Online ISSN : 2249-4596
Print ISSN : 0975-5861

Global Journal of Researches in Engineering: B

Automotive Engineering

Highlights

- Structure-Thermal Analysis
- Viscoelastic Parameter Identification
- Vehicle's Dynamic Behavior
- Influence of Certain Parameters

Discovering Thoughts, Inventing Future

VOLUME 14 ISSUE 3 VERSION 1.0

Global Journal of Researches in Engineering: B
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Volume 14 Issue 3 (Ver. 1.0)

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Contents of the Issue

Global Journal of Researches in Engineering: B
Automotive Engineering
Volume 14 Issue 3 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Viscoelastic Parameter Identification based Structure-Thermal Analysis of Rubber Bushing

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GJRE-B Classification : FOR Code: 090299

VISCOELASTICPARAMETERIDENTIFICATIONBASEDSTRUCTURETHERMALANALYSISOFRUBBERBUSHING

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Zhengui Zhang [α] & Haiyan H Zhang [σ]

Abstract- Rubber bushing, working as flexible connection parts or vibration isolators, is widely used in commercial vehicles, airplane, and off-highway transportation. The appropriate mathematical modeling of it in proper vehicle simulation is becoming more and more demanding recently. This paper focuses on viscoelastic parameter identification based structure-thermal analysis of rubber bushing so that credible predictions of mechanical behaviors and thermal effects of rubber bushing during service can be made. The dynamic mechanical property is characterized as frequency-dependent and the corresponding parameters' identifications are carried out through experiment on DMA. A novel approach to estimating the hysteresis damping is proposed on the basis of interaction between carbon black and molecular chain. The quasi-static harmonic excitation tests are carried out to catch the amplitude-dependent hysteresis damping. FEA simulation is employed to predict the rubber's dynamic response and thermal effect under harmonic excitation with the collected parameters demonstrating mechanical properties.

Keywords: rubber bushing; hysteresis damping; parameter identification, temperature distribution.

I. Introduction

Quality requirements of rubber bushing, such as stability, vibration transmission, and reliability life are becoming more and more demanding in recently decades for design of vehicle suspension systems(1-3). Rubber elements are the cheapest and most recommended parts when a vibration isolator with certain stiffness is required (4, 5). Furthermore, rubber bushing are highly acceptable for reducing noise transmission, accepting misalignment of axes and accommodating oscillatory motions, etc(6). Rubber bushing can be found in vehicles, airplanes, and tractors, such as chassis, suspension, engine mount, exhaust muffler support, vibration isolator, etc. A modern transportation vehicle may have more than 30 pieces of elastomeric bushings integrated in its structure.

Due to the nonlinear force-deflection relationship, the credible prediction of the mechanical behavior and math model of the rubber is a great challenge. The rubber bushing models of the suspension and the whole vehicle system are generally simple, which are often presented using a linear spring and a viscous dashpot connection in parallel or in series. Nevertheless, in comparison with other materials, the mechanical properties of rubber are very complicated. The forces-displacement and moment-rotation relationships are characterized as nonlinear and time dependent (7), thus, the non-linear hysteresis behaviors of rubber bushing and the frequency-dependent loss modulus should be included. Due to its nonlinearities, the cumulative hysteretic energy accumulation inside the elastomeric bushing can cause its mechanical properties to change significantly at various temperatures (8). The changes of carbon black concentration, filler's structure, processing and curing affect the dynamic properties, such as modulus and damping response of rubber(9), this makes the test procedure and instruments used for measuring important in determining the corresponding material parameters(10). Especially, the characteristics of time-dependent force-deflection relationship of rubber bushing should take into account preload, excitation amplitude and excitation frequency in order to present the superposition of elastic force, viscoelastic force and friction force(11).

In most of the published researches about rubber's behaviors or models of suspension components, the thermo-dynamical effects upon dynamic excitation received few attention, especially the thermal contribution from the hysteresis damping(12).The primary energy loss in rubber bushing upon harmonic excitation is attributed to the viscoelastic-frequency dependent behaviors commonly represented by spring and dashpot elements in classical models. The second energy loss resulted from the hysteresis damping which is attributed to the nearly rate-independent internal material friction between molecular chains and carbon black particles(13). The composition of rubber and properties of fillers determined the ratio of two types of damping and its rough quantification is out of the discussion of this paper (1). The effect of hysteresis damping on the energy dissipation can be fully described using the non-ellipse loop obtained from rubber components when viscoelastic behavior is negligible, usually quasi-static harmonic excitation. Plenty of comprehensive researches have been done to identify the behavior of friction-resulted hysteresis damping in the rubber components. Hysteresis damping is slightly mentioned in early classic models characterizing the damping effect of viscoelastic materials since just the frequency-dependent dynamic excitation has been investigated.

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Another widely accepted damping in structural analysis is Rayleigh damping coefficient, which expresses the damping as proportional to mass and stiffness of component, that expression has experimentally validated especially under higher frequency condition (5). Different viscoelastic models are mentioned trying to characterize the dynamic behavior of rubber components and balance the burden of experiment measurement as well as computational complexities. In sum, a good model should be concise enough to match the complicated mechanical properties without bringing in redundant parameters (14).

The main purpose of this paper is to predict the structure response and temperature distribution of rubber bushing through combining the heat accumulation caused by viscoelastic and hysteresis damping. Considering the balance of computation complexity of adding more elements, practical applicability and reliability, Berg's model is employed in this paper. The principle of proper selection of elements to represent mechanical and physical properties of rubber without bringing in excessive calculation is discussed. The proposed hysteresis damping upon static loading is modeled with three springs in series connection and then in parallel to another three in series connected springs. Parameter identification is realized by employing the multivariable nonlinear optimization analysis to guarantee the minimum errors of predicted curves against experiment measurements. Quasi-static and dynamic harmonic excitations with ramp frequencies and amplitudes are applied on the rubber components to represent amplitude dependency of stiffness and damping. With the identified parameters, the dynamic behavior of rubber bushing under harmonic excitation is simulated in COMSOL Multi-physics, which tallies with the expected distribution. Furthermore, the estimation of temperature distribution is presented with great satisfaction.

II. Principle of Model Construction and Constitutive Relationship

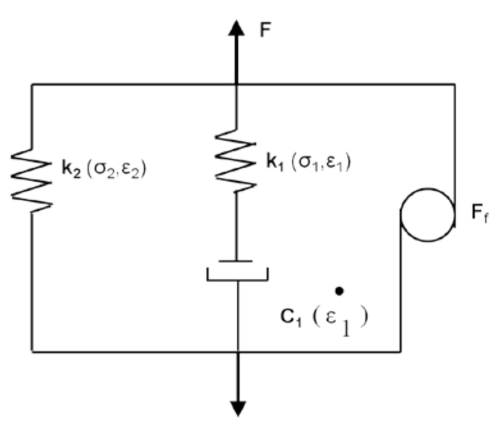


Figure 1 : Berg's three branches model

Many models are propose dtrying to accurately reproduce viscoelastic materials' mechanical behaviors using lumped or discrete springs and dashpots (15, 16). In the commercial software like Abaqus, the generalized Maxwell model using in-series connection of spring and dashpot is recommended to properly represent frequency-dependent dynamic behaviors of rubber. Berg's three branches model (Fig. 1) incorporating the comprehensive effect of elasticity, viscosity and especially friction effect is a great progress characterizing the amplitude-related hysteresis damping of rubber component upon static loading conditions. The total force of applied uniaxial load is shared by the three branches while each branch displays the individual strain. Spring elements k_2 is selected to represent the elastic behavior of rubber busing, especially the modulus of viscoelastic material after infinite relaxation time (branch 1). Spring elements k_1 and dashpot in series forms Maxwell model (branch 2) which describes the attributes of the amplitude and frequency dependency of viscous damping. Maxwell module can properly predict frequency-dependent stiffness and damping properties of rubber components but not applicable for higher frequencies excitation and constant stress conditions. The third branch is a friction element which describes static friction (hysteresis damping) F_f caused by the relative movement between carbon black and molecular chain. This construction leads to a nonlinear reproduction of the parameter dependency of hysteresis damping and dynamic stiffness in a large range of frequency.

a) Quasi-Static Loading(Hysteresis Damping)

In Berg's model, a pure algebraic relationship between displacement and friction force is set after configuring the turning point of hysteresis branches (17). The stiffness increases from the lower turning point to the upper turning point representing the auxiliary stiffness induced by the commonly hysteresis harshness. Although the algebraic approach describes the amplitude dependency of stiffness well, it's short of comprehensive coverage of the stiffness variation at every stage of loading and difficult to formulate the random excitation, the latter case is also commonly used in reality. To avoid this drawback of missing particular stiffness evolution, multiple spring elements with special stiffness value for each stage shown in Fig.2 are suggested to present the typical static characteristic, hysteresis loop. Similar to the bilinear model describing the mechanical properties of elastic-plastic materials, the nonlinear stiffness in the static force deflection stage can be simulated step by step using tri-linear model.

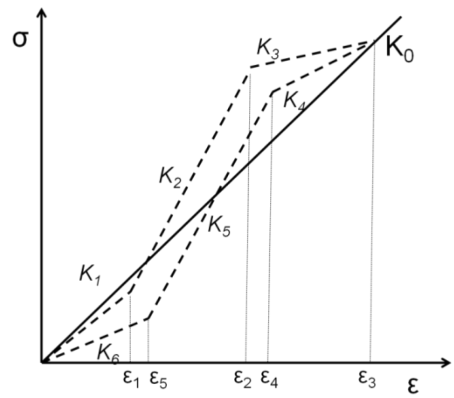


Figure 2 : Typical hysteresis curve of rubber under quasi-static harmonic excitation

In Berg's model, maximum force and turning point of amplitude is needed to derive the half of the maximum force which is useful parameter to describe the frequency-independent hysteresis stiffness. Similarly, Fig 2 also displays four turning points which split the loading and unloading curves into three pieces. The auxiliary stiffness of hysteresis damping upon static friction effect are represented with spring K_2 and K_5which are located between turning points and much more hardened than the remaining springs. Due to the different stiffness of each piece of curve, a tri-linear model with multiply springs K_i is suggested, where i=1, 2, 3, 4, 5, and 6. Stresses of different pieces of hysteresis loop should be written as: $\sigma = K_1\varepsilon_1$ for strain ranging from 0 toε_1; Stage 2for strain ranging from ε_1 toε_2: $\sigma = K_2\varepsilon + b_2$ and stage 3 for strain ranging from ε_2 toε_3: $\sigma = K_3\varepsilon + b_3$. In order to balance the model complexity and computation efficiency, the six springs stiffness can be simplified by setting K_2=K_5; K_1=K_4 and K_3=K_6 according to the acknowledged profile of hysteresis curve. The total energy lost (E_f) per cycle caused by hysteretic damping can be produced by calculation of the loop area,

$$E_f = \frac{K_1\varepsilon_1^2}{2} + \frac{K_2(\varepsilon_2^2-\varepsilon_1^2)}{2} + \frac{K_3(\varepsilon_2^2-\varepsilon_2^2)}{2} - \frac{K_4(\varepsilon_3^2-\varepsilon_4^2)}{2} - \frac{K_5(\varepsilon_4^2-\varepsilon_5^2)}{2} - \frac{K_6\varepsilon_5^2}{2} + b_2(\varepsilon_2-\varepsilon_1) + b_3(\varepsilon_3-\varepsilon_2) - b_4(\varepsilon_3-\varepsilon_4) - b_5(\varepsilon_4-\varepsilon_5) \quad (1)$$

The typical S-shaped force-deflection curve also presents larger elastic elongation accompanying the stiffness reduction again, which is named as Mullins effect, it explains the micro-level damage mechanisms of rubber subjected to large strain (18). The rate-independent response upon static excitation is the crucial phenomenon in modeling internal material friction force and exploring the corresponding hysteresis damping. Under static or quasi-static conditions, time independent and amplitude dependent hysteresis loops are reported in plenty of literatures, even a change of magnitude of deformation rate couldn't lead to significant variation of the hysteresis loops. This interesting conclusion indicated that the widely accepted model of viscoelastic material is insufficient to characterize the quasi-static force-deflection response of rubber bushing. Therefore, the proposed tri-linear model of springs seems to coherently represent the response of rubber component due to the fact that the stiffness relaxation, hardening and relaxation occur with the ramping of strain. Furthermore, the tri-linear model can be adjusted according to the turning point of stiffness if more complicated hysteresis loop is produced in reality.

The mechanism of stiffness hardening and relaxation received great attention and the commonly accepted statement can be explained from the relative motion between molecular chains and carbon black particles. It is well known that tiny carbon black particles are frequently added into polymer to enhance materials' damping, stiffness and abrasion resistance. Agglomerates of carbon black particles are linked together by those molecular chains of polymer of different lengths. Irreversible slipping process between polymer molecule chains and fillers can happen when the critical deformation of chain is reached. From the force-deflection test, the reduction of stiffness happened over a large range of strain, which depends on characters of different chain lengths. For molecular chain with different lengths, slipping process starts at different critical stretch. Furthermore, with the additional increase of strain, the relative slipping among carbon black agglomerates is stimulated when the elastic limit of those filler particles is exceeded (14, 19). Another logical explanation focuses on recoverable straightening and rupture of molecule chains subjected to recycle loading. Molecular chains cluster are partially trenched straight while remaining molecular chains are still in relaxation because of the different lengths and different elastic limits of the molecular chains. It is assumed that the movement of carbon black particle is instantaneous and molecular chains are more delayed. During initial loading or under small strain, molecular chains cluster are mainly slack without any contribution of rubber hardness. When carbon black particle starts move, the stiffness of rubber increases obviously since more and more molecular chains stretched and starting to undertake load. Further increase of loading or lager strain push the carbon black particle move more, as a response, molecular chains cluster will start to break

Global Journal of Researches in Engineering (B) Volume XIV Issue III Version I Year 2014

once the elastic limit is reached. Due to different length of molecular chains, the hardening and reduction of stiffness happens gradually over a certain range of strain, which brings certain difficulty to detect the strain of turning points. The straightening and breakage of molecular chains are partially reversible during unloading. As a result, the non-overlapping force-deflection curves upon loading and unloading caused noticeable static hysteresis damping.

b) Dynamic Loading (Viscoelastic Damping)

Besides static friction, the remaining branches form the standard linear solid model. The first and second branch of current module are placed together to formulate the kinetic equation characterizing the dynamic viscoelastic behaviors. The stress and strain of the two branches are represented in Equation (2),

$$\sigma = \sigma_1 + \sigma_2 \text{, and } \varepsilon = \varepsilon_1 = \varepsilon_2 \quad (2)$$

Where σ, ε are total stress, σ_1, ε_1 are stress and strain of Maxwell elements in series with mass, and σ_2, ε_2 are stress and strain of spring mass elements. The constitutive equation of the standard liner solid is expressed as Equation (3),

$$\frac{d\varepsilon}{dt}(k_1 + k_2) + \frac{\varepsilon k_2}{\tau} = \frac{\sigma}{\tau} + \frac{d\sigma}{dt} \quad (3)$$

The road spectrum of vehicle vibration are collected in time domain and usually transferred to frequency domain before application and analysis. To facilitate the further application of current model, the harmonic excitations are assumed in the following discussion, which leads to,

$$\sigma = \sigma_0 e^{i(\omega t+\delta)}\text{; } \varepsilon = \varepsilon_0 e^{i\omega t}\text{; } \frac{d\sigma}{dt} = \sigma_0 i\omega e^{i(\omega t+\delta)}\text{; and } \frac{d\varepsilon}{dt} = \varepsilon_0 i\omega e^{i\omega t} \quad (4)$$

Replace the Equation (4) into Equation (3) to get the complex modulus depending on frequency,

$$k^* = k' + ik'' = k_2 + k_1\frac{\omega^2\tau_r^2}{1+\omega^2\tau_r^2} + ik_1\frac{\omega\tau_r}{1+\omega^2\tau_r^2} \quad (5)$$

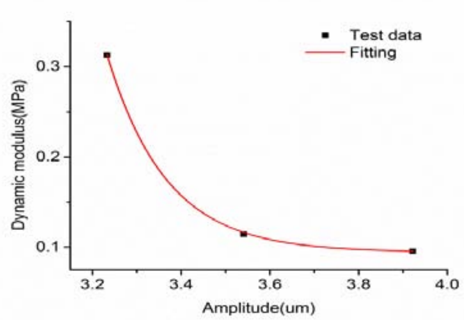
Where the $\tau_r = C/k_1$ is relaxation time, representing the ratio of dashpot and spring stiffness in Maxwell model. In the case of viscous damping, the dynamic modulus of standard linear model is given as: $k_{dyn} = \sqrt{k'^2 + k''^2}$ and $\tan\delta = k''/k'$.

III. Parameterization Identification Procedure

The experimental results of rubber components under static load and harmonic excitation are obtained to identify parameters of each element in the advanced rubber model. All the data measurement are finished using equipment dynamic mechanical analysis (DMA) which measures the influence of frequencies, time and temperature on materials mechanical properties. Harmonic excitation operated using this instrument can be selected over a wide frequency range (0.001 - 200HZ), but the frequency lower than 0.01HZ cannot be loaded in this experimental measurement. Parameterization is complicated and time consuming, furthermore, it is usually separated into two steps, static loads and high frequency harmonic excitation.

a) Friction Force (Hysteresis Damping)

In the case of static loads, loading with lower velocity and excitation frequencies are utilized to simulate the quasi-static loading condition due to impractical static loading. Considering the accuracy and reliability, the excitation frequencies of quasi-static condition is chosen from F=0.01 to F=0.1HZ. The very low frequencies are required to keep the contribution of viscous damping in a negligible position. The stress is ramped from 0.001MPa to 0.05MPa to study the amplitude dependency when frequencies are fixed. The corresponding reports about stiffness, damping, tan delta and amplitude will output automatically as long as the pre-set working condition is reached and being stable. Fig. 4 shows the variation of amplitude of the rubber component is subjected to quasi-static low frequency excitation.



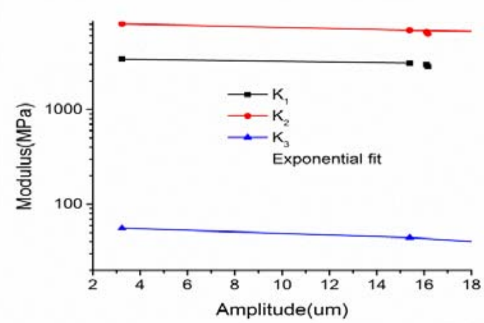


Figure 3 : Amplitude dependency of quasi-static (dynamic) excitation (a) Modulus; (b) modulus of K_1, K_2 and K_3

The observed stiffness dependency upon excitation amplitudes in Fig.3is the well known Payne effect commonly appearing in fillers strengthened rubber compounds. The reduction of stiffness of rubber components with the increasing excitation amplitudes is attributed to the weak van der Waals bonds existing in the agglomerates formed from carbon black particle (20). The recoverable rupture of physical bonds accumulates when imposing higher amplitudes is imposed, resulting in a significant relaxation of stiffness in the macro-level. For the very small amplitude, friction plays dominant contribution to the raise of stiffness. As the amplitude tends to become larger, part of molecular chains break in the micro-level which leads to friction release in macro-level. Considering the quasi-static hysteresis loop and the amplitude dependency of static stiffness, the tri-linear model has been suggested and its coefficients of springs can be estimated using multivariable constrained method. The equation formulated for parameterizing the hysteresis loop is based on the ratio of energy dissipation over total storage energy,

$$\min \sum \left[\frac{\left| \frac{S^{'}}{S} - \tan\delta \right|}{\tan\delta} \right] \tag{6}$$

Where S' is the area in side of hysteresis loop, and S is the storage energy during loading. As to the reported tan delta of every loading condition, corresponding strain can be collected and the area S' and S can be easily estimated using the Equation (1). There are three parameters to identify, which means at least two groups of data under the same or close excitation frequencies required to implement the optimization. Stiffness before and after the hysteresis harness during quasi-static measurement are set as the initial value for K_1 and K_2. The optimization results are illustrated in Fig. 3b. Note that K_1, K_2 and K_3 slightly decrease with increasing amplitudes and K_3 is much lower than K_1, which also agrees well with the previous description of molecular chains. For further calculation, the K_1, K_2 and K_3 are taken as 3.07MPa, 6.62MPa and 0.02 MPa separately. The $\tan\delta$ is taken as 0.05. It is also reasonable to observe that the fracture of molecular chains causes even more reduction of stiffness than the chains' relaxation.

b) Harmonic Excitation (Viscous Damping)

For the dynamic stiffness besides of the hysteresis damping, the module is a combination of advanced Maxwell system and spring, which means three parameters k_1, k_2 and $c_1$are required to determine the frequency response of dynamic behaviors, see Equation (13). The dimension of the rubber sample used for the DMA test is less than 5mm in thickness and about 10mm in diameter, furthermore, stress higher than 0.1MPa could lead to shift of sample and fail to produce valid data. Thus, the corresponding output amplitude is pretty low in consideration of the sample size and loading restriction. In the modeling of railway and vehicle track interaction, vehicle suspensions are designed to make sure of the effective isolation of vibration when the frequency is below 10HZ. Track dynamics gradually play the dominated role than vehicle dynamics when the frequencies reached 20HZ. Under this condition, low frequencies force-deflection relations should be discussed here for stability and passenger comfort(3). In the current parameterization, frequencies of harmonic excitation are ramped from 1HZ to 100HZ to balance the time consuming data collection and representativeness over the large range of frequencies. In order to investigate the amplitude dependency of viscous damping, the stresses of each frequency is run from 0.01MPa to 0.1MPa. For low frequencies such as 0.001HZ and high frequency such as100HZ, the measurements are impeditive and some data are missing due to the testing condition of stresses and frequencies are not applicable to this sample.

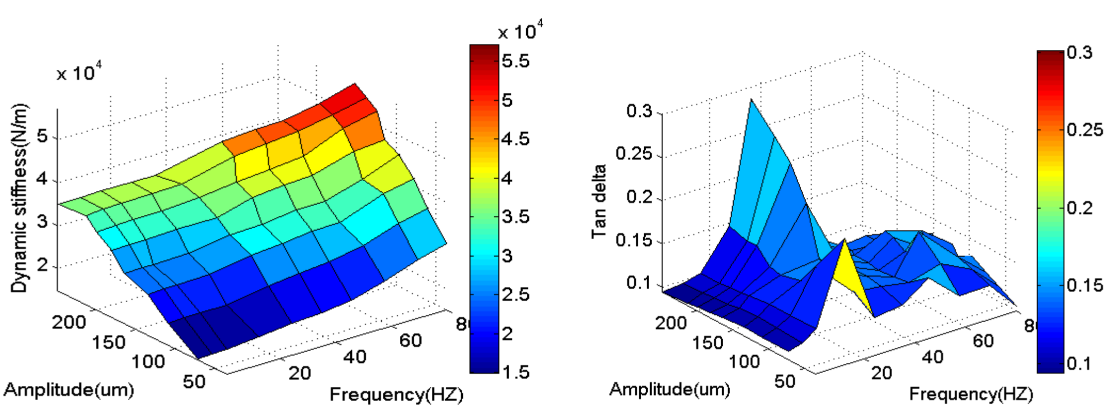


Figure 4 : Response of harmonic excitation versus amplitudes and frequencies: (a)Stiffness (N/m);(b)Tan delta

The overall variation of dynamic stiffness and damping over amplitudes and frequencies are plotted in Fig.4. With the increase of frequencies, amplitude of the same stress will decrease while dynamic stiffness keeps decreasing. As a comparison, the damping presented a peak when the excitation frequency F=30HZ in spite of the variation of amplitude. For more in-depth discussion, the storage modulus, stiffness and other relevant outputs are sketched for more direct demonstration. It can be concluded from Fig.5 that both the storage modulus and dynamic stiffness increase almost linearly with frequency and strain, which clearly illustrated the amplitude and frequencies dependency of dynamic behaviors. The almost linear increase of storage modulus also is proportional in line with energy input from harmonic excitation.

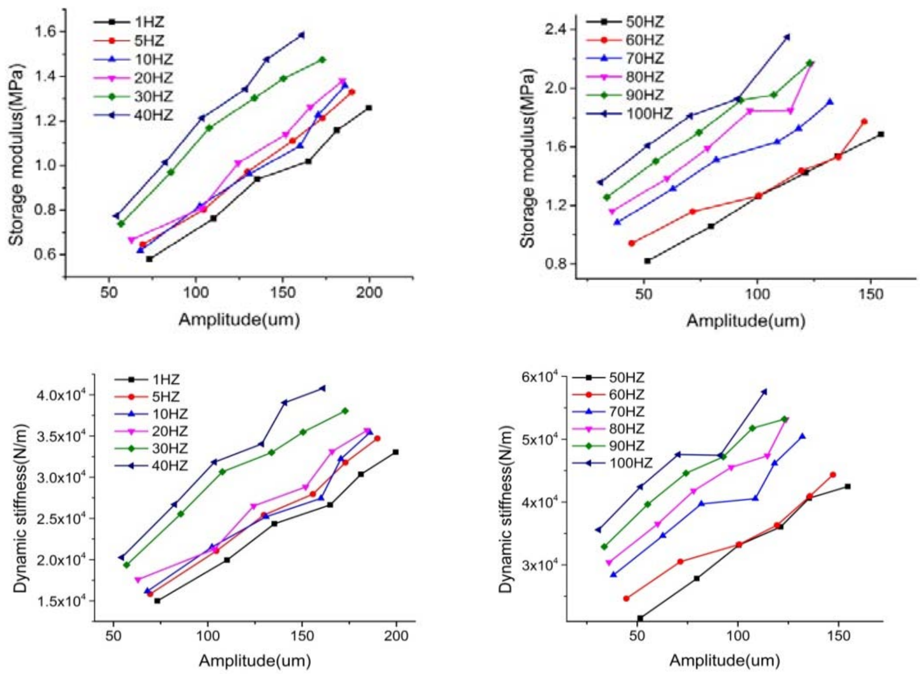


Figure 5 : Illustration of the storage modulus (a, b) and stiffness(c, d) variation on frequencies and deformation amplitudes

As discussed in Fig.4, the energy dissipation presented with tan delta does not monotonously varying with the frequencies or amplitude. Similarly, note that the incongruous increase of loss modulus, damping and tan delta at frequencies F=30HZ in Fig.6, that abrupt increase becomes even more obvious at a slightly higher amplitude. In sum, loss modulus increases with amplitude and damping variation displays the same tendency. In the range of lower frequencies, the increase with strain is slight and the increase of frequencies only slightly affects the position of those lines in Fig.6. It is noticeable that the tan delta data at lower excitation frequencies can be almost fitted using straight horizontal lines. Similar phenomenon is also observed in the quasi-static deformation when harmonic excitation is as low as 0.01HZ. The linear fitting curve for tan delta upon quasi-static loading gives slope-2.12363$\times 10^{-4}$, which illustrated that ratio of hysteresis damping to the energy input is independent of the excitation frequencies at quasi-static or lower frequency condition. It must be mentioned that quasi-static stiffness and tan delta should be excluded to identify the parameters in Equation (13) describing the dynamic behaviors.

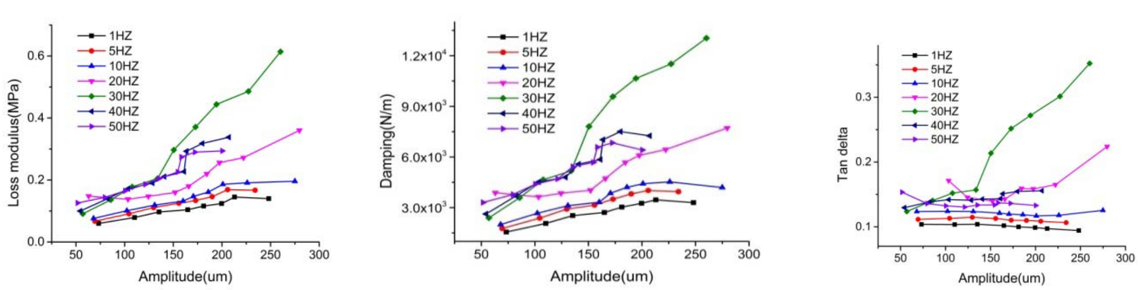


Figure 6 : Illustrationofamplitude and frequencies dependent: (a) loss modulus (MPa), (b)damping (N/m), and (c) tan delta

As to damping, it increases with frequencies gradually at the very beginning and abruptly reaches maximum at frequency around 30HZ. After this peak, damping decreases with continually rising frequencies. This dependency become seven more obvious with the increase of amplitude. The dependency of damping on frequencies can be split into three stages according to the mechanism in the macro-level. All molecular chains of rubber response to harmonic excitation of pretty low frequency changes almost simultaneously with the load and barely lag of phase. This stage is commonly named as high elastic rubber and display limited energy dissipation, which manifests as lower damping and tan delta. While, molecular chains can totally lag behind the deformation of rubber components when harmonic excitation frequencies are within a high range, such as more than 50HZ in the current case. Also, the rubber components upon high frequencies excitation are close to glass state and display much less energy dissipation. A more complicated dynamic behavior is the response of rubber upon the medium range frequencies excitation, for example 30HZ in Fig.6. In that case, part of molecular chains can follow the macro-deflection of rubber, at the same time, resulting in a larger lag of angle delta and higher energy dissipation.

In order to reproduce the variation of stiffness and damping response with the frequencies, there are three parameters k_1, k_2 and $c_1$needed to be identified with the experimental measurement subjected to medium and high-frequency harmonic excitation. From previous analysis, an optimization function should be formulated to satisfy the frequency-dependent stiffness and tan delta together. The multivariable equation is presented in Equation (7),

$$\min \sum \left[\frac{\left| \sqrt{k'^2 + k''^2} - \frac{\sigma_0}{\varepsilon_0} \right|}{\frac{\sigma_0}{\varepsilon_0}} + \frac{\left| \frac{k''}{k'} - \tan\delta \right|}{\tan\delta} \right] \qquad (7)$$

Dynamic stiffness is defined as $k_{dyn} = \sqrt{k'^2 + k''^2} = k'[1+\tan\delta^2]^{1/2}$. Tan delta is less than 0.2 in almost all testing conditions, therefore, k_{dyn} is approximate to k' with error less than 2%. Furthermore, k' is close to k_2 as long as the excitation frequencies are pretty low, finally, dynamic stiffness k_{dyn} is selected to place the initial value of k_2. Considering the friction effect of rubber upon the quasi-static deformation and its contribution to the hysteresis stiffness, the data used for the dynamic behavior's parameter identification should reduce the quasi-static stiffness and tan delta. The decrease of hysteresis stiffness becomes weak if the amplitude of dynamic excitation is set as pretty large since the reduction from the rapture of physical of bond between carbon black particles is only confined within a certain range of strain. The static stiffness variation upon amplitude is usually described exponentially or hyperbolically decreasing model. It can be concluded that the static stiffness with the auxiliary of friction effect can be treated as constant as the amplitude at higher frequencies is in hundreds. The initial value of k_1 usually starts from 0.7 k_{dyn} to accelerate the optimization calculation. Damping coefficient is relative low and 1000N/m should be a good initial point.

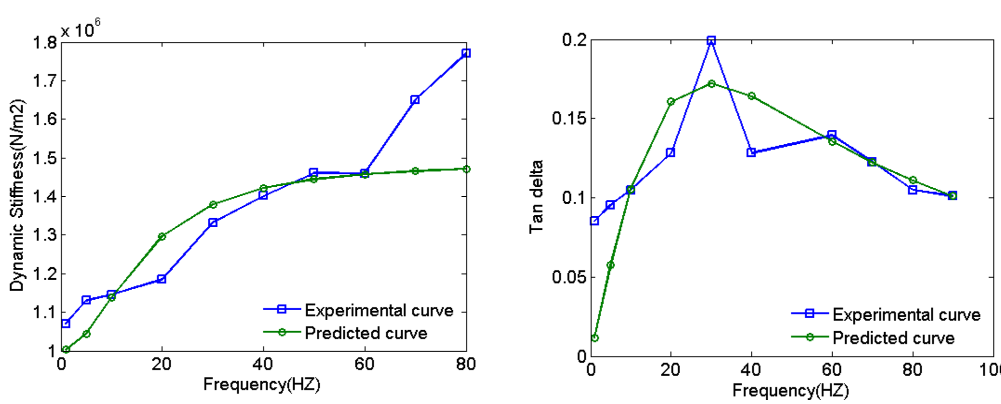


Figure 7 : Experiment measurements against predicted behaviors: (a) Dynamic modulus (N/m^2) (b) Tan delta

Fig.7 shows the comparison of experiment curve against predicted curve plotted with the parameters obtained from optimization. The stress for this group of data is set as 0.05MPa. It is commonly to have the much better fitting for dynamic modulus than the tan delta fitting. Approximate correction can minimize the relative error of tan delta fitting, while that barely changes the parameter identification results. The fitting results in Fig.7 give k_1= 0.49MPa; k_2= 1.009MPa and c=0.028MPa.t. The obtained stiffness k_2 is pretty close to the dynamic stiffness when excitation frequency f=1HZ, that result is verified against the proper assumption of initial values for optimization procedure. It can be seen easily that dynamic modulus increases with frequencies and there is a peak of damping with the increasing of frequency. As discussed from previous amplitude dependency, the dynamic stiffness and damping is generally amplitude dependent. Actually, DMA tests over a stress range 0.01MPa to 0.1MPa are carried out to found the best data for parameter identification, which is realized with the error analysis.

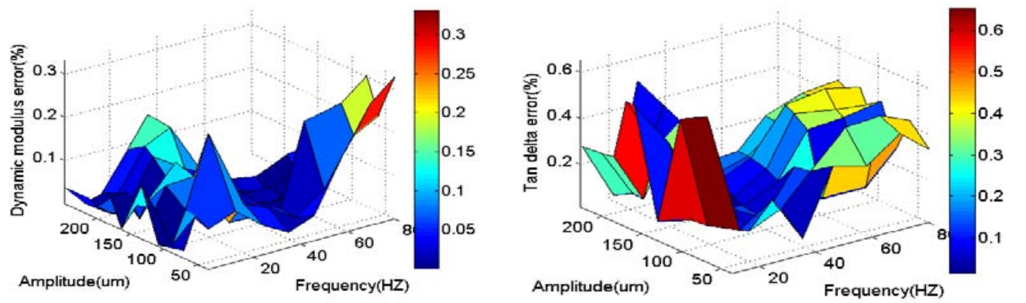


Figure 8 : Erroneous analysis of dynamic stiffness and Tan delta upon with the variation of amplitudes and frequencies

To verify the optimal stress and frequency excitation condition to collect data for accurate model parameter identification, the three-dimensional diagram of dynamic stiffness and tan delta error varying with increasing amplitude and frequency are plotted in Fig.8.As to the medium frequencies excitation, dynamic modulus and tan delta almost reach the maximum value, then, relative error of dynamics stiffness is minimized due to the absolute increment of stiffness. A better selection of excitation amplitude is located in the central part of the amplitude spectrum. The error analysis results indicated that optimization with experiment data upon lower stresses is poorer compared with that from medium or higher stress excitation. This may be attributed to the error of hysteresis stiffness estimated for quasi-static condition, which highly affects dynamic output upon lower frequencies excitation. While the tan delta of quasi-static loading is barely varied with amplitudes, thus, the Tan delta representing dynamic loss shows no obvious variation of relative error changing with amplitudes. As illustrated, the determinacy of frequency becomes more obvious in determining the error, which suggests the medium frequency as better experiment data range. Since the error distribution characteristics of dynamic stiffness and tan delta are consistent in the optimal selection of excitation stresses and frequencies for parameter identification, harmonic excitation are carried out with stresses set as 0.05MPa. Higher stress and higher frequency excitation condition is kind of out of the service scope of DMA test equipment, Again, excitation of too lower or too higher frequency leads to higher relative error, that makes the medium frequencies as much more cautious selection to collect the reliable experiment data.

IV. The FEA Analysis about Temperature Distribution

The FEA simulation with multi-physical COMSOL will be used as an instructive prediction about the heat generation magnitude and temperature distribution. The simulation includes two steps, the first is the force-frequency analysis to estimate the heat generation rate and the next step is the temperature distribution at steady state. The mechanical properties of viscoelastic materials are expressed in Prony series since the commonly recommended generalized Maxwell model introducing many parameters. The general Prony series expression representing shear stress relaxation modulus is

$$G(t) = G(\infty) + \sum_{i=1}^{N} G_i \exp^{(-\frac{t}{\tau_i^G})} \qquad (8)$$

Where τ_i^G is the relaxation time for per series components, $G(\infty)$ is the long term shear modulus when t is approximated to infinite and $G(\infty) = G(t)_{t=\infty} = E_2/(2(1+\mu(t))$. In the current standard linear model, N=1, and $G_1 = E_1/(2(1+\mu(t))$. Ignore the time factors, the Poisson ration μ is taken as constant 0.495 considering the impressible properties of rubber, that give $G(\infty)$ =0.3375 MPa, G_1=0.1639 MPa and τ_r =0.0561s. Static MTS test is run to obtain the static elastic modulus, with which the bulk modulus needed for the FEA can be derived. Fig. 9 is the stiffness of rubber at different strain rate ranging from 0.01 mm/s to 0.8mm/s. Under the real road spectrum collection or experiment loading condition, the strain of rubber component in a rubber bushing is actually pretty low, thus, stiffness less than 10% of strain are chosen to representing the static elastic modulus 5MPa. The corresponding bulk modulus is 166.6667MPa and shear modulus is 1.6722MPa.

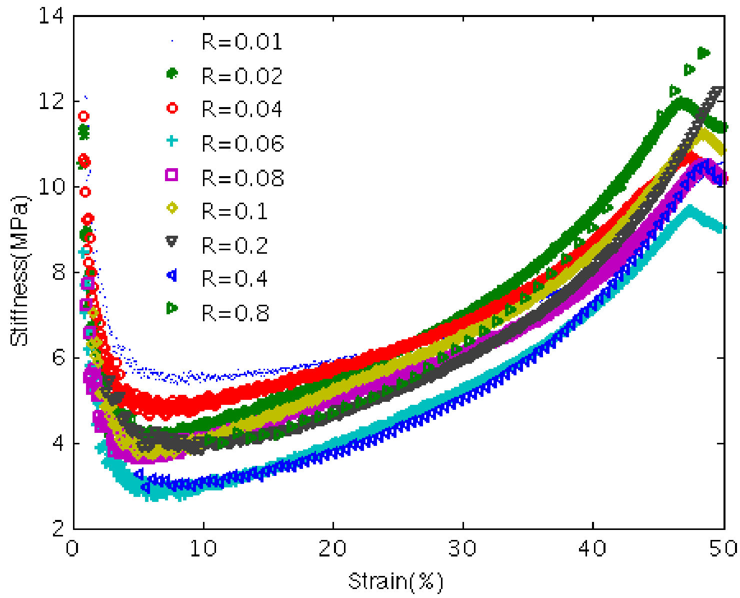


Figure 9 : The effect of total strain and strain rate R (mm/s) on the stiffness of rubber

It is important to claim that the heat generation rate comes from two aspects, one is the viscoelastic damping, and the other one is the hysteresis damping. From the specification of viscoelastic material, the heat generation results of force-frequency analysis merely presenting the viscoelastic damping. Thus, the hysteresis damping describing the friction effect can be set as heat source and the amplitude is determined from structure analysis.

Table 1 : Physical properties of rubber

Density	Heat Capacity	Thermal diffusivity	Thermal conductivity	Heat transfer coefficient
952.54 (Kg/m3)	1611.44 (J/Kg.K)	0.202 (mm^2/s)	0.343 (W/m.K)	10 ($W=(m^2/K)$)

To get more precise prediction about temperature distribution, Hot Disk thermal analysis instrument based on the transient plane source (TPS) method is applied to measure the thermal diffusivity and thermal conductivity (Table 1).The probe of the instrument can provide heat source and record the temperature variation with time. The density and heat capacity are estimated using the mixing rule with the weight percentage of polymer and carbon black, which is estimated with thermal gravity analysis (TGA). The loading frequency is set as9.0134 HZ according to the time history of the loading from the field test.

Fig.10 shows the structure and thermal coupling analysis results produced by COMSOL software. The energy loss coming from the viscoelastic damping is presented as the power dissipation density (W/m^3) which plays as the major heat source for temperature rising. The secondary heat source is hysteresis damping which is defined as constant heat flow since the displacement amplitude is determined under specified load. The results display that the two faces of the rubber bushing accumulated maximum power dissipation density, in turn, the temperature of that two areas are higher. Gent (21) found the center of the bonded surface displays maximum compressive stress which is almost twice the average and again even much higher than the edges. The current FEA results display the same tendency of stress and temperature distribution which are decreasing from the central zone to the edge of the rubber block.

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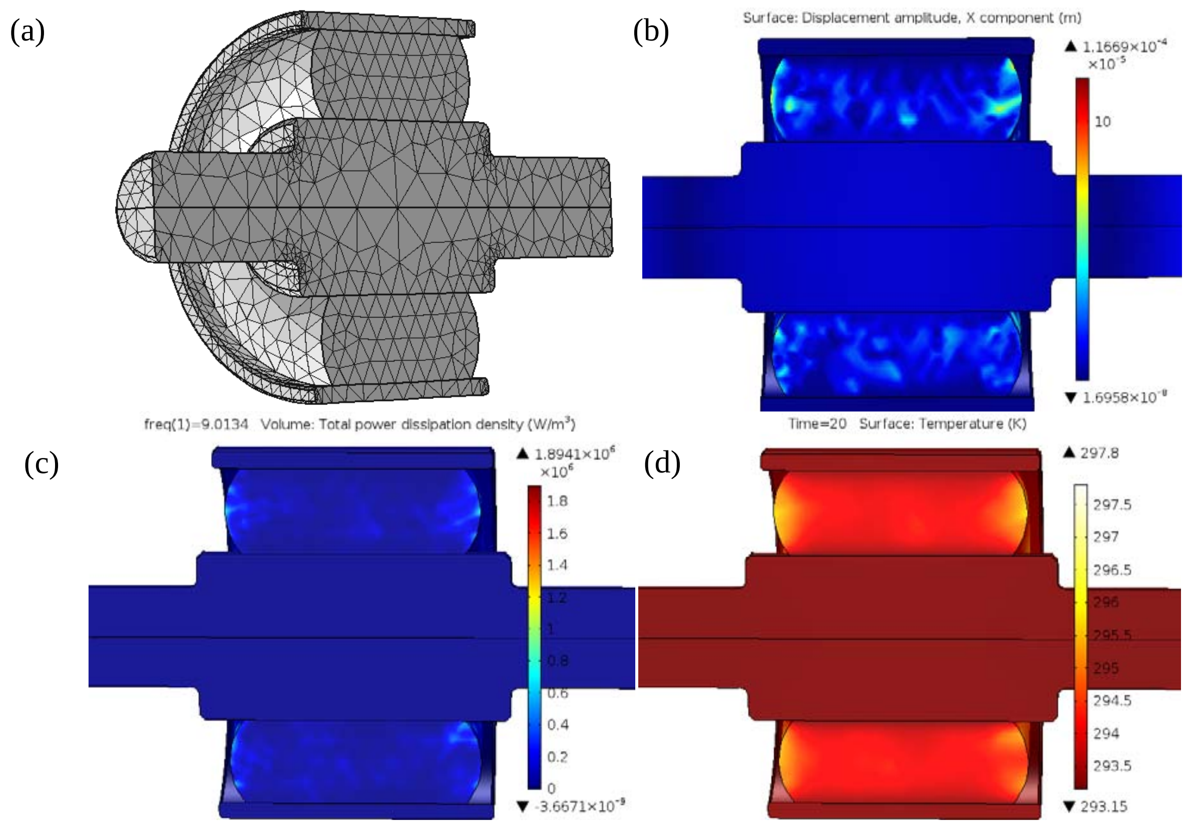

Figure 10 : The FEA result from COMSOL simulation (a) mesh, (b) displacement amplitude in x component(m), (c) Total power dissipation density (W/m3), (d) the temperature of rubber bushing at time=20s

V. Conclusion

A standard linear model parallel to a friction element is employed in this paper to represent the dynamic and quasi-static mechanical properties of rubber with high accuracy and credibility. Spring elements with different stiffness at corresponding stages of deformation are presented to frame the hysteresis damping subjected to the static loading. The tri-linear model is more specific in emphasizing the stiffness hardness and relaxation for each piece of the loop. DMA of different frequency and stress are measured and the model is parameterized using multivariable constrained optimization where data from medium stresses and frequencies are suggested to obtain the optimal dynamic parameters to controls the error. Observed from experimental measurements, the amplitude dependency of hysteresis stiffness illustrates exponential decrease while the dynamic stiffness of rubber increases with the amplitude. Parameter identification procedures are computationally inexpensive and easily applicable, along with the error erroneous analysis. The most adaptable experimental conditions are suggested to demonstrate the model that most precisely matches the real rubber mechanical performance. The powder dissipation density is obtained and its effect on temperature distribution has been analyzed. In the future, the thermal effect on life expectation of rubber bushing will be investigated.

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Global Journal of Researches in Engineering: B
Automotive Engineering
Volume 14 Issue 3 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Drop Damping Seat to Reduce Whiplash Injury in Rear-end Collision

By K. Alkhulaifi, M. Alardhi, J. Alrajhi & A. Abed.
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Abstract- Neck injuries caused by rear end collisions have become a major problem in traffic safety over the last two decades. This situation calls for more research in the field. One area of interest is a damping seat slide to reduce neck injury. To reduce neck injury (Whiplash), based upon new biomechanical research, the motion between head and torso should be reduced. In case of a rear end impact new seat will slide backwards during the impact which allows the motion to damp. Working Model software was used first to simulate and analyse the behaviour of the new system. Also the sled test rig was developed for experimental purposes. The results show occupant protection increases with the new damping seat by up to 75%.

Keywords: neck injuries; rear collisions; whiplash; damping seat; NIC.

GJRE-B Classification : FOR Code: 090299

DROPDAMPINGSEATTOREDUCEWHIPLASHINJURYINREARENDCOLLISION

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Drop Damping Seat to Reduce Whiplash Injury in Rear-end Collision

K. Alkhulaifi [α], M. Alardhi [σ], J. Alrajhi [ρ] & A. Abed. [ω]

Abstract- Neck injuries caused by rear end collisions have become a major problem in traffic safety over the last two decades. This situation calls for more research in the field. One area of interest is a damping seat slide to reduce neck injury. To reduce neck injury (Whiplash), based upon new biomechanical research, the motion between head and torso should be reduced. In case of a rear end impact new seat will slide backwards during the impact which allows the motion to damp. Working Model software was used first to simulate and analyse the behaviour of the new system. Also the sled test rig was developed for experimental purposes. The results show occupant protection increases with the new damping seat by up to 75%.

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I. Introduction

Rear-end car collision typically occur in traffic situation with dense traffic and relatively small distances between vehicles in the small lane. Rear-end collisions often result in neck injuries to the occupants of the struck car. During the collision the vehicle is subjected to a forceful forward acceleration and the car occupants are pushed forward by the seat-backs. The head lags behind due to its inertia forcing the neck into a swift extension (rearward binding) motion. This head motion continues until the neck reaches the end of its motion range or, hits a head restraint or some other structure behind the head. From this point on, the head moves forward and stops in a somewhat flexed (forward bent) neck posture. This type of swift injurious extension-flexion motion of the neck (1, 2) and is commonly called "Whiplash motion".

Neck injuries in rear-end collisions mostly occur at very low impact velocities, typically less than 20 Km/h (3,4) and are mostly classified as minor injury (AIS 1) on the abbreviated injury scale (5, 6,7) since the scale classifies injuries according to fatality risk. (8) suggested that the elastic rebound of the seat back could be an aggravating factor for the whiplash extension motion. The rebound of the seat back can push the torso forward relative to the vehicle at an early stage of the whiplash extension motion when the head begins rotating rearward. This in turn increases the relative linear and angular velocity of the head relative to the upper torso at the same time as it delays contact between the head and head-restraint, thus causing a larger maximum extension angle. Subsequent studies support this theory (9,10). If the seat back of the front seat collapse or yields plastically during a rear-end collision, the elastic seat back rebound is likely to be reduced.

To date, the underlying injury mechanism has not yet been established. Several hypotheses have been suggested by various researchers, but are not conclusive. It seams to be generally agreed upon the fact that such injury is related to sudden movement of the head-torso complex (11).

II. Seat Design for WAD Mitigation

Several seat systems are presented to prevent whiplash injury. Volvo presented the WHIPS seat (12) which is equipped with a recliner that allows controlled backward movement of the backrest during rear-end impact. The motion is performed in two steps: a translational rearwards movement of the backrest is followed by a rotational motion reclining the backrest. Another system, called WipGARD (13), also enables the backrest to perform a translation followed by a rotation. Both the WHIPS and the WipGARD require a critical load to activate the system. The Saab active head restraint (SAHR) system (14), for instance, consists of an active head restraint that automatically moves up and closer to the occupant's head in rear-end impacts. Thus the distance between the head restraint and the head is reduced. The third system is Cervical Spine Distortion injuries (CSD), and the functional principle of the CSD system is based on a defined energy absorption in the backrest. This principle has been employed successfully for a number of years. In standard series seats, the deformation element is located in the recliner. During rear impact, a parallel backwards movement of the seat back begins at a point of critical load, which motion is then transformed into rotation (15). The backwards movement is limited so that the seat back will offer sufficient protection in a high-speed rear impact.

III. Drop Damping Seat

The Drop Damping Seat (DDS) proposal was to develop a mechanism which can be attached to production car seats to reduce the relative motion between the head and lower end of the neck. As stated in the literature [17,18,19] this will reduce the risk of whiplash injury. The DDS was developed to overcome

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this problem by limiting rearward movement but permitting vertical movement to increase the efficiency of whiplash reduction system. The DDS contains four linkages attached to the seat base and the trolley (car floor). During a change in motion of a vehicle, they provide for a change in position of the seat in the form of rotational dropping movement in a generally backward direction opposite the direction of move of the car (Figure 1). As the seat and the occupant of the seat move rearward relative to the car, the head of the occupant accelerates over a longer time. The design was found to work in a satisfactory manner, without the risk of the seat pivoting rearward as in a standard motor vehicle seat.

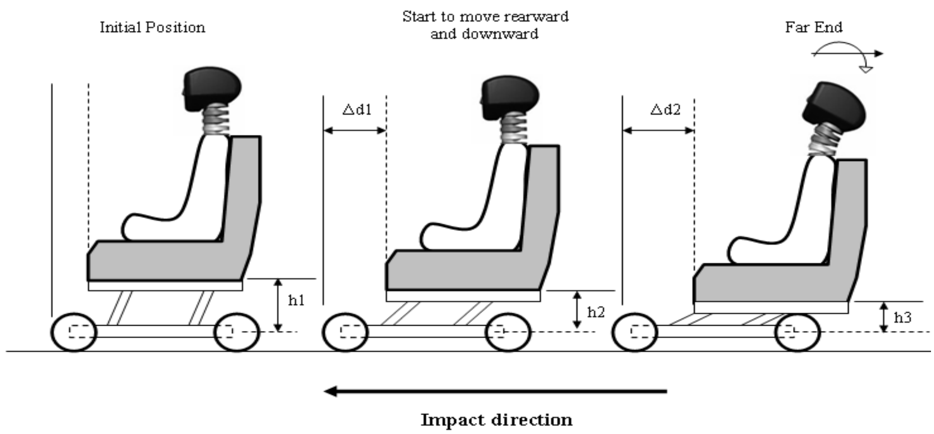

Figure 1 : Drop damping seat during rear-end impact

Different vehicle protection systems have been proposed including those dependent on inertia and those with power drive. Inertia type devices are reactive to inertial forces. Power-derived safety devices have many disadvantages. They require that a sensor react to an event and start an action. Such requirements need exact timing and can fail to perform within the time period available, or at least can fail to perform soon enough for the device to do its job within that period of time. Also, power-operated safety devices are very costly and have a number of mechanisms that can fail. By contrast, on vehicle impact, the DDS reacts completely to the inertia of the vehicle seat to begin its action, the device functions instantly in reaction to the shock force of a rear-end impact. The present device is not expensive and has only a few parts and as well it is maintenance free (Figures 2 and 3).

The DDS generates a movement of the seat that dissolves the backward energy of the occupant by moving the occupant downward as well as rearward. This movement increases both the distance and time of travel of the occupant and reduce the head acceleration, and there is minimum head snap or whiplash injury. The seat motion is controlled by four identical linkages with pivotal connections between the trolley (vehicle floor) and seat base frame. The initial linkage angles should be less than 90°to insure the rearward and downward motion (not rearward and upward as would occurs if the angle is more than 90 degree) Figure 2. One target is that the DDS start motion of the seat at the instant acceleration of the rear-end impact begins. An additional objective is that the DDS maintains the controlled seat motion for the length of acceleration of the occupant.

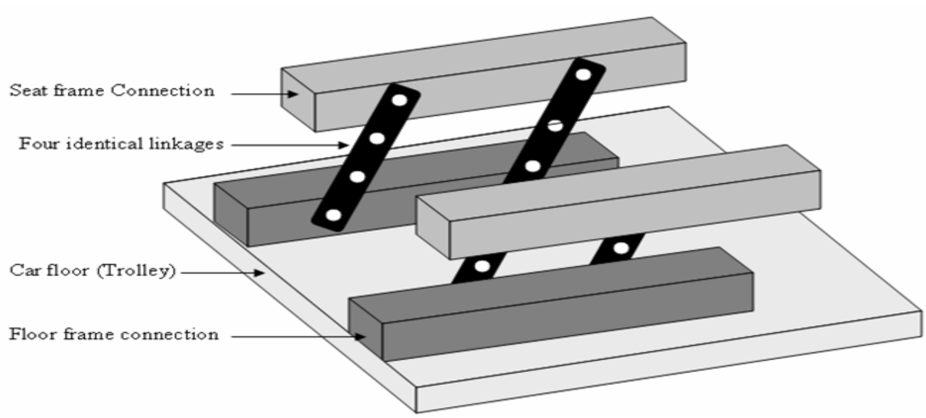

Figure 2 : Schematic drawing of the linkage arrangement

Figure 3 : Drop damping seat, (a) showing the linkages (b) the motion of the system during rear-end impact

IV. Method

The Working Model dynamic simulation program was used to study the effect of stander seatback compared with Drop Damping seat during the rear-end impact.

To analyze whether the new drop damping seat offers the possibility of preventing neck injuries, sled test were performed. The sled test rig was designed and developed to validate the simulation model and to be flexible for different verity of rear-end impact test such as head restraint position or seatback stiffness.

V. Experimental Results

The experiment results show a comparison between DDS results with RS and LDS. The sled test accelerations of the head have been plotted against time. The Hybrid III head-neck complex was used with and without the car seat on the sled test rig. The results from the DDS compared to the RS and LDS are shown in Figures 4, 5 and 6.

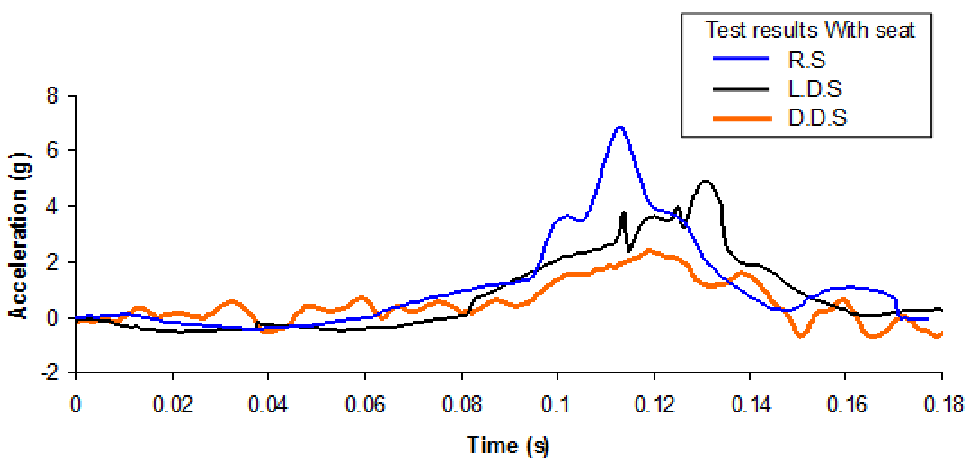

Figure 4 : Test results comparison between RS, LDS and DDS with seat at 14km/h-4 g

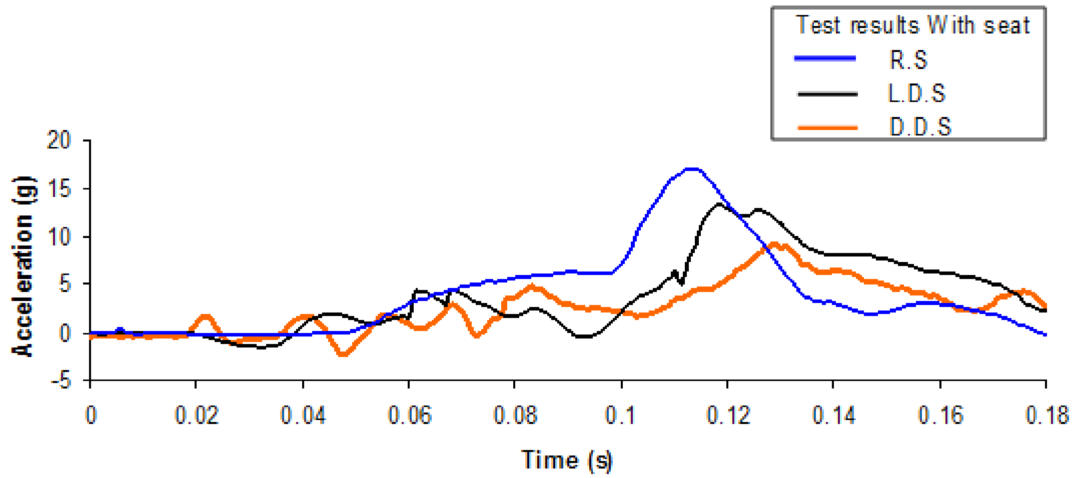

Figure 5 : Test results comparison between RS, LDS and DDS with seat at 18km/h-4 g

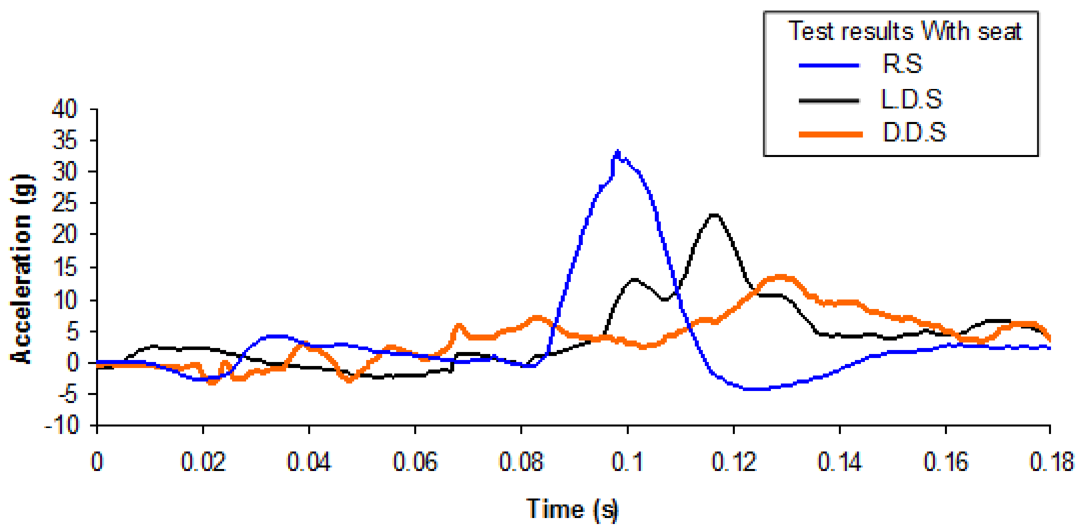

Figure 6 : Test results comparison between RS, LDS and DDS with seat at 18km/h-7 g

During rear-end impact, the both rearward and downward movements of the DDS were occurred. The results for the head acceleration peak values are 2.5 g at 120 ms, 9 g at 131 ms and 14 g at 129 ms as shown in Figures 5-34, 5-35 and 5-36. These figures also compare the DDS with the RS and LDS results. The results indicate major head acceleration reductions by using the DDS for the same sled conditions with respect to RS and LDS. Figure 5-37 summaries the head acceleration results for RS, LDS and DDS, and shows that the amount of head acceleration ranges from 47 % up to 64 % with respect to RS. This significant reduction was due to the energy absorbed by the DDS system.

In general the DDS results show a significant reduction in the head acceleration peaks for all sled test results. Also the gradual rise of the head acceleration as shown (Figures 4, 5 and 6) are due to the kinematic motion of the DDS.

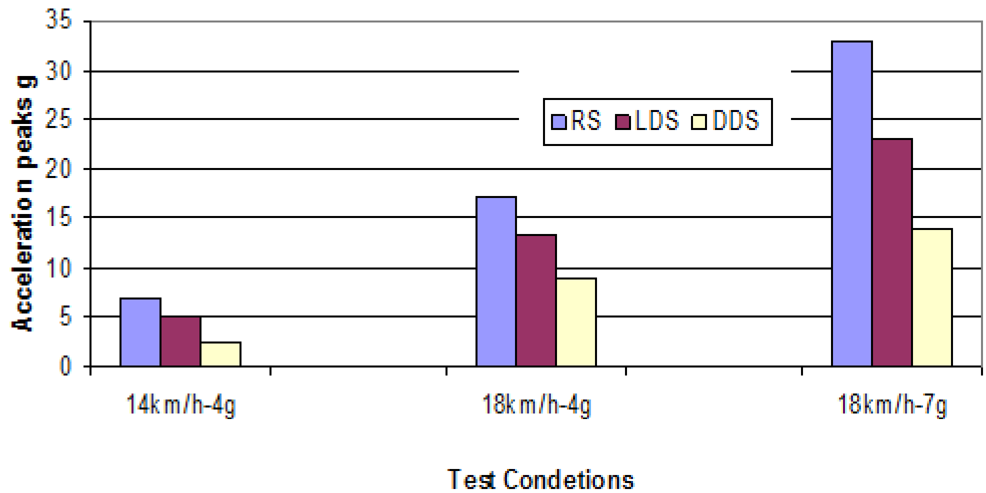

Figure 7 : Sled test head acceleration peaks results comparison between LDS, DDS, and RS (with seat)

VI. Conclusions

The new Drop Damping Seat design for reduction in whiplash injuries, allows less motion between head and torso as shown in the experimental results (trail sled tests), linear damper shows lessen the movement of the neck (spring) extension. A comparison between three cases is created to show the effect of DDS on reducing the neck acceleration during impact.

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Global Journal of Researches in Engineering: B
Automotive Engineering
Volume 14 Issue 3 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Experimental Study on the Influence of Certain Parameters over Vehicle's Dynamic Behavior

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Eng. George Ene Phd Attendee, Eng. Corneliu Mînzatu,
Eng. Irinel Dinu & Eng. Marius Simionescu

Abstract- Tougher request that are being formulated again and again regarding a vehicle's dynamic performances and its fuel efficiency require a deeper study over the influence of various parameters over to the vehicle dynamic behavior. In the specialty literature we find appreciations both quantitative and qualitative regarding the influence of certain functional parameters, and how their adjustments have an impact on to the vehicle's performances. We have to mention that the literature guides its self when analyzing the influence of certain parameters after a very restrictive methodology: when studying how a parameter influences a certain behavior all the other parameters are considered to be constant, which obviously does not happen in reality.

Keywords: vehicle dynamics, correlation analysis, variance analysis, information theory, sensitivity analysis.

GJRE-B Classification : FOR Code: 090202, 290400

EXPERIMENTALSTUDYONTHEINFLUENCEOFCERTAINPARAMETERSOVERVEHICLESDYNAMICBEHAVIOR

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I. Introduction

Throughout the paper, a study is being carried out onto the main functional parameters and how do they influence the dynamic and economy performances of vehicles. The performed study eliminates the mentioned restriction, that regarding that the other parameters but the observed one remain constant, especially in the case of onboard computer fitted vehicles which is the main object of this paper. There are accentuated functional interdependencies and the experimental research confirms that the parameters are not constant in time, their dynamic behavior being the predominant one during normal vehicle operation. Likewise, throughout the paper the study is based on experimental data gathered when testing a vehicle that has onboard computer, transducer and actuators that are already building since fabrication and using specialized data acquisition equipment.

II. Correlation Analysis

In order to show if functional parameters are independent or not and in order to establish the character of their dependencies (linear or nonlinear), frequently the correlation coefficient comes into focus defined through relation [1]:

$$\rho_{xy} = \frac{R_{xy}(0)}{\sqrt{R_{xx}(0)R_{yy}(0)}} \tag{1}$$

That ranges $\rho \in [-1;1]$, a perfect linear dependency is described by $\rho^2 = 1$. If ρ=1 than a perfect direct linear dependency is described and if ρ=-1 than we are dealing with a perfect indirect linear dependency; if $0 < \rho \leq 1$ there is a direct dependency and if $-1 \leq \rho < 0$ there is an indirect dependency. Finally if ρ=0, than the two parameters x and y are independent. So, if ρ^2 is further distanced from the value of one (without reaching zero), the nonlinearity is accentuated.

Furthermore, in expression (1), on the counter side we have the inter correlation function in the origin of discreet time, that τ=0, and under the square root we have the self-correlation functions for the same value of τ=0.

In order to exemplify, figure 1 presents the values for the correlation coefficients in the case of 50 acceleration test-runs and 50 regular runs (usual vehicle behavior) for the Logan Laureate vehicle; the parameters (influencing parameters) are engine speed n, throttle's position ξ (describing engine load), and the resulted parameter is vehicle speed V.

As we can see from these charts, there is no experimental test run that has the correlation coefficient zero, thus the analyzed parameters are not independent, which was expected from a functional point of view. Also, observing that in the case of all test runs the correlation coefficients have sub unitary values, we can draw the conclusion that between these parameters there are non-linear dependencies; the most obvious one is between the throttle's position and vehicle speed in the case of normal operation, the correlation coefficients having the lowest values, including the overall average ρ=0.418. This last aspect leads us to the conclusion that the vehicle movement needs to be described by nonlinear differential equations in order for the afferent model to precisely describe the phenomenon.

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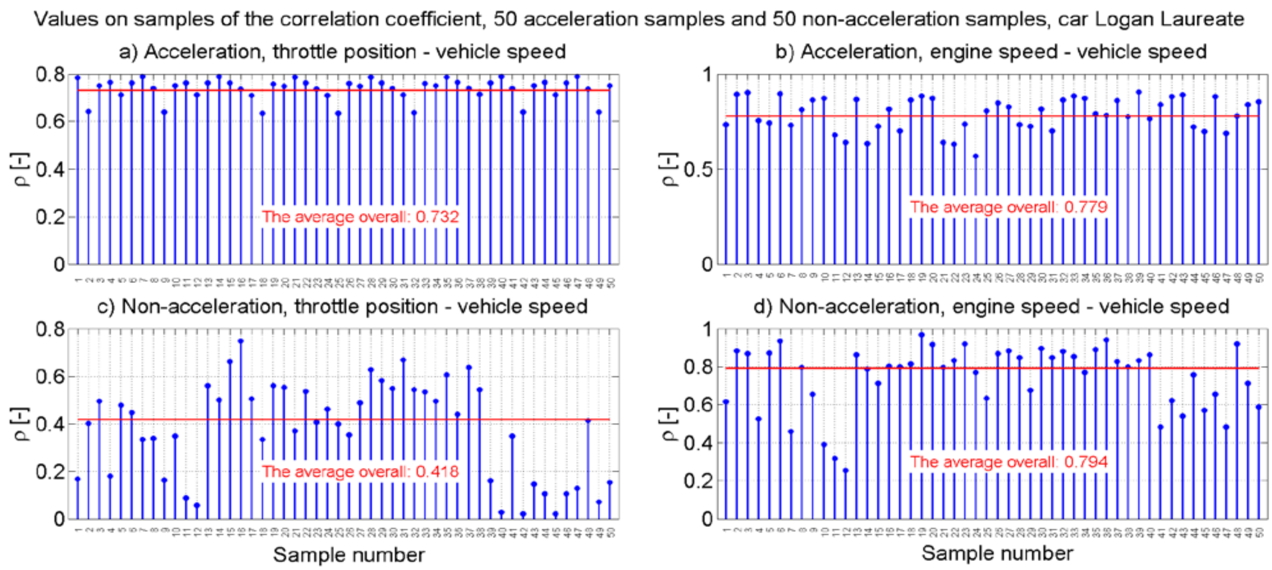

Fig. 1

A simple correlation was applied on the presented example, where one influencing parameters was considered (engine speed or engine load); if they are both, or even more, taken into consideration at the same time or we have to rely on multiple correlation analysis [1].

III. Variance Analysis

Studying the influence of functional parameters calls on variance analysis (ANOVA – ANalyse of Variance, MANOVA – Multivariate ANalyse of VAriance); variance is of outmost importance when analyzing the influence of certain parameters that describe a dynamics process [1].

Ronald Fisher, mathematician and statistics specialist, which is the creator of variance analysis, proved that estimating a certain characteristic's variance undergoing a certain parameter's influence, and afterwards eliminating this influence and comparing the two variances we get quantitative information regarding that influence. So, variance analysis is all about comparing the two types of variances, residual and factorial. If factorial variance is greater than the residual one, than that specific parameter has a sensitive influence over the analyzed process. Backwards, if factorial variance (individual or interacting with another parameter) is smaller than the residual one, than that specific parameter has a negligible influence over the targeted process. This comparison actually sets the percentage contribution of each parameter to the total variance.

Figure 2 presents the results when applying the generalized MANOVA algorithm (the analyzed parameters and their afferent interactions are considered) studying how engine speed n and throttle's position ξ influences vehicle speed V. Similarly, figure 3 highlights the results of generalized MANOVA application studying how engine speed and throttle's position influences hourly fuel consumption C_h.

From figure 2a we can see that in the case of acceleration test-runs, the residual variance is practically zero (so all targeted parameters need to be taken into consideration), higher values than this is specific for engine speed (25.42%), throttle's position (65,38%) and the interactions between engine speed – throttle's position (9.2%). So in the case of accelerated test-runs the throttle's position (giving information about engine load) has the highest influence over the vehicle's speed, almost 2.6 times higher than the influence of the engine speed.

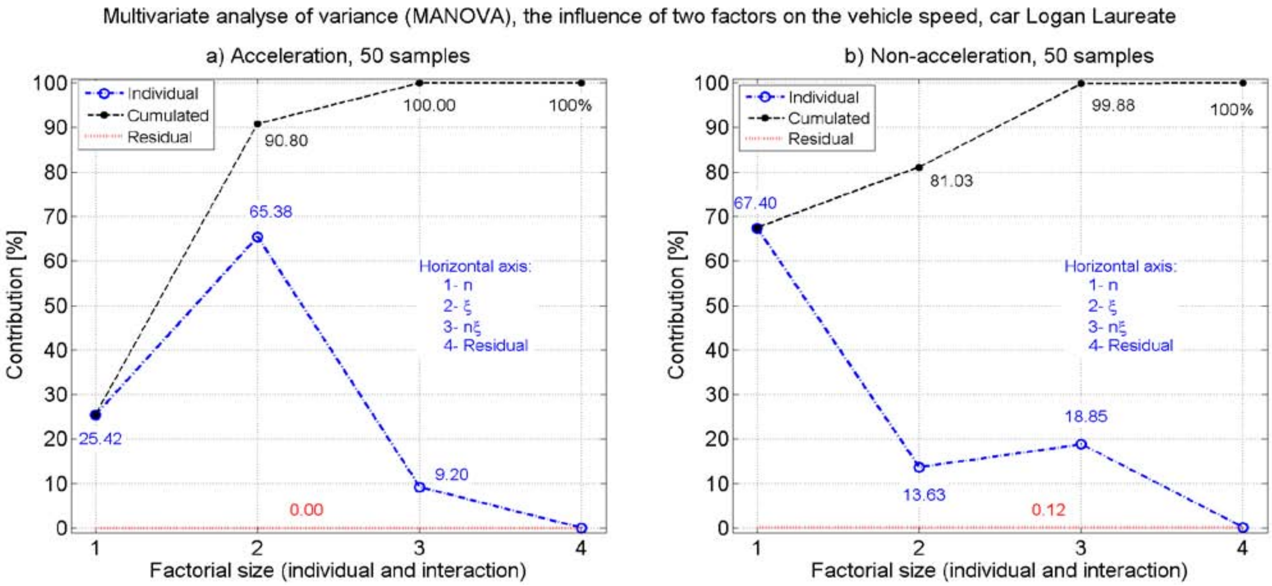

Fig. 2

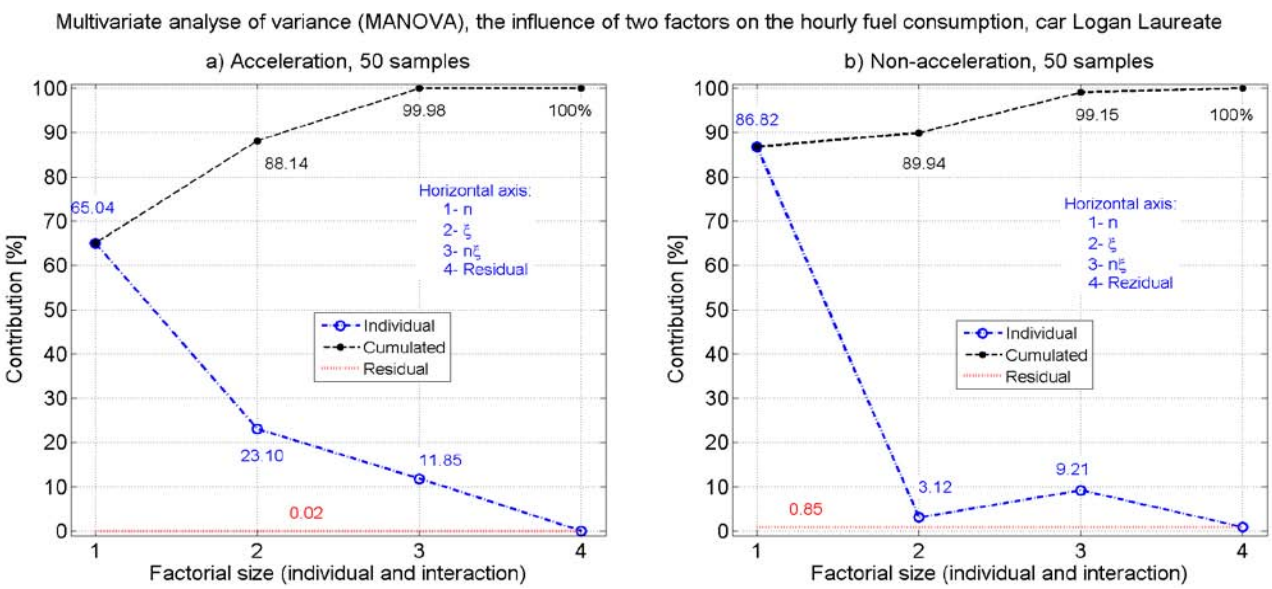

Fig. 3

From figure 2b we can observe that in the case of non-accelerated test-runs, the residual variance has a lower value, of 0.12%, all targeted parameters having grater contributions to the total variance. But this time, engine speed has the largest influence over the vehicle's speed (with a 67.4% contribution to the total variance), the throttle's position now has a 4.9 times less contribution than the previous case (13.63%). From the graph also we can see that interaction between engine speeds – throttle's position has an important contribution of 18.85%, which is higher than the case of throttle's position; this aspect shows the necessity that when analyzing the influence of certain parameters onto vehicle dynamic behavior we have to take into consideration the parameter's interactions.

The graphs from figure 3 shows that in the case of hourly fuel consumption, the highest influence is due to engine speed, both in the case of accelerated (fig 3a) and non-accelerated (fig.3b) test-runs; this influence is much more important in the case of non-accelerated test-runs. Besides, as we can see from figure 3b, the interaction between engine speeds – throttle's position has a higher influence (9.21%) than that of the throttle's position (3.12%).

IV. Information Theory

The information analysis of vehicle dynamic behavior, based on experimental data gathered during test-runs, allows for establishing the relevant parameters that define vehicle movement, so those parameters that need to be taken into consideration when establishing mathematical models. Information analysis is based on two main concepts of the field's theory: entropy and information [2]. *Information* represents the fundamental concept when predicting and is characterized by a probability distribution *p*. Hartley define information contained in *n* events $x_i \in X$ using the following relation:

$$I(x_i) = -\log_2 p(x_i) \quad (2)$$

In order to characterize the uncertainty of an event happening, the concept of entropy is being used; Shannon himself, the one who introduced the notion, used the term of uncertainty. *Entropy* is the product between the probability and the available information overall events $x_i \in X$:

$$H(X) = \sum_{i=1}^{n} p(x_i) I(x_i) \quad \Rightarrow \quad H(X) = -\sum_{i=1}^{n} p(x_i) \log_2 p(x_i) \quad (3)$$

The higher the entropy gets, the higher the uncertainty is and thus the prediction is less and less precise. When a certain system evolves, entropy is at its maximum when the systems find itself at a static equilibrium; so a dynamic system behavior, characterized by the reduction of its entropy ensures a good prediction, better than the case of static system.

Taking into consideration two parameters *X* and *Y*, for which we have a common probability density *p*(*x*,*y*). In this case, the common entropy of the two variables (*co entropy*) is calculated with the relation:

$$H(X,Y) = -\sum_{x}\sum_{y} p(x,y) \log_2 p(x,y) \quad (4)$$

Just the same, we define conditional entropy (or *condentropy*):

$$H(Y|X) = -\sum_{x}\sum_{y} p(x,y) \log_2 p(y|x) \quad (5)$$

A vary used concept is *mutual information*, which is established by the following relation:

$$I(X;Y) = H(X) - H(X|Y) \quad (6)$$

and represents a quantitative measurement of *X*'s uncertainty if *Y* is known. Mutual information is a concept that offers a quantitative measurement of how much the uncertainty is reduced, or how much the accurate prediction level increases. As higher the mutual information is, the uncertainties reduce thus better predictions. For this reason, mutual information is a basic concept when studying system's dynamic behavior and *represents a measurement of parameter's interdependencies.* From this reason, when establishing mathematical models, those parameters that are characterized by the highest mutual information need to be chosen because they ensure the highest prediction levels; these are called relevant parameters, regarding the concept of relevance. From the mentioned reasons, we consider that information theory is a generalization of the classical correlation analysis and mutual information represents a measurement of relevance.

For exemplification, figure 4 presents a graph that show the result of an information analysis in the case of fuel consumption when covering 100 kilometers as a deduced parameter (placed on the top) and taking into account other 6 parameters (influence factors): engine speed and engine load (the latter expressed by the throttle's position), injection duration, intake air pressure, ignition timing and the quality of air-fuel mixture (expressed by the air excess coefficient). The graph's nodes present the *H* entropy values. We can see that the highest entropy is specific for engine speed, of 7.7 bits, and the lowest one is characteristic for fuel consumption and injection duration: *H*=1.5 bits; according to what was said we can conclude here that using the engine speed in dynamic calculus results in lowering the prediction level. On the graph's arches mutual information of two parameters is presented. We can see that the first two relevant parameters (that have the highest influence over the fuel's consumption) are the throttle's position (mutual information with the consumption of 0.632 bits) and injection duration (*I*=0.409 bits). Figure 4 gives us the mutual information between 6 parameters; we can see that the highest mutual information is shared by the throttle's position and injection duration, of 0.654 bits, exceeding those that were previously presented; this confirms the necessity that when studying the vehicle's dynamic behavior the interdependency of certain parameters needs to be addressed, not only between them and the analyzed parameter but also between themselves, as presented the case of fuel consumption when covering 100 kilometers.

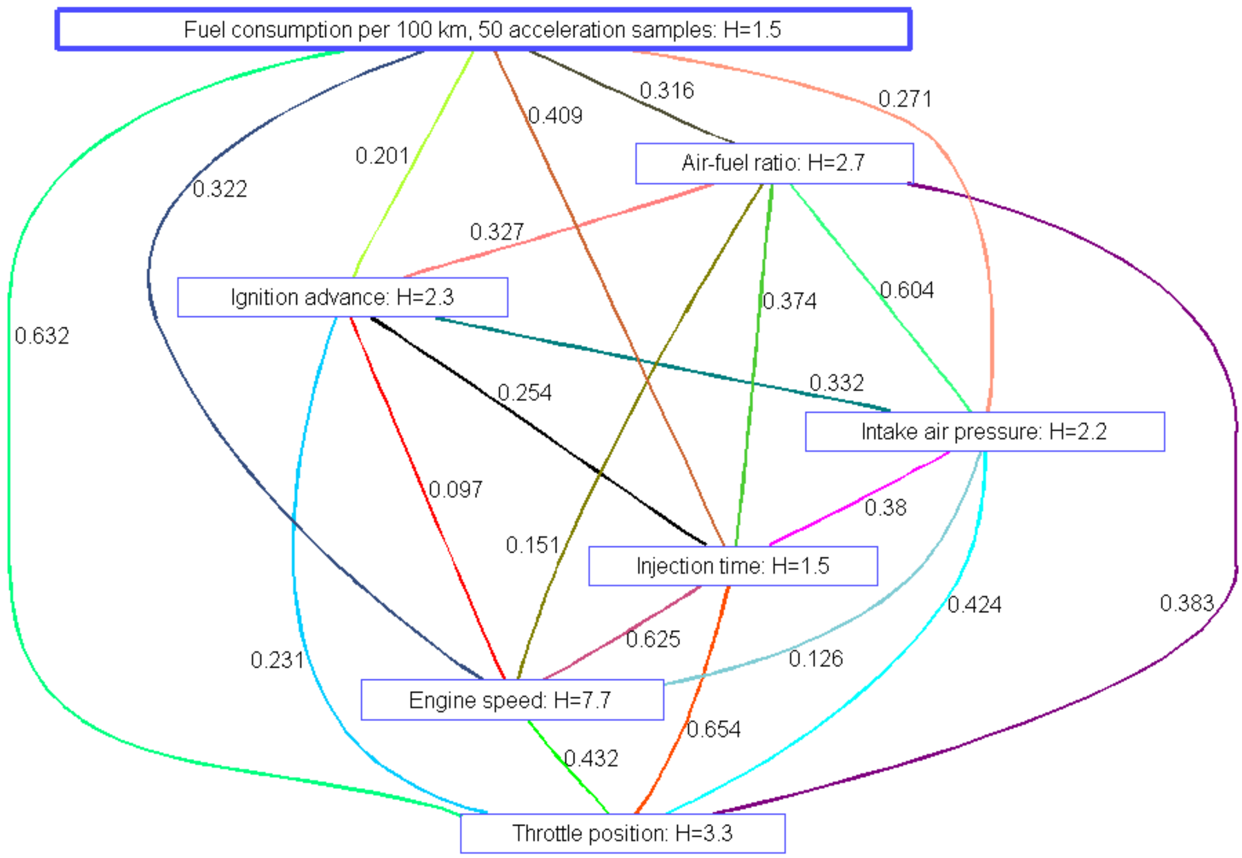

Fig. 4

V. Sensitivity Analysis

Sensitivity expresses a parameter's property to change its value under the influence of the factorial parameter [1]. If there is a single factorial parameter than the simple sensitivity is targeted, otherwise the multiple sensitivity is analyzed; in the first case, local sensitivity is defined (the classic one which calls on sensitivity function), and in the second case global sensitivity is addressed, which relies on variance and has Sobol index as its quantitative measurement [3]. In the second case, the Sobol index (marked here with S) represents the divergence afferent to the targeted parameter and the total divergence of the deduced parameter; thus we have the following relation:

$$\sum_{i} S_i + \sum_{i}\sum_{j>i} S_{ij} + \sum_{i}\sum_{j>i}\sum_{k>j} S_{ijk} + \ldots = 1 \qquad (7)$$

Where for the influencing parameter *I* there is the Sobol index *S* of first degree (or the main Sobol index), for the interactions between *i* and *j* parameters we have the Sobol index S_{ij} of second degree etc. As we can see, global sensitivity takes into consideration the interactions between the targeted parameters, as information theory does.

For example, figure 5 presents the first degree Sobol index for vehicle speed and for vehicle acceleration. As we can see from the upper graphs, in the case of the accelerated test runs, vehicle speed is most sensitive when the throttle's position is modified (S=0.76), and in the case of non-accelerated test-runs is most sensitive to engine speed (S=0.634), aspect which is confirmed by the variance analysis from figure 2.

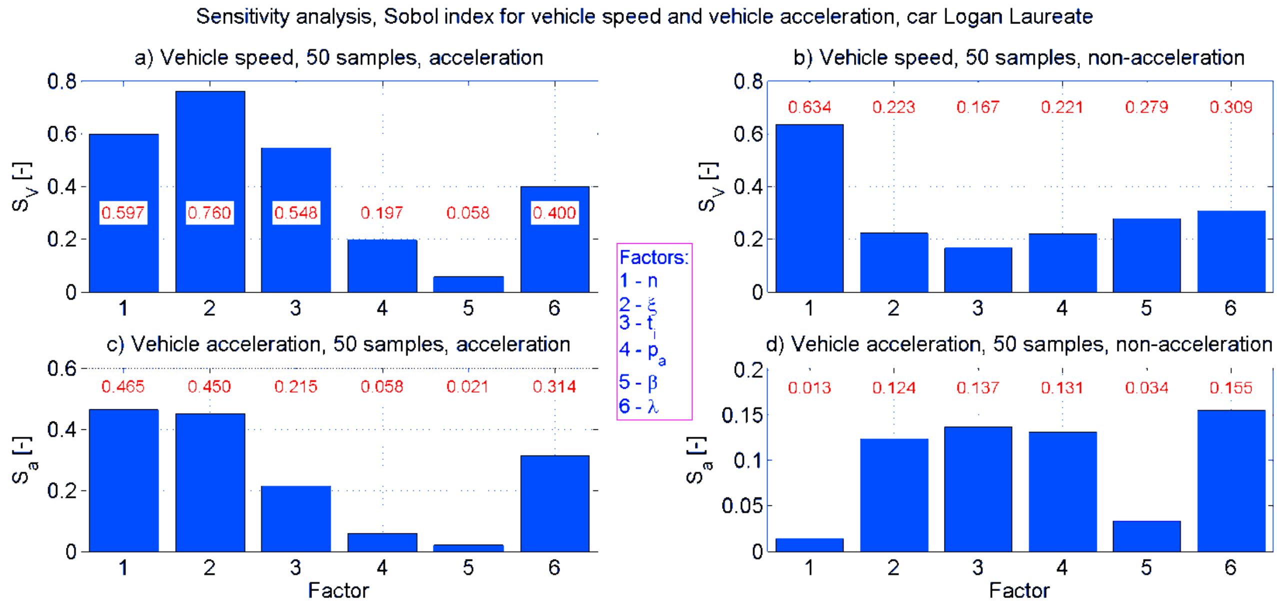

Fig. 5

VI. Summary

We can conclude that the study of various parameters onto the vehicle's dynamic behavior needs to take into consideration the interactions between factors, as well as the fact that the factorial parameters vary simultaneously throughout vehicle movement, these two being the main differences compared to classical approach described in technical literature.

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Global Journal of Researches in Engineering: B
Automotive Engineering
Volume 14 Issue 3 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Linear Damping Seat to Reduce Whiplash Injury in Rear-end Collision

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Abstract- Neck injuries caused by rear end collisions have become a major problem in traffic safety over the last two decades. This situation calls for more research in the field. One area of interest is a damping seat slide to reduce neck injury. To reduce neck injury (Whiplash), based upon new biomechanical research, the motion between head and torso should be reduced. In case of a rear end impact new seat will slide backwards during the impact which allows the motion to damp. Working Model software was used first to simulate and analyse the behaviour of the new system, also a test rig was developed for experimental purposes. The results show occupant protection increases with the new damping seat slide by reducing the NIC 35%.

Keywords: neck injuries; rear collisions; whiplash; damping seat; nic.

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LINEARDAMPINGSEATTOREDUCEWHIPLASHINJURYINREARENDCOLLISION

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Linear Damping Seat to Reduce Whiplash Injury in Rear-end Collision

M. Alardhi [α], K. Alkhulaifi [σ], J. Alrajhi [ρ] & A. Abed. [Ѡ]

Abstract- Neck injuries caused by rear end collisions have become a major problem in traffic safety over the last two decades. This situation calls for more research in the field. One area of interest is a damping seat slide to reduce neck injury. To reduce neck injury (Whiplash), based upon new biomechanical research, the motion between head and torso should be reduced. In case of a rear end impact new seat will slide backwards during the impact which allows the motion to damp. Working Model software was used first to simulate and analyse the behaviour of the new system, also a test rig was developed for experimental purposes. The results show occupant protection increases with the new damping seat slide by reducing the NIC 35%.

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I. Introduction

Rear-end car collision typically occur in traffic situation with dense traffic and relatively small distances between vehicles in the small lane. Rear-end collisions often result in neck injuries to the occupants of the struck car. During the collision the vehicle is subjected to a forceful forward acceleration and the car occupants are pushed forward by the seat-backs. The head lags behind due to its inertia forcing the neck into a swift extension (rearward binding) motion. This head motion continues until the neck reaches the end of its motion range or, hits a head restraint or some other structure behind the head. From this point on, the head moves forward and stops in a somewhat flexed (forward bent) neck posture. This type of swift injurious extension-flexion motion of the neck [1] and is commonly called "Whiplash motion".

Neck injuries in rear-end collisions mostly occur at very low impact velocities, typically less than 20 Km/h [2,3] and are mostly classified as minor injury (AIS 1) on the abbreviated injury scale [4,5,6] since the scale classifies injuries according to fatality risk. [7]Suggested that the elastic rebound of the seat back could be an aggravating factor for the whiplash extension motion. The rebound of the seat back can push the torso forward relative to the vehicle at an early stage of the whiplash extension motion when the head begins rotating rearward. This in turn increases the relative linear and angular velocity of the head relative to the upper torso at the same time as it delays contact between the head and head-restraint, thus causing a larger maximum extension angle. Subsequent studies support this theory [8, 9, 10, 11] If the seat back of the front seat collapse or yields plastically during a rear-end collision, the elastic seat back rebound is likely to be reduced.

To date, the underlying injury mechanism has not yet been established. Several hypotheses have been suggested by various researchers, but are not conclusive. It seams to be generally agreed upon the fact that such injury is related to sudden movement of the head-torso complex [12].

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II. Seat Design

Several seat systems are presented to prevent whiplash injury. Volvo presented the WHIPS seat [13] which is equipped with a recliner that allows controlled backward movement of the backrest during rear-end impact. The motion is performed in two steps: a translational rearwards movement of the backrest is followed by a rotational motion reclining the backrest. Another system, called WipGARD[14], also enables the backrest to perform a translation followed by a rotation. Both the WHIPS and the WipGARD require a critical load to activate the system. The Saab active head restraint (SAHR) system [15], for instance, consists of an active head restraint that automatically moves up and closer to the occupant's head in rear-end impacts. Thus the distance between the head restraint and the head is reduced. The third system is Cervical Spine Distortion injuries (CSD), and the functional principle of the CSD system is based on a defined energy absorption in the backrest. This principle has been employed successfully for a number of years. In standard series seats, the deformation element is located in the recliner. During rear impact, a parallel backwards movement of the seat back begins at a point of critical load, which motion is then transformed into rotation [16]. The backwards movement is limited so that the seat back will offer sufficient protection in a high-speed rear impact.

III. Linear Damping Seat

A Linear Damping Seat (LDS) to reduce or prevent neck injury is presented in this research. The concept, though the mechanism of whiplash injuries is not completely understood, a decrease in neck motion is thought to lessen whiplash injuries. Expressing the above ideas visually, figure 1. shows the concept for reducing the likelihood of whiplash injuries or lessening the severity. Also this study was evaluate the properties of a seat independently of the corresponding car structure. The new linear damping seat (LDS) designed to prevent or reduce whiplash injury was developed. The uniqueness of this design is that the arrangement contains a seat which will move in a controlled manner against the direction of movement during a change in velocity, and that the seat is provided with guidance devices which are intended to give the seat and the person sitting in it a linear movement against the direction of movement.

The LDS is constructed by modifying the seat base connection joints with the trolley (car floor) as shown in figure (1). The new connection contains tracks and rollers which allow a translational motion of the seat with respect to the trolley while the spring/damper damps this motion. In this research, the damping mechanism was active all the time, but it could be attached to a trigger system or acceleration sensor to active the LDS in the rear impact event. In the LDS tests, the spring force and damping coefficient were varied to analyse the effect of these parameters on the head and neck motion. During the impact the occupant moved backward opposed to the car direction and applied a force on the seat- back; this force will force the seat to move backward and the damping system should control the movement. This motion reduces the torso acceleration and decreases the relative velocity between the upper torso and the head which both lessen the whiplash injury.

One practical disadvantage of the LDS was that when the seat moves backward there is a chance that it will crash into the knees of rear-seat occupants or there may be some other limit. Therefore this research has sought to resolve this issue and to have better protection system for all the car occupants. The result of the advanced research was the Drop Damping Seat.

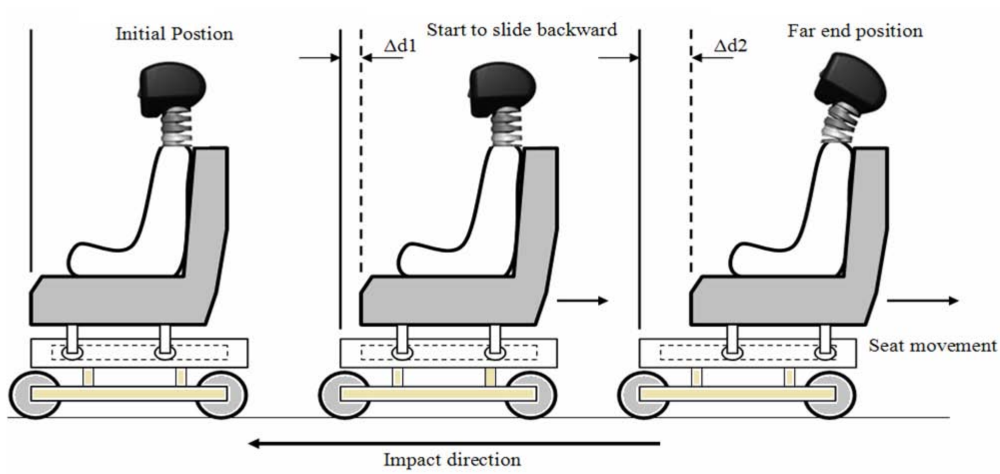

Figure 1 : Linear damping seat during rear-ends impact

IV. Experiment Details

The Working Model dynamic simulation program was used to study the effect of stander seatback compared with Linear Damping seat during the rear-end impact. To analyze whether the new linear damping seat offers the possibility of preventing neck injuries, sled test were performed. The sled test rig (figure 2) was design and developed to validate the simulation model and to be flexible for different verity of rear-end impact test such as head restraint position or seatback stiffness.

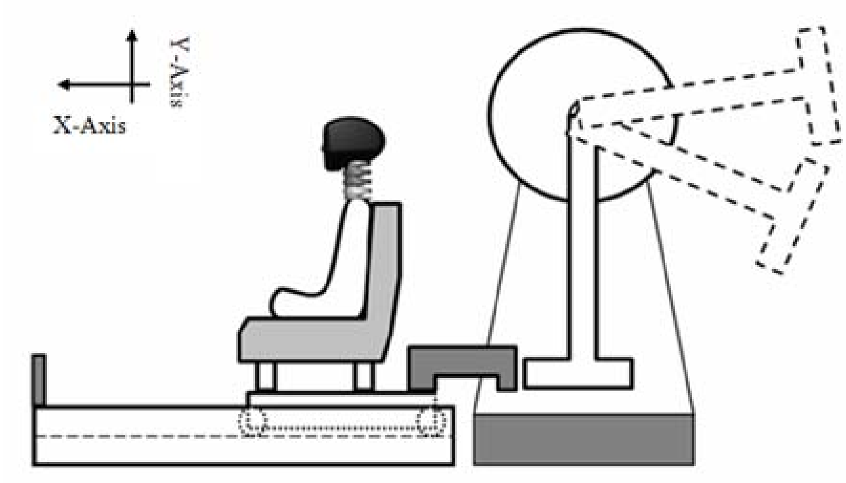

Figure 2 : Sled pendulum facilities used to simulate rear end impact loading to head and neck complex

Table 1 : Test conditions projected for the sled test

Parts	Minimum	Maximum	Notes
Impactor mass	20 Kg	80Kg	
Impactor speed	14 Km/h (3.8 m/s)	18 Km/h (5m/s)	Two position marked for mass of 22 Kg
Head mass	4.5 Kg	4.5 Kg	Standard ADR
Neck mass	1.5 Kg	1.5 Kg	
Torso mass	10 Kg	10 Kg	
Base mass	4 Kg	5 Kg	With –out linkages
Total Trolley mass	20 Kg	25 Kg	

V. Experimental Results

The reference seat (RS) is a production seat without head restraint. Also, the reference seat term was used to describe the head and neck complex fixed on the seat base directly with no seat (as described in chapter three). Rear impact sled tests are obtained for the both reference seat and reference seat with head-neck complex (Hybrid neck III). The test results show head acceleration with time for different collision conditions.

Experiment results in figure (3) show that head acceleration peak value for LDS decreases by approximately 28 % as compared with RS at 14km/h speed and 4g acceleration. As impact speed increased head acceleration increased as shown in figure (4) and (5).

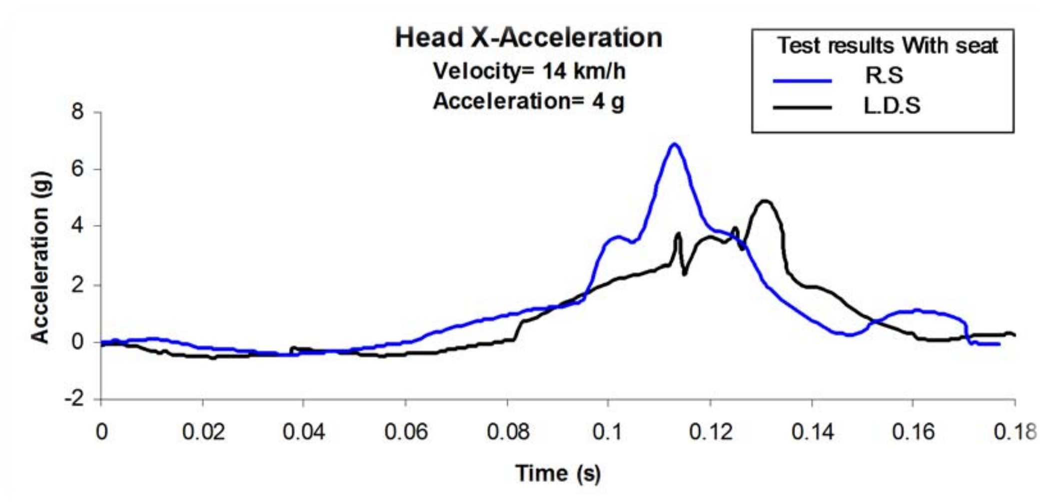

Figure 3 : Test results comparison between RS and LDS with seat at 14km/h-4 g

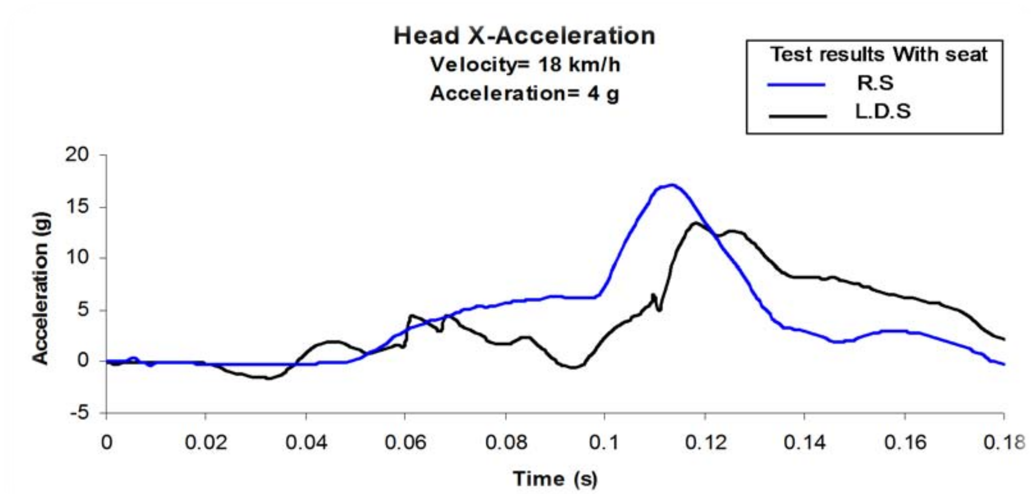

Figure 4 : Test results comparison between RS and LDS with seat at 18km/h-4 g

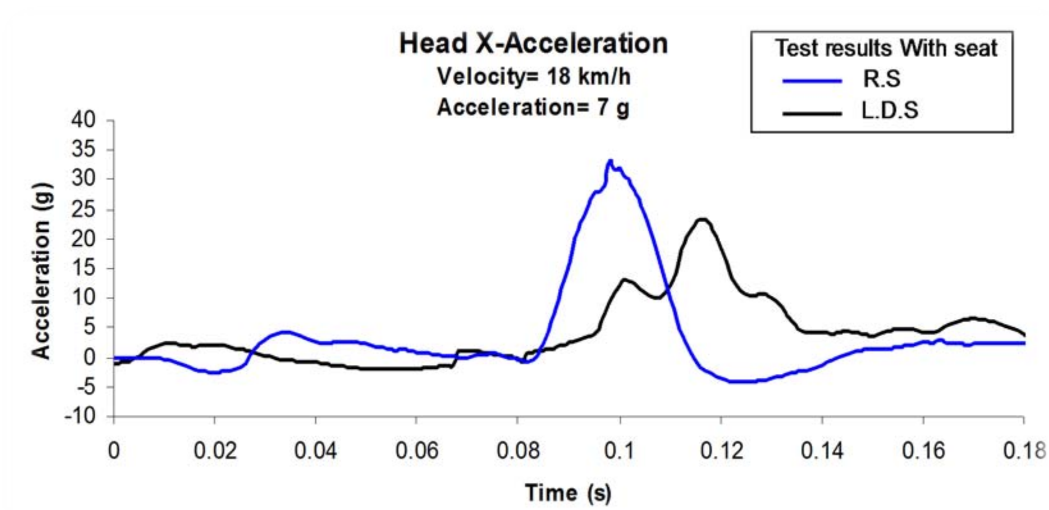

Figure 5 : Test results comparison between RS and LDS with seat at 18km/h-7 g

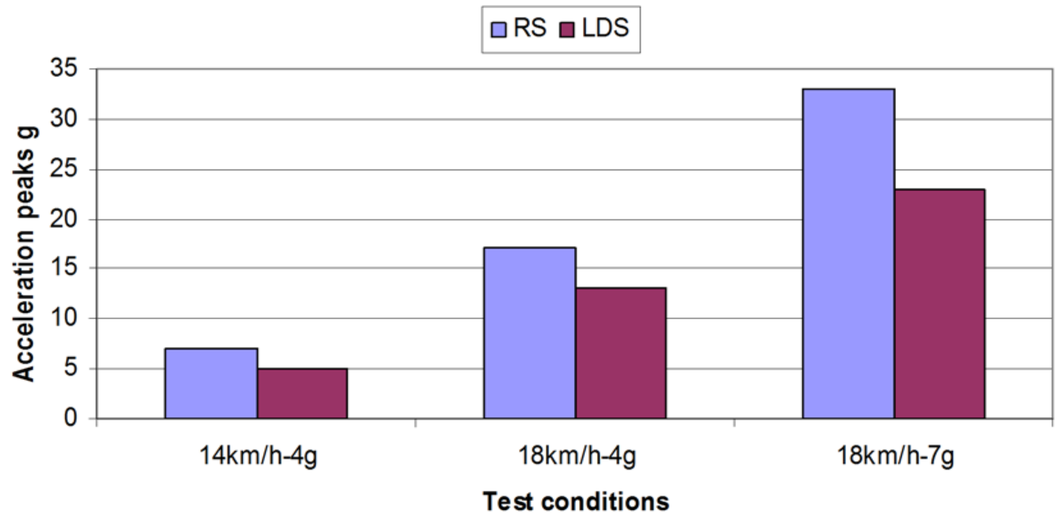

Figure 6 : Sled test head acceleration peaks results comparison between LDS and RS (with seat)

VI. Conclusions

The new Linear Damping Seat design for reduction in whiplash injuries, allows less motion between head and torso as shown in the experimental results (trail sled tests), linear damper shows lessen the movement of the neck (spring) extension.

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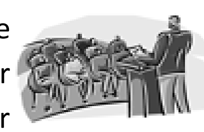

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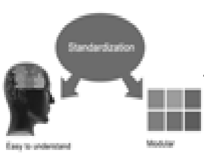

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The FARSE member can apply for grading and certification of standards of their educational and Institutional Degrees to Open Association of Research, Society U.S.A. Once you are designated as FARSE, you may send us a scanned copy of all of your credentials. OARS will verify, grade and certify them. This will be based on your academic records, quality of research papers published by you, and some more criteria. After certification of all your credentials by OARS, they will be published on your Fellow Profile link on website https://associationofresearch.org which will be helpful to upgrade the dignity.

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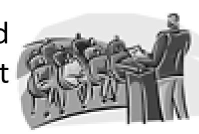
The IFOARS institution is entitled to form a Board comprised of one Chairperson and three to five board members preferably from different streams. The Board will be recognized as “Institutional Board of Open Association of Research Society”-(IBOARS).

The Institute will be entitled to following benefits:

The IBOARS can initially review research papers of their institute and recommend them to publish with respective journal of Global Journals. It can also review the papers of other institutions after obtaining our consent. The second review will be done by peer reviewer of Global Journals Incorporation (USA)
The Board is at liberty to appoint a peer reviewer with the approval of chairperson after consulting us.
The author fees of such paper may be waived off up to 40%.



The Global Journals Incorporation (USA) at its discretion can also refer double blind peer reviewed paper at their end to the board for the verification and to get recommendation for final stage of acceptance of publication.

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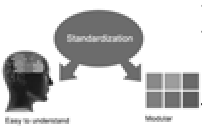

After nomination of your institution as "Institutional Fellow" and constantly functioning successfully for one year, we can consider giving recognition to your institute to function as Regional/Zonal office on our behalf.
The board can also take up the additional allied activities for betterment after our consultation.

The following entitlements are applicable to individual Fellows:

Open Association of Research Society, U.S.A (OARS) By-laws states that an individual Fellow may use the designations as applicable, or the corresponding initials. The Credentials of individual Fellow and Associate designations signify that the individual has gained knowledge of the fundamental concepts. One is magnanimous and proficient in an expertise course covering the professional code of conduct, and follows recognized standards of practice.

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Note :

"

- In future, if the board feels the necessity to change any board member, the same can be done with the consent of the chairperson along with anyone board member without our approval.
- In case, the chairperson needs to be replaced then consent of 2/3rd board members are required and they are also required to jointly pass the resolution copy of which should be sent to us. In such case, it will be compulsory to obtain our approval before replacement.
- In case of "Difference of Opinion [if any]" among the Board members, our decision will be final and binding to everyone.

"

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The paper should be in proper format. The format can be downloaded from first page of 'Author Guideline' Menu. The Author is expected to follow the general rules as mentioned in this menu. The paper should be written in MS-Word Format (*.DOC,*.DOCX).

The Author can submit the paper either online or offline. The authors should prefer online submission.Online Submission: There are three ways to submit your paper:

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(II) Choose corresponding Journal.

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1. General,

2. Ethical Guidelines,

3. Submission of Manuscripts,

4. Manuscript's Category,

5. Structure and Format of Manuscript,

6. After Acceptance.

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Complete support for both authors and co-author is provided.

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The recommended size of original research paper is less than seven thousand words, review papers fewer than seven thousands words also.Preparation of research paper or how to write research paper, are major hurdle, while writing manuscript. The research articles and research letters should be fewer than three thousand words, the structure original research paper; sometime review paper should be as follows:

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(a)Title should be relevant and commensurate with the theme of the paper.

(b) A brief Summary, "Abstract" (less than 150 words) containing the major results and conclusions.

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(e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition; sources of information must be given and numerical methods must be specified by reference, unless non-standard.

(f) Results should be presented concisely, by well-designed tables and/or figures; the same data may not be used in both; suitable statistical data should be given. All data must be obtained with attention to numerical detail in the planning stage. As reproduced design has been recognized to be important to experiments for a considerable time, the Editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned un-refereed;

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(i) References in the proper form.

Authors should very cautiously consider the preparation of papers to ensure that they communicate efficiently. Papers are much more likely to be accepted, if they are cautiously designed and laid out, contain few or no errors, are summarizing, and be conventional to the approach and instructions. They will in addition, be published with much less delays than those that require much technical and editorial correction.

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Many researchers searching for information online will use search engines such as Google, Yahoo or similar. By optimizing your paper for search engines, you will amplify the chance of someone finding it. This in turn will make it more likely to be viewed and/or cited in a further work. Global Journals Inc. (US) have compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

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One must be persistent and creative in using keywords. An effective keyword search requires a strategy and planning a list of possible keywords and phrases to try.

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- One should avoid outdated words.

Keywords are the key that opens a door to research work sources. Keyword searching is an art in which researcher's skills are bound to improve with experience and time.

Numerical Methods: Numerical methods used should be clear and, where appropriate, supported by references.

Acknowledgements: Please make these as concise as possible.

References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

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6. Use of computer is recommended: As you are doing research in the field of Computer Science, then this point is quite obvious.

7. Use right software: Always use good quality software packages. If you are not capable to judge good software then you can lose quality of your paper unknowingly. There are various software programs available to help you, which you can get through Internet.

8. Use the Internet for help: An excellent start for your paper can be by using the Google. It is an excellent search engine, where you can have your doubts resolved. You may also read some answers for the frequent question how to write my research paper or find model research paper. From the internet library you can download books. If you have all required books make important reading selecting and analyzing the specified information. Then put together research paper sketch out.

9. Use and get big pictures: Always use encyclopedias, Wikipedia to get pictures so that you can go into the depth.

10. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right! It is a good habit, which helps to not to lose your continuity. You should always use bookmarks while searching on Internet also, which will make your search easier.

11. Revise what you wrote: When you write anything, always read it, summarize it and then finalize it.

12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

13. Have backups: When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

14. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

15. Use of direct quotes: When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

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- The **major constraint** is that you must independently make all content, tables, graphs, and facts that are offered in the paper. You must write each part of the paper wholly on your own. The Peer-reviewers need to identify your own perceptive of the concepts in your own terms. NEVER extract straight from any foundation, and never rephrase someone else's analysis.
- Do not give permission to anyone else to "PROOFREAD" your manuscript.
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- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

Index

A

C

P

V

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ISSN 9755861