Vibration Measurement and Evaluation of Tractor Seats

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Nowadays, agricultural machinery enabling comfortable and safe operations of various farm works are required to be developed. With regard to tractor operations, it is one of the important points in designing and using tractors to find out comfortable riding-seats which can prevent operators from occupational diseases caused by wholebody vibration. Measurement of vibration is a basis for developing a good tractor-seat and various methods of measurement are formulated such as ISO standard etc.. However, there still remain several problems to be solved. In this paper, results of the authors' research and related problems will be presented.

Methods of measuring vibration characteristics of tractor seats

For grasping vibration characteristics of the seats, it is most important to measure in the field the actual vibration of a tractor-seat-human system. For the purpose of improving the tractor ride by reducing seat vibration, it is also important to make comparative test-runs on the artificial tracks with highly consistent vibration inputs, as well as to measure dynamic and static characteristics of a seat itself.

The primary quantity used to describe the intensity of a vibration environment shall be the acceleration. The magnitude of a vibration, that is the acceleration, should be expressed in terms of m/s^2 of root-mean-square values, or dB changed from m/s^2 rms by the following equation (1) or (2). The dB of rms values of acceleration without frequency weighting is expressed as the vibration acceleration level, while the dB of rms values of acceleration after the frequency weighting made by ISO 2631[1] for each direction of the vibration is expressed as the vibration level. As the reference acceleration used to express the dB, 10^{-5} m/s^2 is adopted in the most cases in Japan, but 10^{-6} m/s^2 is employed in some reports and measuring apparatus of other countries. In order not to cause confusions, it is necessary to give a note on the reference acceleration in any report. In the present paper, 10^{-5} m/s^2 is used.

Vibration acceleration level (VAL)

$$20 \cdot \log (a/a_r) \quad \cdots\cdots (1)$$

a : rms value of acceleration measured
a_r: reference acceleration

Vibration level (VL)

$$20 \cdot \log (a_x/a_r),\ 20 \cdot \log (a_y/a_r),\ 20 \cdot \log (a_z/a_r) \quad \cdots\cdots (2)$$

a_x, a_y, a_z: rms values of acceleration after frequency weighting was made for each of x, y, and z directions.

Vibration measurement of tractor-seat system in operation

1) Selection of sites for measurement

(1) Farmfield and farm road: Actual exposure of operator to the vibration can be known, so that it offers important data in setting a target for reducing the vibration. But this method has a defect that surface profiles as a vibration input source are hardly reproducible.

(2) Artificial track for tractor ride tests: To carry out the tests by giving enforced vibration to tractors, reproducible results

Plate 1. Test run on artificial rough tracks

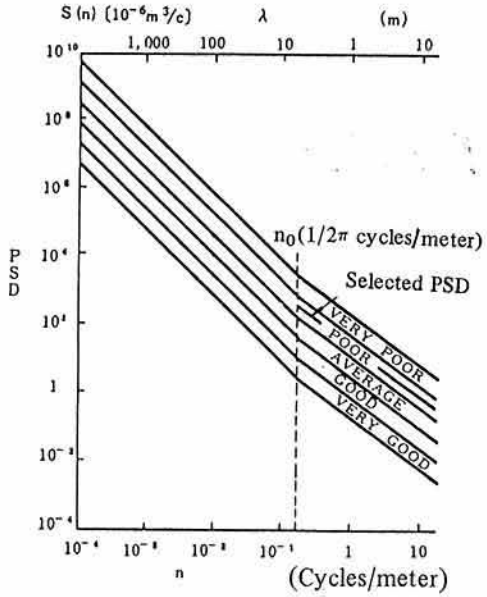

Fig. 1. Classification criteria of roads after BSI, and PSD (power spectral density) of artificial tracks selected for the use in the present study

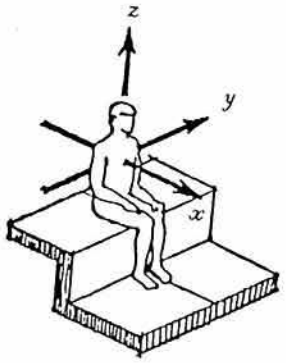

Fig. 2. Directions of vibration on a sitting operator

have to be obtained under a given condition. There are several methods of inducing the enforced vibration, but at present, artificial tracks with irregular profiles are commonly used. The authors selected the PSD (power spectral density) which falls just in the middle of the "poor" class of road surface indicated in the proposal of a panel of British Standard Institution (BSI), shown in Fig. 1. Based on it, an artificial rough track of total length 55 m was constructed (Plate 1)[7] and used for the tests. For constructing artificial tracks, it would be better to apply profile values of the rougher track of 35 m and smoother track of 100 m, both defined in ISO 5008[2]. As compared with the use of woods for profile construction, the use of steel tubes (Plate 1) can give a faithful profile and good

durability.

2) Measurement of vibration acceleration

(1) Direction of vibration: As shown in Fig. 2, fore-and-aft, side to side and longitudinal directions are defined as x, y, z, respectively.

(2) Measurement of vibration on the seats: An operator sits down on a vibration acceleration transducer placed on the seat. As to the vibration acceleration transducer, there are the thin book type, used centering Germany and Austria, and the disc type centering England and adopted in ISO 5008. The latter is felt better than the former in use, but the disc type is liable to be influenced by other factors than vibration input for horizontal directions (x,y). Therefore, as shown in Fig. 3, the disc type tends to give different results from the results obtained by the book type in the low frequency range under 4 Hz, which is problematic for ride comfort, although the result for vertical direction is same with both types. The type of the transducer used for measurements must be indicated.

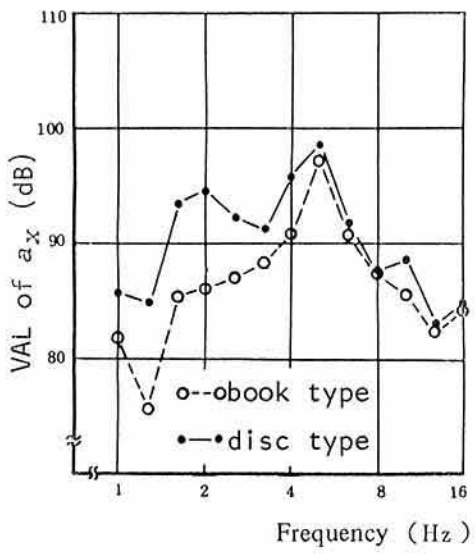

Fig. 3. Comparison of acceleration spectra obtained by two types of transducers (seat: BX. 7 km/hr)

(3) Measurement of vibration under the seats: The vibration acceleration transducer is attached to near the seat-attaching point of the tractor.

(4) Set up of running velocity: The ISO 5008 defines 12 km/hr for smoother tracks and 5 km/hr for rougher tracks, but it is better to make the measurement at other velocities. The authors set up 6, 8, 10 km/hr for big tractors with engine exhaust exceeding 1500 cc, and 6, 7, 8 km/hr for other (small) tractors.

(5) Body weight of operator: The ISO 5008 recommends 55 kg and 98 kg ($\pm$ 10%), but they are not general for Asian people, including Japanese. In the authors' tests, 2 operators with 60 kg and 70 kg each are employed, but it seems necessary to have measurements with a level of 50 kg, in view of the increasing number of female operators.

(6) Measuring duration: Standard duration is 60 sec, and minimum duration 30 sec.

(7) Characteristics of measuring equipments: The total characteristics of a transducer, an amplifying device, and recorder, in combination, must satisfy at least the following condition:

Frequency range: 1–100 Hz
Acceleration range:
on the seat: 0.01–30 m/s^2 rms
under the seat: 0.01–100 m/s^2 rms

(8) In addition, suspension system of seat, spring adjustment, type and model of tractor, running velocity and other necessary items are all to be kept on record.

3) Analysis of vibration acceleration

(1) Basic principle: The ISO 2631 is applied. The total characteristics of analytical apparatus need to satisfy the condition listed in (7) above.

(2) Expression of vibration magnitude: Out of the vibration components measured and recorded, those less than 80 Hz are subjected to the calculation of rms values of acceleration. Using the filter shown in Fig. 4, the dB of rms values after frequency weighting is expressed as dBVL, and that without frequency weighting as dBVAL. The rms values are obtained as follows, when the

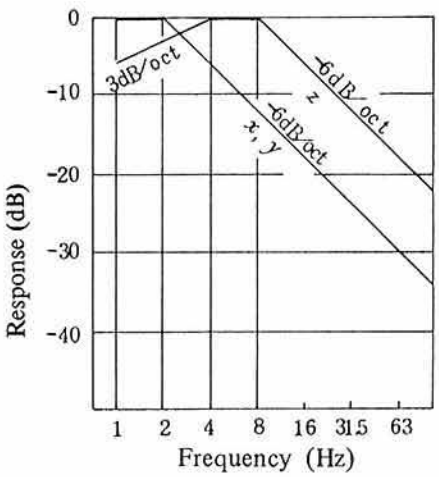

Fig. 4. Response to frequency-weighting network (from ISO 2631)

measuring duration is T,

$$a_{rms}=\sqrt{\frac{i}{T}\int_0^T a^2(t)dt} \quad \cdots\cdots(3)$$

For the calculation, a ride meter which can compute for an optional T is used. Also, it is necessary to pay attention to that the VL values of a_x and a_y measured by a vibration level meter fitted to JIS C1510[6] are greater by 3 dB than the values which should be obtained by ISO 2631.

(3) Frequency analysis: VAL vibration components (1–80 Hz) are generally subject to a one-third octave band frequency analysis by using a real time spectram analyzer.

(4) Crest factor (CF): CF is an absolute value of vibration peak divided by VL. When CF>6, evaluation of vibration by ISO 2631 is not possible.

Method of measuring dynamic characteristics of the seat itself

For designing the seat suspension system or examining a new suspension mechanism, dynamic characteristics of the seat itself are equally important as the static characteristics to be described later. It is desirable to make the measurement of the characteristics for each of x, y, z, but at least the measurement for z direction is essential, and is made by the method shown in Fig. 5.

(1) Input signal: Sine wave.

(2) Frequency to be measured: Range of 1–10 Hz, at a 0.2 Hz interval (0.1 Hz interval at the range near the natural frequency).

(3) Weight on the seat: Solid body of 55 kg (ca. 65 kg, equivalent to body weight of an operator. According to the 150/TC 108/SC 4/WG 5 document[3], weight of human model on the seat is 75 kg).

(4) Transmissibility: Mechanical transmissibility is the complex non-dimensional ratio of the response amplitude of a system

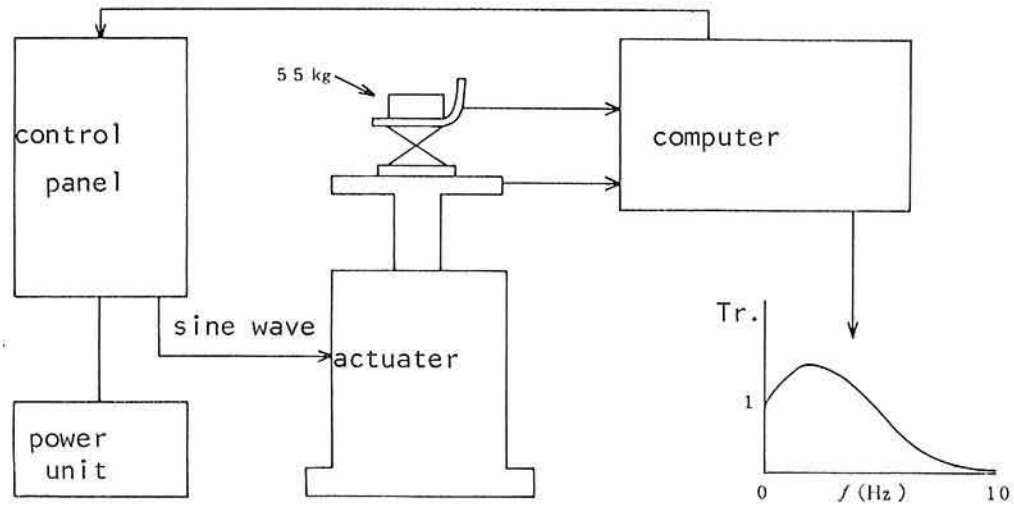

Fig. 5. Measurement of seat dynamic characteristic

in steady state forced vibration to the excitation amplitude. The ratio may be either of forces, displacements, velocities, or accelerations.

Transmissibility (ω) = output (ω) / input (ω)

(5) Vibrating table: To generate a vibration of low frequency and great amplitude, an electro-hydraulic vibration exciter is excellent for generating a vibration of low frequency and large amplitude.

Method of measuring static characteristics of the seat itself

A static load-deflection curve in z direction is obtained by using the apparatus shown in Plate 2, and is employed for designing suspension system of the seat.

1) Maximum load: 1500 N
2) Loading velocity: the velocity regarded as static load
3) Limit of loading: the faster one, either the suspension mechanism reaches the maximum displacement or the load becomes 1500 N.
4) Loading and measuring points: 200 mm forewards from the seat reference point.

Evaluation of results of measurement

It is general that the vibration at the time of operating or travelling of tractors is

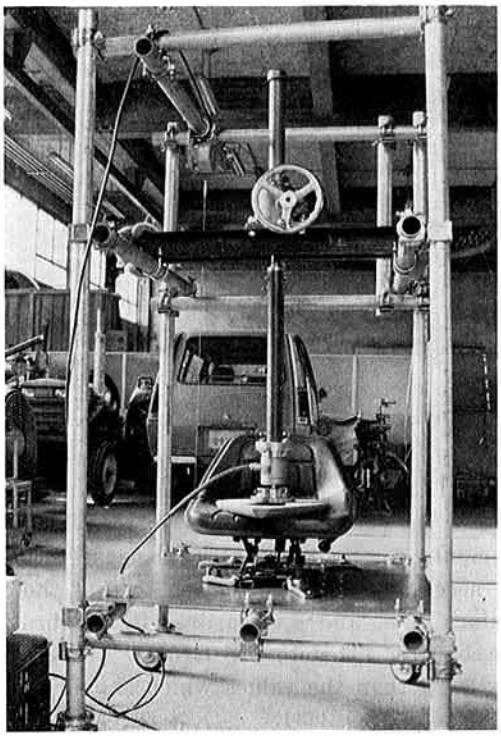

Plate 2. Measuring apparatus of seat static characteristic

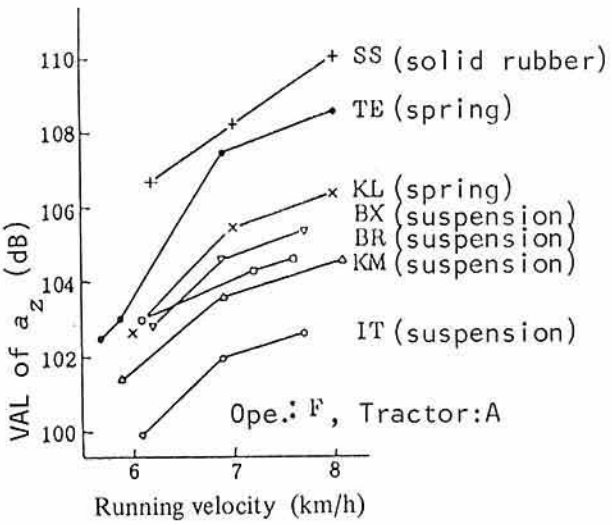

Fig. 6. Vibration level of seats

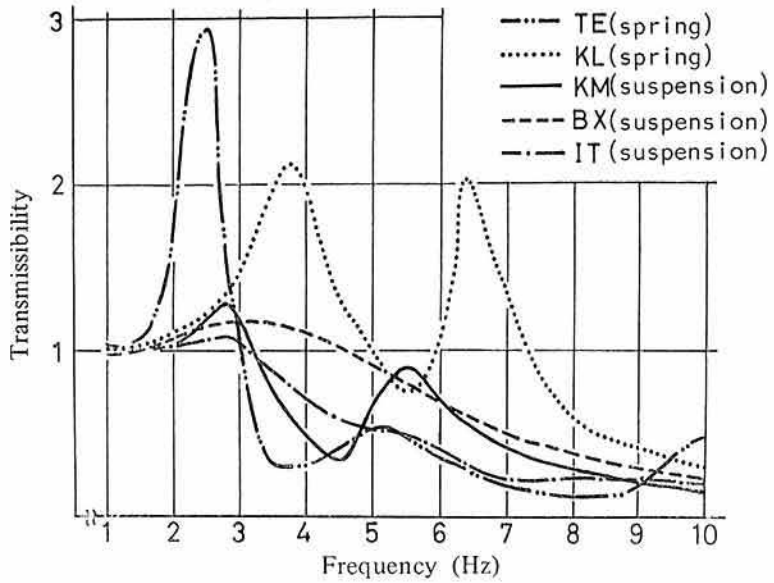

Fig. 7. Transmissibility of seats on vibrating table

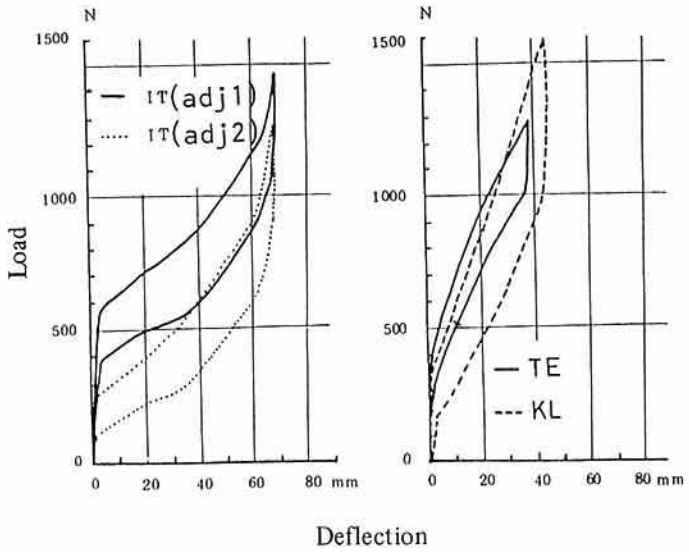

Fig. 8. Static characteristic of seats

evaluated on the basis of a group of curves of fatigue-decreased proficiency boundary (FDP) described in ISO 2631. As to the dynamic characteristics, it is highly evaluated that the natural frequency is less than 2 Hz, and the maximum transmissibility is as small as possible. As to static characteristics, it is regarded desirable that the displacement within the range of usual loadings used is large.

Several examples of results of measurement

The vibration on the seat[7], dynamic characteristics[4], and static characteristics[5], measured for several kinds of the seats with different suspension mechanisms are given in Fig. 6 to Fig. 8.

References

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3) ISO/TC 108/SC 4/WG 5: Mechanical transmissibility of the human body, Second draft proposal (1982).
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