RESEARCH ARTICLE

SAMRIDDHI Volume 13, Special Issue 2, 2021 Print ISSN : 2229-7111 Online ISSN : 2454-5767

Fabrication and Replication of Unstructured and Prestructured Magnetorheological Elastomer

Bharat Bhagwat Waghode[1*], Netra Pal Singh[2]

[1,*] Oriental University, Indore, Madhya Pradesh, India; e-mail : bharatwaghode6@gmail.com

[2] Oriental University, Indore, Madhya Pradesh, India.

ABSTRACT

Magneto rheological (MR) elastomer becomes very strenghful and advanced smart material that can be tuned and responded fastly in respect of mechanical properties by an application or without application of magnetic field. These are basically elastomer material in that iron elements are discrete in elastomer matrix. According to use of magnetic flux application at the time of fabrication process they are classified as Isotropic and Anisotropic MR elastomer. The distribution of magnetizable particles in matrix of elastomer are well distinct and arranged with regards to their types. Their morphology had been seen by Scanning Electrons Microscopy (SEM) with their performance been seen by Fast Fourier Transform (FFT) analysis. With their better morphological and mechanical features they can be used to innumerable applications like vibration absorbers, isolators, seismic devicesetc.

Keywords : smart material, magneto rheological, elastomer, carbonyliron particles, scanning electron microscopy

SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology, (2021); DOI : 10.18090/samriddhi.v13spli02.29

INTRODUCTION

As the growing trends of superior and relaxed regime has directed to rising response for both new variable technologies plus materials, innovative smart with bright functional provisions have been getting a large considerations in latest years. The smart resources are those well-regulated with external surroundings such as electrical or magnetic flux, mechanical stresses, heat, plus light [1]. Amongstthese, magneto rheological (MR) resources become important greatest vital smart resourcesin regards their vast industrial promises. They are categorized as a practical smart type material resources owning rheological with viscoelastic assets for example yield and shear mechanical stress, various damping belongingsonce an exterior magnetic flux is useful. On the new hand, MREs be able to categorized into dual altered groups, that are isotropic (unstructured) and anisotropic (prestructured) MR elastomers, fabricated on contrivances of attractively polarized particle structure in the MREs. The polarized diverged particles are evenly adjourned in an isotropic or unstructured MRE, means that the MRE indicates homogenous type of physical performances in every single direction. Also For an anisotropic or prestructured MRE, dispersed magnetic elements are ranged along by way of the response magnetic flux lines [2,3,4]. These type of material was selected in this study due to its inherent belongings under the exterior magnetic flux and smart application in vibration absorbing devices [5,6].

Corresponding Author : Bharat Bhagwat Waghode, Oriental University, Indore, Madhya Pradesh, India; e-mail : bharatwaghode6@gmail.com

How to cite this article : Waghode, B.B., Singh, N.P. (2021). Fabrication and Replication of Unstructured and Prestructured Magnetorheological Elastomer. *SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology,* Volume 13, Special Issue (2), 288-295.

Source of support : Nil

Conflict of interest : None

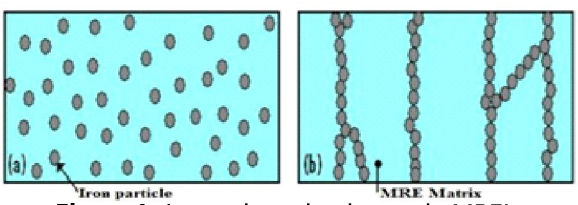

Figure 1: Isotropic and anisotropic MRE's

In given examination work construction of isotropic (unstructured) plus anisotropic (prestructured) MRE's were performedby means of15 plus30 percent of iron elements or particles as per by weight of elastomer matrix [2,3,5,7] And studied samples in regard to transmissibility ratiowith percentages of vibration absorption by using Fast Fourier Transforms(FFT) exploration[2]. SEM analysis has to be performed to observe the internal morphological structure of isotropic(unstructured) and anisotropic (prestructured) material [4,5,8].

Consruction Of Isotropic As Well As Anisotropicmagneto-Rheological Elastomer

The anisotropic type of MRE is a benevolent of pre-structured settled magnetic elastomer. Throughout the curing procedure, an exterior magnetic flux is functional to the blend of elastomer matrix with magnetic elements. The isotropic type of MR elastomer is a benevolent of unstructured settled magnetic elastomers. Throughout the curing, no exterior magnetic flux was functional on the mixture. MRE is a elastomer material comprising with carboxyl Fe particles in it by cured in existence of magnetic flux or nonexistence of magnetic flux depends on thatkind [2,3].Elastomer castoff for MRE is PDMS available in categoryA (base) and category B (curing element), iron particles were used with 15% and 30% by weightof elastomer matrix mixed with Si oil. PDMS elastomer was selected due to its easy curing process and wide temperature applicability [9].Magnetic flux were functional with the help of permanent neodymium magnets at the time of curing procedure of anisotropic type of MREs. The curing period of 48 hours were set for both samples.Total four samples have been made out of them two are isotropic and other are anisotropic. MRE 1 and MRE 2 have been prepared with 15gm of CIP in existence of magnetic flux or nonexistence of magnetic flux depends on its kind.MRE 1 was isotropic(unstructured) MRE and MRE 2 was anisotropic (prestructured) MRE [10].

Table-1: Content by weight used for MRE (1 and 2)

Sample Type	Part A	Part B	Si Oil	CIP	Curing Time
Unstructured & Prestructured MRE	100	10	15	15	48

(Both samples are of same contents, Sample 1 and 2)

Table-2: Content by weight used for MRE (3 and 4)

Sample Type	Part A	Part B	Si Oil	CIP	Curing Time
Unstructured & Prestructured MRE	100	10	25	30	48

(Both samples are of same contents, Sample 3 and 4)

Actual image of isotropic (unstructured) MRE and anisotropic (prestructured) MRE with 15gm of CIP is as shown in figure 2.

Figure 2: Unstructured (MRE-1) and Prestructured (MRE-2)

Actual image of isotropic (unstructured) MRE and anisotropic (prestructured) MRE with 30gm of CIP is as shown in figure 3.

Figure 3: Unstructured (MRE-3) and Prestructured (MRE-4)

Morphological Properties of MRE's

In the MR elastomer, the deferment of magnetic particles with the grip amongst the carboxyl iron particles withthe medium are precise significant to the belongings of the MR elastomer. The morphology of unstructured with prestructured MREs is perceived over and done with scanning electron microscope (SEM)[JSM-IT 200, BTRA, Mumbai]. To detect the structure of the MRE, the model isabsorbed in LN2 and censoredvertically. By this morphology reflection, matrix and distribution state of magnetic elements can be perceived [11]. The image4a is SEM image of an unstructured MRE fabricated deprived of a magnetic flux with15gm of CIP and Figure 4b is SEM image of prestructured MRE 15gm of CIP fabricated in magnetic fluxthrough curing. The image shows randomly distributed magnetizable particles in matrix. The image 4b is SEM pictures of prestructured MRE sample. Contrasting Figure 4a SEM image, the carbonyl ironelements are ranged in the elastomeric matrix, this settles that it is prestructured MR elastomer. These internal structure features are intensely related to the mechanical as well MR features of MREs and shows vital factors for applications [12].

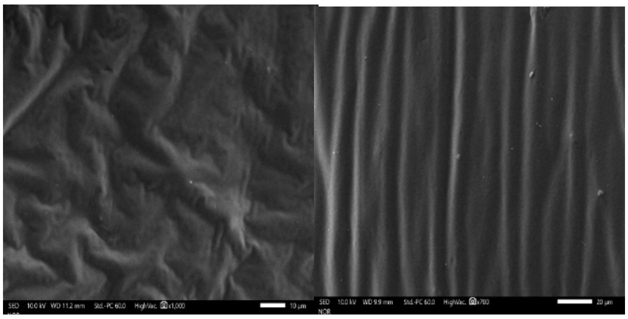

Figure 4: SEM appearance of unstructured/MRE-1 (a) and prestructured/MRE-2 (b)[JSM-IT 200, BTRA, Mumbai.]

Similarly, image5a is SEM appearance of an unstructured MRE fabricated deprived of a magnetic flux with 30gm of CIP and image 5b is SEM appearance of prestructured MRE 30gm of CIP fabricated in magnetic field during curing.

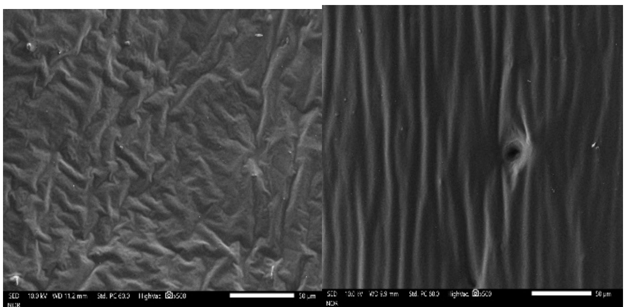

Figure 5: SEM appearance of unstructured/MRE-3 (a) and prestructured/MRE-4 (b)[JSM-IT 200, BTRA, Mumbai.]

As seen in figure 4 and figure 5, it is clearly shown the variability of volume concentration of CIPs in the matrix of elastomer. Although the variability of volume concentration of CIPs was shown butthe principle of types of MRE with their nature with respect to magnetic flux applied was completely satisfied by both the figures.

Response Analysis of MRE's

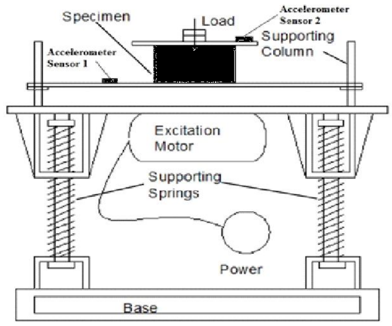

Figure 6: Design of Experimental Setup

To find capability of prepared MRE samples in vibration absorbing parameters in regards to transmissibility and percentage of vibration absorption, it was necessary to go through the experimental examination which was briefly discussed in given research article. The design of experimentation was shown in figure 6.

The investigational set up comprise of convenientchannel FFT, excitation table, system and two accelerometers sensors. The frequancies and amplitude of vibration have been sensed by the accelerometers and recorded in FFT analyzer. The test arrangement used was as shown in figure 4.Before the start of the testing the entire set up was ran for 10 min for resonance followed. The excitationtable was activated that changed the rotationalwave of the motor axle into rectilinearback and forth motions. The samples were verifiedunder different loading conditions.The amplitude force was sensed by both accelerometer sensor. The investigation was done with both the samples of unstructured and prestructured MRE under different loading conditions.

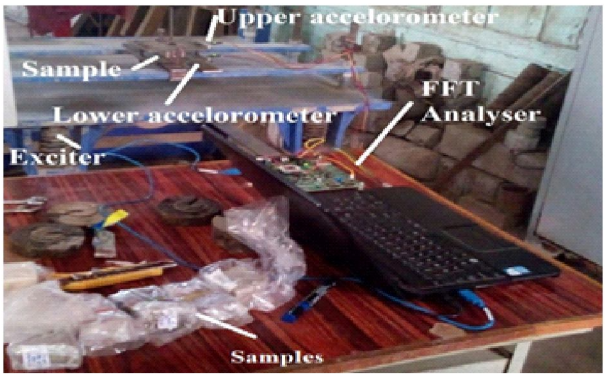

Figure 7: Experimental set up with FFT

We are selected different loads as 0N, 10N, 20N, and 30N according to the size of MRE samples. The amplitude and frequency were measured under these applied conditions of load for all MREs

Unstructured MRE1

Table-3: Result table for MRE-1

Position	Vibration Amp.	Transmissi-bility	Vibrat. Absorb %
	Under No Load		
Upper Amp.	7.13	0.744	25.6
Lower Amp.	9.58		
	Under 10N		
Upper Amp.	6.89	0.731	27.0
Lower Amp.	9.43		
	Under 20N		
Upper Amp.	6.78	0.730	27.0
Lower Amp.	9.29		
	Under 30N		
Upper Amp.	6.28	0.724	27.6
Lower Amp.	8.67		
All reading are computed by FFT analyzer at 48.3 Hz			

MRE-1 with no load and 10N load condition

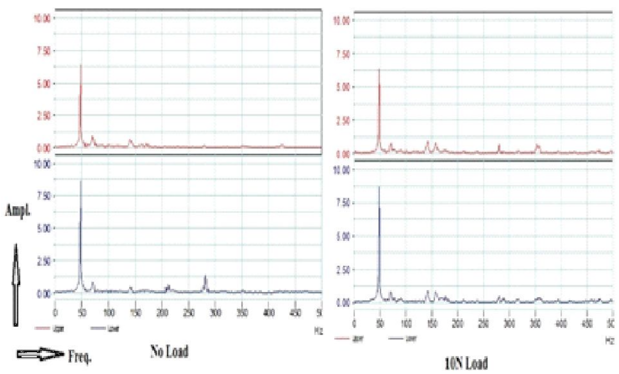

Figure 8: FFT graph for MRE-1 with no load and 10N

As seen in FFT graph for MRE-1 with no load and 10N load, vibration amplitude of both position is measured at natural frequency 48.3Hz by both accelerometer sensors. From measured amplitude, transmissibility ratio and percentages of vibration absorption have to be calculated. MRE-1 shows 25.6% vibration absorption at zero load condition and 27% at 10N load condition.

MRE-1 with 20N load and 30N load condition

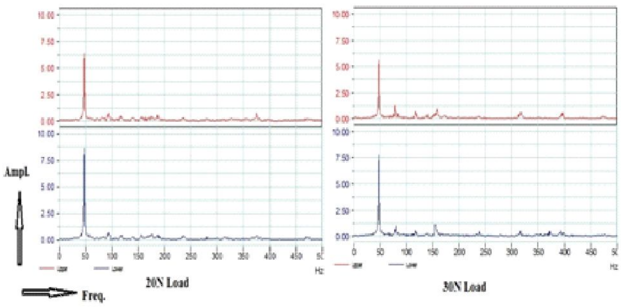

Figure 9: FFT graph for MRE-1 with 20N and 30N

As seen in FFT graph for MRE 1 with 20N load and 30N load, vibration amplitude of both position is measured at natural frequency 48.3Hz by both accelerometer sensors. From measured amplitude, transmissibility ratio and percentages of vibration absorption have to be calculated. MRE 1 shows 27% vibration absorption at 20N load condition and 27.6% at 30N load condition.

Prestructured MRE-2

Table-4: Result table for MRE-2

Position	Vibration Amp.	Transmissi-bility	Vibrat. Absorb %
	Under No Load		
Upper Amp.	6.91	0.723	27.1
Lower Amp.	9.48		
	Under 10N		
Upper Amp.	6.89	0.731	26.9
Lower Amp.	9.42		
	Under 20N		
Upper Amp.	6.66	0.739	26.1
Lower Amp.	9.01		
	Under 30N		
Upper Amp.	6.01	0.74	26.0
Lower Amp.	8.12		
All reading are computed by FFT analyzer at 48.3 Hz			

MRE-2 with no load and 10N load condition

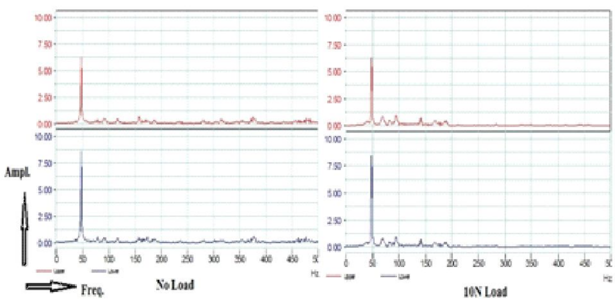

Figure 10: FFT graph for MRE-2 with no load and 10N

As seen in FFT graph for MRE 2 with no load and 10N load, vibration amplitude of both position is measured at natural frequency 48.3Hz by both accelerometer sensors. From measured amplitude, transmissibility ratio and percentages of vibration absorption have to be calculated. MRE-2 shows 27.1% vibration absorption at zero load condition and 26.9% at 10N load condition.

MRE-2 with 20N load and 30N load condition

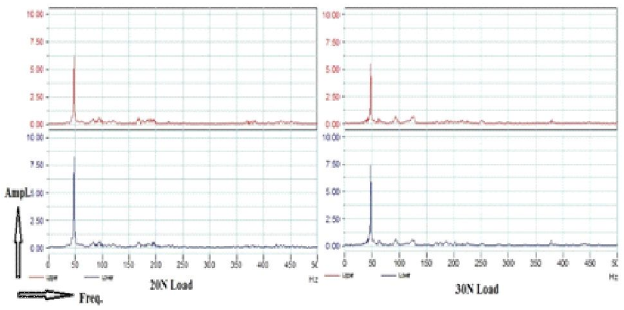

Figure 11: FFT graph for MRE-2 with 20N and 30N

As seen in FFT graph for MRE-2 with 20N load and 30N load, vibration amplitude of both position is measured at natural frequency 48.3Hz by both accelerometer sensors. From measured amplitude, transmissibility ratio and percentages of vibration absorption have to be calculated. MRE-2 shows 26.1% vibration absorption at 20N load condition and 26.0% at 30N load condition.

For unstructured and prestructured MRE samples with 15gm of CIPs by weight, amplitudes of vibration, transmissibility and vibration absorptionpercentage were perceived, it shown both samples exposed satisfactorily results with respect to parameters considered. As compared to all samples these two samples have some lagging results by MRE samples prepared with 30% of CIPs. Transmissibility is in less amount considered higher percentage of absorption along the material. For a good result very low amount of transmissibility ratio indispensable with high amount of percentage of absorption.The MR recital of prestructured MRE was grander to that of unstructured MRE.

Unstructured MRE-3

Table-5: Result table for MRE-3

Position	Vibration Amp.	Transmissi-bility	Vibrat. Absorb %
Under No Load			
Upper Amp.	6.48	0.653	29.5
Lower Amp.	9.19		
Under 10N			
Upper Amp.	6.41	0.69	3.10
Lower Amp.	9.28		
Under 20N			
Upper Amp.	6.39	0.686	31.4
Lower Amp.	9.31		
Under 30N			
Upper Amp.	6.32	0.674	32.6
Lower Amp.	9.38		

All reading are computed by FFT analyzer at 48.3 Hz

MRE-3 with no load and 10N load condition

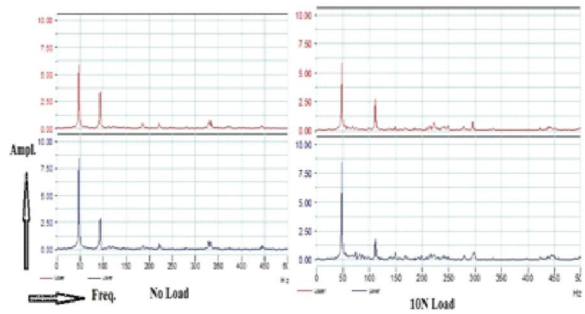

Figure 12: FFT graph for MRE-3 with no load and 10N

As seen in FFT graph for MRE-3 with no load and 10N load, vibration amplitude of both position is measured at natural frequency 48.3Hz by both accelerometer sensors. From measured amplitude, transmissibility ratio and percentages of vibration absorption have to be calculated. MRE-3 shows 29.5% vibration absorption at zero load condition and 31% at 10N load condition.

MRE-3 with 20N and 30 N load condition

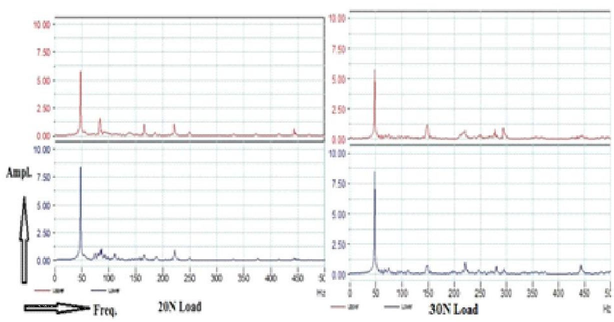

Figure 13: FFT graph for MRE-3 with 20N and 30N

As seen in FFT graph for MRE-3 with 20N load and 30N load, vibration amplitude of both position is measured at natural frequency 48.3Hz by both accelerometer sensors. From measured amplitude, transmissibility ratio and percentages of vibration absorption have to be calculated. MRE-3 shows 31.4% vibration absorption at 20N load condition and 32.6% at 30N load condition.

Prestructured MRE-4

Table-6: Result table for MRE-4

Position	Vibration Amp.	Transmissi-bility	Vibrat. Absorb %
Under No Load			
Upper Amp.	5.26	0.581	41.9
Lower Amp.	9.06		
Under 10N			
Upper Amp.	5.12	0.614	38.6
Lower Amp.	8.34		
Under 20N			
Upper Amp.	5.55	0.622	37.8
Lower Amp.	8.92		
Under 30N			
Upper Amp.	5.57	0.634	36.6
Lower Amp.	8.79		

All reading are computed by FFT analyzer at 48.3 Hz

MRE-4 with no load and 10N load condition

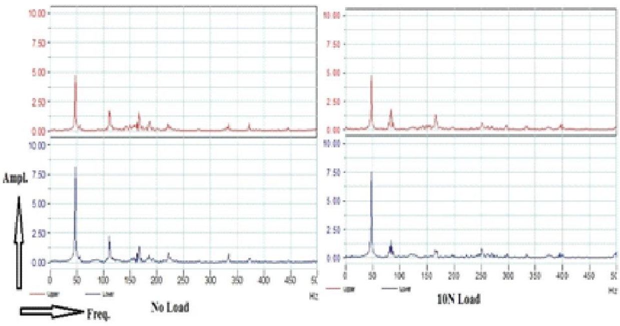

Figure 14: FFT graph for MRE-4 with no load and 10N

As seen in FFT graph for MRE-4 with no load and 10N load, vibration amplitude of both position is measured at natural frequency 48.3Hz by both accelerometer sensors. From measured amplitude, transmissibility ratio and percentages of vibration absorption have to be calculated. MRE-4 shows 41.9% vibration absorption at zero load condition and 38.6% at 10N load condition. Amongst the all MRE specimens MRE-4 under zero load condition shows a very high percentage of absorption with least amount of transmissibility ratio.

MRE 4 with 20N and 30 N load condition

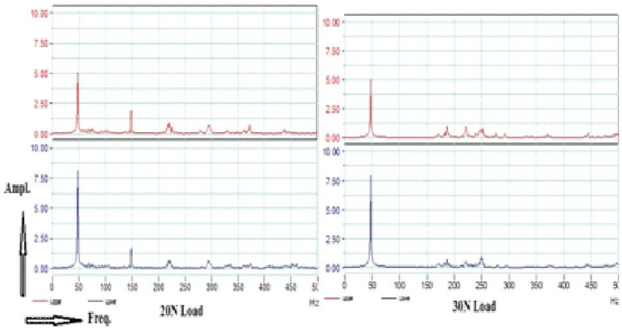

Figure 15: FFT graph for MRE-4 with 20N and 30N

As seen in FFT graph for MRE-4 with 20N load and 30N load, vibration amplitude of both position is measured at natural frequency 48.3Hz by both accelerometer sensors. From measured amplitude, transmissibility ratio and percentages of vibration absorption have to be calculated. MRE-4 shows 37.8% vibration absorption at 20N load condition and 36.6% at 30N load condition. For unstructured and prestructured MRE samples, amplitudes of vibration, transmissibility and vibration absorption percentage were perceived, it shown both samples shown good results with respect to parameters considered. As seen in the comparative column graph, the clear understanding amongst all MRE specimens with respect to their performance and capability in vibration absorption have been acknowledged. MRE 4 which is anisotropic (prestructured) MRE with 30gm of CIPs by weight shown a much estimated result in vibration absorption capability.

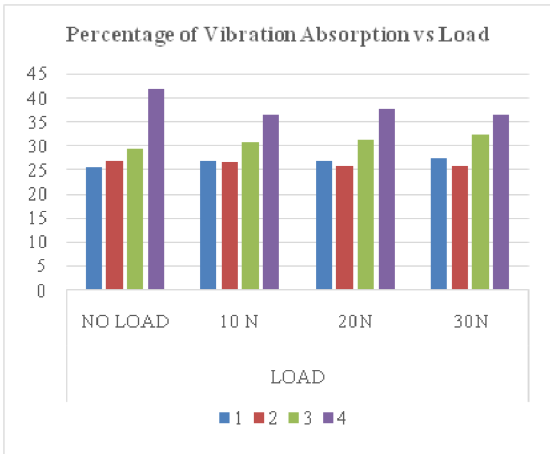

Figure 16: Comparison of % of vibration absorption vs. load

As seen the percentage of vibration absorption of all the samples, anisotropic MRE with 30gm of iron particles shown better results having 41.94% of vibration absorption with no load condition and also shown better performance with different loading conditions. Behind this sample isotropic MRE within 30gm of iron elements shown decent results of vibration immersion with different loading conditions. MREs with 15gm of CIPs exposed satisfactorily results with respect to parameters considered. As compared to all samples these two samples have some lagging results by MRE samples prepared with 30% of CIPs.

Conclusion

In this study, we briefly studied and observed fabrication, classifications, belongings, and uses of smart MREs. While the structure of unstructured and prestructured MREs was normally detected with SEM pictures together with their mixture and physical appearances. Concluded this morphology reflection, medium and diffusion state of ironelements can be perceived. SEM pictures of an unstructured MRE fabricated deprived of a magnetic flux shown randomly discretecarbonyl particles in matrix. SEM pictures of prestructured MRE fabricated in magnetic flux during curing shown the magnetizable particles are bring into line in the elastomeric matrix, and this relaxes that it is anisotropic (prestructured) MREs. By seeing morphological structure of all MREs, it is clearly shown the variability of volume concentration of CIPs in the matrix of elastomer. Although the variability of volume concentration of CIPs was shown but the principle of types of MRE with their nature with respect to magnetic flux applied was completely satisfied by both the figures.These morphological features are intensely linkedin the mechanical with MR features of MREs and are vital aspects for applications.

Also vibration belongings of MREs are clarified based on transmissibility and percentage of vibration absorption. The MR recital of prestructured MRE was grander to that of unstructured MRE. As when the MRE was confirmed without magnetic field (For isotropic MRE samples) under nil load, 10Newton load, 20Newton load and 30Newton load individually decreased the lower amplitudes of vibration at unchanged frequency, transmissibility decreases and percentages of vibration absorption rises with growth in the loads. And as once the MR elastomer was confirmed with magnetic flux under nil load, 10Newton load, 20Newtonload and 30Newton load individually transmissibility rises and percentages of vibration absorption decreases with rises the loads. Transmissibility is in less amount considered higher percentage of absorption along the material. For a good result very low amount of transmissibility ratio indispensable with high amount of percentage of absorption.

References

[1] Susmita Kamila, "Introduction, Classification and Applications of Smart Materials: An Overview", *American Journal of Applied Sciences* 10 (8): 876-880, 2013

[2] S. R. Kumbhar, SubhasisMaji and Bimlesh Kumar, "Fabrication and Response Analysis of Magnetorheological Elastomer", *Material Science Research India*, Vol. 9(1), 111-116, 2012

[3] S. R. Kumbhar, SubhasisMaji, Bimlesh Kumar "Development and Characterization of Isotropic Magnetorheological Elastomer", *Universal Journal of Mechanical Engineering* 1(1): 18-21, 2013

[4] K. Danas, S. V. Kankanala, N. Triantafyllidis, "Experiments and modeling of iron-particle-filled magnetorheological elastomers", *Journal of the Mechanics and Physics of Solids* 60, 120–138, 2012

[5] Yanfen Zhou, Stephen Jerrams, Anthony Betts, Lin Chen "Fatigue life prediction of magnetorheological elastomers subjected to dynamic equibiaxial cyclic loading"*Materials Chemistry and Physics*, vol. 146 , 487-492, 2014

[6] Lin Ge, Xinglong Gong, Yanceng Fan and ShouhuXuan, "Preparation and mechanical properties of the magnetorheological elastomer based on natural rubber/rosin glycerin hybrid matrix", *Smart Materials and Structures* 22, 115029 (8pp), 2013

[7] SriharshaHegde, K.V. Gangadharan, **"**Testing of RTV-Silicone based thick magneto-rheological elastomers under harmonic loading conditions" *International Journal of Scientific & Engineering Research*, Volume 5, Issue 2, ISSN 2229-5518, 2014

[8] S. RaaKhimi, K. L. Pickering, "Comparison of dynamic properties of magnetorheological elastomers with existing antivibration rubbers", *Composites Part B*, 2015

[9] BenxiangJu, Rui Tang, Dengyou Zhang, Bailian Yang, Miao Yu, Changrong Liao, "Temperature-dependent dynamic mechanical properties of magnetorheological elastomers under magnetic field", *Journal of Magnetism and Magnetic Materials*, 374, 283–288, 2015

[10] Weihua Li, Xianzhou Zhang, TongfeiTian, and Weijia Wen, "Fabrication and characterisation of patterned magnetorheological elastomers",*AIP Conference Proceedings* 1542, 129, 2013

[11] KhairunnisaHairuddin, SaifulAmriMazlan, Ubaidillah, HairiZamzuri and NorazmanMohamad "A Feasibility Study of Magnetorheological Elastomer Base Isolator"*Applied Mechanics and Materials*, Vol. 660, 763-767, 2014

[12] Sung Soon Kang, Kisuk Choi, Jae-Do Nam and Hyoung Jin Choi, "Magnetorheological Elastomers: Fabrication, Characteristics, and Applications", *Materials 2020*, 13, 4597, 2020