Vibration Analysis and Control of a Vibration Screed System for Asphalt Pavers

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To reduce shaking of a vibration screed system (VSS) and improve the paving performance of an asphalt paver (AP), the root-mean-square (RMS) acceleration responses at points on the front and rear screed floors are analyzed via an experimental method. A 3D nonlinear dynamic model of the VSS is also built to evaluate the influence of the dynamic parameters of the VSS on the compression efficiency, paving quality, and working stability of the AP based on the objective functions of the vertical, pitching, and rolling RMS values at the centre of gravity of the screed. The angular deviations, $\alpha$ and $\gamma$, of the tamper are then controlled to improve the paving performance. The research results show that the excitation frequency, $f$, and both angular deviations, $\alpha$ and $\gamma$, of the tamper strongly affect the paving performance. The compression efficiency is quickly enhanced, while both paving quality and working stability are significantly reduced with increasing the excitation frequency $f$ and reducing the angular deviations, $\alpha$ and $\gamma$, and vice versa. Additionally, the screed shaking and paving performance of the AP are remarkably improved by control of the angular deviations, $\alpha$ and $\gamma$, under different working conditions.

1. INTRODUCTION

The asphalt paver (AP) was one of the construction machines used to pave asphalt mixture on road surface construction rapidly and uniformly. Therefore, the vibration screed system of an asphalt paver (VSS-AP) was equipped with a vibrator screed and a couple of tamper mechanisms (compacting beams). The tamper was used to compress the asphalt mixture to become tighter and more uniform in density while the vibrator screed was used to improve smooth and the finish of the road surface construction. The paving performance of the AP was mainly assessed by three indexes of the compression efficiency, paving quality, and working stability.

The compression efficiency was affected not only by the operating parameters of the VSS but also by the asphalt materials and ground vibrations. The influence of density, temperature, and size of particles of the asphalt mixture on compression efficiency was studied. The studies showed that the temperature of the hot asphalt-mix greatly impacted on the asphalt density and compression efficiency. In order to achieve the desired density, the temperature of the hot asphalt-mix in the compression process was quickly analyzed by a fuzzy clustering technique. The errors of unequal compaction coverage, temperature, and compaction delay were then controlled based on the compaction monitoring system. The influence of the different temperature regions of the asphalt-mix on compression efficiency was analyzed by using a multi-sensor infrared temperature scanning bar system. Besides, the ground motions and vibrations could affect the performance of machines working on the ground, especially the elastoplastic ground soils. Additionally, with the operating parameters of the VSS, the influence of the compression forces, phase deflections, and excitation frequencies of the tamper on the smoothness of the pavement was also investigated. The results indicated that the vibration excitation of the tamper mainly affected the compression efficiency. However, in all the above research, only the vertical vibration with a quarter model of the VSS-AP was considered.

The paving quality and working stability of the AP were significantly affected by the excitation frequency of the tamper ($f_t$) and of vibration screed ($f_s$). Based on the 2D dynamic model of the VSS, the analysis results showed that the paving quality was better with the vibration excitation of $f_t$ from 10 to 20 Hz and of $f_s$ from 30 to 40 Hz. The optimal paving performance was found at the excitation frequency 15 Hz of $f_t$ and 32 Hz of $f_s$ on a type of asphalt-mix materials. Three different types of asphalt-mix materials of SMA-13, AC-20, and AC-25 were then expanded to fully analyze the influence of the excitation frequency of $f_t$ and $f_s$. All researches showed that compression efficiency was significantly improved, but paving quality and working stability were still low. To solve this problem, the mass of tamper and eccentric distance of the eccentric shaft were optimized to reduce the vibration amplitude on all nodes of the screed which helped to improve the compression surface quality. Both the excitation frequencies of $f_t$ and $f_s$ were also optimized based on a genetic algorithm to decrease the pitching vibration $\phi$ of the screed. Besides, the angular deviation $\gamma$ between the front/rear tampers was also optimized via ADAM.

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