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Homopolymer Based Magnetorheological Elastomer

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ABSTRACT

Magnetorheological rubber belongs to the class of 'Smart Material' whose mechanical properties can be altered continuously and reversibly by an applied magnetic field. Magnetorheological rubber (MRE's) are composites that consists of magnetically polarisable particles mixed into rubber matrix. With suitable controlled algorithms, they respond to change in their environment.

Purpose of this work is to know more about magnetorheological rubber for active stiffness, vibration control and dampening applications. Although few applications of these materials have been reported in the literature, the possibilities are numerous. They can be used for various applications such as vibration absorber, vibration isolator, variable stiffness bush, spring, force sensors, actuators etc.

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I. INTRODUCTION

Magnetorheological elastomers (MREs) are a type of composite material, whose physical or mechanical properties can be altered upon the application of a magnetic field. MREs can be usually prepared by mixing micron-sized magnetic particles into rubber-like matrices. In the presence of a magnetic field, MREs exhibit an effect providing a field-dependent physical or mechanical property, for e.g. a controllable modulus, due to the sensitive response of the magnetic particles to the field. When the field is removed, MREs will reclaim their original property.

First research on MREs was reported by Rigbi and Jilken in 1983, although the discovery of the basic magnetorheological effect was done in 1940s for magnetic fluid. MREs are nothing but solid-state version to magnetorheological fluids (MRFs). They overcome major issues faced in MRFs, for example, the deposition of iron particles, sealing problems, and environmental contamination. Such advantages offer MREs great potential for designing smart devices to be used in various engineering fields, especially in fields that involve vibration reduction, isolation, and absorption. In general, MREs exhibit a unique field-dependent material property when exposed to a magnetic field. Recently the study of the sensing

behavior of MREs have been explosively emerged for sensing mechanical and magnetic signals.

II. MATERIALS

A) Magnetically polarisable particles

Magnetic particles of higher permeability & higher saturation magnetization are highly desirable for obtaining stronger magnetic field-sensitive effect.Carbonyl iron (CI) powder is currently widely used as a magnetic particle for preparing MREs. Diameter of this kind of CI powder is in micrometers.The value of saturation magnetization can reach more than 600 kA/m and there is little remnant magnetization when magnetic field is removed. This results from the fact that the content of Fe element in CI powder is usually more than 97.5% in weight fraction.

Chemical Analysis Report of the CI powder :

SYMBOL	Fe
ELECTRONIC CONFIGURATION	[Ar] $3d^6 4s^2$
ATOMIC NUMBER	26
ATOMIC MASS	55.845 u
MELTING POINT	1,538 °C
PURITY	99.99%
PARTICLE SIZE	30 MICRON
FORM	POWDER

B) Rubber Matrix:

Elastomers containing polyepichlorohydrin, also known as ECO, CO, or GECO according to ASTM, offer an excellent balance of properties, combining certain desired dynamic properties of natural rubber (NR), with much of the fuel, oil, and chemical resistance of other specialty elastomers such as nitrile (NBR), polyacrylate (ACM), and neoprene (CR) rubbers. The combination of the basic properties of oil, fuel, heat, low-temperature flexibility, and ozone resistance imparted by the saturated main chain and the chlorine groups, coupled with low permeability.

ECO-H provides properties such as

- ✓ Oil & Fuel resistance
- ✓ Solvent resistance
- ✓ Good gas impermeability
- ✓ Heat &Weather resistance
- ✓ Good mechanical & physical properties
- ✓ Damping Properties

Technical Data of ECO-H:

- ✓ S.G.:1.37
- ✓ Mooney:45 ML 1+4(100C)
- ✓ Cl content: 37%
- ✓ Tg: -26C

C) Other regular ingredients:

Besides the magnetic particles and the elastic matrices, additives are also key components for preparing MREs. Activator to activate the acceleration of curatives. Curative along with acid acceptor to cure the rubber. Plasticizers for the softening. More dosage of plasticizer improves CI effect. Reinforcing fillers to reinforce the rubber matrix.

Other silane agent for good coupling of CI powder.

Also Lead oxide is carcinogenic to health so Magnesium oxide is used. Ester adipate is plasticizer. NDBC (Nickel-dibutyldithiocarbamate) works as anti-oxidant here. N-550 i.e. FEF Carbon black is reinforcing filler.

Recipe:

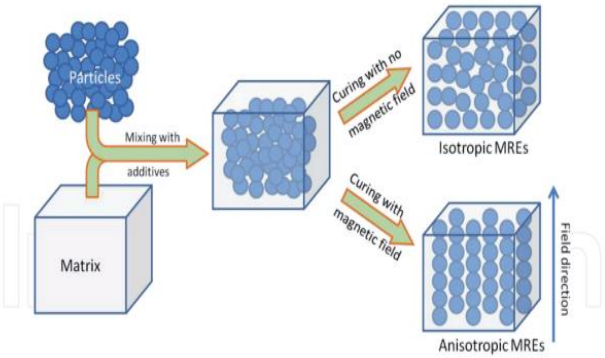
Ingredient	Batch-1 (phr)	Batch-2 (phr)
ECO-H	100	100
NDBC	2	2
N-550	80	80
CI Powder	40	40
Ester Adipate	12	12
MgO(Acid acceptor)	5	5
VtMoEo(Silane)	2	2
NA-22(ETU)	1.5	1.5
S	0	0.5
CBS	0	0.5

III.MANUFACTURING

- ✓ First clean the mixing mill then add raw rubber.
- ✓ Proper mastication time was given.
- ✓ Add NDBC afterwards.
- ✓ Then add ½ C.B + ½ Ester adipate
- ✓ Give proper mixing time.
- ✓ Remaining C.B. & Plasticizer is added.
- ✓ C.I powder is slowly added then.
- ✓ Vinyl based silane is added which acts as coupling agent.
- ✓ Then ETU+S+CBS is added.
- ✓ Batch is ready for testing.

IV. WORKING

The magnetic particles and the matrix are mechanically mixed with some additives into a mixture. Then the mixture is to be vulcanized at a particular temperature. During the vulcanizing, in case of applying a magnetic field, the magnetic particles can move.



V. RESULTS

Various tests were done such as :

Durometer test, Rheometer test, Multimeter test [B1=Batch1, B2=Batch2]

A) Durometer test:

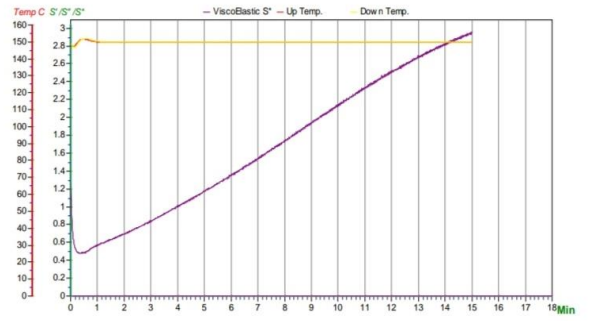
B1 : 45-50 ShoreA

B2 = 70-75 ShoreA

Batch-1

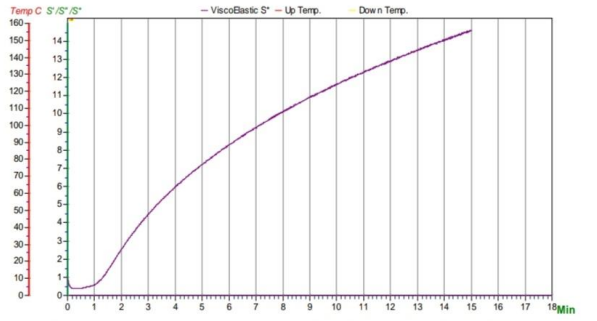
Batch-2

B) Rheograph test :



Date/Time	S/N	Compound	TS1	TS2	TC10	TC50	TC90	ML	MH	S*@ML	S*@MH	CRI	CHK
202002181244	1	ECO-H	6:50	11:4	2:33	8:05	13:14	0.35	2.85	0.33	0.78	66.55	O

Batch-1



Date/Time	S/N	Compound	TS1	TS2	TC10	TC50	TC90	ML	MH	S*@ML	S*@MH	CRI	CHK
202002181541	2	ECO-H	1:30	1:56	1:41	5:12	12:25	0.26	14.46	0.25	2.02	9.54	O

Batch-2

C) Multimeter test : On passing current along the samples it was seen that there was voltage drop hence it suggests that samples can respond to magnetic field.

7. APPLICATIONS:

- Adaptive tuned vibration absorbers
- Vibration isolators
- Variable stiffness bush
- Adaptive tuned dampers
- Magneto-sensitive strain sensors
- Actuators
- MEMS Magnetometer

Other various applications are also there. Recently, microwave response and 3D printing properties of MRE's have been explosively developing.

VI. CONCLUSION

Isotropic MRE's with irregularly shaped iron particles exhibit a large MR effect, hence we prepared that. Materials with poorly dispersed carbonyl iron, results in aggregates of particles, exhibit an MR effect close to that of materials with larger irregular particles. The reinforcement caused by the large amounts of iron particles, makes it very difficult to reach MR effects of more than 60 %. Required MR effect was obtained but more batches of proper hardness will be prepared for further research. Also, the elastomer used goes well with Magneto-rheological application.

VII. ACKNOWLEDGEMENT

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VIII. REFERENCES

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