The Effect of Shape Factor on the Operation Periods of Anti-Vibration Rubber

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Abstract
This research aims to study the shape factor affects on the rubber that resistant to the vibration. Three different shapes of rubber mounts(cylindrical , hexagonal and trapezoidal shapes)having the same volume was prepared. The anti-vibration models was manufactured depended on the pre-selected recipes according to specific specifications suitable for this purpose. In this work, actual application test in AL-Kufa cement factory was done to get knowledge about the efficiency of the manufacturing mounts. Furthermore, simulation for the three above models by ANSYS V.11 Program was done. The actual application result shows that, hexagonal model is the best because the higher operation periods while the simulation shows that ,there is a decreasing in the stress intensity of the hexagonal shape, this may be explain why it has longest operation period than the other two shapes.
Keywords: Shape factor, Stress intensity, Anti-vibration rubber, Hexagonal shape.

Introduction
Rubber is a polymeric material which becomes flexible by vulcanization. as a result of the nature of the rubber compounds which enables it to dissipate energy used for the protection of engineering equipment , bridges, and buildings from the effect of vibrations[1].Rubber is broadly used in the vibration control via isolating the vibration source. It is a material which has elastic and viscous properties. Mounts can have several functions. First, it is a connection point for a part or and vibration from being transferred to the other parts. In some cases, Rubber mounts may also be an adjustment point to maintain a component in proper alignment [2]. The term ‘ rubber blend’ may be defined as a combination of two or more structurally different rubbers giving rise to materials with a range of properties, not delivered by any of the constituents [3].

Elastomer blends find widespread use in several technological applications. Typical compounds include NR, BR and SBR blends. One of the important feature in the rubber product is the shape factor, is a function of element geometry having considerable effects on the compression modulus .The ability to mold rubber into a large variety of shapes, gives the designer higher flexibility in the selection of stress conditions in a finished part[4]. The shape factor can be defined as the ratio of the loaded area to the area which is available for bulging. It considerably affects the mechanical properties of vulcanized rubber in compression. when we reduce the area available to bulge, the rubber product becomes more stiff. In general, the rubber is bonded to metal plates, or detained between surfaces that effectively eliminate slip. In this state, the effect of the shape factor is much important in the design of the rubber mounts and bearings. Figure (1) illustrates the rubber blocks shape factor. The shape factor is a function of element geometry having major effects on the compression modulus. The best shape factor is between (0.5 to 1) [5 and 6].

Rubber composite analysis is very useful in damping application, therefore theoretical analysis (mathematical or numerical) is a very important way for predicting the mechanical properties of different types of rubber composite, also it is very important for predicting the deformation behavior under static and dynamic loading to avoid the experimental work which is normally, costly and time consume and doesn't have high accuracy in applied dynamic field[7].

IVo Machado Guelho(2011) studied the static and dynamic behavior of rubber cork composite materials to characterize their mechanical behavior. From the vibrations examination, he was concluded that increasing in the material shape factor, e.g., reducing thickness, the natural frequency increases due to the increase of the material stiffness [6]. **Dobrinka Atmadzhova(2012)** studied the rubber-metal springs fatigue of rail vehicles. The study includes a simulation analysis carried out by the finite element method in order to predict the distribution of stress and evaluate the behavior of fatigue. There study can be used in the design, modeling and analysis of rubber-metal springs and optimization of their characteristics in terms of material (rubber and metal) [8].**V.S.Chavan., et al. (2013)** studied the analysis of anti-vibration mounts for vibration isolation in diesel engine generator set. Rubber and neoprene materials with and without mount conditions are analyzed. The results shows that the neoprene material gives out the best vibration isolation and the dynamic stiffness is dependent on the frequency [9]. **Patel Sanket (2014)** studied the design and analysis of anti-vibration rubber mount by application of ANSYS software. They were established safe frequency in which no resonance can occur for the particular structure [10].Generally , a few researchers studied the shape factor effect on the damping properties. At previous study, best recipes for anti-vibration rubber application was found [11] and this research trying to detect suitable shape factor that gives better mechanical properties to reduce vibrations with increasing the damping efficiency and increasing operation time in actual application.

Experimental Work

The rubber compounds used in this study were prepared from natural rubber (SMR-20) 60%and BR $_{cis}$40%carbonblack (N330) filled recipes with other compounding materials such as filler; vulcanizing agent (sulfur) and accelerator were prepared with the compound formulations. The rubber compounds used in this work are listed in table (1) according to specifications of Al-Dewaniya Tires Factory.

Table (1): The composition of the batch.

compounding ingredients	Ratio
NR (Acrylonitirile	60
BR $_{cis}$	40
Zinc oxide	5.5
(TMQ)	1.5
Wax	0.5
Oil	5
C.B	48
(CBS)	1.5

With respect to the ability of actual testing in AL-Kufa cement factory and ability of mould manufacturing, three deferent moulds for manufacturing the rubber mounting are made in Al-Dewaniya Tires Factory. Photos of this moulds shown in figure (2,3 and 4).

Volume Calculation

In order to insure the same quantity of rubber that used for producing three deferent specimens shape (Trapezoidal, Hexagonal and original), volume calculation must be done as flows[1]:

1- Calculation of the (cylindrical shape) according to equation

$Vc = \frac{\pi}{4} d^2 l$ ………….. (1)

where d= space diameter ,l = cylinder length and V_c = cylindrical volume as shown in figure(5)

2- Calculation of the trapezoidal model as shown in figure (6) according to:

$V_p = \frac{(A+B)}{2} * HL$. …………..(2)

where H= space diameter , L = cylinder length and V_t = trapezoidal volume

3- Calculation of the right regular hexagonal model according to:

$V_h = 2.6a^2h$ ……….(3)

where h= hight ,a = base edge and V_h = hexagonal volume as shown in figure(7)

Shape Factor Calculation

According to the definition of the shape factor that illustrated in figure(1), value for the three different models that used in this work was calculated as shown in table(2).

Table (1): Shape factor calculation.

Geometry	Equation	Shape factor
Hexagonal	(2.6*50^2)/(6*50*37.35)	0.58
Trapezoidal	(60*75)/((60+75)*48+(2*48.7*75))	0.32
Cylindrical	(3.14/4*75^2)/3.14*75*55	0.34

Actual Application Test

Vibrators are a real application available in (AL-Kufa cement plant) for testing the new design mounts. Every one of the vibrators need two mounts to run properly without unwanted noise. From every one of the three moulds two rubber mounts must be producing. Figure(9) shows the actual application of hexagonal mounts in the cement factory.

Model Constituent Description
The steps to build the model by using FEM are carried out by using the ANSYS V.11codes as follows:
1-Geometry of the Models
The geometry of the three models is created in three dimensions to describe the shock absorber component are shown in the figures (9,10 and 11).
2-Meshing Geometries
The model is meshed by using element size (1-2mm)and element type tetrahedron HYPER158 to obtain best results and the model becomes more active to describe the real case of the analysis as shown in figures (12,13 and 14).
3-Materials Characterization
The model component materials are described by using properties of rubber material which are used in the model according to (Moony –Rivlin) functions that used in ANSYS 11codes, andc1 , c2 are the material constants assumed to be 0.382 and 0.096MPa respectively[6]. As shown in table (3):

Table (3) Material properties used in the model.

E(GPa) elastic modulus	ν possion ratio	Density (kg/m^3)	Damping ratio	C1 MPa	C2 MPa
0.5	0.43	1100	0.6	0.382	0.096

4-Boundary Conditions
The displacement in x,y,z direction is fixed by using the zero (volume displacement) of lower stand of shock absorber on the frame. Upper stand is free because this side carries the machine (vibrator) load which is estimated by 15oo kg at each rubber mount ,the rubber material is able to deform in all direction(except in bolt area) under effect of load.
5-Solution
In addition to the static solution, nonlinear harmonic (dynamic) solution is fundamental in every case, the frequency used in this solution equal to (100) selected by ANSYS 11 from the model shape solution. The result of deformation and the stresses intensity at the static and dynamic conditions in the rubber composite properties are recorded.

Actual Application Results
Table (4) demonstrate the shape model and operation periods for the three models. From this table, the best result accurse at the hexagonal model with the higher shape factor (0.58) , this is compatible with [7].Certification from Al kufa cement factory show in appendix 1

Table (4) The shape model and operation periods[Al kufa cement factory].

Shape model	Operation period
Cylindrical	60 day
Trapezoidal	65 day
Hexagonal	90 day

FEA Results
The result of deformation and the stresses intensity at the static and dynamic conditions illustrated in figures(15 to 26). Figures (15 to 20) representative the distribution for deformation, and stress intensity in all positions of the rubber mounts in case of the static loading. From the prior figures ,at the static mode ,the smallest deformation occurs in the hexagonal model ($0.204{*}10^{-3}$ m) at the bolt area as in figure(17) while the maximum deformation occurs in the cylindrical model ($0.338{*}10^{-3}$ m).Also, the maximum stress intensity occurs in the cylindrical model ($0.30{*}10^{8}$ Pa) while the hexagonal model shows minimum stress intensity ($0.124{*}10^{8}$ Pa), this value is a very close to this in the trapezoidal model($0.15{*}10^{8}$ Pa). in spite of its lower stress intensity value , hexagonal model show the highest stress consternation area due to its shape which have more edge corners than other two shapes. Figures (21 to 26) representative the distribution for deformation, and stress intensity in all positions of the rubber mounts in case of the dynamic loading, the minimum deformation occurs in the hexagonal shape($0.837{*}10^{-4}$ m) while the hexagonal model deformation value was($0.129{*}10^{-3}$ m) and($0.139{*}10^{-3}$ m) in case of the trapezoidal model. The maximum stress intensity value occurs in the cylindrical model ($0.954{*}10^{7}$ Pa) and the minimum value occurs in hexagonal model($0.50{*}10^{7}$ Pa) while the trapezoidal model has stress intensity equal to ($0.647{*}10^{7}$ Pa). In the hexagonal model, the better(minimum) value of stress intensity not necessary mean it has the best performance because the wide strain area, as shown in figure (23) and (24). Also, From the above figures, notice that deformation , stress and strain have higher values in the upper part of the rubber mounting and decreasing sharply this is due to the fact that the upper part faces the impact and there is no time enough for transfer of the stress and strain to neighbor regions ,this result in a weak absorption of the impact in the upper part in which the physical behavior of the material under high strain will be directed to the

solid behavior in opposite to that when its under low strain, in which the strain distributed homogenously in all parts of the material this result in absorption of the impact energy. Also , the reason of the lower stress intensity value in the hexagonal model is the lower thickness value and higher shape factor, that is compatible with[7].

Conclusion

From the current study several conclusions can be made:

1- Validity of the recipe that have been adopted from the first part of the work in the current application as rubber mounts.

2- during the current study, the designed models (trapezoidal and hexagonal) gives the best results in terms of practical application in the (Kufa) cement plant vibrators.

3- The results of numerical analysis of the practically tested samples are compatible with the practical results.

4- Under the same static and dynamic loading conditions, cylindrical shape of the rubber mount show higher deformation and higher stress intensity than trapezoidal and hexagonal models, that is mean, trapezoidal and hexagonal models are better than cylindrical one in this type of applications.

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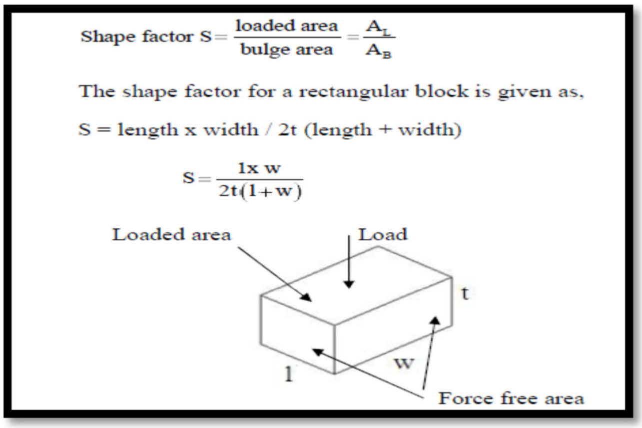
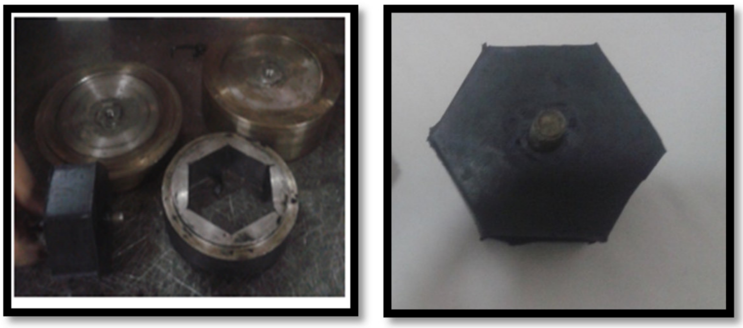
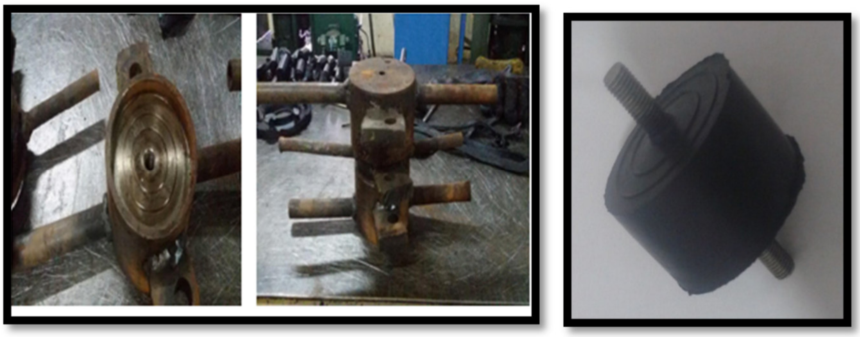


Figures(1): Shape factor of a rubber block[5].

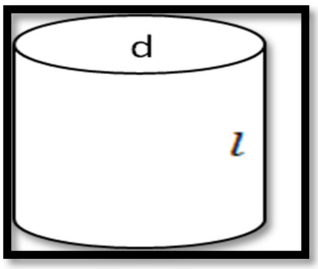
Figure(2):Trapezoidal mould with final model shape.



Figure(3): Hexagonal mould with final model shape.

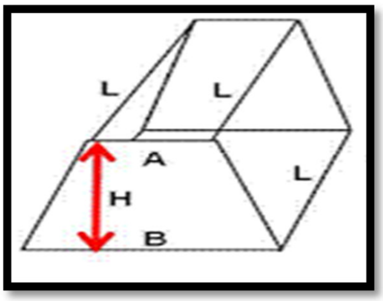


Figure(4): Cylindrical mould with final model shape.



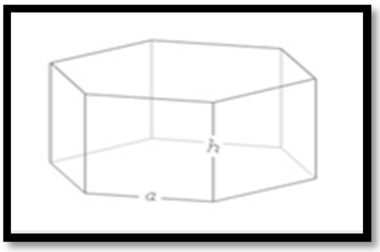
Symbol	**d**	***l***
Dim. (mm)	75	55
V_c. (mm^3)	242982	

Figure(5): Volume of cylindrical shape



Symbol	A	*B*	H	L
Dim. (mm)	60	75	48	75
V_p. (mm^3)	243000			

Figure(6): Volume of trapezoidal shape



Symbol	a	*h*
Dim. (mm)	50	37.35
V_c. (mm^3)	242812.5	

Figure(7): Volume of hexagonal shape.

Figure(8): Actual application of hexagonal mounts.

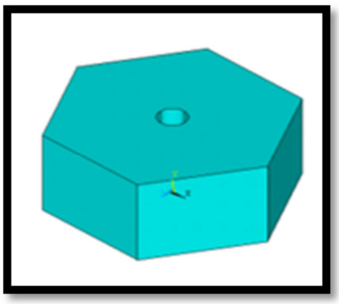


Figure (10) Hexagonal model.

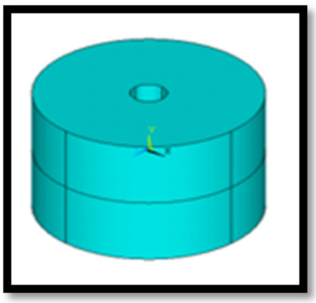


Figure (9) Cylindrical model.

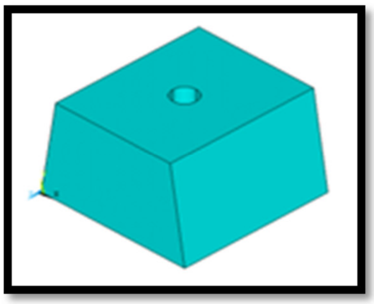


Figure (11) Trapezoidal model.

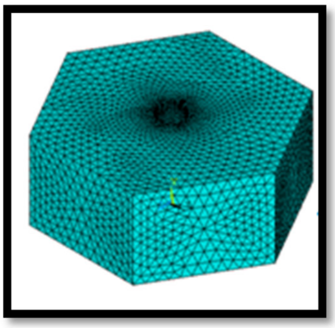


Figure (13) Hexagonal model.

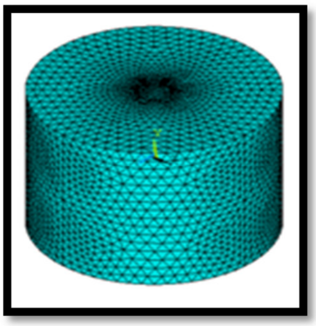


Figure (12) Cylindrical model.

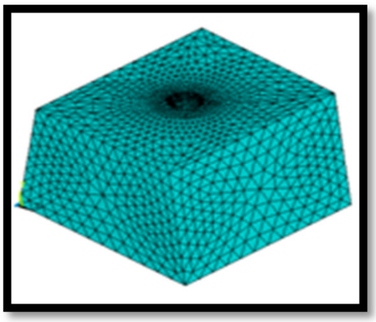


Figure (14) Trapezoidal model.

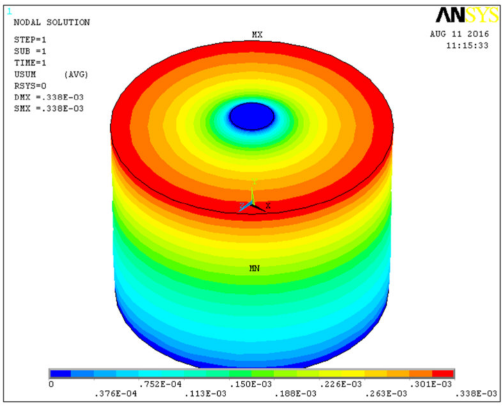


Figure (15) Static deformation of the cylindrical model.

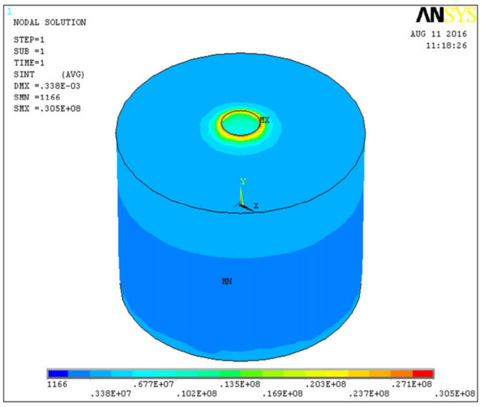


Figure (16) Static stress intensity of the cylindrical model.

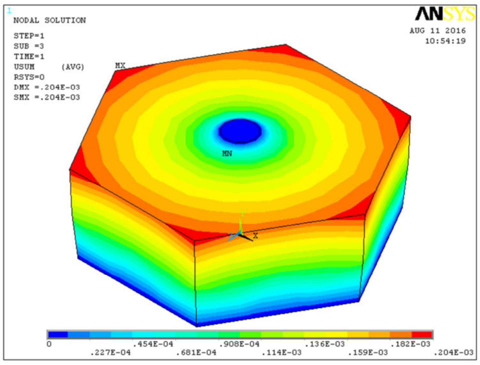


Figure (17) Static deformation of the. hexagonal model.

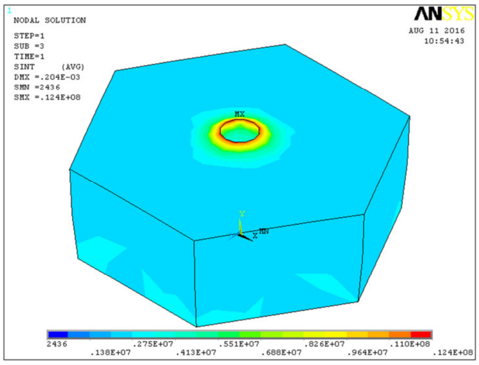


Figure (18) Static stress intensity of the hexagonal model.

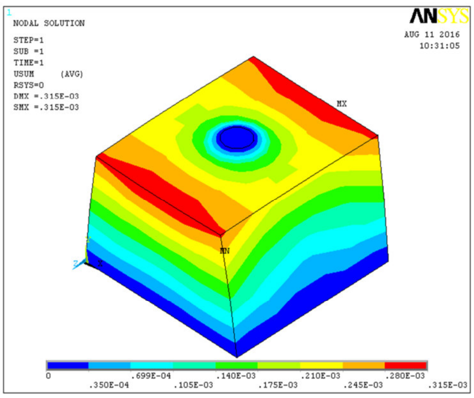


Figure (19) Static deformation of the. trapezoidal model.

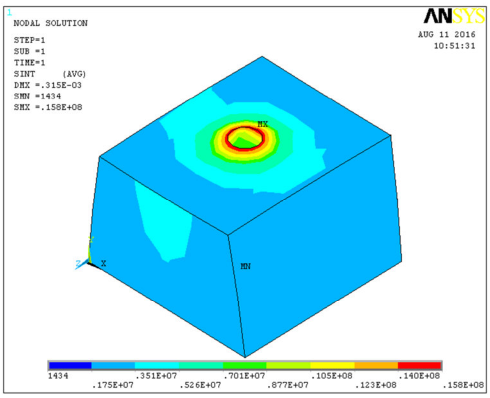


Figure (20) Static stress intensity of the trapezoidal model.

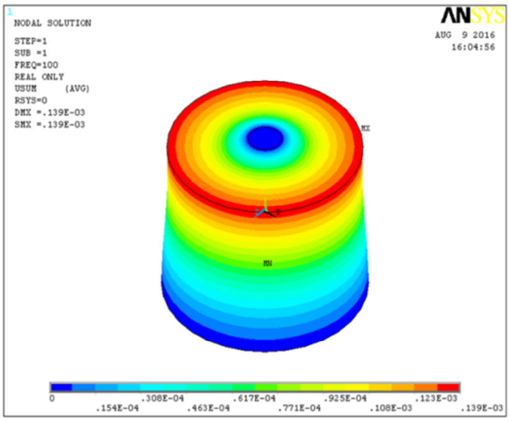


Figure (21) Dynamic deformation of the cylindrical model.

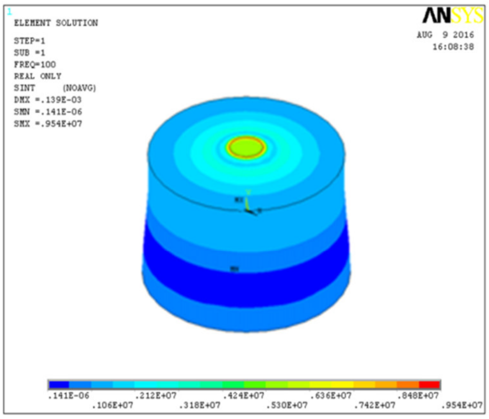


Figure (22) Dynamic stress intensity of the cylindrical model.

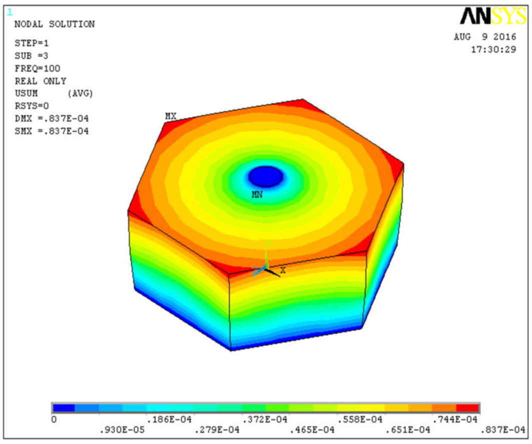


Figure (23) Dynamic deformation of the hexagonal model.

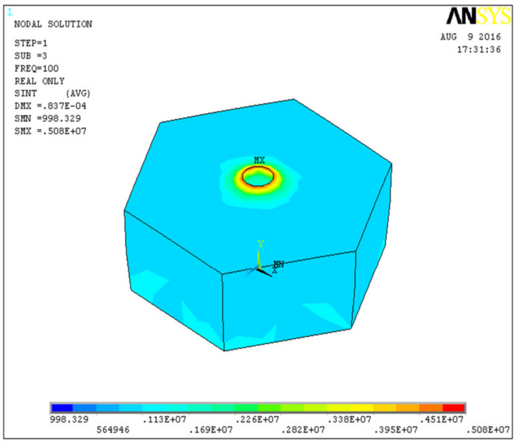


Figure (24) Dynamic deformation of the hexagonal model .

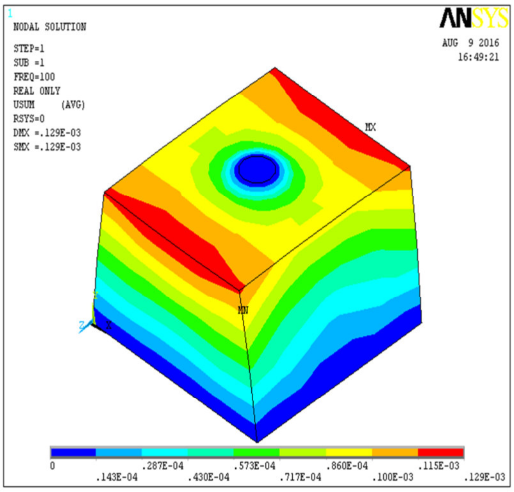


Figure (25) Dynamic deformation of the trapezoidal model.

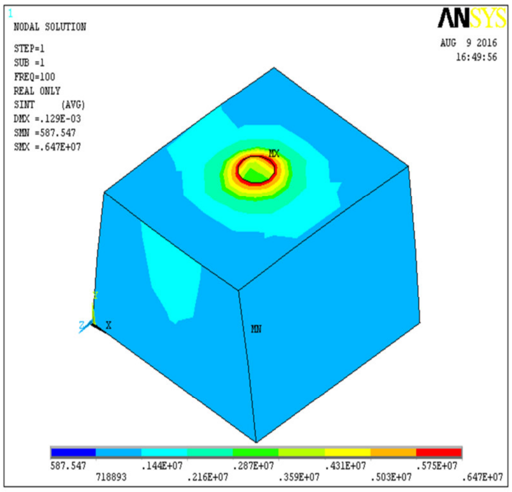


Figure (26) Dynamic deformation of the trapezoidal model.