Design and Fabrication of Hybrid Magneto Rheological Elastomeric Angular Mounts With Iron Nano Particles.

Sudheer Kumar .Battula, Rama Murty Raju.P, CH.Ratnam

Abstract*: *The article mainly focused on the experimental characterization and validation of magneto rheological hybrid elastomers based on SI/PU and NR/PU was fabricated. For optimizing preparation conditions two MRE samples were prepared with Fe_2O_3 nano particles respectively. The MR effect was improved especially by modifying the SI/PU, NR/PU -rubber ratio and compatibility improvement between SI/PU and NR/PU rubber. The preparation conditions influences the bond between the MR effect and microstructure of MRE "magneto rheological elastomer" are discussed in detail. The obtained results confirm that MR elastomer has good MR effect than that of MR elastomers with pure Si/PU matrix with same testing conditions. The existed microstructure in the presence of PU matrix interpenetrating the peculiar former forms as indicated in SEM analysis. Finally the analysis indicates that the use of Fe_2O_3 nano particles would increase the bond strength between rubber matrix and particles. These experimental results were also verified by the SEM images.

Keywords: Magneto rheological, Hybrid elastomer, Characterization,

I. INTRODUCTION

MRE (Magneto rheological elastomer) are a new type of smart materials used for good performance of damping which consisting of non-magnetic matrix field elastomer normally controlled by a suspension of magnetically porous nano particles. In general Fe_2O_3 nano particles are a combination of carbonyl iron, magnetite, iron oxide and barium ferrite. Actually damping usually occurs due to viscous flow of rubber matrix and additional mount of nano particles in rubber gives good interfacial damping while compare to without addition of nano particles and appropriate matrix materials as natural, silicone and polyurethane rubber[1-11] .The main advantage of Magneto rheological applied magnetic elastomers has various applications, good stiffness, damping field during fabrication. The review highlighted the conflicting characteristics of vibration in different range of frequency and amplitude[12].A method of characterizing elastomeric mounts. Their model is capable of accurately capturing both amplitude (Tribo-elastic) and frequency (viscoelastic) dependency. This method is physics-based and utilizes the power law. The power law element consists of a linear spring connected in series with a nonlinear damper [13]. **A** study to find the optimum shape of a rubber engine mounts using parameter optimization. Length, thickness and radius were chosen as the parameters. The optimal values of the parameters were consequently found by minimizing a function of this parameters[14].A new research conducted and studied the influence of the viscoelasticity of rubbers on the performance of the vibration isolator. The transmissibility is simplified to be a function of the frequency ratio and the storage shear modulus. The nonlinearity of the rubber modulus is determined by the peak strain amplitude. The optimal low transmissibility could not be obtained, but the transmissibility could be limited by controlling the storage modulus. Magneto rheological mounts are categorized as a fluid mount[15].A complete non-linear model of a HEM (hydraulic engine mount). The procedure of developing the model was described in great detail. This study started with linear model of a hydraulic engine mount as lumped parameter. The linear model contained linear parameters of the rubber component, inertia track and decouplerm[16]. Magneto rheological (MR) fluids to electro rheological (ER) fluids are both smart fluids containing particles inside the carrier liquids. The main and critical difference between MR and ER fluids is that MR fluids respond to a magnetic field while ER fluids respond to an electric field. Because of the similarity between the magneto rheological (MR) and electro rheological (ER) fluids, MR researchers can learn valuable knowledge from ER counterpart [17] also constructed an MR fluid-elastomer vibration isolator similarly to the previous literature on squeeze mode mounts. However, this study considered that the phenomenological model of the squeeze MR mount was the combination of a variable friction damper and a nonlinear spring. The experimental results actually helped to develop the theoretical model that can predict the behavior of the isolator [18]. Generally nano based materials has numerous environment applications especially in cleaning up impure ground water and soil. In general these nano particles are more reactive than predictable iron powders. Usually these magnetic nano particles play a major role in various areas of applications as physics, material sciences and chemistry. Actually these magnetic nano particles are urbanized by various techniques that may lead to nano size particles like ball milling, sol-gel and hydro thermal process. In these techniques sol-gel co precipitation process is the most general and convenient synthesis process for preparing nanoparticles because it is very simple and good control over crystalline structure size [21].

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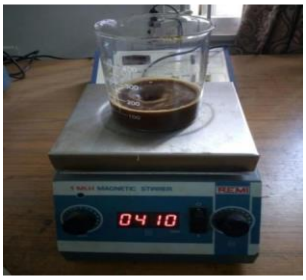
II. EXPERIMENTAL

A. Materials

Generally natural rubber has good outstanding strength and has maintained its position as the most useful material in various engineering applications. it has high strength, long fatigue life and reinforcing even without fillers. It has the flexibility to maintain down the compound to 60^0c. Basically natural rubber has good ability of stress relaxation resistance, good creep, as it is very low cost. Its main disadvantage was its lack of resistance to ozone and oxygen; it has poor oil resistance, although these disadvantages can be reduced to chemical process.SI rubber gives extreme resistance to temperature, normally operated from -100^0 c to 300^0 c. some important properties are creep, cyclic fatigue, tear strength, elongation, dielectric strength at high voltage, compression, fire resistance, thermal conductivity and in some cases, extreme temperature for superior to organic rubber in case of tensile strength and also some few material properties are very lower than special materials. some organic rubber materials has back bone of carbon to carbon which it susceptible to UV, heat and some other aging factors that SI rubber can hold good. From this aspect SI rubber is one of the better choices of elastomers for many significant environments. These materials have good wear resistance and high tear strength, it has typically a limit of upper temperature at 80^0 c, it has good oxidation and excellent resistance to weathering conditions. They even rest some grades of hydrocarbon fuels and mineral oils. These are the best rubber for basic resistance and also used in reciprocating seals. Here we use PU rubber between two solid angular mild steel plates, PU has great environment properties, hardness, good adhesion, mechanical and abrasive resistance etc.

B. Preparation of iron nano particles

Preparation of iron nano particles consists of chloride tetra hydrate (AR) Iron (II), chloride hexahydrate (AR) Iron (III), Ammonium solution (5%), Ammonium hydroxide (28%), double distilled water, Dilute hydro chloric acid. Clean the beaker (500ml), test tubes with dilute hydrochloric acid and dry them. Weigh chloride tetra hydrate Iron (II) and chloride hexahydrate Iron (III) and transfer them into 500ml beaker. At room temperature double distilled water 100ml is added and stir continuously till to achieved complete dissolution.(around 45-60 minutes) in (fig1.a).Then add 100ml of ammonium hydroxide (28%) and to allow the reaction to occur for around 30-40minutes.Remove the liquid formed above the precipitate and after add 40ml of ammonium solution (5%) and further proceed to centrifugation process. After centrifugation remove the particles from test tubes (fig 1.b) and dry the particle for air in a glass plate in (fig1.c).



(a)

(b)

(c)

Fig1(a) Magnetic stirring of solution, (b) Centrifugation of precipitate formed (c) Powdered iron oxide nanoparticles.

C. Compound preparation of MRE and comparative elastomer samples

The formulation of comparative compound samples based on silicone rubber compound to be used, for appropriate amount of curing agent a perfect weigh out of silicone rubber base is used and thoroughly mixed them and create a homogenous mixture as shown in (fig 2.d).while curing the rubber matrix avoid the air entrapped to eliminate voids. The mixed material to be exposed to vacuum about 20 mm mercury level and then the elastomeric samples will be expand, recede and crest about the original level as the bubbles breaks usually it takes 2 min after frothing ceases as shown in (fig 2.e).for achieving fast curing process the elevated temperature may be used for silicone rubber compound will sufficiently takes 24 hrs at 250c temperature as shown in (fig 2.f). As a part of preparing polyurethane elastomers samples stir and shake the sample A & B Mixing Ratio will be depended on the hardness require, kindly refer the technical specification for the proper mixing ratio as shown in (fig 2.g). for homogenous mixing of sample A and sample B, a uniform stirring is applied until a uniform color is obtained, to evacuate the entrapped air from the mixture the container will be placed into a vacuum chamber using vacuum pump capable of achieving 29 inches of mercury level, where the chamber is at atmospheric equilibrium remove the cover plate and taken out from the container. After that the desired material was poured slowly in a steady state stream so the mold material flows evenly over the die pattern. By this method it the minimize the entrapped air bubbles under the flowing material a mold release agent should be applied to the pattern for better flow of the liquid material into the die pattern. After the process is completed allow the cure rubber to 12 hrs at 25^0 c temperature, before removing the cured mold rubber from the pattern it is avoided from accelerated heat for the test sample.

For better results the cure mold sample should be exposed to the atmospheric air and an additional time of 24 hrs before the production as shown in (fig.2.h), for mixing of nanoparticles to rubber take a 500ml beaker and pour the hardener/silicone oil according to the ratio of requirement. Add number of grams of iron oxide nanoparticles into beaker. Place the beaker in the sonicator (fig 2.i) and adjust the time until particles distributed uniformly. After that add the solution to rubber material and leave it for curing.

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Fig (2.d) Mixing, (2.e) Silicone Oil, (2.f) Curing of SI Elastomer (2.g) Hardener and rubber chemical. (2. h) Curing of PU Elastomer (2.i) Sonicator.

III. FABRICATION OF HYBRID ANGULAR MOUNT

In fabrication of angular mounts mainly consists of two materials namely mild steel angular solid plates and elastomers? MS (Mild steel) is the most familiar form of steel as its cost is very low and it provides good material properties that are suitable for many applications. MS (Mild steel) has a comparatively low tensile strength, but it is malleable and cheap; through carburizing surface hardness can be increased. For elastic and viscous properties rubber is a unique material it acts as shock and vibration dampers and isolators. Actually rubbers like materials are categorized by their dynamic properties. In terms of dynamic properties of the rubber mounts the information available was scarce. The rubber could be modeled with hysteresis damping model. Engine mounts are used in various automotive industries and are subjected to various loading conditions depending on the engine working regime. Actually elastomeric mounts must also support the engine weights while being able to cope with high amplitude and low amplitude frequency loads that tend to make the engine bounce. That is the reason why, in order to predict with accuracy the vibration isolation capabilities of a mount, a newly designed angular mounts was fabricated with upper and lower angular mount die and a applied pressure of 24 tones was imposed with a time limit of 20 min and a temperature zone is created around 150^0c in the junction between mild steel angular solid plates and rubber. By this applied temperature the rubber is sandwiched between these angular solid steel plates and the actual shape of the mount is obtained as per dimensions as shown in fig .3 (i, ii, iii, iv) & Table.1

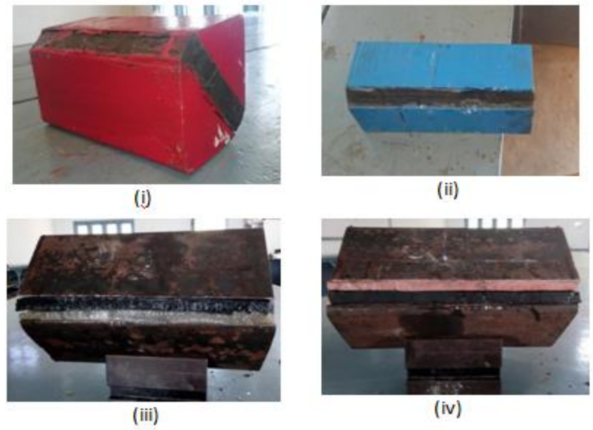

Fig (3.i) Pure PU-rubber (3.ii) Pure SR-rubber (3.iii) NR/SR Hybrid elastomer (3.iv) NR/PU Hybrid elastomer

Table 1: Required design specification of the elastomeric angular mount

Domain	Suggested Design
Mount Specifications	340 X 100 X 105 mm
Displacement	Min 0.67 & Max 1.45
Weight	15 Kg

IV. RESULTS AND DISCUSSION

A . Morphology

Figure 4(a.b.c.d) shows the SEM images of iron nanoparticles; these images confirm the arrangement of Fe_2O_3 nanoparticles. The images validate the spherical shape from the obtained nanoparticles and most of the particles shows and exhibit same face shape. Exact information is obtained about the surface morphology by the sample of SEM micro structure graph and nano range of particle size can be calculated from the XRD results. The observed samples of the morphology determine the fine grains of Fe_2O_3 which are of size200~500 nm. A uniform nano particle Fe_2O_3 distribution in rubber matrix can be seen in PU/MRE without noticeable aggregation in (fig.e).from the Fig.f it shows that the cured and mixed nano particles of PU/MRE sample as expected to form like a chain columnar matrix structure. For the aggregate range of comparative samples we generally evenly distributed in the rubber matrix from below the resolution of SEM see in (fig g). After the allocation of nano particles it can be seen that rubber matrix was occurred as same as obtained.

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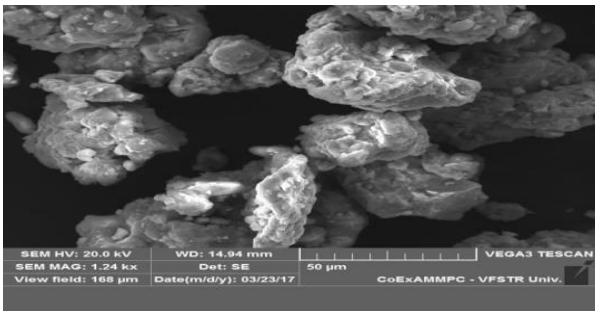
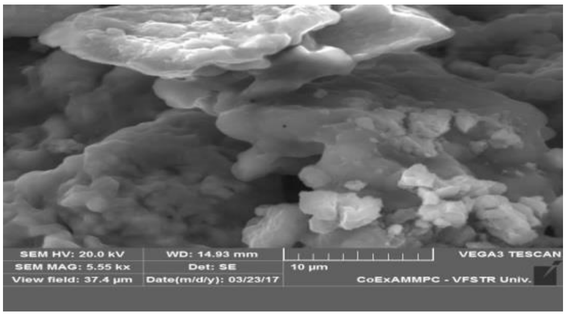


(4.a)



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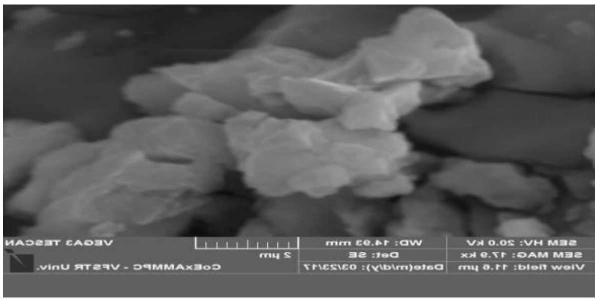

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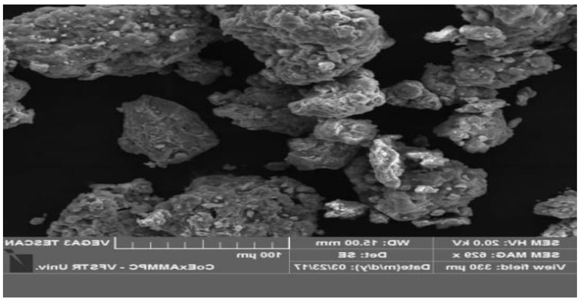

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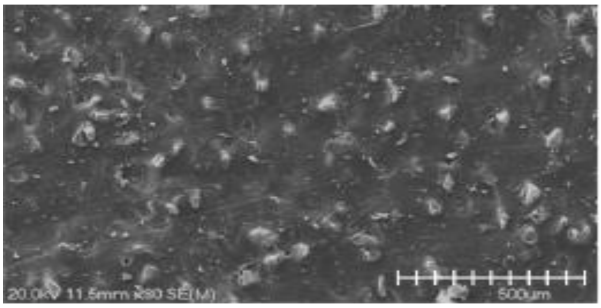
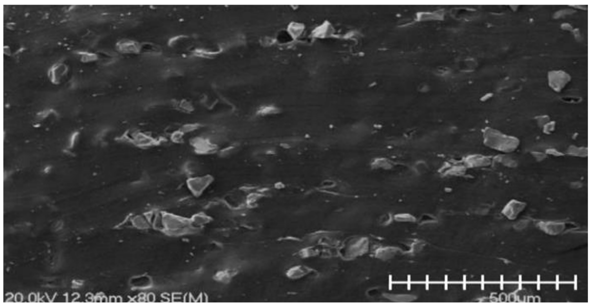
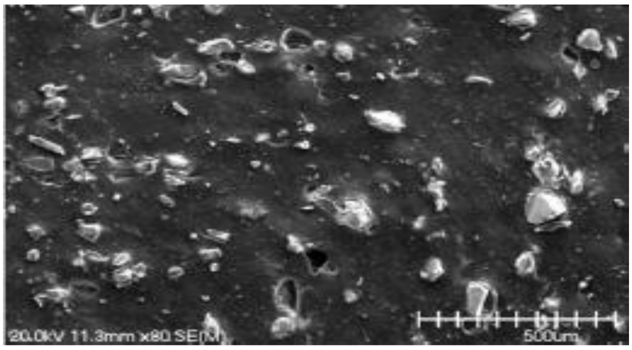


(4.e)



(4.f)



(4.g)

Fig 4 SEM images and surface analysis of Fe_2O_3 nano particle (6.a) Resolution1.24 kX (6.b) Resolution 5.5kX (6.c) Resolution17.9kX (6.d) Resolution629 kX (6.e) MRE/PU (6.f) MRE/SI (6.g) MRE/NR

The compound formulation and composition of nanoparticles mixed with natural rubber, polyurethane rubber and silicon rubber using a conventional laboratory by hand layup method according to ASTM design D412 used in this study with different masses by using the formula, density=mass/volume, calculated the weight of iron nano particles impinged into different rubbers and the test results as shown in fig. The variation of ultimate tensile strength and young's modulus of NR, PU, and SI samples, As the Fe_2O_3 nanoparticles mixed increases then both properties also increases.

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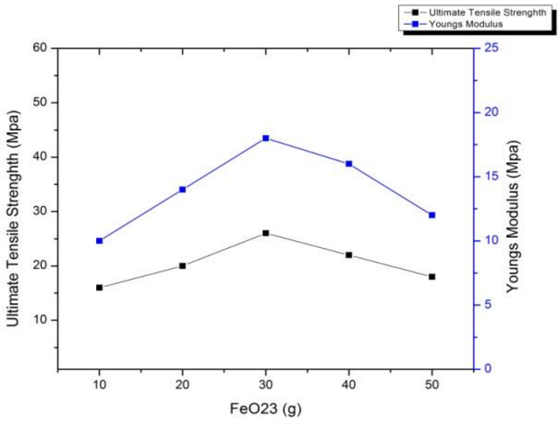
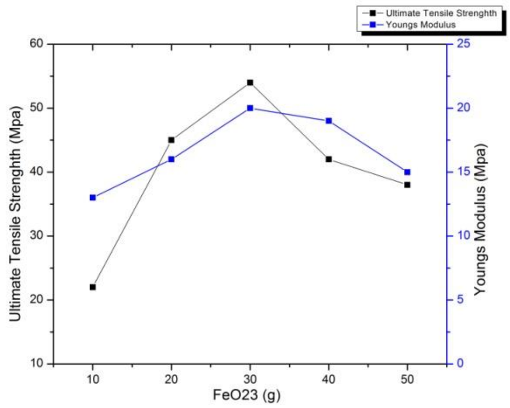
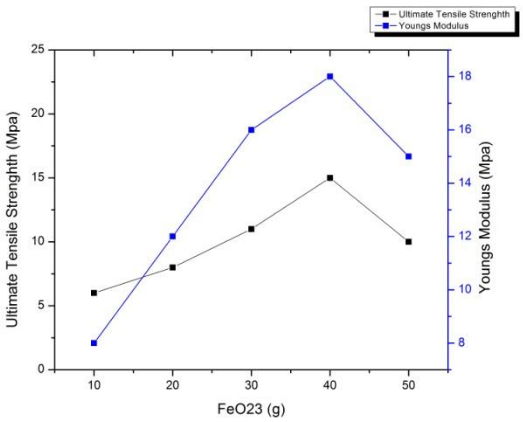
If we increase the nanoparticles mixed more than around 40g then both properties are decreased. As the nanoparticles mixed with with Pu rubber both the properties also increases. If we increase the nanoparticles mixed more than around 35g then both properties are decreased. Nanoparticles mixed with SI rubber both the properties increases. If we increase the Fe_2O_3 nanoparticles mixed more than around 40g then both properties are decreased the computed graphs as shown in (fig 5 a, b, c).



(5.a)



(5.b)



(5.c)

Fig 5 (a, b, c) shows variation of ultimate tensile strength and young's modulus of NR, PU & SI samples

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V. STATIC AND DYNAMIC BEHAVIOR OF ANGULAR MOUNT

The static behavior of the mount is discussed in this chapter. First, the experimental tests performed in order to obtain the mount's static load-displacement curve are presented and its results are shown. The FE model created and analyzed in this thesis for an elastomeric engine mount has the purpose of being able to describe with accuracy its static and dynamic behavior. To do so, one must be able to determine all the properties that influence such behavior. In the case of the static behavior, it's necessary to characterize the constitutive relationship that better describes the behavior of the material used in the mount. The key aspect that sets finite analysis of elastomers (FEA) apart from FEA of metal components is the specification of its material properties. Metals can, generally, be considered as Hookean materials, i.e. materials with a linear stress-strain relationship over its useable stress-strain range. Values for Young's modulus and Poisson's ratio for various metals are available in literature and have generally well-known values. In the particular case when the applied loads are sufficient to cause yielding, a non-linear analysis of the metal component can generally be made using a bilinear stress strain curve or a nonlinear strain hardening rule. In the case of elastomers, each formulation is different, yielding a large spectrum of behaviors, where, generally, there is only a small linear region in the stress-strain curve. Hence, the specification of nonlinear material properties for elastomers is more difficult. To obtain the load-displacement curves for engine elastomeric mount a set of experimental tests were conducted in static condition. These tests were performed in the mechanics of solids Laboratory at IND Equipments Chennai India. The machine used was an IND electromechanical testing machine having a50 KN load cell. In these tests the displacement was the controlled variable with an applied displacement speed of 2.5 mm/min to obtain a quasi-static response. The tests are conducted at a room temperature with 25 ºC, with the engine mount being placed and fixed as shown in (fig.6 a & b).Table 2 shows the static behavior of the angular mounts with various rubber compounding samples apart from this it will shown. As expected an experiment with optimized sample PU/NR showed a significant influence on displacements. In addition to this if we considered both the NR and PU samples with and without mixed matrix of nano particles with curing of rubbers shown.

(6.a) (6.b)

Fig 6 a, b shows Compression test on electro mechanical testing machine

Table 2 Deflection values for hybrid rubber with and without nanoparticles mixed matrix.

Sno	Hybrid Rubber materials	Deflection With nano particles	Deflection Without nano particles
1	SR-NR	0.854	1.982
2	NR-PU	0.675	1.425
3	NR-SR-PU	1.8	2.56

VI. CONCLUSION

An angular mount has been proposed and examined through the rigorous experiment laid out on this paper. It can be applied to cargo ship, submarines. Based on the designs and previous researches the elastomeric angular mount was modified to magneto rheological angular mount with two different optimized samples of NR/PU and Si/PU are suggested in order to the performance and overcome its inherent limitations which are caused by rotating machines of on board ships. the design specifications and fabrication of magneto rheological elastomeric angular mount, such as force and displacements was indentified. There is great controlling of deflection for a particular percentage mixing of Fe_2O_3 nanoparticles to two different rubbers. From, the results of proposed there was observed that hybrid rubber with high damping action for NR/PU-rubber hybrid get deflection 0.675 mm ,SR/NR-rubber hybrid we got deflection 0.854 mm. and PU/SR/NR-rubber hybrid deflection about 1.8 mm, finally we ensure that NR/PU-rubber hybrid has low deflection

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