Development of Vibration Protection Seats for Agricultural Machinery

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Abstract: Seats have been newly developed with an anti-vibration suspension system for agricultural machinery. These seats were examined in a series of laboratory tests to determine their static and dynamic physical characteristics. These seats are specifically designed for the Japanese physique. An artificial track was constructed to simulate a farm field based on BSI (British Standard) and to examine vibration the transmissibility of the seats when installed in machinery. The results indicated that the transmissibility from under the seat to on the seat in the vertical direction was approximately 0.25, although little reduction of vibration was observed in the fore-aft direction. This suggests that these seats are applicable to the agricultural field.

Key words: Anti-vibration seat, body vibration, Suspension system, Agricultural machinery, Artificial track, Whole-body vibration

Introduction

At present, there is a need for the development of agricultural machinery 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 Japanese workers, especially in terms of body weight, as such seats are manufactured in foreign countries. There is machinery with suspension that are seats commercially available in Japan, even larger models of such offer has insufficient vibration protection and more smaller machinery has no seats with such anti-vibration systems.

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 Japanese physique, in particular, the body weight of 45–80 kg instead of the average European 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/s² (106 dB, ref.=10⁻⁵ m/s²) when an agricultural machine with the seat is operated on an artificial track at a speed of 8 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 and damping coefficient of the seats. The dynamic characteristics is a vibration transmissibility using vibration exciter in the laboratory. In addition to these characteristics, vibration reduction effects are required in a working farm field. Objectives of this study were to (1) construct a seat with a suspension system, (2) measure the static and dynamic characteristics of such a system, (3) construct artificial track that have repeatability of vibration values and (4) reduce the effects of vibration using the artificial track.
Construction of the Seat

The preliminary experiment 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 an 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 were constructed to fit the specification. One was a vertical suspension system featuring long strokes (L3: 620*236*463 mm³) and the other was an oblique suspension system moves obliquely to maintain stability of foot condition during an operation (LS2: 540*330*450 mm³) in the Figures 1-a, b.

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 and BS standards. 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 typical Japanese body weight. The seat was designed using the spring D so that the lower limit of body weight was about 50 kg and the spring constant was 108 N/cm. From the results, it was determined that the spring D could be used to expand upper weight limit to about 80 kg and that the spring constant was 112 N/cm, which is nearly the same value of the designed value. For the seat LS2, the spring H was selected.

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

(2) 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 are as important as the static characteristics. This measurement was performed using an experimental apparatus and with experimental conditions as shown in Figure 4 and Table 2. Sinusoidal signals from a function generator were fed into a vibration exciter through a power amplifier. Test seats with a solid weight of 55 kg setting on the vibration exciter were given sinusoidal vibrations. 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 developed seats L2, LS. 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 0.5 except for the result of the test on L2.
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 D 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 spring H and damping element γ were adopted for the seat LS2.

Construction of the Artificial Track

To examine the vibration reduction effect of the developed seats, it was necessary to conduct a trial run of agricultural machinery installed with the seats on an actual working field. It is clear, however, that data obtained on such working field has difficulty in taking repeatability, as the surface condition of the field could not be kept constant state for multiple trials. Therefore, to ensure stable field-surface conditions as well as the use of a single seat for all types of agricultural machinery, a pair of artificial tracks were created for test runs. These artificial tracks had a length of 55 m, on based on BSI (British Standard)\(^7\), which specifies five classes from very good to very poor in terms of PSD (power spectral density), shown in Figure 6.

A poor-class track was used in this study as this was considered to be a representative of a typical track surface. The track was constructed based on a artificial road profile.
of the BSI, and wooden blocks were mounted at 75-mm intervals on the ground.

Repeatability of the running test
To confirm the repeatability of input vibration to the test seat using the artificial track, two examinations of repeatability were conducted that consisted repeated trials with the same operator and tractor. An examination to determine the time history of an unweighted acceleration by different operators with the same tractor was also conducted. These unweighted accelerations were measured under the seat of the tractor during trial runs.

Figures 7-a, b show the results of the frequency analysis for the repeated trials and time history. It was found that two repeated runs showed good repeatability for frequency ranges, and that this track is suitable for the field examination with the artificial track.

**Measurement of Vibration on Tractor Seat**

Test runs were conducted using two seats L3 and LS2 by two operators whose body weights were 55 and 68 kg, respectively, on the artificial track at a tractor speed of 6 km/h and 8 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 in both vertical
and fore-aft directions. To determine a vibration transmissibility, weighted acceleration level was measured both on and under the seats in the vertical direction.

(1) Frequency analysis of tractor vibration

Figures 8-a, b shows unweighted acceleration level against 1/3 oct. band center frequency. These results are samples drawn from among several trials conducted by two operators at a tractor speed of 8 km/h. Vibration amplitude was reduced remarkably as expected at specifications of 4 Hz, 31.5 Hz and 63 Hz, in particular, for 14 dB value obtained at 4 Hz for the seat L3. For the seat LS2, 14 dB reduction was also obtained at approximately 4 Hz. With speed of 6 km/h, vibration reduction obtained at 4 Hz was 15dB for two seats L3 and LS2 in Table 4.

In the fore-aft direction, clear reduction of vibration was not observed over frequency for the two seats L3 and LS2, as shown in Figure 8c.

(2) Transmissibility of seat vibration

Although peak transmissibility values were 1.4 at a resonance frequency of 2 Hz for both the L3 and LS2 seats at a speed of 8 km/h, a transmissibility of 1.4 at a single frequency of a component could not affect overall transmissibility value in Figures 9-a, b. The most effective reduction was obtained at the range between 4 Hz and 8 Hz, which is a hazardous frequency to the human body for the two seats L3, LS2 with both running speeds 6 km/h and 8 km/h. No difference in the results was found between these two speeds of the tractor. This result for the seat L3 suggests that even 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 viewpoint as seen in this case.

(3) 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 12 dB reduction, that is, a 0.25 amplitude reduction for the seat L3 and a 13 dB reduction for LS2. Based on transmissibility values, the target specifications were fully met using the two developed vibration protection suspension seats.

Conclusion
Two seats with a vibration protection suspension system were newly developed for agricultural machinery. The static and dynamic characteristics of these seats were examined in the laboratory. An artificial track was constructed based on the British 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 8 Hz, a vertical vibration transmissibility between 0.2 and 0.3 was observed for two seats at running speeds of 6 and 8 km/h. An overall transmissibility frequency of 0.25 was observed for the two newly developed seats. No vibration reduction was noted in the fore-aft direction. These results indicated that the newly developed seats met the target specifications and that such seats are applicable to actual agricultural use.

References

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