Project report 2020

MARECO

MAgneto-Rheological elastomers for Energy COnversion

MAIN PARTICIPANTS





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OVERVIEW *(keep within this page)*

Starting year: 2015 **Current researchers** (permanent/non-permanent): 3 person-month/year

Positioning *(Multiple selection allowed – total 100%)*	**Transportation**	**Energy**	**Eng. for Health**
Materials and structure design	50%	50%	
Surfaces and interfaces			
Simulation and modeling			

Other:

Include partner from ☐ Outside ELyT ☐ Industry

Main funding source(s)
☒ Public project(s) ☐ Industrial ☒ Own resources

IFS CRP/LyC project? ☐ Yes ☒ No

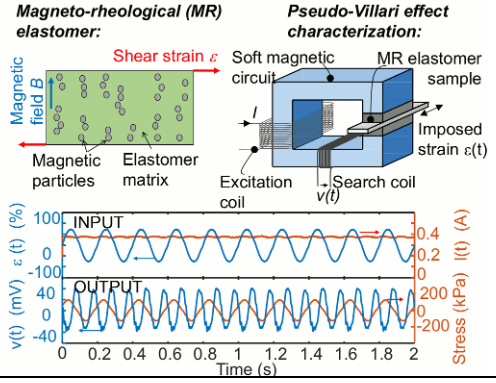
For main projects: Agency / year / name of project *(up to 3, past projects in gray)*

Estimated annual budget: 10k€

Highlights & Outstanding achievements *(3-5 bullet points)*

- The magneto-mechanical energy conversion in polymer composites with magnetic particles was elucidated
- Routes of improvement were proposed, considering that the polymer matrix plays no role in the energy conversion, opening the way of ultra-soft elastomer matrix

Illustration[1] *(5x5 cm² max)*



[1] *After G. Sebald, M. Nakano, M. Lallart, T. Tian, G. Diguet, J.-Y. Cavaille, , Science and Technology of Advanced Materials 18(1) (2017) 766-778*

PROJECT DESCRIPTION

Background (10 lines max; Calibri 11)

In the framework of **energy harvesting from vibrations**, resonant systems exhibit the highest energy conversion potential. Considering the typical frequency range encountered in transportation or energy industries (100Hz and below), it is necessary to explore alternatives to piezoelectric or electromagnetic systems. In this frame, it is investigated the **potential of soft elastomers** composites including magnetic particles. In this framework, the use of soft polymers offers the advantages of being low-cost and mechanically very soft compared to their piezoelectric counterparts.

A Magneto-Rheological Elastomer (MRE) exhibits a **magneto-mechanical coupling**, i.e. a dependence of the mechanical modulus on the magnetic field and a dependence of the magnetic permeability on the mechanical strain. However, the latter effect has been barely considered within the scientific community. MRE can therefore be utilized for energy conversion, such as vibrational energy converted into magnetic one, and through induction in coils, into electrical one.

Key scientific question (2 lines max; Calibri 11)

What are the physical mechanisms driving the magneto-mechanical energy conversion in MRE? What energy density conversion can be reached?

Research method (8 lines max; Calibri 11)

Within this project, we aim at evaluating and enhancing the capability of MRE for energy harvesting by working on three complementary aspects:

- Elaboration and optimization of the material,
- Modeling and characterization,
- Application to the design of an energy harvesting demonstrator.

In 2020, the work focused mostly on (i) an energy harvesting proof of concept, and (ii) a new class of smart material using elastomer foam.

Research students involved *(gray color for previous years)*

Ph.D. candidates (years, institution):

Master/Bachelor students (years):

Visits and stays *(gray color for previous years)*

FR to JP (date, duration):

- Mickael LALLART, JSPS invited researcher at TU, Sept 2019 -June 2020 (10 months)
- Mickael LALLART, visit at TU, March 2019 (10 days)
- Mickaël LALLART, visit at TU, October 2017 (1 week)

JP to FR (date, duration):

COMMUNICATIONS AND VALORIZATION

Journal publications *(gray color for previous years)*

	Authors	Title	Journal	Vol.	pp. / ID	Year	DOI
1	G. Diguet, G. Sebald, M. Nakano, M. Lallart, J-Y Cavaillé	Optimization of the magneto-rheological elastomers for energy harvesting applications	*Smart Materials and Structures*	29(7)	075017	2020	doi: 10.1088/1361-665X/ab8837
2	G. Diguet, G. Sebald, M. Nakano, M. Lallart, J.-Y. Cavaillé	Magnetic particle chains embedded in elastic polymer matrix under pure transverse shear and energy conversion	*Journal of Magnetism and Magnetic Materials*	481	39-49	2019	doi:10.1016/j.jmmm.2019.02.078
3	G. Sebald, M. Nakano, M. Lallart, T. Tian, G. Diguet, J.-Y. Cavaille	*Energy conversion in magneto-rheological elastomers*	**Science and Technology of Advanced Materials**	18(1)	766-778	2017	doi: 10.1080/14686996.2017.1377590
4	M. Lallart, G. Sebald, G. Diguet, J.-Y. Cavaille, M. Nakano	*Anisotropic magnetorheological elastomers for mechanical to electrical energy conversion*	**Journal of Applied Physics**	122	103902	2017	doi: 10.1063/1.4998999

Conferences *(gray color for previous years)*

	Authors	Title	Conference	Date	City	Country	DOI *(if applicable)*
1	G. Diguet, G. Sebald, M. Nakano, M. Lallart, J. Y. Cavaille	Experimental and Theoretical Investigation on the Influence of the Volume Fraction of the	Sixteenth International Conference on Flow Dynamics	, November 6 – 8, 2019	Sendai	Japan	

		Particles on MR and Villari Effect					
2	G. Diguet, G. Sebald, M. Nakano, M. Lallart, J.Y. Cavaille, T. Takagi	Magneto Rheological Elastomers for Energy Harvesting Systems	The 19th International Symposium on Applied Electromagnetics and Mechanics (ISEM2019)	15 – 18 September 2019	Nanjing	China	
3	G. Sebald, M. Nakano, M. Lallart, G. Diguet, J.-Y. Cavaille	Polymer composites for magneto-mechanical energy conversion: experimental comparison of several magneto-rheological elastomers	Smart Fluids & Soft Matters and Their Advanced Applications, at 15th International Conference on Flow Dynamics	November 7-9, 2018	Sendai	Japan	
4	G. Diguet, J.-Y. Cavaille, G. Sebald, M. Nakano. M. Lallart	Magnetic saturation in anisotropic Magneto-rheological Elastomers, the limiting factor of efficiency?	Smart Fluids & Soft Matters and Their Advanced Applications, at 15th International Conference on Flow Dynamics	November 7-9, 2018	Sendai	Japan	
5	G. Diguet, G. Sebald, M. Nakano, M. Lallart, J.-Y. Cavaillé	Saturation of MR Elastomers impact in a pure sheared-based energy harvesting device	The 5th Int'l Conference on Advanced Composite Materials (ACM 2018)	July 14-16, 2018	Kunming	China	
6	G. Diguet, G. Sebald, M. Nakano, M. Lallart	MR Elastomers for Energy Harvesting System	INTERMAG 2018	April 23-26, 2018	Singapore	Singapore	
7	M. Lallart, G. Sebald, G. Diguet, J.-Y. Cavaille, M. Nakano	Modeling of Anisotropic MagnetoRheological Elastomers for Mechanical to	Fourteenth International Conference on Flow Dynamics	November 1-3, 2017	Sendai	Japan	

		Electrical Energy Conversion					
8	G. Sebald, M. Nakano, M. Lallart, T. Tian, G. Diguet, J.-Y. Cavaille	Experimental Testing of Pseudo-Villari Effect in Magnetorheological Elastomers	Fourteenth International Conference on Flow Dynamics	November 1-3, 2017	Sendai	Japan	
9	G. Sebald, M. Nakano, M. Lallart, J.-Y. Cavaille, G. Diguet	Pseudo-Villari Effect in Magneto-Rheological Elastomers	18th International Symposium on Applied Electromagnetics and Mechanics	September 3-6, 2017	Chamonix	France	

Patents *(gray color for previous years)*

	Inventors	Title	PCT #	Year

Others *(gray color for previous years)*

	People	Event	Description	Date