrier fluid and randomly distributed in suspension. When a magnetic or electric field is applied, the microscopic particles align themselves along lines of magnetic flux or electric flux. This increases the viscosity of the fluid. The following images show the behavior of a magnetorheological fluid before and after the application of a magnetic field.

Although the first patents on electro rheology and magneto rheological fluids (MRF) were filed respectively by W. Winslow and J. Rabinow in the forties. Their technical and industrial operations have only been developed over the past two decades.

The applications in the energy and technical-industrial fields of ER and MR Fluids, according to the three modes of operation mentioned above, are numerous and varied nowadays, among which we can mention:

In the field of mechanics of the MR fluid flow mode has been applied in recent years with great technical and commercial success in the realization of adaptive and intelligent dampers of the MagneRide type, by the American company: Delphi Corporation (Troy, MI), on the active suspension of luxury and sports cars, such as: Audi R8, Buick Lucerne, Cadillac STS Chevrolet Corvette, Ferrari 599GTB.

In the fields of anti-seismic infrastructures, the use of shock absorbers operating with MR fluid has enabled Japan to produce, with the collaboration of the American company Lord Corporation, world leader in the field, various anti-seismic infrastructures that can effectively counterbalance and with high speed telluric forces of up to 20 tons, as in the case of the suspension system, which equips the building of the Japanese National Museum of Emerging Sciences. Controllable shock absorbers operating with MR fluid have also been used with great success by Lord Corporation to solve the problem of harmful vibrations to which the famous Ding Tong bridge in China was subjected.

In the medical field, several types of knee joint prostheses, based on Lord company technology, are already available from Biedermann Motech. Also, Northeastern University has managed to develop a new light system called Akrod, allowing to control in real time, by the use of an actuator based on ER fluid, the articulation of the legs and artificial arms.

In the field of polishing crystals and gemstones A specialized machine nowadays applies the MR fluid flow mode, as a highly effective polishing tool. The latter does not wear out like conventional tools, thanks to a continuous and controlled circulation of the fluid, maintained by a hydraulic pump. The fluid becomes rigid and abrasive only at the level of the piece to be polished which must be placed directly under the action of a modulated magnetic field according to the precision to be achieved in the polishing operation, precision which may be lower in certain case at 10 nanometers thick.

In the field of military engineering, the US Army has recently and successfully applied, within the framework of the project known as 'The warrior of the future', the mode of compression of fluid ER in the design of a relatively light body armor which can be transformed at will or by a percussion of a bullet into an impenetrable solid body.

In the field of electronics, several electrical or electronic devices can be made flexible by integrating an ER fluid into their design, as in the case of a PC keyboard, which as soon as it is supplied with current becomes rigid and ready to be used as usual.

In the field of space, the application of MR fluids has recently led to the development of magneto-liquid telescope mirrors which articulate and deform to cancel out the harmful effect of star scintillation.

In the end, despite the applications of nanofluids and smart ones in most fields, their actual use remains modest, so that most of the contributions are confined to the field of research, or monopolized by special groups, which necessitates expanding the scope of their spread and employment, especially towards the industrial sector that relies mainly on classical materials. Because these best performances obtained so far as well as the limitations imposed on these fluids make us optimistic about a better contribution, especially if future research work in this field is better directed.

Acknowledgments

Special thanks to all members of the research laboratory Fundamental and applied physics laboratory FUNDAPL.

Conflicts of interest

The author declares there is no conflicts of interest.