Investigation of Vibration Characteristics of a Hand Tractor and Detection of Target Vibration Reference Points based on Transfer Path Analysis Technique

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Title: Investigation of Vibration Characteristics of a Hand Tractor and Detection of Target Vibration Reference Points based on Transfer Path Analysis Technique
（歩行式トラクタの振動特性の把握と伝達経路解析に基づく目標振動参照点の検出）

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Thesis Summary

In Cambodia, agricultural mechanization has recently improved agricultural labor savings, energy efficiency, productivity, and profitability, instead of conventional farming using livestock and human power. In Southeast Asian countries, including Cambodia, walking tractors are the most widespread agricultural machinery, especially in rural areas, where they have also been used for multiple purposes transportation and mobility. Therefore, the operator is exposed to mechanical vibration for a long time, resulting in fatigue and discomfort due to agricultural work in the field and driving on farm roads and public roads. With the above background, to reduce the vibration of the walking tractor, the objectives of this study are 1) to grasp the vibration characteristics of the walking tractor, 2) to obtain essential characteristics of transmission between vibration on the handgrip, where the vibration is transmitted directly to the operator, and other parts of the walking tractor, and 3) to identify reference parts with high vibration contribution to the handgrip.

Chapter 1 outlines the current state of agricultural mechanization in Cambodia, the popularity and use of walking tractors, and the effects of vibration exposure on operators. In addition, the objectives of this study were clarified by reviewing issues related to previous measurement methods for the vibration characteristics of walking tractors and the evaluation of vibration exposure to operators. Furthermore, the importance of reducing the vibration of walking tractors and detecting reference parts with high vibration contribution to the handgrip is clarified.

In Chapter 2, a walking tractor's vibration intensity and frequency characteristics were investigated under long operation conditions on Cambodia's farm roads. MEMS inertial sensors were installed at four locations (handgrip, engine cover, chassis frame, and top of gearbox) to measure translational acceleration and rotational angular velocity. The results showed that the vertical acceleration at the handgrip was the largest, followed by the engine top, gearbox, and chassis in the idling condition. In the actual traveling case (average speed: 1.4 m/s), the handgrips, followed by the engine top, generated the most considerable vibration, indicating that the handgrips, which directly exposed the operator to the vibration, had greater vibration intensity than the parts closer to the vibration source. Furthermore, a frequency analysis of the measurement time series was also conducted. As a result, although the primary frequency component peaked at a period corresponding to the engine speed at all measurement points, multiple peaks appeared at low frequencies during traveling. These results indicate that it is necessary to investigate hand tractors' vibration characteristics at different engine speeds and driving speeds.

In Chapter 3, to clarify the essential vibration characteristics of a walking tractor, inertial sensors were

installed at a total of seven locations: at the handgrip, where vibration is directly transmitted to the operator, and at the top of the engine, front, rear, chassis frame, top of the gearbox, and center of the hand-arm, as determined by the rigidity of the machine and the source of vibration. Simultaneous 3-axis translational accelerations were measured at each of the above seven locations following the ISO standard (ANSI/ASA S2.70-2006) for measuring vibration exposure of handgrip sections under idling conditions. The Power Spectral Density (PSD) and the root mean square (RMS) were calculated from time series data of the accelerometer of each part, and the frequency characteristics and vibration intensity at seven measurement points on the walking tractor were compared. Furthermore, the vibration of the walking tractor was evaluated based on the WHO health risk index for vibration exposure. As a result, it was shown that the RMS values of acceleration of the hand-arm part exceeded healthy limits at all engine speeds.

In Chapter 4, to reduce the tractor's body vibration, especially the vibration of the handgrip, the inertia sensors were installed at the seven locations shown in Chapter 2. They were used to measure the vibration during dynamic driving. In addition, Transfer Path Analysis (TPA) was performed to clarify the transfer locations contributing to the vibration of the handgrip. In the TPA, the vibration of the handgrip was taken as the response (target) point, and the vibrations of the other six locations as the reference points. The third-order tensor data of the PSD of the measured response and the reference points' accelerations at different running speeds were decomposed of singular values. The Root Mean Square Error (RMSE) between the measured and the estimation reconstructed of the response point data with the contributing components was calculated to detect the highest contributing reference point. As a result, it was found that the chassis and the upper part of the gearbox were the most effective locations for vibration transmission to the handgrip.

The primary results and implications of this study are summarized in Chapter 5. The measured acceleration time series at seven locations on the hand tractor showed that the lateral vibration at the top of the engine was the largest at low frequencies. The vertical vibration of the handgrip section has large values over all frequencies. In addition, the vibration of the hand-arm and handgrip exceeded the WHO guideline at all engine speeds. Therefore, vibration measures are necessary. Furthermore, the vibration of the handgrip of a walking tractor is highly dependent on the vibration of the chassis and gearbox based on the analysis of transmission paths, and it was suggested that anti-vibration measures be applied to these locations to reduce vibration on the handgrip.