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Static and Vibrational Analysis on Automobile Composite Seat

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Abstract:

In Automobile, seat is one of the most important component of the vehicle, designing an optimal seat is always a challenging task for the engineers as the design parameters and comfort contains are always complex because it contains many parts and mechanisms for occupant safety and comfort. To design and develop an automobile seat with lesser cost and better occupants comfort is a prime principle for the engineer. Generally professional drivers spend eight to ten hours per a day, which will create a lot of presser on the human tissue. Continues or immobilized sitting with a contact posture for a long time will cause a lot of presser and leads sub-dermal tissue damage. Tissue damage is occur because the total human weight is caring by it, which will causes a permanent deformation and ultimately rises the pressure on the human body. There are three main parameters in the seat design, Comfort, safety and health of the occupant.

This work accelerate and economize the development and design process of automobile seat and its reusability. Designing a seat which have moderate comfort and better vibrational stability is the objective of this work. The vibrations caused by the automobile and the uneven roads will effects the occupant health and its mode, these vibrations will create a lot of fatigue on the human body and will create stress concentration on critical zones on the human body. The modeling of the automobile seat is done in the CREO-2.0 parametric and the finite element analysis is conducted by using ANSYS 15.0. Polyurethane foams are used as the cushion and backrest materials for analysis. Higher density foam can absorb vibrations because of its closed packed Molecular structure, at the same time because of its closed packing arrangement it will be rigid in nature.

To achieve both vibrational stability and comfort ness composite seat is proposed where different materials are stacked one up on another so we get both comfortless and vibrational stability.

1. Introduction:

In today's international automobile market companies are driving the automobile characteristics sole for the customer choice and satisfaction. The working environment in the automobile is caricaturized as a confined space where the occupant interact with the automobile and adapt to perform the driving task. During the design and development of the car seat the occupant poster is very important, because it will create the comfort for driving engineers are said to be maximize the comfortless. The human perception of comfort will change through short and long period of operation. Seat means a structure which will support the occupant and provide the safety and comfort to the occupant.

Generally seat is mounted on a metal frame which is joined to the chassis or body of the automobile, when vibrations are generated due to the uneven road conditions where start at the tire of the automobile and it finally reaches to the driver. These vibrations will exerts forces on the human tissues and which will experiences a muscle contraction and final leads pain in long run. The material s used for are usually made form elastic material so that it will give greater comfort for the occupant but because of its elastic nature it will transmits the vibrational forces through it, which has to minimize for drivers safety. Materials which have better damping coefficient will absorb the vibrations better. Generally polyurethane were used as the material for seat, because of its elastic property and it`s molecular structure.

From the research C.R. Mehta, V.K. Tewari concluded that PU foams which have the highest density can absorb vibrations greatly. There are many other parameters which can affect the design of seat, they are listed below.

a. Structure design
b. Ergonomics Related
c. Comfort Related Parameters
d. Pressure Distribution Over Seat
e. Thermal Comfort
f. Vibration
g. Support
h. Shape and Size

These are some parameters that effects the design parameters.

1. Literature review

Various design and analysis where carried out on seat for optimizing and developing the design. Gru-jicic et al. (2009) had studied the stress destitution over the seated human and related the data with real time environment. C.R. Mehta, V.K. Tewari had conducted there research on the damping coefficient of the materials and its vibration reduction property. Xiaolu Zhang and his time had studied how the vertical vibrations are transmitted to the seat and how it is varying with cushion height. George had performed an experimental analysis on the seat and its comfort. Pragyan and his team used the finite element approach to study the pressure distribution through cushion thickness. Any other studies are carried out on the design of the seat which are concentrated on the modification and redesigning the seat to the at most satisfactory comfort. Most of the researches are synthesized new materials which can be used for both comfort and vibration reduction are absorption, as the materials which can have comfort cannot offer the vibrational stability or damping coefficient and vice-versa. This paper is concentrated on increasing the reusability and optimal design both in comfort and vibration absorption.

2. Problem Identification

Because of its elastic nature the foam are usually have the less life pan, ones it lost it elasticity it has to replace completely. This happens because of the long running load, and material will lost its elastic limit and undergo permanent deformation. Most of the time the 50% percentage foam can still be reusable, but entire foam have to replace because of its size and shape (single piece). If the seat cushion is assembled as a sandwich structure we can simply remove the single portion and we can use the remaining. At the same time we can also use different materials so that existing materials can use. In this 3 different materials with 3 different seat cushion dimensions and followed by 18 different stacking orders.

3. Modeling

Modeling is done in Cero parametric 2.0 a solid modeling software and the design is taken from Heritage Silver truck seat, design dimensions are taken from its main server. There are primarily 3 models which having the cushion heights/thickness 75mm, 85mm and 100mm models are shown in fig 4.1. After analyzing the effect of thickness sandwich model is modeled and with over thickness equal to 100mm and spited to three which having thickness 30mm, 30mm and 40mm. This odder are again change to study how the thickness and material are related.

Fig 4.1 Models with thickness 75mm, 85mm and 100mm from left side.

The composite seat-1 is modeled and assembled with a thickness 30mm, 30mm and 40mm respectively in fig 4.2.

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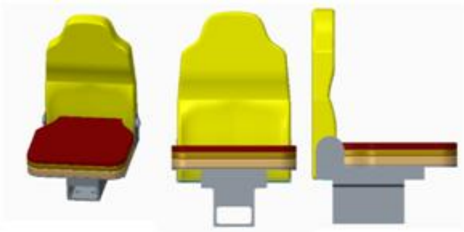

Fig 4.2 Composite seat-1 with 40mm cushion bottom

The composite seat-2 is modeled and assembled with a thickness 30mm, 40mm and 30mm respectively in fig 4.3.

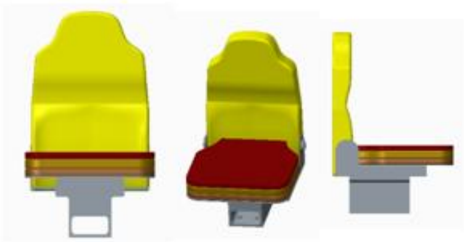

Fig 4.3 Composite seat-2 with 40mm cushion middle

The composite seat-3 is modeled and assembled with a thickness 40mm, 30mm and 30mm respectively in fig 4.4.

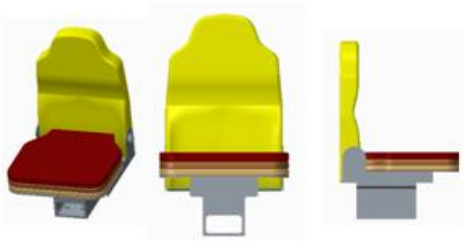

Fig 4.3 Composite seat-3 with 40mm cushion Top

4. Analysis

Analysis is conducted in a Finite element analysis tool ANSYS 15.0, static structural, model and harmonic analysis are carried out in ansys. Ansys work bench is used for solving the problem. For all analysis in ansys there are total five steps to be followed.

a. The first stage with Engineering Data where all material properties are stored for carry out the analysis. Three different materials are used in research, they are PU-16, PU-40 and PU-60. Material properties are taken from the base papers. Properties of each materials are tabulated in table-1

Table:-1 List of material properties

S.No	Material	Density (kg/m^3)	Young Modules (Kpa)	Poisons ration
1	PU-16	16	18	0.27
2	PU-40	40	20	0.27
3	PU-60	60	200	0.27

b. The second stage is geometry where importing the model in to the analysis interface and it will read the model and shows any errors with model we can validate our model, sometime the typical contours are unable to mesh in meshing stage we can check it here.

c. The third stage is called as model, where all the materials are assigned to the model here. Seat is assembled with frame, back support and cushion, the material of the frame is aluminum alloy and the material is PU-60. But this material will change according to the analysis.

d. The fourth and fifth stage is shown separately but those can accessed with in third. The name of this stage is Mesh, where model is meshed with the finest elements so that it can attain the convergence.

e. The firth stage is setup where boundary conditions and loading conditions are assigned for model and solver. After applying everything to the solver, press the solve option for commutating the problem. After plot the results for understanding.

All the analysis where follow the similar pattern.

5. Design and analysis

The objective of this paper is to have a better seat design with better stacking sequence. The results evaluated for understanding the seat performance are total deformation and equivalent stress developed in the seat. The Weight of the occupant is converted to presser and applied on the top surface of the cushion, the practical problem and FEA representation is shown in the fig 6.1.

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The weight considered in this paper is 100kg, and then it is assumed that the entire load is applied on the total surface of the seat.

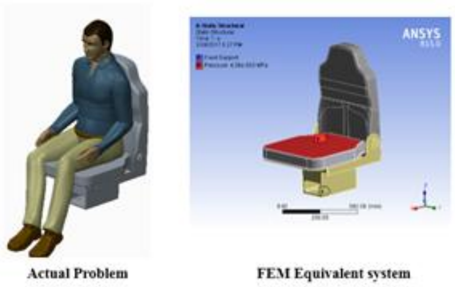

Fig 6.1 Equivalent system representation

The presser is calculated from the basic formula,

Pressure $P = \frac{F}{A}$

Where P = Pressure

F = Force

A = Area

$$\mathbf{P} = \frac{100*10}{2.4615*10^5} = \mathbf{4.0625\ 10^{-3}}$$

The imported model is mashed to it at most finest and the meshed body is shown in the fig 6.2

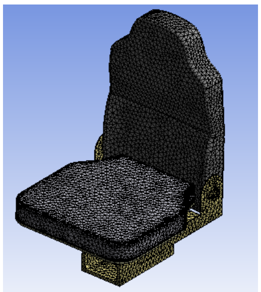

Fig 6.2 Meshed body in Ansys

The FEA constrained body is shown in the fig 6.3 were the boundary conditions and loading conditions are shown in detail.

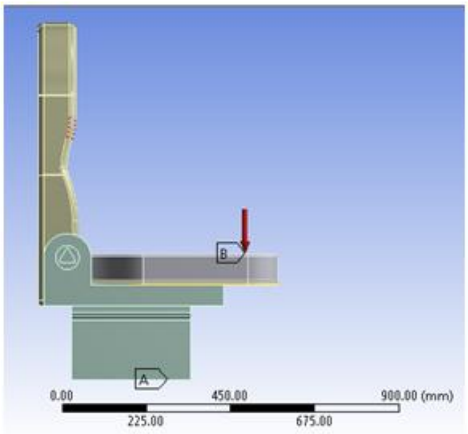

Fig 6.3 FEA Constrained body

6.1 Material

From this analysis the total deformation and equivalent stress generated in the foam bodies are shown in the fig 6.4 and the results are tabulated in the table-2. In this analysis PU-60 where used as the cushion and back rest material and the cushion height is 75mm, Aluminum alloy is used as the fame material.

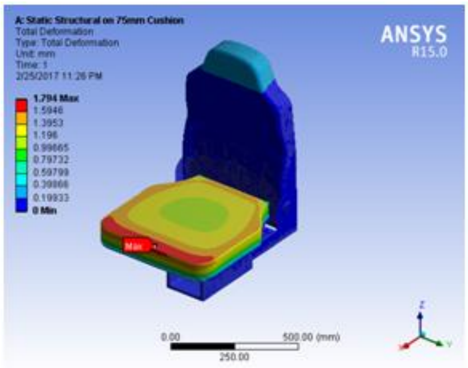

Fig 6.4 Total Deformation in seat

The total deformation is observed as 1.794mm, which is maximum in the cushion. The maximum stress in the cushion is recorded as 13.538 Kpa, shown in the fig 6.4. The fine comfortless stress of this form is given as 250 Kpa that means this stress is not a problem for the form and there won't be any permanent deformation. But coming to the total deformations it approximately equal to the 2mm, from this result the PU-60 material is not a good material in terms of comfort.

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The more the deformation the better the comfort. But since the density is high it can absorb vibration very well.

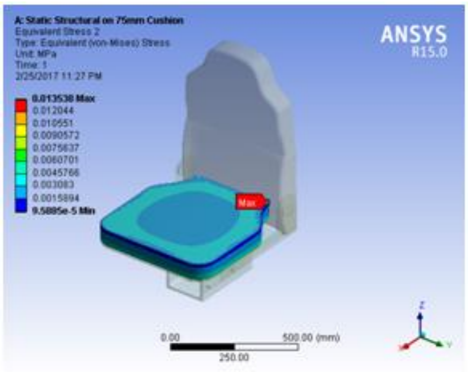

Fig 6.5 Localized Equivalent Stress

Table 3 Listed Results for seat with PU-60 foam

Material	Total Deformation (mm)	Stress on Cushion (Kpa)	Stress on Back rest (Kpa)	Strain Energy (mJ)
PU-60	1.794	13.538	2.525	0.408
PU-40	15.229	13.373	2.402	0.656
PU-16	16.896	13.375	2.43	0.729

From the above results the PU-60 form material has less deformation but has greater strength and vibrational stability. From the material properties table the Young`s modules of PU-60 is given as 200Kpa which is much rigid material compared to remaining two material. The total deformation and the equivalent stress generated in this model with PU-40 is shown in fig 6.6 and 6.7 respectively, results are tabulated in table 3.

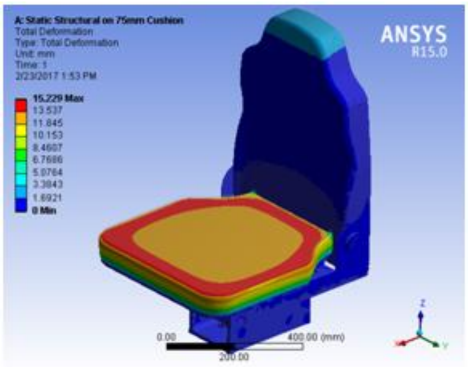

Fig 6.6 Total Deformation with PU-40

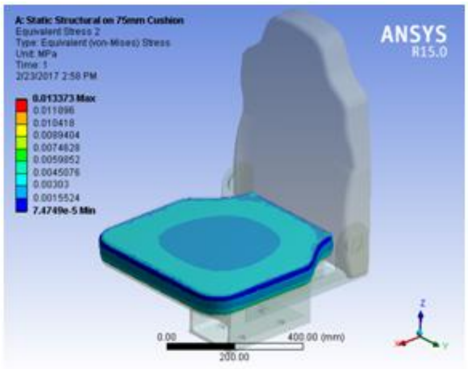

Fig 6.6 Localized Equivalent stress with PU-40

The total deformation is observed as 15.229mm and the equivalent stress is recorded as 13.373Kpa, the very fine comfort stress is 10Kpa which means the life of this foam is less compared to the PU-40. From this both materials are unable to fit it purpose properly. PU_16 is also analysis the maximum deformation is 16.896mm which is recorded closed to the PU-40. And the maximum stress induced in the cushion is 13.375 Kpa which same as the PU-40. PU-16 and PU-40 both has the similar form comfort value. The total deformation and equivalent stress are shown in the fig 6.7 and 6.6.

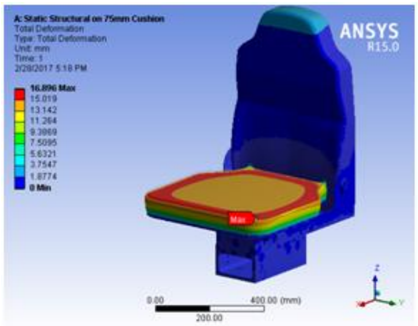

Fig 6.7 Total Deformation with PU-16

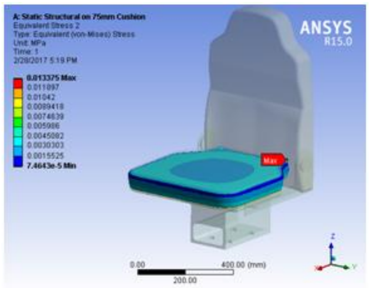

Fig 6.8 Localized Equivalent stress with PU-16

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6.2 Thickness of Cushion

The width/thickness will decently effect the performance of the seat, 3 thickness where studied in this research which are 75mm, 85mm and 100mm respectively. The total deformation and equivalent stress both changed because of the thickness. The stress increased in the 85 mm thickness and reduced in 100mm. which is because the support offered by the backrest. The backrest created a support in 85mm thickness cased and this leads to increases the stress at the contact point. But in 100mm thickness the curvature given an extra space for deformation in cushion and the support portion is also less. The results are tabulated below in the table number 4.

Table 4. List of the results of different material with thickness

Thickness	Material	Total Deformation (mm)	Stress on Cushion (Kpa)	Stress on Back rest (Kpa)	Strain Energy (mJ)
75MM	PU-60	1.794	13.538	2.525	0.408
	PU-40	15.229	13.373	2.402	0.656
	PU-16	16.896	13.375	2.43	0.729
85MM	PU-60	2.345	17.92	2.331	1.485
	PU-40	18.016	16.898	2.223	7.0352
	PU-16	19.958	16.889	2.224	7.8169
100MM	PU-60	2.7069	15.165	2.868	1.5198
	PU-40	21.434	14.155	2.863	9.5712
	PU-16	23.754	14.155	2.863	10.634

6.3 Results and Discussion Composite seat

By combining the materials and design ne and improvised design has been proposed. There are 3 models and by changing materials of each slide total 18 types of models are there the list of the results are shown in the table 5.

Trail Number	Cushion width	Material	Total Deformation	Localized Deformation	Localized Equivalent stress	Stress in Backrest
Composite Seat Trail-1	30MM	PU-16	14.47	14.47	9.128	1.851
	30MM	PU-40		9.509	12.986	
	40MM	PU-60		2.414	22.813	
Composite Seat Trail-2	30MM	PU-60	14.505	14.505	19.749	3.075
	30MM	PU-40		13.816	12.252	
	40MM	PU-16		9.45	11.823	
Composite Seat Trail-3	30MM	PU-40	15.27	15.27	11.631	2.611
	30MM	PU-60		10.026	36.508	
	40MM	PU-16		9.172	11.378	
Composite Seat Trail-4	30MM	PU-16	15.202	15.202	11.777	2.475
	30MM	PU-60		9.364	34.94	
	40MM	PU-40		8.488	11.716	
Composite Seat Trail-5	30MM	PU-60	14.297	14.297	19.53	3.036
	30MM	PU-16		13.603	11.218	
	40MM	PU-40		8.918	12.167	
Composite Seat Trail-6	30MM	PU-40	14.339	14.339	9.366	1.9464
	30MM	PU-16		9.868	12.892	
	40MM	PU-60		2.397	22.568	
Composite Seat Trail-7	30MM	PU-16	16.415	16.415	9.943	
	40MM	PU-40		11.556	10.588	
	30MM	PU-60		2.084	29	2.018
Composite Seat Trail-8	30MM	PU-60		14.294	19.205	
	40MM	PU-40		13.611	9.406	
	30MM	PU-16	14.294	8.069	12.069	2.892
Composite Seat Trail-9	30MM	PU-40		13.573	11.148	
	40MM	PU-60		8.37	30.588	
	30MM	PU-16	13.573	7.21	10.929	2.506
Composite Seat Trail-10	30MM	PU-16		13.608	11.697	
	40MM	PU-60		7.799	28.884	
	30MM	PU-40	13.608	6.623	11.153	2.385
Composite Seat Trail-11	30MM	PU-60		14.454	19.165	
	40MM	PU-16		13.769	8.577	
	30MM	PU-40	14.454	7.553	12.413	2.872
Composite Seat Trail-12	30MM	PU-40	16.459	16.459	10.31	
	40MM	PU-16		12.026	10.097	
	30MM	PU-60		2.057	29.379	2.134
Composite Seat Trail-13	40MM	PU-16	16.565	16.565	9.6	
	30MM	PU-40		9.765	10.073	
	30MM	PU-60		2.054	27.832	2.114
Composite Seat Trail-14	40MM	PU-60		12.435	3.084	
	30MM	PU-40		11.584	7.145	
	30MM	PU-16	14.095	7.586	11.206	2.39
Composite	40MM	PU-40	15.67	15.67	13.287	1.896
Seat Trail-15	30MM	PU-60		8.646	20.596	
	30MM	PU-16		7.617	10.792	
0Composite Seat Trail-16	40MM	PU-16		15.977	13.545	
	30MM	PU-60		8.137	19.462	
	30MM	PU-40	15.977	7.081	11.01	1.85
Composite Seat Trail-17	40MM	PU-60		12.417	30.645	
	30MM	PU-16		11.556	5.112	
	30MM	PU-40	14.063	7.101	11.583	2.374
Composite Seat Trail-18	40MM	PU-40	16.207	16.207	8.245	
	30MM	PU-16		10.172	9.96	
	30MM	PU-60		2.0337	27.563	2.163

From this analysis there are 3 results which has the better deformation and less stress destitution. Trail 12, trail 13 and trail18 has the maximum deformation and among them trail 18 has the least stress vales compared to the other two trials. But in case of maximum deformation trail 13 is better but the stress induced in trail 13 is more compared to trail 18, so the trail 18 is the better among them. Dynamic stability is also studied for the three models and the vibrational characteristics are also understand to proposing the final model. The natural frequency list is shown in fig 6.9.

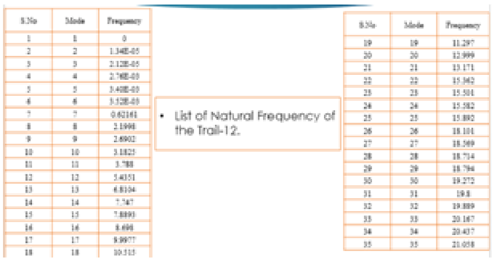

Fig 6.9 List of natural frequency of trail-12

From harmonic analysis the maximum amplitude is absorbed at 20Hz where from the Model Analysis there are 2 sets of frequency closed to the harmonic frequency.

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S.No	Mode	Frequency
33	33	20.167
34	34	20.437

From this, Trail-12 model is not a better one in vibrational point of view. Similarly same analysis are conducted on the trail-13 and trail 18 among them trail 18 has the better dynamic stability because the working frequency and the natural frequency are not overlapping with each other, even from the normalizing curves the Phase angle are also in opposite direction to working frequency.

S.No	Mode	Frequency
1	1	0
2	2	1.08E-05
3	3	1.77E-05
4	4	2.53E-03
5	5	3.02E-03
6	6	3.21E-03
7	7	0.62162
8	8	2.1998
9	9	2.6902
10	10	3.1825
11	11	3.788
12	12	5.1026
13	13	6.8104
14	14	7.3374
15	15	7.3482
16	16	8.698
17	17	9.9977
18	18	10.515

- List of Natural Frequency of the Trail-18.

S.No	Mode	Frequency
19	19	11.298
20	20	13.171
21	21	13.87
22	22	15.362
23	23	15.501
24	24	15.582
25	25	15.892
26	26	18.101
27	27	18.41
28	28	18.975
29	29	19.53
30	30	19.795
31	31	19.889
32	32	21.058

Fig 6.10 List of natural frequency of trail-18

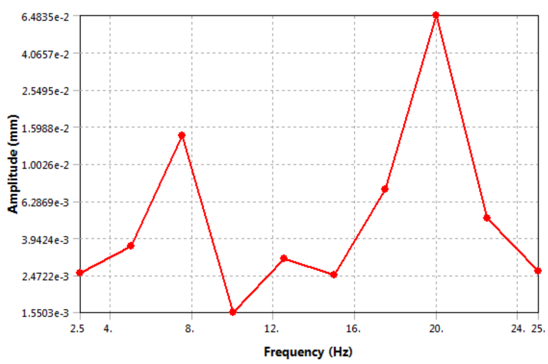

Fig 6.11 Frequency Response Directional Deformation trail-18

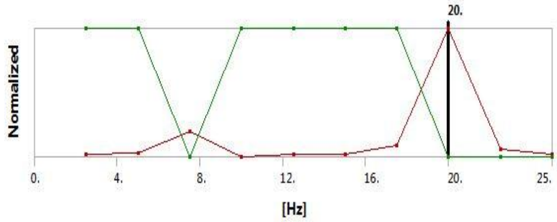

Fig 6.12 Normalized Curve in Directional Deformation trail-18

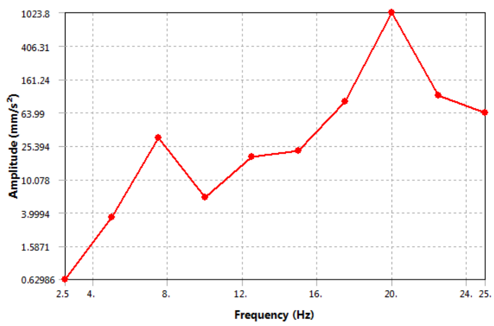

Fig 6.13 Frequency Response Directional Acceleration trail-18

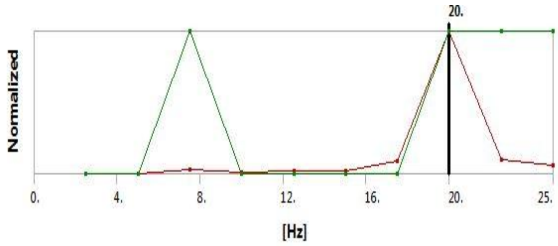

Fig 6.14 Normalized Curve in Directional Acceleration trail-18

7 Conclusion:

The present work present with a composite seat which can perform well both in static and dynamic conditions. With the composite seat the reusability of the foam will increases and the cost of modification will reduce. Because of the different in density the vibrations generated at the bottom of the seat will be reduced ant this will change the occupant performance. The stress developed in the human tissue will be minimized because of the different in densities.

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