# University Of Technology- Iraq
# Department of Materials Engineering
# General Materials Branch
# Fourth class

## Smart Materials

## Lecture 4 : Smart Fluid

Class Code on Google Classroom :2shhens

# Smart Fluid

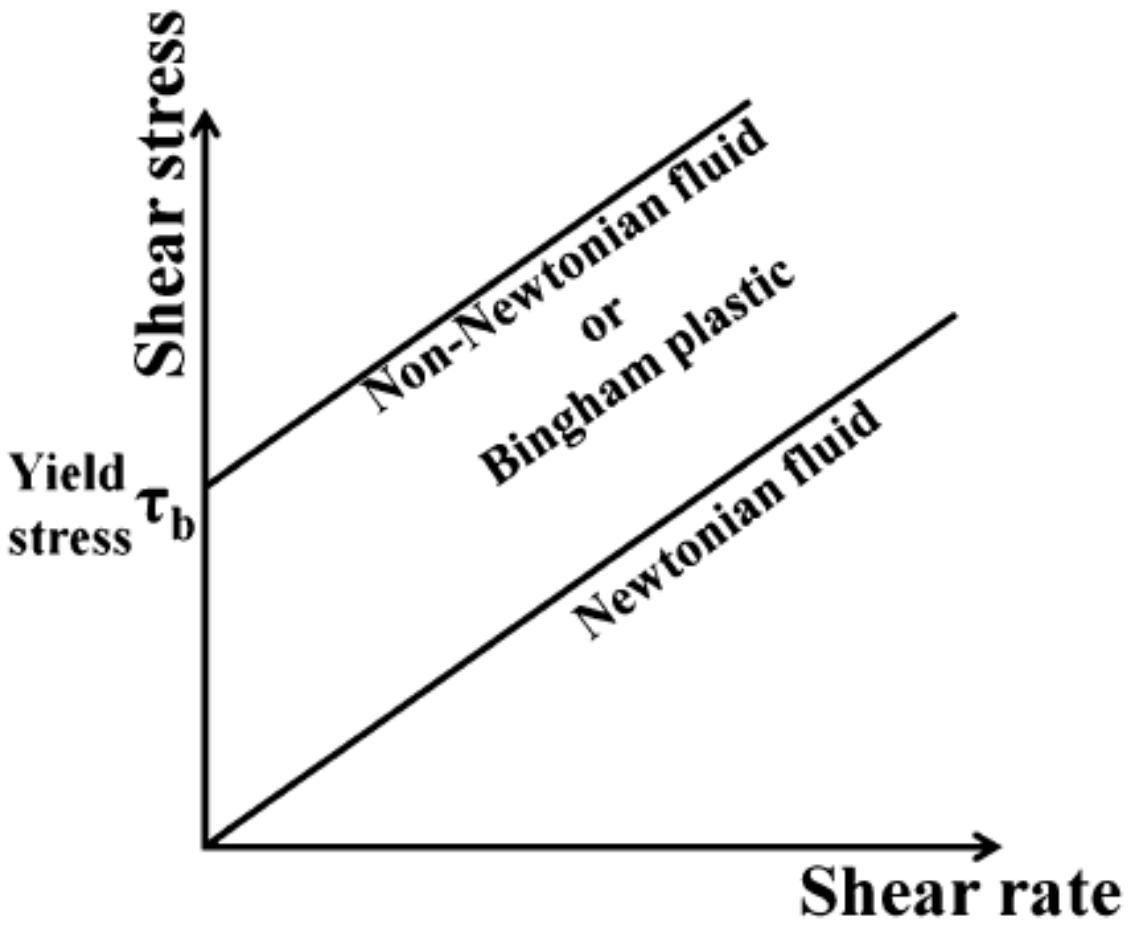
- A smart fluid is a fluid whose properties (e.g., the viscosity) can be changed by applying the stimuli (electric field or a magnetic field)
- Rheological materials are one type of smart fluid.
- Smart fluids can be divided into five main classes:

1. electro-rheological (ER) fluids
2. magneto-rheological (MR) fluids
3. magneto-rheological elastomer (MRE) fluids
4. electro-conjugate liquids,
5. Photorheological fluid

- The word rheology comes from greek words (rheo means flow and logia means study) . It deals with the study of the flow of matter.
- It addresses the behavior of the materials with properties intermediate between those of ideal solids and ideal liquids.
- When subjected to external forces, solids (or truly elastic materials) will form, whereas liquids (or truly viscous materials) will flow

# Rheological materials

- Rheological materials are non-Newtonian fluids.
- Non-Newtonian fluid is a class of fluids whose viscosity changes with the strain rate unlike the Newtonian fluid, in which the viscosity changes with temperature but does not change with the strain rate



# Rheological materials

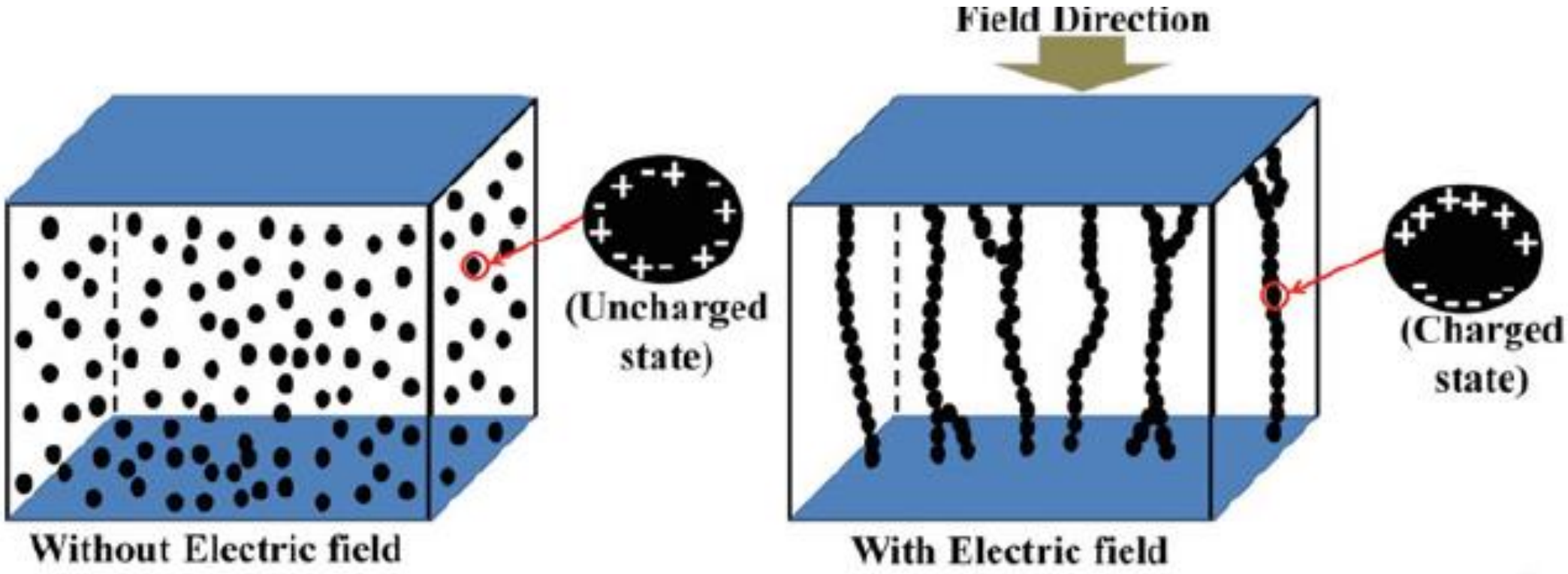
- Both the ER and MR fluids can be characterized by Bingham plastic behavior. When the applied field (electric or magnetic) is zero, then the smart fluid is Newtonian-like in behavior.
- The application of a suitable field and the subsequent formation of particle chains causes yield stress to develop This yield stress must be overcome before flow can occur
- Thus the fluid behaves in a fashion similar to a Bingham plastic. Two regimes are then defined:

1. pre-yield, where the yield stress ɽbis not exceeded and thus fluid flow does not occur
2. post-yield, where ɽb is exceeded and consequently flow occurs

# Electro-Rheological fluid

- major type of smart fluid is electro-rheological or ER fluids, whose resistance to flow can be quickly and dramatically altered by an applied electric field (note, the yield stress point is altered rather than the viscosity) .
- Electrorheological fluids, also called as electro-viscous fluids or electro-responsive fluids, are functional fluids, normally in the liquid state with good fluidity

# Behavior of suspended particles in electro-rheological fluid under electric field



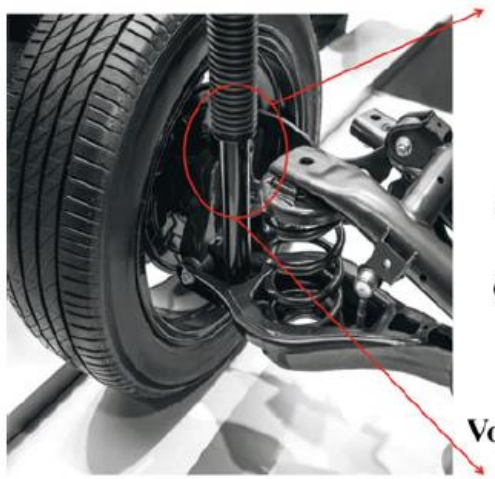
# Electro-Rheological fluid

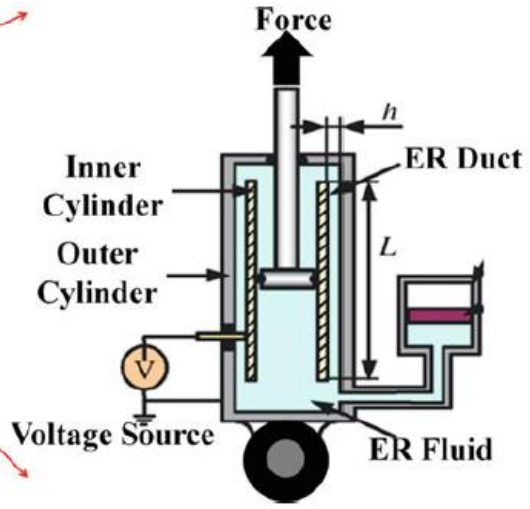
- This phenomenon is reversible and repeatable.
- This makes the use of electro-rheological fluids highly competent in several applications such as

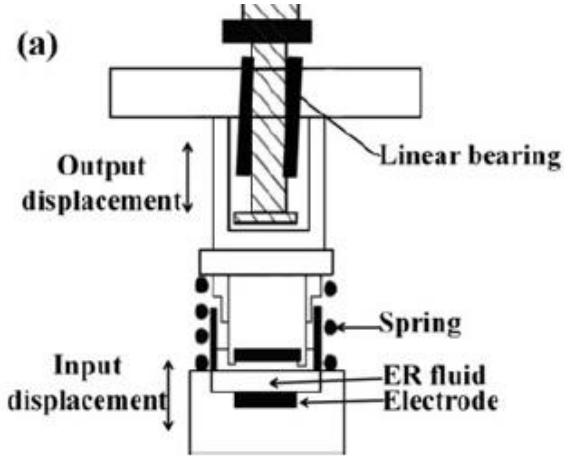
# Various carrier fluids and particles applied for ER fluid

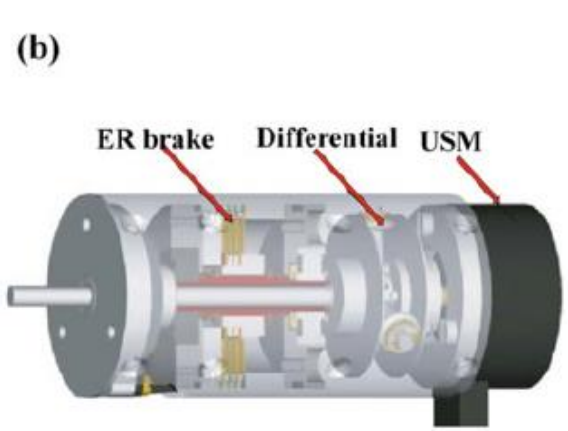
| Typical carrier fluids | Additive particles |
|---|---|
| Aldehydes, Aliphatic Esters, Aroclor, Carbon Tetrachloride, Caster Oil, Chlorobentzenediphenyl Alkanes, Chloroform, Cottonseed Oil, Di-2-Ethylhexyl Adipate, DibutylSebacate, Dielectric Oils, Different types of Ethers, Diphenyl Ethers, DiphenylSulphoxides, Grease, Hydrocarbon Oil, Ketones, Kerosene, Linseed Oil, Liquid Paraffin, Mineral Oil, Nitrobenzene, Olefins, Olive Oil, Orthochlorotoluene, Polychlorinated Biphenyls, Poly ChloroTrifluoroethylene, Polyalkylene Glycols, P-xylene, Polychlorinated biphenyls, Resin Oil, Silicone Oils, Transformer Oil | Alfa Silica, Alfa Methacrylate, Alginic Acid, Alumina, Alumina Silica Mixture, Aluminium Oleate, Aluminium Octoate, Aluminium Stearate, Boron, Azaporhin Systems, Barium Titanate, Cadmiumsulphide Phosphor, Calcium Stearate, Carbon, Cellulose, Ceramics, Charcoal, Chlorides, Colloidal Silica, Colloidal Kaolin Clay, Crystalline D Sorbitol, Diallylether, Diethylcarbocyanine Iodide, Diphenylthiazoleanthra Quinone, Divinylbenzene, Dyes, Gypsum, Iron Oxide, Mannitol, Metallic Semiconductors, Methyl Acrylate, Methyl Methacrylate, Microcell-C, Microcrystalline Cellulose, Micronized Mica, Monosaccharides, Molecular Sieves, N-Vinylpyrrolide, Nylon Powder, Olefins, Onyx Quartz, Polyvinyl Alcohol, Onyx Quartz, Pizo-ceramic, Phenolformaldehyde, Phthalocyanine, Polystyrene Polymer, Porhin, Phosphototungstomolybic Acid, Polymethacrylate Mixtures, Pyrogenic Silica, Quartz, Rotten Stone, Rubber, Silica Gel |

# Application Of Electro-Rheological fluid



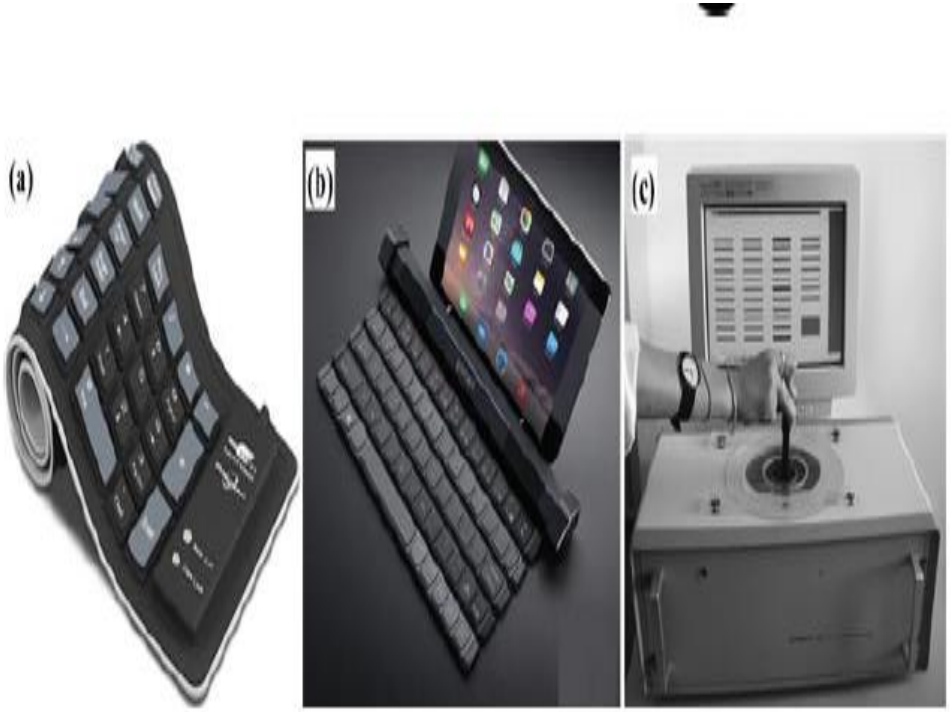



1. Mechanical Engineering (Clutches, Dampers ,Brakes, Shock absorbers, Hydraulic valves)
2. Military Applications (Bulletproof vests where quick engagement and activation are important)
3. Electronics (flexible electronics, in which the fluid is embedded in elements such as keyboards and rollable, haptic controller)

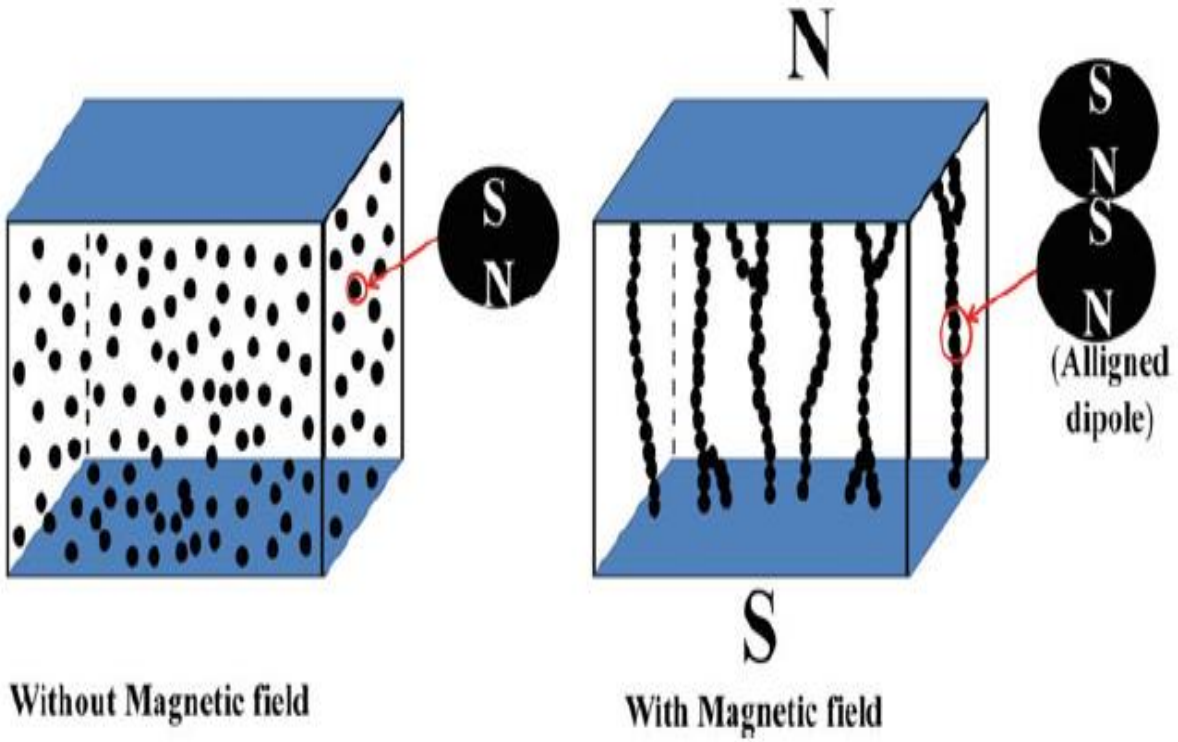
# Application Of Electro-Rheological fluid




# Magneto-Rheological Fluid

- A magneto-rheological fluid (MR fluid, or MRF) is a type of smart fluid. MR fluid, when subjected to a magnetic field (Fig. 6.13), the fluid greatly increases its apparent viscosity, to the point of becoming a viscoelastic solid. Importantly, the yield stress of the fluid when in its active ("on") state can be controlled very accurately by varying the magnetic field intensity. MRFs show a sharp variation of their non-Newtonian behavior, increasing their viscosity upon the application of an external magnetic fie

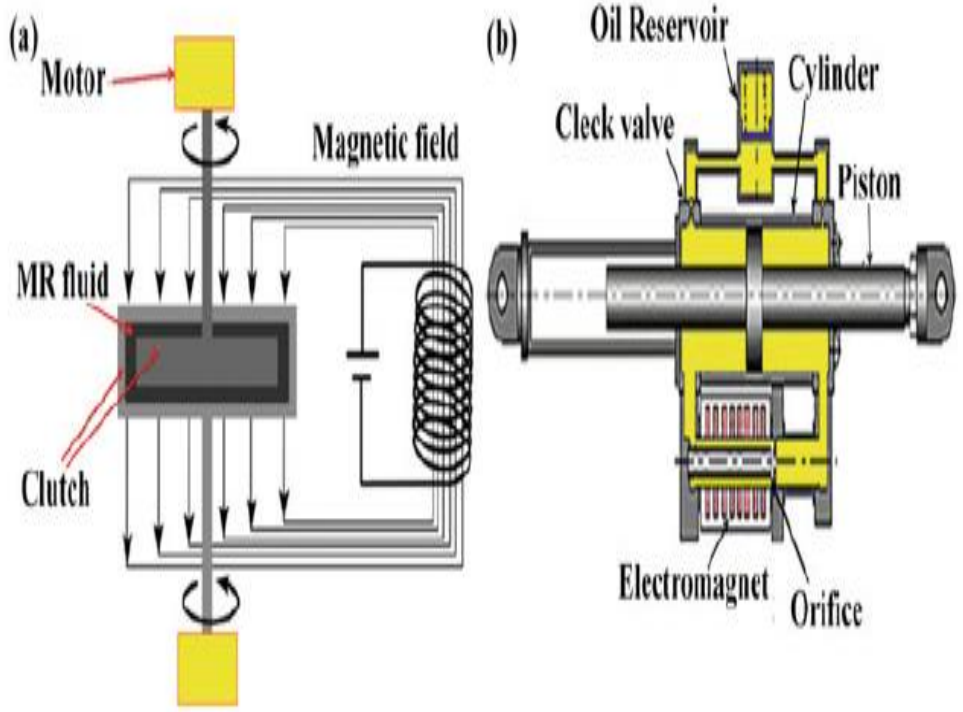
# Magneto-Rheological Fluid




| Magnetic particles | Carrier fluid |
|---|---|
| Iron, nickel, cobalt, Carbonyl iron particles, Iron-cobalt alloys, Ferrite etc. | Silicon oils, Mineral oils, Water etc. |

# Application of MR

1. Automobile and Heavy Machinery Industries (magneto-rheological damper figure shows the MR clutch and MR fluid suspension. (magneride) active suspension system allows the damping factor to adapt to the conditions once per millisecond. General Motors (in collaboration with Delphi Corporation) has developed this technology for automotive applications. He made his debut in Cadillac as “MagneRide”



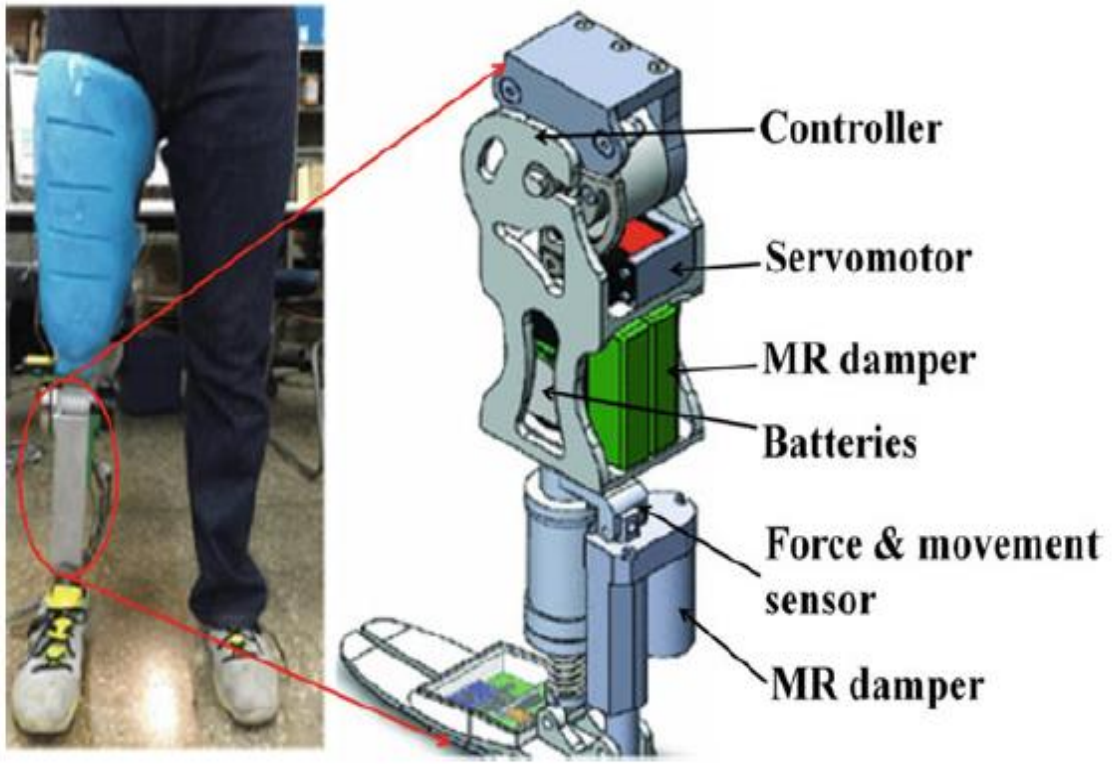
# Application of MR

2. Military and Defense Industries Magneto-rheological dampers are designed for use in military and commercial helicopters, as a safety device in the event of an accident. It is used to reduce trauma to the spine of passengers by reducing the level of injuries sustained during the accident

# Application of MR

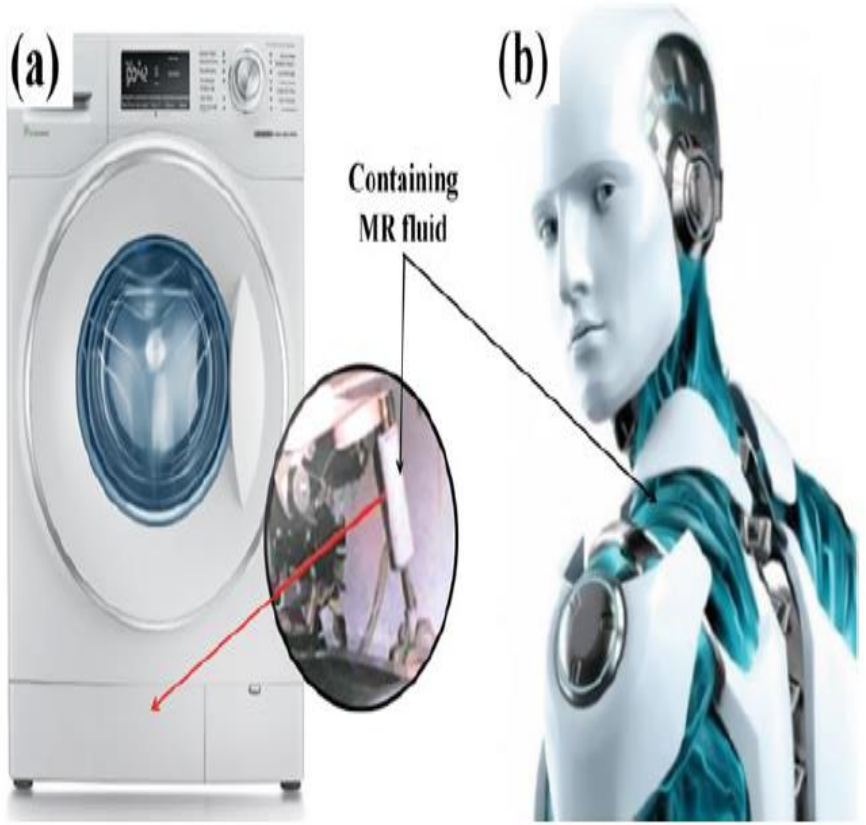
- Biomedical Industries

3. Magneto-rheological dampers are used in the semi-active human leg muscles. Similar to those used in military and commercial helicopters, a prosthetic leg reduces the trauma to the patient's leg while jumping. This results in increased agility and mobility of patients.



# Application of MR

4. Other Application
   Robotics ,
   Electrical
   Industries ,
   Costructions



# Other Types of Smart Fluid

- Ferro Fluid ( ferromagnetic fluid ) Aerospace (satellites ), Electronic (Hard disk), Medical Application (MRI)
- Magneto-rheological Elastomers
- Electro-Conjugate Liquids (dielectric fluid)
- Photo-Rheological Fluid (UV Lambs)