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Investigation of tractor driver seat comfort level using passive suspension system

[#1]A. S. Thorat, [#2]V. M. Mhaske

[1]thoratajit95@gmail.com
[2]vilas_mhaske@yahoo.com

[#1234] Amrutvahinicollege of engineering, Sangamner, SavitribaiPhule Pune University.

ABSTRACT

An agricultural tractor seat with passive suspension system gives a number of advantages when compared with currently available seat designs. Analysis on the vibration of tractor seat suspension system by using the different types of the suspension system is carried out for the different types of operation and analyze the suspension system separately to find out the reduction in the vibration level and Root mean Square acceleration (RMS) of the seat. These advantages are discussed within the context. It is known that a soft suspension system with low natural frequency gives more comfort than a stiffer one and also the operator requires more space. We knew that conventional dampers is a compromise between limiting seat motion around the natural frequency and have good attenuation of higher-frequency inputs. The experimental results show that the non-linear seat reduces the vibration transmitted to the tractor driver compared to a linear mechanical seat. The combination of non-linear seat suspension system and the linear seat suspension system showed a possible reduction in RMS acceleration compared to a linear seat system. The improved suspension system would improve mainly the shock control of the seated driver and in this way enhance his comfort as well as his health. At the same time, it would increase the durability of the seat suspension system. This design has another advantage that it has low cost and robust.

Keywords— **Acceleration,Damper,Frequency, Seat design, Damper, Passive suspension**.

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I INTRODUCTION

Increased vehicle speed and capacity, induced by higher work costs, create a lot of vibration problems, reducing the vehicle lifetime, working precision and driver's comfort. Suspension systems should be developed in such way that they minimize the transmission of harmful vibrations and shocks as much as possible. The low-frequency range (2–8 Hz) is crucial for good driver comfort and health, and work efficiency. The suspension system of suspension seats is most likely to hit the end-stop buffers when excited at its resonance frequency, and so performance at this frequency will influence it send-stop impact performance. In a field survey of the whole-body vibration experienced by tractor drivers, Stiles et al. found that 45% of seats increased the acceleration levels experienced by the driver. Much of the increase was said to be due to end-stop impacts. It has been suggested that for some drivers the end-stop impacts can be so severe that they would rather weld the suspension system to avoid end-stop impacts.

A. Tractor seats

Unlike passenger vehicles, the suspension systems of many off-road vehicles, such as tractors, consist only of the tire and the seat, as there is no primary suspension system connecting the vehicle wheel to the chassis. Pre-1960s tractor operators sat in a metal bucket and relied upon a cushion for comfort. Modern tractors incorporate a variety of suspended seat designs including compact mechanical seats for small tractors and self leveling seats in larger tractors. The main design criterion for these is minimization of the root-mean square(RMS) acceleration level of the driver in accordance with International Organization for Standardization (1997)(ISO 2631:1997) comfort levels. The suspension system on most commercially available tractor seats comprises a mechanical spring and damper. This type of system responds passively to vibrations transmitted to the driver from the terrain over which the tractor is driven. The performance of passive commercial tractor seats has been widely researched and it was found that drivers were often subjected to vertical vibration levels that exceed the ISO exposure limits. The latter found considerable performance differences between eleven commercial seats and the inference is that some commercial passive seat designs are far from optimal. Note that studies into tractor seats tend to focus on vibrations in the vertical direction. However, research into fore-and-aft suspension systems for tractor seats were undertaken and consequently, some commercial seats now offer the option of fore-and -aft isolators.

B. Vehicle Primary Suspensions

Primary suspension is the term used to designate those suspension components connecting the axle and wheel assemblies of a vehicle to the frame of the vehicle. This is in contrast to the suspension components connecting the frame and body of the vehicle, or those components located directly at the vehicle's seat, commonly called the secondary suspension. There are two basic types of elements in conventional suspension systems. These elements are springs and dampers. The role of the spring in a vehicle's suspension system is to support the static weight of the vehicle. The role of the damper is to dissipate vibrational energy and control the input from the road that is transmitted to the vehicle. The basic function and form of a suspension is the same regardless of the type of vehicle or suspension. Primary suspensions will be divided into passive, active adjustable and semi active systems.

C. Spring rates

Passive vertical seat suspension systems incorporate either a mechanical spring or a self-leveling pneumatic system. Both have a limit to the reduction in vibration isolation that they can achieve. Practical constraints due to the allowable suspension working space limit the extent to which vibrations transmitted to the driver can be reduced. Typical commercial tractor seats have a working space of 740 mm. While the use of low stiffness springs is desirable, (they filter a wider range of input vibrations than high stiffness springs) the accompanying increase in length restricts their use. KAB Seating (a manufacturer of tractor seats) gave a typical stiffness value for a mechanical commercial seat as approximately 5.5kN/m.

D. Damping level

The level and type of seat damping must be considered. This comprises two elements; friction and viscous damping. It is claimed that some friction in a seat improves ride comfort but seat manufacturer Grammar, claims improved seat performance through the inclusion of bearings in the mechanism resulting in low friction. In this work, the effect of low friction is investigated. An effective damping system in an off-road seat should ideally be able to attenuate the full range of input frequencies expected from typical working conditions.

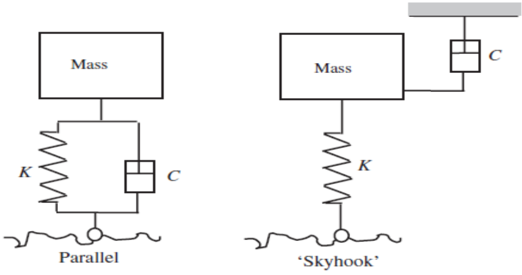

Fig.1. Parallel & Skyhook damping

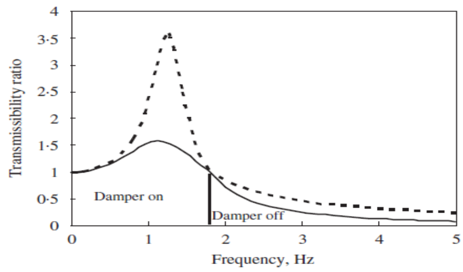

Fig 2. On–off damping scheme:best configuration, damper switched on for low frequency, off for high, worst configuration damper switched off for low frequency, on for high

The seat dynamic behavior is influenced by a number of parameters. The grade of influence, for a certain set of parameters is determined by the excitation magnitude. For the spring component part, not only the stiffness will play a role but also the linkage friction. For the damper component part, there exists non-frictional damping which provides the required damping under ideal circumstances, and there exists Coulomb damping. The friction through Coulomb damping is generated by the oil seals and the rod against the wall in the cylinder. The non-frictional damping is generated by the oil flow through the damping holes (viscous damping). At high frequencies, the displacements are so small and the direction of the force changes so fast that the oil has no time to pass through the cylinder holes which provide the damping effect. Because the oil is not compressible, the damper will react as a rigid structure through which vibrations can be transmitted to the driver. Although the damping c of an oil damper is called constant, at higher frequencies it tends to infinity. Still used a linearized suspension seat model, and found that Coulomb friction was more influential than viscous damping and that the coefficients of both should be reduced to improve the ride performance.

E. Passive Suspensions

A passive suspension system is one in which the characteristics of the components (springs and dampers) are fixed. These characteristics are determined by the designer of the suspension, according to the design goals and the intended application. Passive suspension design is a compromise between vehicle handling and ride comfort, as shown in Figure 1.3. A heavily damped suspension will yield good vehicle handling, but also transfers much of the road input to the vehicle body. When the vehicle is traveling at low speed on a rough road or at high speed in a straight line, this will be perceived as a harsh ride. The vehicle operators may find the harsh ride objectionable, or it may damage cargo. A lightly damped suspension will yield a more comfortable ride, but can significantly reduce the stability of the vehicle in turns, lane change maneuvers, or in negotiating an exit ramp. Good design of a passive suspension can to some extent optimize ride and stability, but cannot eliminate this compromise.

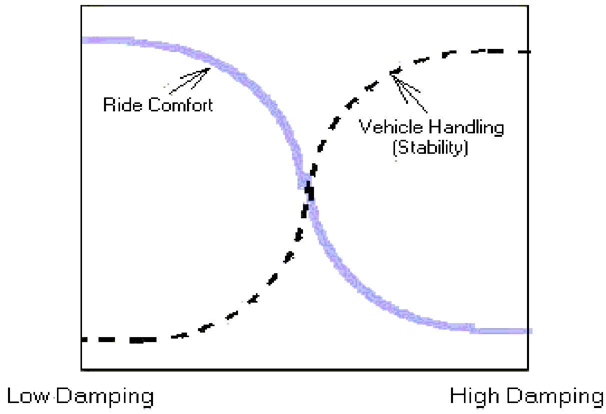

Fig 3. Damping Compromise for Passive Dampers

. *Lowering spring rate*

A linear extension spring positioned as shown in Fig.1.5 has a non-linear effective spring rate with respect to the vertical vibrations. This arrangement gives a softening spring rate with respect to the vertical force, see Fig 1.6 and 1.7. As the seat mechanism compresses, the spring rate decreases. When in static equilibrium, the seat has a low vertical stiffness at that point. For a working space of approximately 740mm a seat stiffness of about 4kN/m can be achieved at the equilibrium point. Thenatural frequency of the seat at the equilibrium point is approximately 1.1Hz. This compares with 1.3Hz for a seat with a stiffness of 5.5kN/m and 85.5 kg mass. Thus, an effectively lower natural frequency can be achieved by using non-linear elements. The stiffness increases as the seat extends and decreases as the seat compresses, until it hits the end stops. Note that the positioning of the end stops is critical in this arrangement, because if the seat passes through a critical point it would collapse. In order to take maximum advantage of the low stiffness characteristics of the system, the end stops are mounted just before the collapse point.

G. Active damping-skyhook concept

To overcome the passive suspension compromise, active and semi-active suspension systems have been developed. Since the 1970s there has been extensive research into semi-active damping systems with ‘skyhook’ algorithms incorporating variable, multi-stage or on–off damping. The ‘skyhook’ principle is shown in Fig1.1. The damper which is normally in parallel with the spring is positioned such that the damper force is a function of the absolute velocity of the mass, not the relative velocity as in a conventional parallel system. Karnopp found the ‘skyhook’ system to be a far better vibration isolation system than the parallel system. To achieve a ‘skyhook’ system, a damper with a variable rate replaces the passive damper in a parallel system. The variable rate damper applies the same force to the mass as a ‘skyhook’ damper, except when energy needs to be added rather than dissipated, in which case the damping tends to zero. This is achieved by feeding back the absolute velocity of the mass to a micro controller where the required ‘skyhook’ force is calculated and applied to the mass. These systems have the potential for low cost manufacture and require no hydraulic or pneumatic power systems. Laboratory testing of the ‘skyhook’ system led to practical methods for its implementation, relating to feedback signals and switching times. One of the simplest systems is the on-off ‘skyhook’ damper as it can be achieved with solenoid valves and simple algorithm.

II. LITERATURE SURVEY

1.M. Duke, G. Goss had studied an agricultural tractor seat with non-linear stiffness and on–off damper offers a number of advantages when compared with traditional and currently, commercially available designs. These advantages are discussed within the context of the constraints imposed by the restricted seat travel space. It is known that a soft suspension system with low natural frequency offers more comfort than a stiffer one, and also, that the former requires more travel space. It is also known that conventional dampers tend to be a compromise between limiting seat motion around the natural frequency and having good attenuation of higher-frequency inputs. They have been observed that this work shows that having the damper switched on for low-frequency ‘harsh’ bumps and off for higher frequency inputs reduces seat accelerations while preventing end stop impacts. Experiments on the combination of non-linear stiffness and the relative displacement switching of the damper showed a possible 40% reduction in RMS acceleration compared to a linear seat, passively damped seat is obtainable, with no end stop impacts.[6]

2.A. Marsili, L. Ragni, G. Santoro, P. Servadio, G. Vassalinihad studied the vibration transmitted through the seat of a four-wheel drive tractor, developing 92 kW at the p.t.o., and equipped with front suspension axle and shock absorber for the implement, were measured and analysed according to the ISO standard. Several tests were carried out in different conditions considering type of operation (transfer with and without mounted implement, ploughing, harrowing); type of track (conglomerate bituminous track, macadam dirt track, country lane); connected and disconnected suspension and/or shock absorber and a range of forward speeds. In the transfer test on track, the vehicle suspension caused an average acceleration reduction of about 15%, and it could reach 30%. The shock absorber displayed a variable behavior depending on the test condition; it could cause both attenuation and amplification, although the combination with the suspension often involves a high average reduction in acceleration (24%). In the soil tillage tests, the suspension could cause a substantial reduction in acceleration (up to 36%), but only in some conditions. [1]

3.T.P. Gunstona, J. Rebelleb, M.J. Griffina**,**had compares two alternative methods of modelling the non-linear dynamic behavior of two suspension seats whose dynamic characteristics were measured in the laboratory. A 'lumped parameter model', which represented the dynamic responses of individual seat components, was compared with a global 'Bouc–Wen model' having a non-linear degree-of-freedom. Predictions of the vibration dose value for a load placed on the seats were compared with laboratory measurements. They have been observed that both models were limited by deficiencies in the simulation of top end-stop impacts after the load lifted from the seat surface. The lumped parameter model appears best suited to the development of the overall design of a suspension seat. The Bouc–Wen model can provide a useful simulation of an existing seat and assist the optimization of an individual component in the seat, without measuring the dynamic properties of components in the seat except those of the component being optimized.[26]

4.P. Servadioa, A. Marsilia, N.P. Belfioreb had study, vibrations transmitted from the ground to the driver's seat have been analysed using methods that meet (ISO) standards using a four-wheel-drive tractor, equipped with a front suspension axle and a suspended cab, operating at 11.1 and 13.9m/s. The test runs simulating the transportation of agricultural implements were conducted on a rectilinear plane track of aconglomerate bituminous closed track. Two different tire types, coded 'A' and 'B', were tested at different forward speeds. They have been observe that the values for the root-mean-square (RMS) accelerations for each measurement axis and the corresponding vector sum measured on the tractor rear axle were not proportional to the forward speeds 11.1 and 13.9m/s for tire A. For tire B, the vector sum decreased by 18%. No significant difference was found in the acceleration values on the driver's seat.[15]

5.I. Hostens, K. Deprez, H. Ramon had studied the Different suspension systems of the type 'full travel' used in agricultural machinery seats over the last 20 years are evaluated. The effects of the type of spring and damper are discussed through theoretical analysis and experimental tests. They have been observed that the use of air damping further eliminates the friction damping. By adding an extra air volume, which can be placed next to the seat or integrated in the cabin, a lower resonance frequency is possible without creating problems in the placement of the air spring and packaging. Combining the three features (air spring, extra air volume, and air damper (throttle valve)) creates a suspension system that provides the best vibration attenuation, when considering passive suspension systems, for agricultural machinery or other vehicles with similar vibration inputs.[23]

6.C.M. Lee, A.H. Bogatchenkov, V.N. Goverdovskiy, Y.V. Shynkarenko,had studied the use of the ''negative'' stiffness' phenomenon is a unique concept to minimize stiffness of a vibration isolating device and improve the quality so that protected object becomes motionless in inertial space. Though control strategy for the device with minimum stiffness sufficiently differs from the approaches based on attenuation of extraneous resonant responses. An approach for positioning such a device is proposed focusing on motion stability in large. The paper proposes an approach of position control for seat suspensions with a focus on the vibration isolation of vehicle drivers in the infra-frequency range within which the standard controlled devices are ineffective in normal gravitation. The approach is based on stiffness minimization by coupling a mechanism containing the spring with adjustable ''negative'' stiffness in the large and organization of variable structure of air-damping control. A control algorithm corresponding to this approach can be used with a multi-channel pneumatic control system designed with simple commercial off-the-shelf pneumatic components, if high precise positioning is not required. [2]

7.C.M. Lee, V.N. Goverdovskiy, A.I. Temnikovhad present an approach, based on the consistent theory of thin shells, for designing compact springs in terms of their compatibility with the room available for packaging the vehicle suspensions and simultaneous extension of the height control region where fundamental frequencies are kept minimal. The minimization, in turn, leads to improving of vibration isolation up to an absolute immobility of an object under infra-frequency (extremely low) vibrations, which are the most harmful and dangerous to a vehicle driver and some other objects must to be protected. In the approach, a generic model of a simple springing element with ''negative'' stiffness in the large is proposed. A simple iterative procedure is formulated to solve the geometrically nonlinear problem of large amplitude post-bucking of springing elements and to represent them in a way that enables an optimal, computable scheme for the design of springs. Validity of the approach is assessed by a comparison of the computation and measurement results. Using the approach, we propose a generic spring module applicable to any vehicle suspension, whether it is a seat suspension, a cab mounting, or a cargotainer platform. [12]

8.M. Silveira, B.R. PontesJ, J.M. Balthazar had studied the behavior of two different types of shock absorbers, symmetrical (linear) and asymmetrical (nonlinear) is compared for use on passenger vehicles. The analyses use different standard road inputs and include variation of the severity parameter, the asymmetry ratio and the velocity of the vehicle. They have been observed that the comparison between the symmetrical and asymmetrical systems under several inputs and with quarter-car and half- car models showed that the asymmetrical system, with nonlinear characteristics, tends to have a smoother and more progressive performance. [24]

9.C.R. Mehta, M. Shyam, Pratap Singh, R.N. Verma had studied the vibration in tractor driving can cause deafness and disorders of the spinal column and stomach. The effect of implements on tractor ride is not well understood in India. The present study was undertaken to quantify ride vibration of a low horse power tractor-implement system. Tractor ride vibration levels have been measured at the person seat interface along three mutually perpendicular axes, longitudinal, lateral and vertical, under different operating conditions. It was observed that the acceleration levels increased as forward speed of travel increased under most of the operating conditions. There was no conclusive difference in measured acceleration levels on a tar-macadam road and a farm road during transport mode. The measured ride vibration levels under different operating conditions were evaluated as per ISO 2631/1 (1985), Geneva, and BS

6841 (1987), London, standards. On the basis of this study, it is concluded that the exposure time for the tractor operator should not exceed 2.5 h during ploughing and harrowing operations.[3]

10.S. Loutridis, Th. Gialamas, I. Gravalos, D. Moshou, D. Katerishad studied the effect of electronic speed adjustment on tractor ride vibration levels is examined. With normal pedal operation the engine rotational speed drops with an increasing load. The electronic regulator provides a constant speed mode of operation independent of the load. Vibration levels were measured under different operating conditions and surfaces. As a first series of tests, the tractor was driven on a conglomerate bituminous track at speeds of 20, 25 and 28 km/h. Vibration was measured upon the surface of the operator seat simultaneously in the x, y and z directions. They have been observed that an investigation on the effects of the electronic speed regulator on whole-body vibration measurements is presented. Vibration levels were recorded on the operator seat in all three reference axes defined in ISO 2631-1 and ISO 5008:2002. Based on the results obtained from the analysis of vibrations measurements, selection of constant speed mode of operation can cause higher r.m.s acceleration values over all three axes during transportation on bituminous track and for speeds ranging from 20 up to 28 km/h. The vector sum weighted acceleration is from 8% up to 9.4% higher when electronic speed adjustment is functioning. The highest differences are noted in front to back acceleration along x axis and are attributed to the fast speed changes made by speed control electronics. On the contrary, the vector sum weighted acceleration for the case of conventional foot pedal operation in field task tests was between 4.3% and 8.6% higher than the case of electronic engine speed control operation. In field tasks the load variation is much more intense than when the tractor is driven on asphalt road. The operator reaction comes with a time lag meaning that the variations in the vehicle speed are great. In this case, the speed control electronic system is able to maintain a much more constant speed resulting in reduced overall vibration levels and therefore automatic speed regulator should be selected .

III. PROBLEM STATEMENT

A. Gaps Identified From the Literature

1] A significant amount of experimental and analytical work has been done on the suspension of tractor seat. The reason is that the vibration of the tractor seat can be reduced to the comfort level of the driver.
2] On the other hand, very little attention has been paid analytically to reducing vibration by using non linear passive suspension system.

B. Problem Statement

From the critical discussion on literature survey and gaps identified from the literature the problem statement for the current project will be, to reduce the vibration of tractor seat by using non linear spring damper passive suspension system and analyse with the current suspension system.

C. Objective of the Project

1] To use the non linear spring damper passive suspension system.
2] To study the effect of the suspension system on seat vibration.
3] To optimize the best results found from the systems.

D.Scope of the Project

The scope of the project is to minimize the vibration of the tractor seat with the help of non linear spring damper suspension system combined with the current suspension system. So that the comfort level of the driver will be increases.

IV. METHODOLOGY AND EXPERIMENTATION

A. Experimental setup

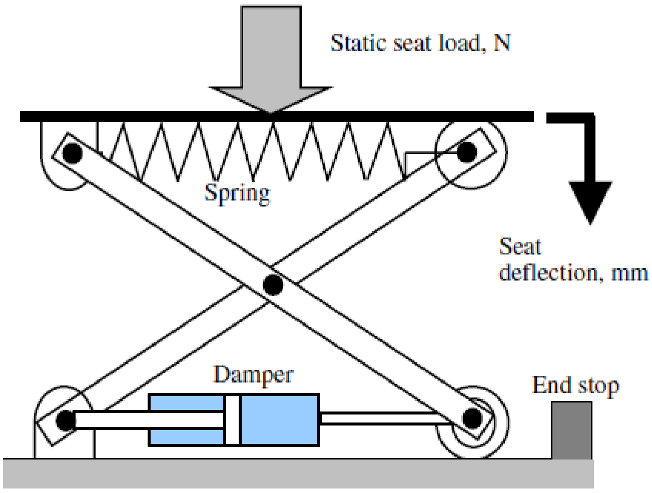

Fig. 5.Non linear seat configuration

The non linear passive seat configuration is shown in fig 4.1. It consists of a spring and damper system. The spring and damper are connected parallel to each other. The spring and damper are connected to each other by using cross bars which is hinged at the center. One end of the spring is hinged to one end of the bar and is fixed to the seat of the tractor, where the other end of the spring is hinged to the one end of the other bar by using the roller. Similarly the damper one end is hinged to one end of the bar which is fixed to the chassis, where other end is hinged to bar using roller. The system consists of an end stop as shown in fig 5.

A linear extension spring positioned as shown in Fig.4.1has a non-linear effective spring rate with respect tothe vertical vibrations.This arrangement gives a softening spring rate withrespect to the vertical force. As the seatmechanism compresses, the spring rate decreases. The stiffness increases as the seat extends and decreases as the seat compresses, until it hits the end stops.

V.EXPECTED OUTCOMES

The experimental results show that the non-linear seat reduces the vibration transmitted to the tractor driver compared to a linear mechanical seat. The combination of non-linear seat suspension system and the linear seat suspension system showed a possible reduction in RMS acceleration compared to a linear seat system. The improved suspension system would improve mainly the shock control of the seated driver and in this way enhance his comfort as well as his health. At the same time, it would increase the durability of the seat suspension system.

VI. ACKNOWLEDGEMENT

Department of Mechanical Engineering, here knowledge is considered as the liable asset and it is proved that the power of mind is like a ray of sun; and when strenuous they illume.

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