DSTA 2021 dys-ta.com
16th INTERNATIONAL CONFERENCE
Dynamical Systems – Theory and Applications
December 6-9, 2021, On-line

Application of bulk granules as a damping material for sports boards

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Abstract: Sporst boards like snowboard decks or skis undergo continuous deformation caused by manoeuvres performed on irregular surface of snow, which leads to rapid vibrations during dynamic ride. A container partially filled with bulk granules was attached to the top layer of different boards to suppress lateral or torsional vibrations by dissipating energy through non-conservative interactions among colliding granules. The system is generally a layered cantilever beam, subjected to various dynamic loads. The performance of such dynamic systems was verified experimentally on a custom designed laboratory stand and on-snow. An empirical mode decomposition and Hilbert transform were used to track the damping performance. Vibration amplitude was proven to be reduced more effectively in laboratory and on-snow, when granules fill the container, than when the boards were damped intrinsically.

Keywords: granular material, vibration, damping, bending, experiment

1. Introduction

During dynamic gliding, snowboard decks or skis experience random vibrations caused by continuous deformations from the irregularities of the snow surface. An important challenge is to provide a certain amount of damping, without adding too much weight or bending stiffness, ensuring that thee sport experience is not compromised.

The dominating approach to mitigate these vibrations is to introduce damping layers to the inner structure. A rather rare approach uses external damping elements attached to the deck. The presented solution explores the possibility of using bulk granular material to attenuate these unwanted vibrations. Movement of the loose granules causes dissipation of energy through non-conservative interactions.

A container was attached to the upper surface of the ski and snowboard tip, and filled with different number of spherical granules. The transient response was expected to be nonlinear, with granular damping varying over amplitude. A Hilbert transform (HT) analysis, based on the approach developed by Feldman, as well as Huang et al. [1, 2] was performed.

In the laboratory, ski and snowboard were fixed to a massive support and secured between the toe and the heel piece of the binding with a clamp, while the shovel remained free. Laser sensors were used to record displacement at the selected point of the excited board.

During on-snow pilot study performed in one of the ski resorts, a container with granules was fixed to one ski, while the other one was only damped intrinsically. Skis were instrumented with wireless accelerometers with integrated data recorder. The experimental stand used in laboratory, the photo taken during on-snow tests and exemplary results from field tests are presented in **Fig. 1**.

2. Results and Discussion

It takes some time for granules to reach peak damping, since in the initial phase of motion, granules are resting on the bottom of the container and need at least one full swing of the ski or snowboard to start impacting the lid. During laboratory tests, in cases of higher initial deflection, a larger degree of damping is observed during the first stage of motion. The intrinsic damping ratio for skis reaches 0.1 for amplitudes from 40-20 mm, while granular damping is up to 2.5 times higher, reaching almost 0.25 for selected number of granules.

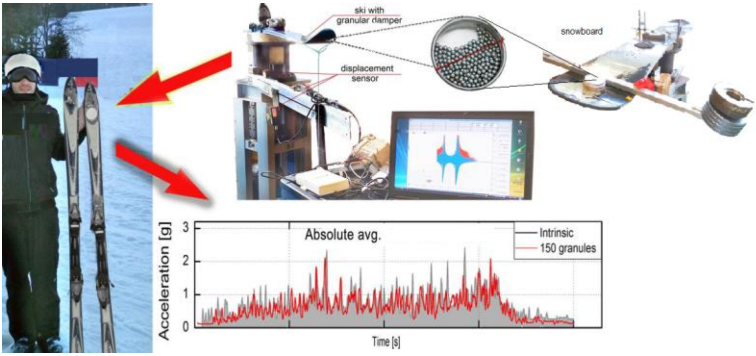

Fig. 1. Graphical abstract of the research: experimental stand, on-snow tests and field recorded results for damping of the ski with 150 granules.

When filed-tests are concerned the granular damper device is most efficient when absorbing large oscillations of the shovel on moguls, hardpacked or icy snow. Although the recorded acceleration history seems similar for both skis, the granular damper reduces peak amplitudes quickly after excitation. The calculated average amplitude of all peaks above 1 g was 2.42 g for intrinsic damping and 2.2 g for granular damping. An average value of acceleration reveals that vibrations of a ski with granular damper are usually below values obtained for intrinsic damping. Granular damping remain effective usually in short periods, reducing acceleration peaks.

3. Concluding Remarks

The experimental and field test results showed, that it is possible to modify the damping of full-size sport boards with loose granular material. The solution is passive, but the efficacy can be adjusted by changing the fill ratio of the container. The damping ratio depends on the amplitude, since transient vibrations can be divided into stages corresponding to different granular damping capacities. Vibratory energy is dissipated within granules especially well during the first cycles of the motion. With a small weight penalty, granular damping can be up to 2.5 times higher than intrinsic damping.

References

[1] FELDMAN M.: Non-linear system vibration analysis using Hilbert transform-I. Free vibration analysis method 'FREEVIB', *Mech. Syst. Signal Process* 1994. **8**(2):119–127.

[2] HUANG E., ZHENG S., LONG S.R., ET. AL.: The empirical mode decomposition and the Hilbert spectrum for nonlinear and non-stationary time series analysis 1998, **454**:903–995.