論 文 の 内 容 の 要 旨

論文題目　ENERGY HARVESTING IN A ROTATING TIRE ENHANCING NON-LINEAR VIBRATION

（非線形振動を励起させることによる回転するタイヤ内でのエナジーハーベスティング）

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A model for energy harvesting from a rotating automotive tire is exploited by application of the principle of stochastic resonance to enhance energy harvesting efficiency. A bistable response characteristic can be obtained by recourse to a small harvester comprising a magnetically repellant configuration, in which an instrumented cantilever beam can flip between two physical response states, when suitably excited by the rotation of a car wheel into which it is fitted. The rotation of the wheel creates a periodic modulation which enables stochastic resonance to take place, and as a consequence of this for energy to be harvested from road noise transmitted through the tire. A concisely mathematical model of the harvesting system is presented based on a series of experimental tests, and it indicates that a ten-fold increase in harvested energy is feasible over a comparable monostable case. In practice, the suggested application for this harvester is to provide electrical power for a tire pressure monitoring system.

For the case of actual wheel rotation, the present study investigates the effectiveness of a piezoelectric energy harvester, with the application of stochastic resonance to optimize the efficiency of energy harvesting. It is hypothesized that the energy harvester is subjected to on-road noise as ambient excitations while the wheel rotates at variable speeds, and meanwhile a tangentially acting gravity force as a periodic modulation force that can stimulate stochastic resonance. For a laboratory experiment, the energy harvester was miniaturized with a bistable cantilever structure, and the on-road noise was measured for the implementation of a vibrator. A validation experiment revealed that the energy harvesting performance of system was improved to capture powers, which were approximately 12 times that of the captured under only on-road excitation and 50 times that of the captured under only the periodic gravity force.

Moreover, through the investigation of up-sweep excitations with an increasing rotational frequency, it is confirmed that stochastic resonance is effective in improving the performance of the energy harvester, with a certain bandwidth of vehicle speeds. Furthermore, it is found that the ability of the energy harvesting can be enhanced over a wider rotational frequency under considering the combination of stochastic resonance and the high energy orbit phenomena of the bistable systems. An actual-vehicle experiment validates that the prototype harvester using stochastic resonance is capable of improving power generation performance for practical tire application.

On the other hand, nonlinear energy harvesters have already been exhibited to draw energy from ambient vibration owing to their particular dynamic characteristics, in which are feasible to desirable responses for broadband excitations of bistable and monostable systems. However, due to coexistence of the lower energy orbit, it is still a challenging topic that is how to achieve the stability of the high energy orbit oscillating to improve the valid broadband of the excitations. This study also focuses on proposing a stiffness tunable energy harvester for rotational applications.

As the rotationally angular velocity gradually increases, the tensile stress to the cantilever beam is also self-adjusted with the increscent centrifugal force, causing the potential barriers of bistable type to become shallow, so that the cantilever beam has the ability to maintain the high energy orbit motion from bistable hardening type to monostable hardening behavior. From the implemented results, the valid bandwidth of angular frequency can be improved from 26 rad/s–132 rad/s to 15 rad/s–215 rad/s, under the case of the effect of centrifugal force on nonlinear vibrating behavior. In an actual-vehicle experiment, it is simultaneously demonstrated that the centrifugal force can significantly promote the performance of nonlinear energy harvesters in the tire applications.