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Random Vibration and Noise Analysis of Vehicle Seat Using Numerical Method

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Abstract: The development of vehicle seat used is a challenging task for the automotive industry. In this research the safeness of automotive seats by structural analysis and a random vibration analysis were studied. Hence, the main objective of this study is to determine the suitable vehicle seat configuration based on Noise, Vibration, and Harshness (NVH) performance. In order to achieve this objective, CFD software which is ANSYS was used to analyse frequency and deformation using different force distributed and different material on seat vehicle structure which the force applied from 250 N until 1000 N. The material used is aluminium alloy, magnesium alloy and structural steel to analyse the strength of seat structure. At the end of the study, the effect of different types of material vehicle seat structure was studied. The results confirm that by changing the seat structure material, the rattle noise and in general BSR noise can be improved or controlled accordingly. Consequently, for the seat system which has an identifiable structural dynamic, the BSR noise can be managed and controlled in early design phase by using the seat CAE model.

Keywords: Noise, Vibration, and Harshness (NVH), buzzes, Squeaks and Rattles (BSR), ANSYS, random vibration

1. Introduction

Vehicle seat noise BSR is one of the issues related to NVH quality performance in vehicles. At different speeds, NVH is quite unpleasant and causes tiredness in both the vehicle and the people [1]. Some purchasers prefer a quiet passenger vehicle, while others appreciate a certain car's exhaust noise. Instead of making the car quieter, designers need to consider the natural frequency of structure does not exceed the force of vibration.

Squeak noise frequencies typically vary from 200Hz to 8kHz [2]. Rattle noise is impact induces noise and its low frequency vibration contact produces frequency noise with the majority of its content at 50Hz to 8kHz [3]. Now, an international effort is being made to present a consensus on the limits of human exposure to vibration in the frequency range 1-80 Hz based on the three generally recognized criteria of comfort, working efficiency, and health, taking into account what is known about the frequency, intensity, and time dependence of the human response [4]. The objective of this study is to evaluate the impact of various force distributions on the vehicle seat construction and investigate the impact of various car seat materials on NVH performance. From this get to determine the suitable vehicle seat configuration based on NVH performance.

1.1 Customer Discomfort

According to a market survey, after six months of ownership, squeaks and rattles are the third most important customer issue in automobiles [5]. BSR is caused by frictional movement between two components or by impact between two parts. The study of comfort or discomfort in Malaysian automobile engineering is still in its early stage

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[6]. Figure 1 shows that noise and vibration discomfort factor on seat was the second highest. Vehicle vibration frequently causes pain, weariness, and sometimes harm to passengers [7].

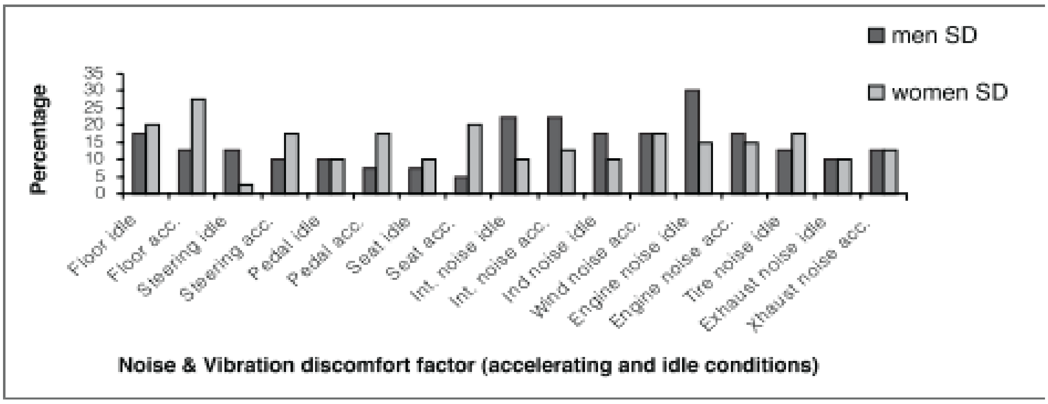


Fig. 1 - Comparison of men and women drivers for slight discomfort response for noise and vibration discomfort factor

1.2 Noise, Vibration and Harshness (NVH)

NVH are all sounds produced by vehicle components and assemblies and can be caused by a variety of internal and external causes [8]. It is critical to remember that interior vehicle noise is influenced not only by acoustic and vibration sources, but also by the many transmission pathways between the sources and the receivers [9].

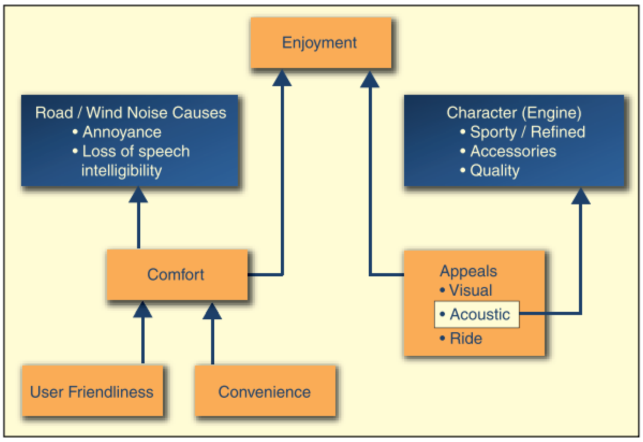


Fig. 2 - Impact of NVH on overall vehicle harmony

There are two types of transmission channels in a vehicle, each with its own set of energy-transmission mechanisms: structure-borne paths and air-borne paths. At low frequencies, the structure-borne noise transmission channel often dominates in an automobile [10]. The role of noise and vibration factors on the vehicle harmony elements is summarized in Figure 2. Since interior noise is an important aspect of evaluating vehicle comfort, if it exceeds a certain level it will cause user complaints manufacturing enterprises have been in pursuit of a low noise level inside the car, designed a low noise level inside the car [11]. In other words, today's automobiles must provide a comfortable and entertaining environment while performing all the functions that drivers and passengers anticipate. Human-factors experts' role is to bridge the gap between form and function for each vehicle class and type, and to set a desired balance between these two aspects [12-16].

2. Materials and Methods

2.1 Research Flowchart

The overall research process for this study is shown in Figure 3. Reading articles, research papers, and journals related to thesis and simulation is part of the literature review. The seat vehicle design using SolidWorks 2021 and simulation is generated in ANSYS by using static structural to get total deformation and equivalent stress. A total of three type of materials and three force applied to the vehicle seat design. The analysis concentrated on frequency data from modal analysis and at which nodes maximum deformation comes out.

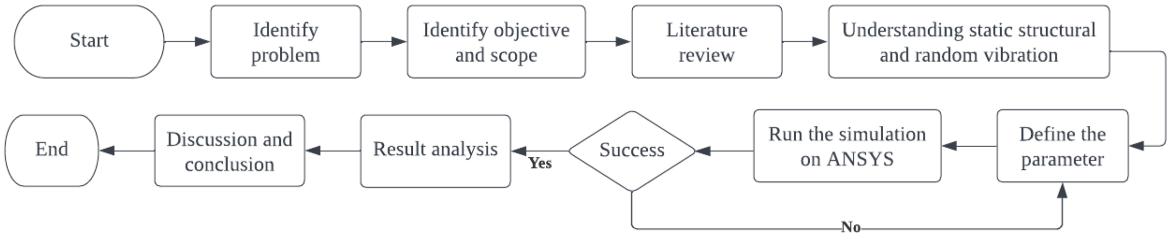


Fig. 3 - Research flowchart

2.2 Computational Methods

Mesh refers to the discretization of a model into a set of elements. It is the stage of a flow simulation study that is most crucial. The validity of the outcome depends on the mesh quality. ANSYS software was used to mesh the seat vehicle model. An example of the mesh formed is shown in Figure 4. The elements and nodes for this meshing were 80k and 175k.

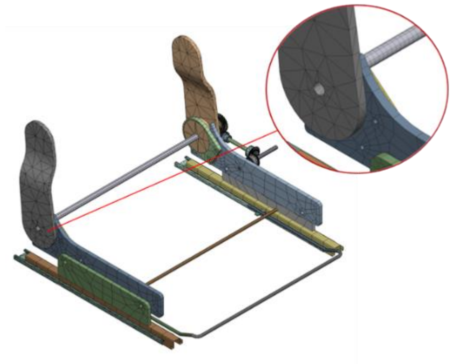


Fig. 4 - Mesh generated of seat models

Boundary conditions for the computational region before running the Random Vibration simulation is crucial. The boundary conditions for numerical setup for this study can be simplified as Table 1 below:

Table 1 - Boundary condition

Software	Material	Force
ANSYS	• Aluminium Alloy • Magnesium Alloy • Structural Steel	• 200N • 620N • 1000N

In this simulation, the seat cushion part was suppressed because all the simulations running have the same material which is polyurethane (PUR) foam. This does not amplify the objective of the project to analyse the effect of different vehicle seat material on NVH performance.

2.3 Parameter Setup

The boundary condition and the static load were used to conduct the structural analysis. It was assumed that the automotive seat frames which the track mechanism were fixed to the lower part of the model. The force applied based on world human weight which is 62 kg [13]. In this simulation, the force applied from 62 kg to 100 kg to get the deformation result if force significant to the frequency result. The force applied to the frame seat back was -200 N towards Axis-X and -620 N and -1000 N at the side frame seat cushion towards Axis-Y. Representatively, Figure 5 shows the fixed support and the applied force.

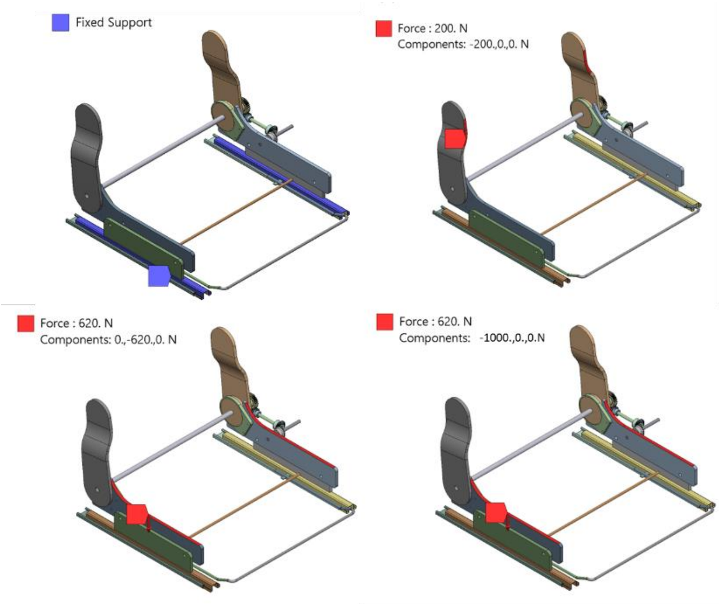


Fig. 5 - Constraint conditions for force applied

3. Results and Discussion

The result of this project will be explained. The project flow can be clearly seen after all the studies and research relating to the topic including Grid Independent Test (GIT), static structural, modal analysis and random vibration.

3.1 Grid Independent Test (GIT)

Figure 4, the number of elements was increased from 80 k to 1500 k element numbers. Based on the number of elements size for a line graph from 900 k to 1500 k, there are no significant changes of the temperature rise with the average relative error is below than 1 percent in stress. Thus, the subsequent simulations are set approximately greater or equal to 1500k element numbers [14].

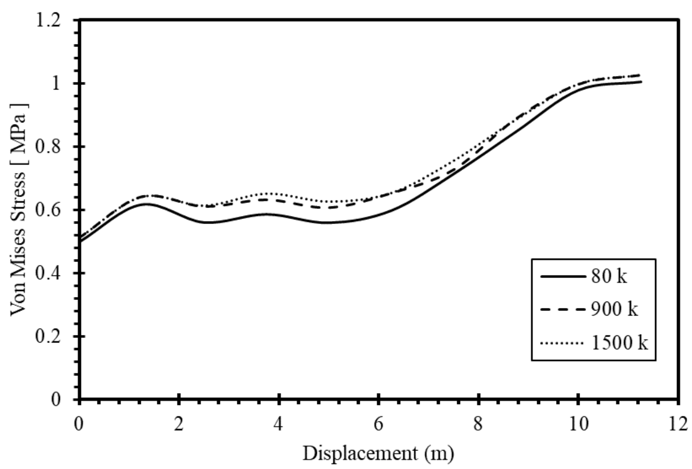


Fig. 6 - Grid Independence Test result with three different elements number

3.2 Total Deformation

Total deformation refers to the change in shape or size of an object that has undergone a load or force that applied to the surface or body. Total deformation of models was compared with each different type of material and force. Figure 7 shows that the minimum total deformation was on structural steel with 0.014874 mm when 620 force applied. The maximum total deformation was 0.066142 mm for magnesium alloy. This shows that structural steel has the best total deformation when the force applied was high.

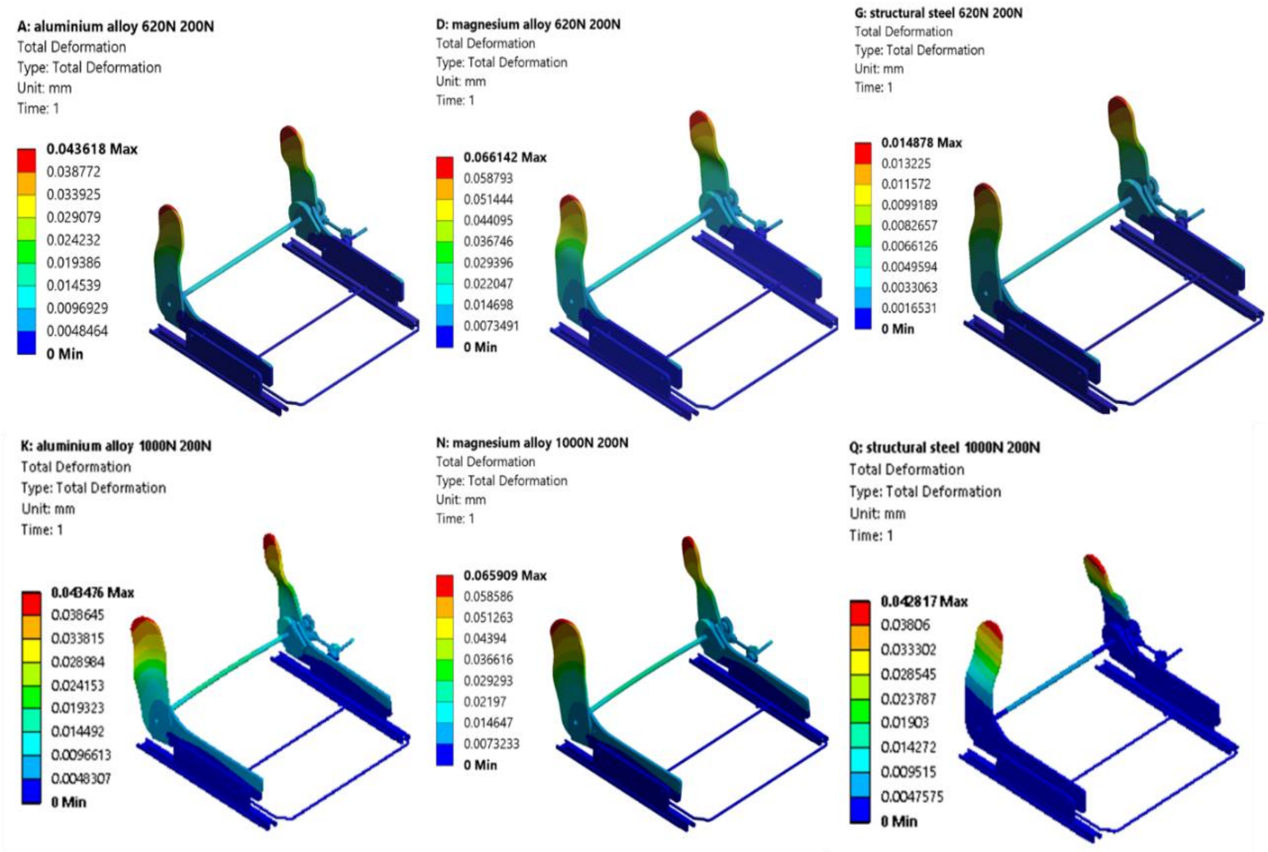


Fig. 7 - Total deformation result at structural analysis

3.3 Equivalent Stress

Equivalent stress is a measure of the stress on a material that considers both the magnitude and distribution of the applied stresses. There are several methods for calculating equivalent stress, but one of the most used is the von Mises stress, which is based on the theory of plasticity. The distribution of stresses in the contact area between frame seat back and frame seat cushion when force is applied 620 N and 1000 N were show in the Figure 4.3 and if the stresses are high, it will affect the wear of the contact area that leads to a decrease in performance efficiency. As seen in Figure 4.3 for each model's equivalent stress, the minimum equivalent stress was when the 1000 N force applied at structural steel, equivalent stresses was 3.7609 MPa compared to the material magnesium alloy 6.0547 MPa.

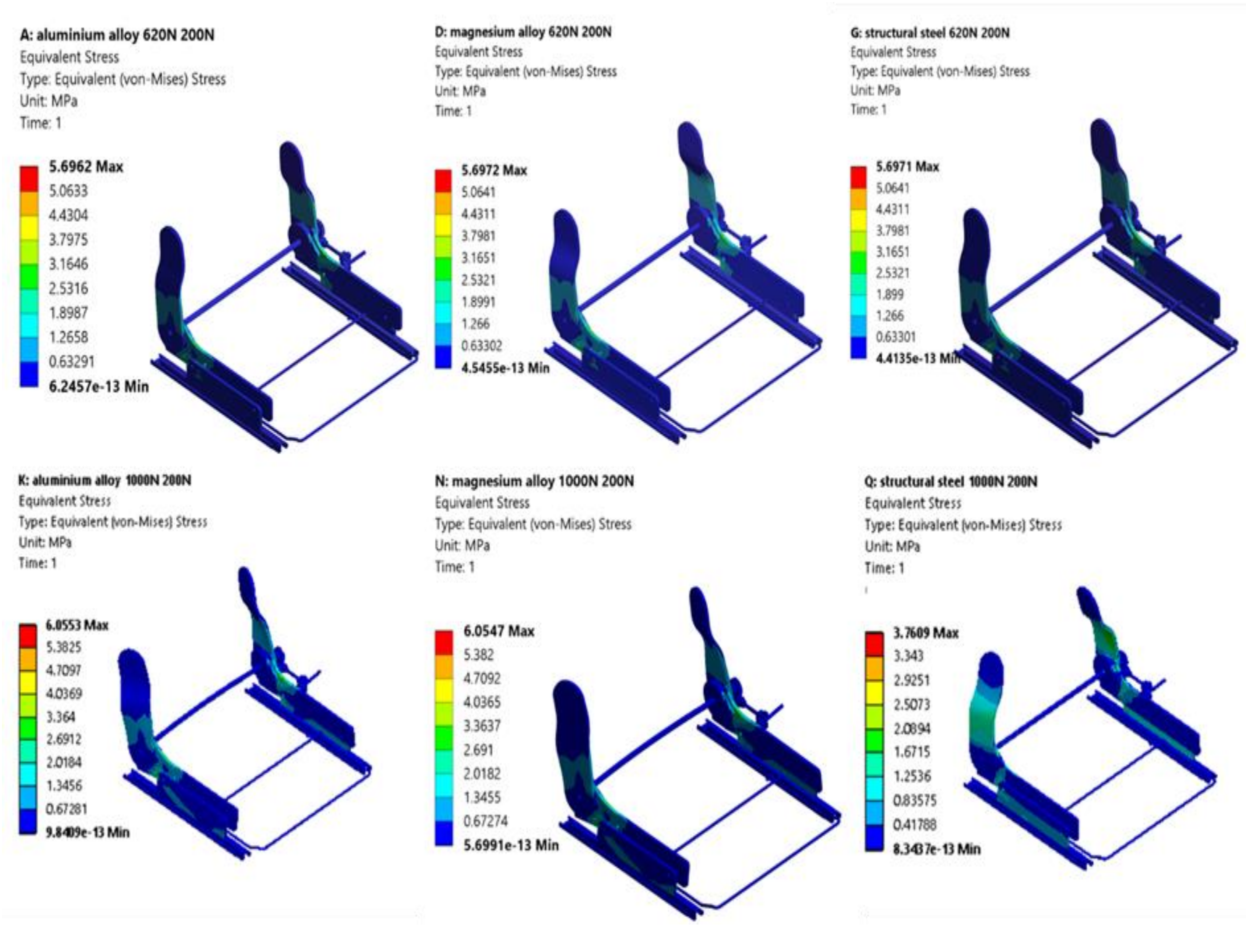
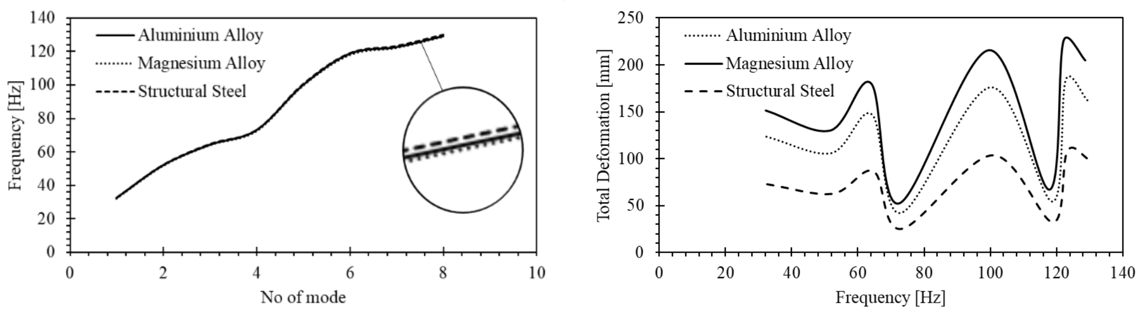


Fig. 8 - Equivalent stresses at structural analysis

3.4 Modal Analysis

Modal analysis is a technique used to determine the natural frequencies and modes of vibration of a structure or system. The basic 8 modes contain 4 linear motions and 4 rotation motions. This mode shows different places where the deformation point happened. Figure 9 (a) shows that structural steel has the slightly different frequency other than aluminium alloy and magnesium alloy. The different of the frequency only 1 to 2 Hz which 129.22 Hz, 128.77 Hz and 130.02 Hz for aluminium alloy, magnesium alloy and structural steel but the deformation from the different material shows that magnesium alloy has the maximum value which 225.54 mm at mode no 7. Otherwise, it will create a resonance that increases the intensity of a noise.

By this it can be seen that the best material was structural steel from Figure 9 (b) which deformed only 108.01mm at 123.32Hz. This is the highest deformation and when designing the seat structure, designer need to consider the natural frequency of structure is not exceeding the force of vibration which was 123.32Hz.

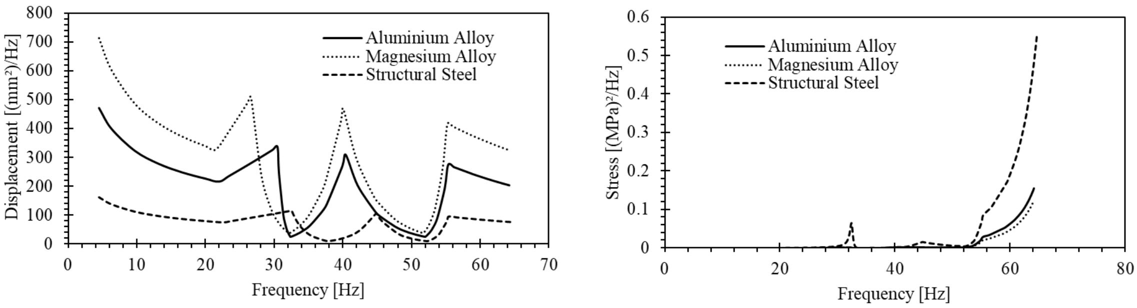


(a) (b)

Fig. 9 - (a) Value of frequency from no of mode; (b) total deformation graph for different material

3.5 Random Vibration

The structure was analyzed under random vibration which PSD Displacement in Axis-X. The result type chosen for the random vibration was displacement and stress. PSD refers to the distribution of the signal energy which the following Figure 10 is the PSD of the seat structure in different material applied on vehicle seat frame. Respond PSD Displacement shows that structural steel has the minimum displacement compared to aluminium alloy and magnesium alloy. Respond PSD for stress type graph shows that structural steel has the maximum value of stress when the maximum frequency happened.



(a) (b)

Fig. 10 - (a) Respond PSD displacement; (b) respond PSD stress

4. Conclusion

The connection between random vibration and noise analysis is that the fluctuating motion of a system due to random vibration can contribute to the noise produced by the system. The frequency spectrum of the noise produced by a different material can be affected by the frequency spectrum of the random vibration acting on the vehicle seat frame. Additionally, the level of noise produced by a vehicle seat frame can be influenced by the magnitude of the random vibration. As such, understanding and analysing the random vibration characteristics of a vehicle seat can be important in the noise analysis. Modal analyses of seat structures have confirmed the type of material has a big impact on the frequency of the vehicle seat. In this research, structural steel was the best material for the vehicle seat frame because the deformation from frequency is the lowest than other material, magnesium alloy and aluminium alloy only 108.01mm when frequency 123.32Hz. The effect of different force distributed on vehicle seat structure was not significant to the NVH performance. So structural steel the suitable vehicle seat configuration based on NVH performance result.

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