Preventing Shock and Vibrations Using Angular Mount with Polyurethane Elastomer

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Research Article

Abstract: Shock & vibration are unwanted motions required to be reduced, to improve durability of engines and other running machines. Shock and vibration mounting system prevents one object from affecting another. This system are used extensively to isolate machinery (industrial and marine), civil engineering structure (base isolation in buildings, bridges etc.,) and sensitive components from foundation/base. Shock and vibration isolation system reduce the propagation of base vibration to the isolated object and abate the transmission of vibration energy of machinery to the base. In addition to the above, in vehicular, marine & some industrial machines as well as seismic applications, isolators are also expect to lower the impact of shock from base to isolate object and vice-versa. Rubbers being a soft, visco-elastic material have a unique combination of elastic (spring) and viscous (damping) properties makes it such a useful material for vibration and shock mount. Generally S&V mount consists of vulcanized rubber bonded to metal parts facilitating load distribution and installation. For this development work, polyurethane elastomer is used as shock and vibration absorbing part of mount as this polyurethane elastomer can be designed to get better mechanical properties with improved ageing life.

1 Introduction:

The terms shock and vibration are generally used to refer to the dynamic mechanical excitation that may cause a dynamic response of a physical system, usually a mechanical structure that is exposed to that excitation. To be more specific, a shock is a dynamic excitation with a relatively short duration, and a vibration is a dynamic excitation with a relatively long duration as compared to the time required for a physical system exposed to that excitation to fully respond. Both shock and vibration excitations can appear either as an input motion or force at the mounting points or as a pressure field over the exterior surface of the physical system of interest. In either case, the basic description of a shock or vibration is given by the instantaneous magnitude of the excitation as a function of time, which is called a time historyShock and vibration excitations can be broadly classified as being either deterministic or random (also called stochastic). A deterministic excitation is one where, using analytical calculations based upon fundamental physics or repeated observations of the excitation produced under identical circumstances, the exact time history of the excitation in the future can be predicted with only minor errors. For example, a step input with a fixed magnitude at the mounting points of an equipment item would constitute a deterministic shock, while the excitation produced by an unbalanced shaft rotating at constant speed would produce a deterministic vibration. On the other hand, a random excitation is one where neither analytical calculations nor previous observations of the excitation produced under identical circumstances will allow the prediction of the exact time history of the excitation in the future. For example, a chemical explosion produces a pressure time history with detailed characteristics that are unique to that particular explosion, while the vibration of a pipe produced by the turbulence in the boundary layer between the pipe and the high velocity flow of a fluid through the pipe will also be random in character.These shock and vibrations have been occurred in many engines, material handling equipments, ships & sub-marines and so on. But here we consider only in ships & sub-marines.Why we use shock and vibration mounts in ships & submarines because in ships and submarines a lot of machines are there when they are in operations they generate lot of vibrations and noise. These vibrations and noise will transmit to sea water via machine foundation and through well. These vibration and noise will be a passive target for enemy ship and submarine, so it has to be reduced by putting some isolation (mount) or damping between machines and foundation or source and receiver.

2 Angular mounts:

These types of mounts are widely used in ships and sub-marines because these mounts can bear heavy loads when compared to the remaining mounts which are discussed above. These are placed under the engines of ships. We can place many number of mounts.

For example, if the engine weight is 2970lbs, then we can place 4 or 8 mounts under the engine to eliminate shock and vibrations which are generated from the engine. If we increase number of mounts then load per mount is decrease.

Actual shape of the angular mount is showed below.

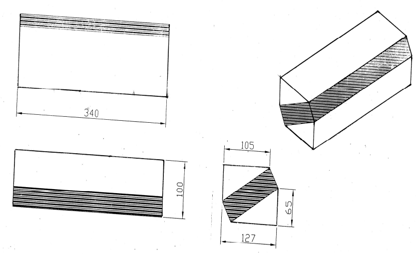

Figure 1: angular mount.

In our project we use Angular Mounts. While using these mounts we can eliminate the shock and vibrations upto 90%.

3 Materials used:

In angular mounts we use two materials, they are.

1) Mild steel.
2) Rubber (Polyurethane).

Here rubber is sandwiched between two steel plates.

Mild steel: Mild steel is the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications. Low carbon steel contains approximately 0.05–0.15% carbon and mild steel contains 0.16–0.29% carbon, therefore it is neither brittle nor ductile. Mild steel has a relatively low tensile strength, but it is cheap and malleable; surface hardness can be increased through carburizing.

Rubber:

Rubber is a unique material that is both elastic and viscous. Rubber parts can therefore function as shock and vibration isolators and/or as dampers. Although the term rubber is used rather loosely, it usually refers to the compounded and vulcanized material. In the raw state it is referred to as an elastomer. Vulcanization forms chemical bonds between adjacent elastomer chains and subsequently imparts dimensional stability, strength, and resilience. An unvulcanized rubber lacks structural integrity and will “flow” over a period of time.

Rubber has a low modulus of elasticity and is capable of sustaining a deformation of as much as 1000 percent. After such deformation, it quickly and forcibly retracts to its original dimensions. It is resilient and yet exhibits internal damping. Rubber can be processed into a variety of shapes and can be adhered to metal inserts or mounting plates. It can be compounded to have widely varying properties. The load deflection curve can be altered by changing its shape. Rubber will not corrode and normally requires no lubrication.

4 Polyurethane Rubber:

Common name: POLYURETHANE RUBBER.
Chemical name: ----------
Abbreviation: AU (polyester) EU (polyether).
Trade names: Adiprene, Estane, Genthane.

These materials have high tear strength and good wear resistance. Their upper temperature limit is typically 80C. They have excellent resistance to weathering and oxidation. They resist hydrocarbon fuels and mineral oils but some grades hydrolyze in hot water. They are one of the best rubbers for abrasion resistance and are therefore used in reciprocating seals. Some grades are castable.

Here we use polyurethane rubber between steel plates. Polyurethane rubber has a great hardness and it is also have better environmental properties, mechanical properties, good adhesion, abrasion resistance etc

- Very Stable (Low Out gassing).
- Maintains Hardness.
- Maintains Performance for life of product.
- Maintains Rebound.
- Maintains Coefficient of Friction.
- Oxygen & Ozone Resistant.

5 DEVELOPMENT OF POLYURETHANE ELASTOMER COMPOUNDS:

Polyurethane elastomers are rubber-like materials that can be created with a wide variety of properties and molded into almost any shape. Depending on the intended use, polyurethane elastomers can provide resistance to:

- Abrasion.
- Impact and shock.
- Temperature.
- Cuts and tears.
- Oil and solvents.
- Ageing.

The low weight of elastomers and their machinability make elastomers a great choice for dozens of applications. Plus, polyurethane elastomers do a great job of returning to their original shape after stressed (i.e., compressed, bent or stretched).

Polyurethane elastomers can be used virtually everywhere. “Snowplow blades” are made with polyurethane to reduce road damage caused by metal scrapping the roads. Wheels for shopping carts, skateboards, roller coasters and heavy trash containers are all produced from polyurethane, due to its high load-bearing capacity and abrasion resistance. And since polyurethane elastomers are so easily machines, they can be molded and processed for custom uses such as valves, snow blower angers, balls and factory fixtures.

Environmental resistance of polyurethane elastomer versus conventional rubber:

Environment	Polyester	Polyether	Natural Rubber	Neoprene Rubber	Styrene Butadiene Rubber
Heat	G	F	F	G	G
Cold	G	G	E	G	G
Weather	E	E	P	G	F
Ozone resistance	E	E	P	F	P
ASTM NO:1 oil	E	F	P	G	P
ASTM NO:3 oil	E	P	G	P	P
Aliphatic solvents. Eg:(Heptane)	E	F	P	G	P
Chlorinated solvents. Eg:(Trichloro Ethane)	F/G	P	G	P	P
Aromatic solvents. Eg:(Toluene)	F	P	P	F	P
Dilute Acids Eg: 5%HNO3	P/F	F	G	G	F/G
Dilute Alkalies. Eg: 5% NaoH	P/F	F	G	G	F/G

E-EXCELLENT, G-GOOD, F-FAIR, P-POOR.

Table1: Environmental properties.

6 Polyurethane composition:

PU MOUNT COMPOUND		
SNO:	A	B
MILLATHANE CAM	200.00 gms	200.00 gms
ZNO	20.00	10.00
STE-ACID	2.00	2.00
MB-2	6.00	-
P WAX	2.00	-
C.I RESIN	30.00	30.00
HAF-BLACK (CARBON)	20.00	20.00
P-JELLY	8.00	-
SULPHUR	3.00	2.00
MBTS	12.00	10.00
TMTD	2.00	1.00

TABLE2: PU-composition.

7 Manufacturing of PU Rubber:

For getting better hardness polyurethane must contain above composition. After that PU-rubber is manufactured. For manufacture of PU-Rubber mainly there are three steps. They are:

- Mixing.
- Molding.
- Vulcanization.

7.1 Mixing:

Adequate mixing is necessary to obtain a compound that processes properly, cures sufficiently, and has the necessary physical properties for end use. The Banbury internal mixer is commonly used to mix the compound ingredients. It contains two spiral-shaped rotors that operate in a completely enclosed chamber. A two-step procedure is generally used to ensure that premature vulcanization does not occur. Most of the ingredients are mixed at about 120°C in the first step. The vulcanizing agents are added at a lower temperature in the second step. Here we mix the PU-compound upto 10minutes.

7.2 Molding:

Compression, transfer, and injection-molding techniques are used to shape the final product. Once in the mold, the rubber compound is vulcanized at temperatures ranging from 100 to 200°C. The cure time and the temperature are determined beforehand with a curemeter, such as the oscillating disk rheometer. After removal from the mold, the rubber product is sometimes postcured in an autoclave. The post curing gives improved compression-set properties. After that we get a bulk of rubber material.

7.3 Vulcanizing:

Vulcanization is the process by which the elastomer molecules become chemically cross linked to form three-dimensional structures having dimensional stability. The effect of vulcanization on compound properties is shown in Fig.9.3.3. Sulfur, peroxides, resins, and metal oxides are typically used as vulcanizing agents. The use of sulfur alone leads to a slow reaction, so accelerators are added to increase the cure rate. They affect the rate of vulcanization, cross-link structure, and final properties.

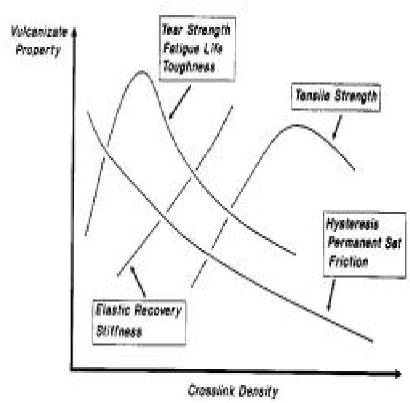

Fig 2: Vulcanizate properties as a function of the extent of vulcanization.

8 PU-RUBBER TESTING:

After getting required Polyurethane rubber, we have to cut the rubber into some small pieces for performing different tests.

- **BEFORE AGEING:**
  - Mechanical Testing:
    - Tensile test.
    - Hardness test.
    - Compression test.
  - Seawater resistance test.
- **AFTER AGEING:**
  - Mechanical Testing:
    - Tensile test.
    - Hardness test.
    - Compression test.
  - Seawater resistance test.

We have to perform the mechanical testing on PU-rubber in two cases.

1) Before ageing.
2) After ageing.

8.1 AGEING:

Here ageing means applying some agent to the rubber for sometime. After that we have to find if any volumetric swelling is occurred or not.

Here we use the fluid agent as (70% Iso-Octane+30% Toluene). We have to place the PU-rubber in this agent for 22hrs at 40ºC.

8.2 Test results of PU-rubber compound:

s.no	Description	Specifications	Results
1	Specific gravity	----	1.16
2	Hardness (IRHD)	55+5 -4	54.5
3	Tensile Test: a)Tensile strength(Mpa)	7.7	17.8
	b)Elongation at Break %	450	473
4	Compression set test: (24hrs at 70ºC): Compression Set %	30	18.2
5	Fluid Ageing: (22 hrs at 40ºC) (70%Iso-Octane+30% Toluene) Volumetric swelling %	30	30.06

Additional test:

6	Ageing in Sea water: (24 hrs at room temperature) Change in wt%	----	1.16

TABLE 3: Results of PU-rubber.

We have to select our mount based on the following calculations:

STEPS:

Step1:

Calculate the load on each on mount. If the load is evenly distributed, divide the total load by the number of mounts.

Load per mount = $\frac{total\ load}{no.of\ mounts}$ =------------------ **lbs. (1)**

Step2:

Calculate the lowest disturbing frequency (f_d) based on the operation speed in cycles per second (Hz). Convert f_d from revolutions per minute (RPM) to cycles per second (Hz).

Disturbing frequency (f_d) = $\frac{RPM}{60\ sec/min}$ **------Hz. (2)**

Step-3:

Calculate the natural frequency (f_n) that the system needs for 80% isolation.

Natural frequency (f_n) = $\frac{f_d}{2.45}$ **-------- Hz. (3)**

Step-4:

Calculate the required static deflection (d_s) to obtain the desired natural frequency (f_n) .

Static deflection (d_s) = $\frac{9.8}{(f_n)2}$ **-------- inches. (4)**

Step-5:

Calculate the required spring rate (K) to obtain the desired natural frequency (f_n).

Spring rate (k) = (load per mount) / (static deflection). (5)

Step 6:

After that we have to select the mount and find the deflection (d) using UTM (universal testing machine).

Step 7:

After selecting the vibro-isolators we should calculate the transmissibility based on the actual spring rate for the selected mount.

Actual deflection (d) = value of deflection getting on UTM machine.

Actual natural frequency (f_n) = $\sqrt{\frac{9.8}{d}}$ **(6)**

Transmissibility (T) = $\frac{1}{\left[\frac{f_d}{f_n}\right]2-1}$ **(7)**

Isolation (%) =1-T **(8)**

9 Development of Mount:

Angular Mount Die:

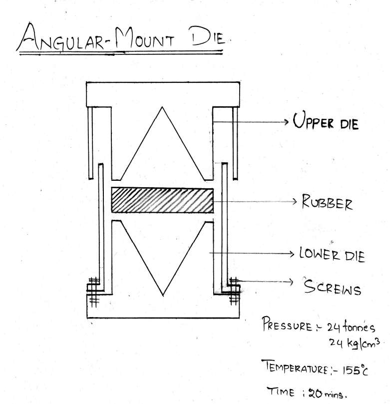

Fig4: Angular mount die.

We can generate the angular mount by using the angular mount die which is shown in above fig:

Angular mount die consists an upper die and lower die. Where upper die is movable and lower die is fixed by using screws. First of all we have to place the angular steel plates at both dies. After that we place the PU-rubber in between the dies (upper and lower). On the top of the upper die we have to apply the pressure of 24tonnes upto 20minutes. By applying 24tonnes of pressure, we get temperature of 155ºC at the junction of rubber and steel plates. So, at that temperature PU-rubber is sticked to the angular steel plates. By this way we prepare the angular mounts.

Shape:

After getting the mount, the actual shape of angular mount is shown below:

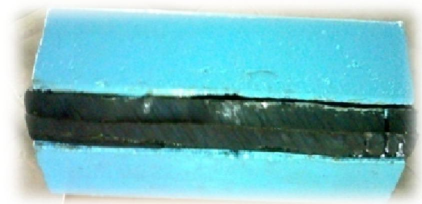

Fig 5 : Actual angular mount.

We place this mounts below the engines by using stud-bolts. By using Stud-bolts, we can fix the lower part of the angular mount to the base and upper part is fixed to the engine.

After developing the angular mount we have to perform the static and dynamic tests.

9.1 Static Test:

After the development of shock and vibration mount, we have to calculate the deflection using UTM (universal testing machine) as shown in fig. We place the mount in between the jaws of UTM machine and apply the load 2970lbs. Then we get the deflection about 1.878mm.

Fig 6: Universal Testing Machine (UTM)

Static testing is a form of software testing where the software isn't actually used. It is generally not detailed testing, but checks mainly for the sanity of the code, algorithm, or document. It is primarily syntax checking of the code or and manually reading of the code or document to find errors. This type of testing can be used by the developer who wrote the code, in isolation. Code reviews, inspections and walkthroughs are also used. This is the verification portion of Verification and Validation. These are verification activities. Code Reviews, inspection and walkthroughs are few of the static testing methodologies.

9.2 Finding Isolation (%) by using Calculations for the Angular Mount:

Specifications:

a) Size: 340*125*100mm.
b) Weight: 21kg.
c) Working load: 1350kg (2970lbs).
d) Deflection: 1.878mm (0.074inches).

Here we take number of mounts =8, engine RPM =2400.

Calculations:

$$\frac{load}{mount} = \frac{2970}{8} = 371.25\,\frac{lbs}{mount}$$

$$f_d = \frac{2400}{60} = 40 \text{ Hz.}$$

$$f_n = \frac{40}{2.45} = 16.33 \text{ Hz.}$$

$$(d_s) = \frac{9.8}{(16.33)2} = 0.0367\text{inches.}$$

$$k = (371.25) / (0.0367) = 10102.125.$$

$$d = 0.074 \text{ inches.}$$

$$\text{Actual } f_n = \sqrt{\frac{9.8}{0.074}} = 11.5128 \text{ Hz.}$$

$$T = \frac{1}{\left[\frac{40}{11.5128}\right]2-1} = 0.09032.$$

Isolation (%) = 1-T =1-0.09032 = 0.9096 = 90.96%.

% of isolation for different engine rpms:

RPM	ISOLATION (%)
2000	87
2400	91
3000	95
4000	97
5000	98

Table 4: Comparison between % of isolation and RPM.

Graph between RPM vs. Isolation (%):

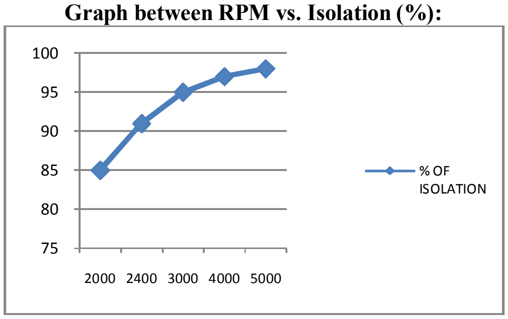

Fig 7: RPM vs % of Isolation.

If we increase number of mounts then the load per mount is decrease and there is no change in the isolation %.

For number of mounts and load per mount:

No. of mounts	Load per mount (lbs)
2	1485
4	742.5
6	495
8	371.25

Table5: Comparison between no. of mounts and loads per mount.

Graph between no. of mounts vs. load per mount:

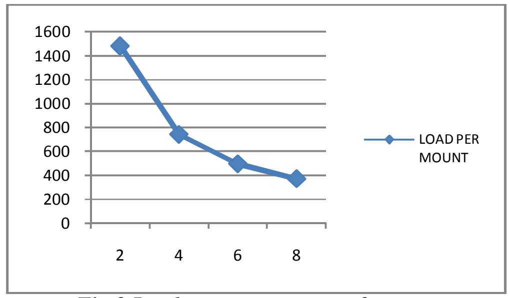

Fig 8 Load per mount vs no. of mount.

Earlier NSTL (Naval Science and Technological Laboratories) use NBR (Nitrile Butadiene Rubber). Now-a-days they preferred for the PU-rubber because of three reasons.

NBR	PU-rubber
Hardness: Hardness of NBR is 45 IRHD only	Hardness: Hardness of PU-rubber is 54.5 IRHD.
Deflection: If NBR used then the deflection is nearly 3 to 4mm.	Deflection: If PU-rubber used then the deflection is 1 to 2mm.
Life Span: If NBR used mount life span is only 5-6 years.	Life Span: If PU-rubber used mount life span is 10-15 years.

Table 6 : Difference between NBR & PU rubber.

Because of these three reasons they preferred PU-rubber instead of NBR.

10 Dynamic Test:

In dynamic testing the software must actually be compiled and run. Dynamic analysis refers to the examination of the physical response from the system to variables that are not constant and change with time. Some of dynamic testing methodologies include unit testing, integration testing, system testing and acceptance testing. Dynamic testing is the validation portion of Verification and Validation. These are the Validation activities. Unit Tests, Integration Tests, System Tests and Acceptance Tests are few of the Dynamic Testing methodologies. Here we use the software ANSYS for analysis.

10.1 Ansys Modelling:

By using ANSYS we can find deflection and stresses in the mount in two dimensional (2D) and three dimensional (3D).

Materials used and their properties are:

MILD STEEL PROPERITES:

DENSITY = 7200 KG/M^3

POISONN'S RATIO = 0.3

YOUNGS MODULUS = 70 GIGA PASCAL

PU RUBBER PROPERTIES:

DENSITY = 1150 KG/M^3

POISONN'S RATIO = 0.4

YOUNGS MODULUS = 0.01-0.1X10^9 N/M^2

= 17, 00,000 Pa
= 17.00 GIGA PASCAL

10.2 Mount model:

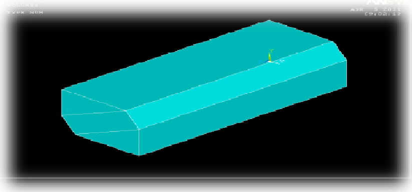

Fig 9: Mount model.

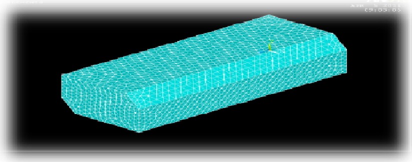

Fig 10: Mesh model.

10.3 Load:

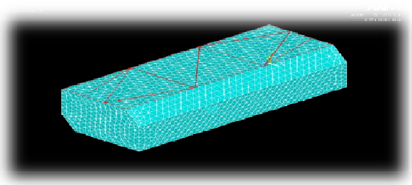

Fig 11: Load model.

11 Results:

1) **Deflection:**

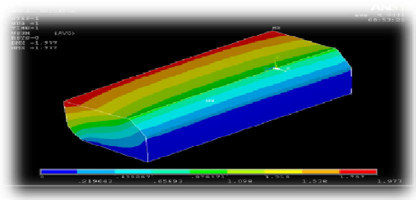

Fig 12: Deflection model.

We get the deflection d= 1.977mm.

2) **X component stress**:

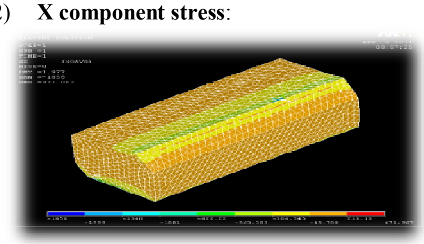

Fig 13: X component stress.

3) **Y component stress**:

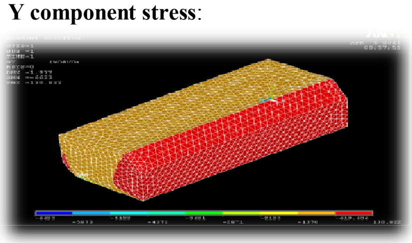

Fig 14: Y component stress.

4) **Z component stress**:

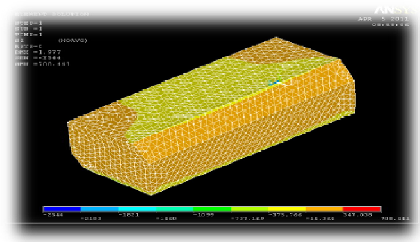

Fig 15: Z component stress.

5) **XY component shear stress**:

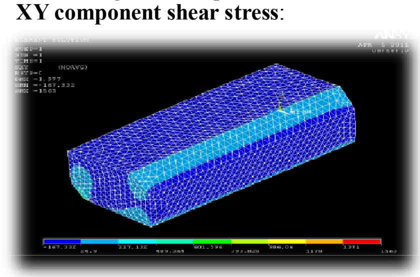

Fig 16: XY component shear.

6) **YZ component shear stress**:

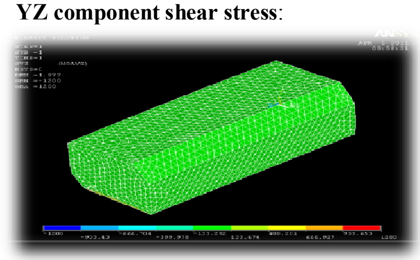

Fig 17: YZ component shear.

7) **XZ component shear stress**:

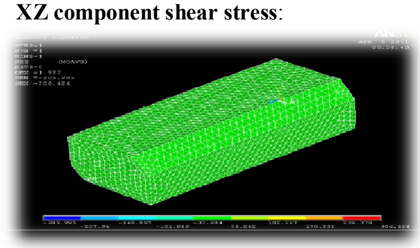

Fig 18: XZ component shear.

Von-mises stress:

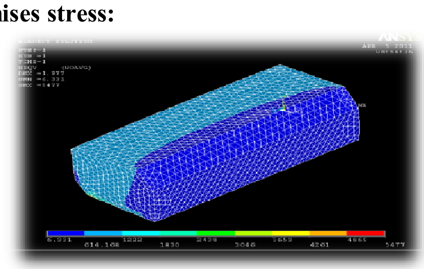

Fig 19: Von-mises stres

11.1 Ansys Results:

Stress	Max. (N/mm2)	Min.(N/mm2)
X-component	471.967	-1858
Y-component	130.822	-6623
Z-component	708.441	-2544
XY-shear	1563	-167.332
YZ-shear	1200	-1200
XZ-shear	306.424	-305.95
Von-mises stress	5477	6.331

Table 15: ansys results.

11.2 Comparison of Results:

Static test (practical)	Dynamic test (ansys)
Deflection d= 1.878mm	Deflection d= 1.977mm

Table 15.1: results.

12 Conclusion:

By using these VIBRO-ELASTROMERS we can reduce the Shocks and vibrations for Industrial purpose like machines, turbines etc, Automotive purpose like cars, heavy load containers etc,. Naval ships, army boats.

ANGULAR MOUNTS with NBR (Nitrile butadiene rubber) having a life span of 5-6 years only…so by using our ANGULAR MOUNTS with POLY URETHANE ELASTROMER gives a life span of 10-15 years which is proved by statistics and calculations.

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