Development and Optimization of Vibration Protection Seats (Tempered Springs) for Agricultural Tractor

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Abstract:
Seats have been developed and optimized with an anti-vibration suspension system (Tempered Springs) for agricultural tractor. These seats were examined and determined their static and dynamic physical characteristics. These seats are designed on the basis of ISO standards. An artificial track was constructed to simulate a farm field based on BIS (Bureau of Indian Standard) and to examine vibration the transmissibility of the seats when installed in tractor. The results indicated that the transmissibility from under the seat to on the seat in the vertical direction (Oblique Tempered Spring Q) was approximately 0.22, although little reduction of vibration was observed in the fore-aft direction. The results of these experiments indicate that significant differences exist between the characteristics of tempered springs and non- tempered springs of seat. This suggests that the oblique seats with tempered springs are applicable to the agricultural field.

Considerable effort has been made to establish the optimum design parameters for tractor seats. Further reductions in the level of ride vibrations experienced by tractor seats appear to be necessary and some possible methods of achieving significant improvements have been outlined. These methods have led to the evolution of several seat suspension systems and emphasize the use of the principles of ergonomics in the operator's seat design. In this paper, a review of the work done in this area, particularly with respect to tractor seat, is presented and discussed.

Standardized (ISO) methods of agricultural vehicle WBV measurement require further development to permit quantification of the likely effectiveness of tractor WBV-reducing design features during in-field operation(s).

Key words: Anti-vibration seats, Suspension system, Agricultural tractor, Artificial track, Whole- body vibration (WBV), Tempered Springs.

Introduction:
At present, there is a need for the development of agricultural tractor that enables more comfortable and safe performance of various agricultural tasks. With regard to tractor operations, one of the important points in the design and use of tractors is the invention of comfortable seats that can prevent occupational diseases caused by whole-body vibration. It was found that conventional tractor seats with anti-vibration systems are not suitable for operators, especially in terms of body weight, as such seats are manufactured as per BIS standards. There is tractor with suspension that are seats commercially available in Indian, even larger models of such offer has insufficient vibration protection and smaller one has no seats with such anti-vibration sytems[1-3)].
Both seats used covered foam cushions, steel coil springs, oil dampers and rubber end-stop buffers.
To create seats with a suspension system that offers vibration protection, it was necessary to determine the target specifications of the suspension system. These specifications were established to develop a new suspension system with the following features:
1) The seats should fit the average Indian physique, in particular, the body weight of 45-80 kg instead of the average physique, body weight of which is 65-130 kg.
2) The natural frequency of the seats should be below 2 Hz so as to reduce vibration transmissibility.
3) Weighted acceleration on the seats should be below 2 m/s^2, when an agricultural tractor with the seat is operated on an artificial track at a speed of 10 km/hr.
4) The transmissibility of the vertical vibration from under the seat to on the seat should be below 30%.

Static characteristics, dynamic characteristics of the seat itself and vibration reduction effect of the seats were examined to achieve anti-vibration seats. The static characteristics in the present study are the spring constant, damping coefficient of the seats, and the dynamic characteristics are vibration transmissibility. In addition to these characteristics, vibration reduction effects are required in a working farm field. Objectives of this study were to (1) compare the vertical and oblique seats (2) measure the static and dynamic characteristics of such a system (3) construct a oblique seat with a suspension system(tempered springs), and (4) reduce the effects of vibrations of seat.

Comparison of two Seats:

The preliminary experiment[4] consisted of examining two types of the seats, one with under a suspension and other with rear a suspension. The seat with rear suspension was adopted in this study because it could be save a space above operators' head in a cabin of the machinery so as to construct a smaller cabin due to the design consisting of two steel springs and one damping element. Then, two types of seats with rear suspension, one was a vertical suspension system and the other was an oblique suspension system moves obliquely to maintain stability of foot condition during an operation in the Fig. 1 a, b, c, and d.

The two seats are fitted with springs, which are heated up to recrystalisation temperature, and tempered to increase the spring's stiffness. Compared the two seats with their characteristic values shown in Fig. 5

Fig. 1a

Fig.1b

Fig. 1c

Fig. 1d

Measurement of Static and Dynamic Characteristics of the Seats:

(1) Measurement apparatus

Figure 2 shows a measurement apparatus of the static characteristic that was constructed based on the specification of ISO[5] and BIS standards[6]. A test seat was inserted between the support plate and the load plate. Original adjustment was made depending on a human-body weight so as to make a half length of maximum strokes of suspension. The load was altered with a load supplier. Weight and displacement values for each load were measured using the transducers.

The results were plotted and shown in Figure 3, which shows the relation between the load and displacement of the test seats as a parameter of the weight loading on the test seats according to body weight. The vertical seat was designed using the Spring P, so that the lower limit of body weight was

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about 45 kg and the spring constant was **30 N/mm**. From the results, it was determined that the spring P could be used to expand upper weight limit to about 80 kg and that the spring constant was **54 N/mm**, which is nearly the same value of the designed value. For the oblique seat, the spring **Q** was selected.

Table 1 shows the designed-spring constants and observed values.

(1) Measurement of the dynamic characteristics of the seat

When designing a seat suspension system or examining a new suspension mechanism, the dynamic characteristics of the seat itself is as important as the static characteristics. This measurement was performed using an experimental apparatus and with experimental conditions as shown in Figure 4 and in Table 2.

The output signals of a vibration meter from two accelerometers both on the seat and under the seat were supplied to a computer to calculate the transmissibility.

The results of the transmissibility test are shown in Figure 5. along with the results of tests on the seats of springs P and Q. At a resonance frequency of approximately 2 Hz, all test seats (spring and damping element) had high transmissibility, ranging from 1.5 to 3.5. The results of transmissibility tests at 4 Hz show a value of approximately 1.0 for both the springs P and Q.

Frequency 4 Hz is an important frequency because resonance of body trunk will be induced and a human body is exposed to a high level of vibration at this frequency. Based on these results, the spring Q was adopted, as its resonance frequency was the lowest one, according to the target specification. A damping element was also adopted for the final experiment on an artificial track, although transmissibility exceeded 1 at the resonance frequency. Based on the results of tests on spring constant and transmissibility at various resonance frequencies in Table 3, the Tempered spring Q and damping element “c” were adopted for the Oblique seat.

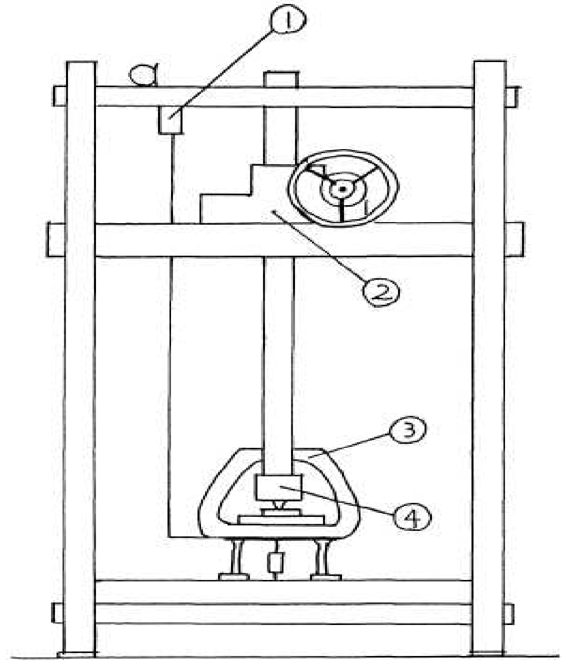

Fig. 2. Measurement apparatus of static characteristic of the seat
① Displacement transducer, ② Load supplier, ③ Test seat, ④ Load transducer.

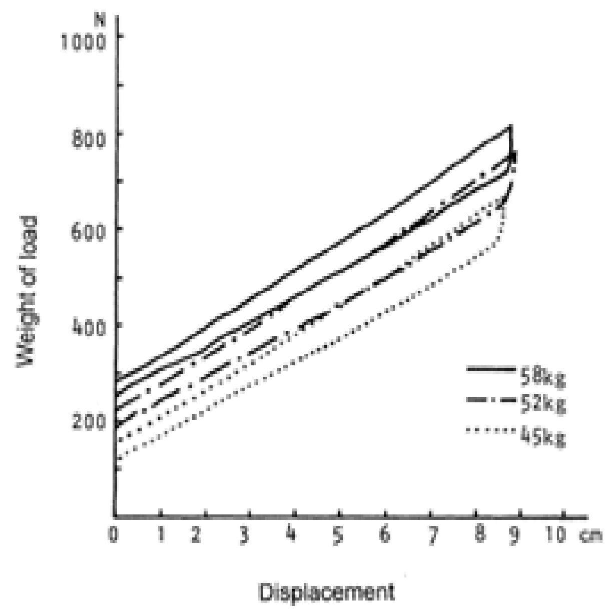

Fig. 3. Results of static characteristic of the seat as a parameter of the weight itself loading on the test seat not exactly the same as the human body-weight.

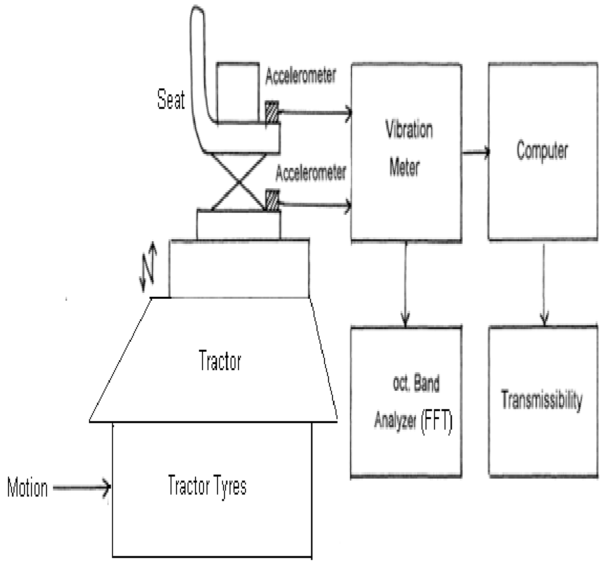

Fig. 4. Apparatus of examination of dynamic characteristic

Table 1. Specification of Spring Constant

Spring	Type	Spring Constant Designed N/mm	Spring Constant Observed N/mm
P	Vertical Plane	30.00	54.00
Q	Oblique Plane	33.00	59.00
Temp. P	Vertical temp. P Plane	48.00	85.00
Temp. Q	Oblique temp. Q Plane	81.00	143.00

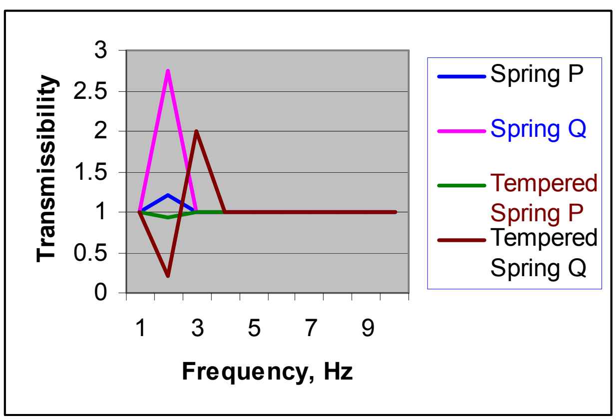

Fig. 5 Results of Dynamic Characteristic of a Tractor

Table 3. Dynamic characteristic of suspension system

Type	Damping Factor C (N-s/mm)	Natural Frequency	Transmissibility 2 Hz
Vertical Plane (spring P)	13.816	1.2	1.10
Oblique Plane (spring Q)	9.511	1.2	1.50
Vertical Plane (Tempered spring P)	10.55	1.48	0.90
Oblique Plane (Tempered spring Q)	1.91	1.91	0.22

Table 2. Experimental conditions	
Input signal	Sinusoidal vibration
Frequency Range	1-10 Hz
Weight on seat	45-80 kg
Transmissibility	Vibration acceleration On the seat/ Under the seat

Measurement of Vibration on Tractor Seat

Test runs were conducted using two seats vertical and oblique by two operators whose body weights were 45 and 80 kg, respectively, on the artificial track at a tractor speed of 10 km/h. The unweighted acceleration of the tractor was measured both on the seat and under the seat with an accelerometer installed in a rubber disk[8] in both vertical and fore-aft directions. To determine a vibration transmissibility, weighted[9,10)] acceleration level was measured both on and under the seats in the vertical direction.

(1) Transmissibility of seat vibration

Although peak transmissibility values were 0.9 at a resonance frequency of 2 Hz for both the seats at a speed of 10 km/h, a transmissibility of 0.9 at a single frequency of a component could not affect overall transmissibility value in Figure 5. The most effective reduction was obtained at the range between 1 Hz and 3 Hz, which is a hazardous frequency to the human body for the two seats with running speed 10 km/h. Much difference in the results was found between these two seats of the tractors. This result for the seat of tempered spring P suggests that even

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reduced transmissibility of dynamic response itself could not be obtained described above in Table 3, it could be recover to get reduced transmissibility as a final examination affected by the actual run on the track from practical view point as seen in this case.

(2) Evaluation of the seats

Table 4 shows the weighted acceleration level both on and under the two seats. The overall transmissibility value enabled an approximately 70% reduction, that is, a 1.02 amplitude reduction for the seat of tempered spring Q and a 30% reduction for tempered spring P. Based on transmissibility values, the target specifications were fully met using the Oblique plane with tempered spring Q developed vibration protection suspension seat.

Table. 4 Weighted and Unweighted Acceleration level On and Under the Seat with Suspension System installed in Agricultural Tractor.

Type	Weighted Acceleration (rms), m/s^2		Unweighted Acceleration (rms), m/s^2	
	On	Under	On	Under
1.Tempered Spring P	2.4	1.0	1.6	1.0
2.Tempered Spring Q	1.1	1.25	1.0	1.2

From the results, oblique seat with tempered spring was selected shown in Fig. 6 (a, b, c, and d). and Fig. 7.

Fig. 6a

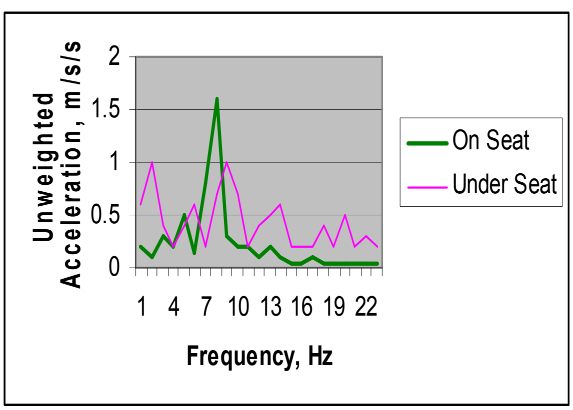

Fig. 6b

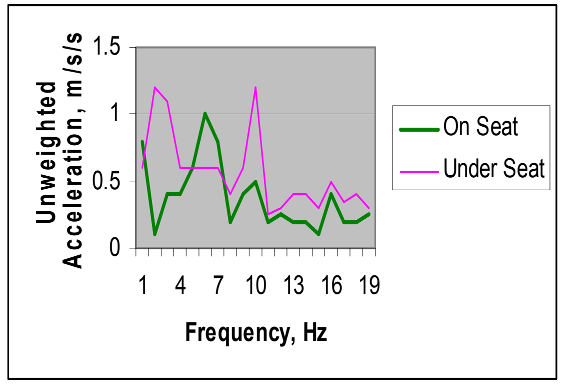

Fig. 6c

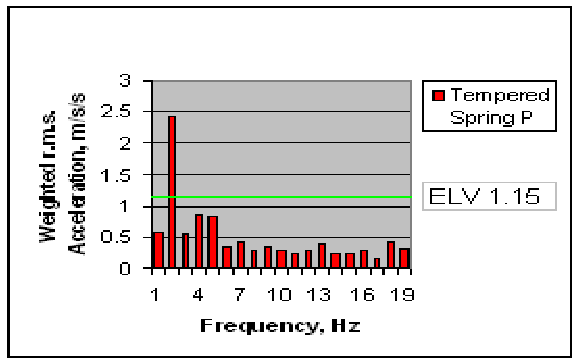

Fig. 6d

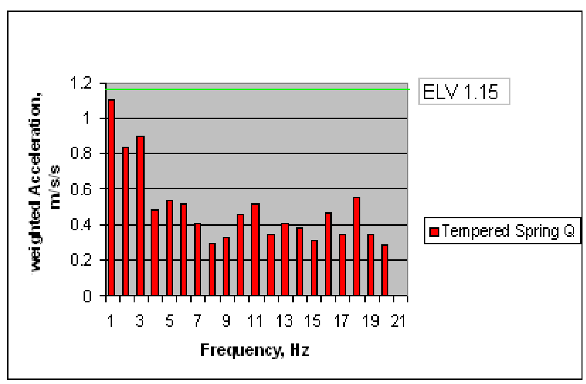

Fig. 6 Comparison of Vertical seat (Fig. a, c) and Oblique seat (Fig. b, d) with Tempered Springs P & Q.

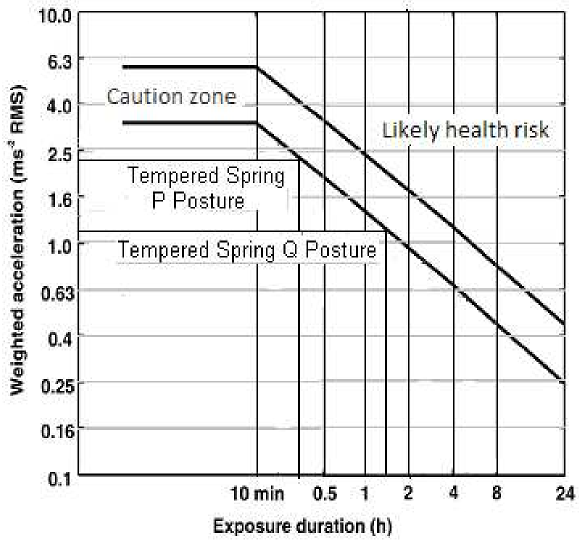

Fig. 7 Health Guidance Zone according to ISO Limits

Conclusion

Two seats with a vibration protection suspension system were newly developed for agricultural tractor. The static and dynamic characteristics of these seats were examined in the laboratory. An artificial track was constructed based on the BIS standard to examine vibration transmissibility from on the seat to under the seat installed a tractor. The results of the examination using the artificial track indicate that in a frequency range from 4 to 10 Hz, vertical vibration transmissibility 1.0 was observed for two seats at running speed of 10 kmph. An overall transmissibility frequency of 0.22, exposure limit value (ELV) of 1.1, and exposure duration of 1.5 hour were observed for the tempered spring Q of Oblique plane. No vibration reduction was noted in the fore-aft direction. These results indicated that the newly developed oblique seat with tempered spring Q met the target specifications and that such seat is applicable to actual agricultural use.

RECOMMENDATIONS

In the light of the findings of this work, the following recommendations may be made:-

__ Further investigation is required to establish linkage between the test track WBV emissions characteristics of a given vehicle, and subsequent WBV emissions and operator daily WBV exposures encountered during typical agricultural operations;

__ Further investigation is required in this study to be endured by a tractor operator for 8 hours in a day;

__ It would be desirable to attempt short-term delay of the proposed PA (V) D until the findings of such an investigation (which is currently underway) become available.

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