The 2014 Conference of the International Sports Engineering Association

Investigation and assessment of the edge grip of snowboards with laser vibrometry – a proposal of a standardised method

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Abstract

The edge grip of a snowboard defines its ability of holding the arc of a carving turn without intending to break out. In order to assess the vibrational movements of the edge under simulated loading conditions, two boards were put on the edge on a soft foam surface and loaded with 400 N such that the boards bent under the added load and the edge was in full contact with the surface. The shovels of the boards were excited with a swept sine signal from 5-200 Hz and the displacements measured with a laser vibrometer. The last edge point in contact with the surface proved to have the largest movement range. Maximal displacement was caused by the first torsional mode at 115-125 Hz, followed by combined bending/torsional modes at lower frequencies (23-30 Hz, 80-90 Hz). One board exhibited a larger movement range in the first torsional mode compared to the other board, and the frequency peak of this mode was wider. The mobility index of this board, introduced in this study as the normalized area under the displacement curve of the last edge point, was 1.5 times higher than the index of the other board. The method used in this study offers an accurate quantification of the movement of the edge under standardized load conditions.

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Keywords: snowboard, edge grip, vibrations, edge displacement, frequency response function, laser vibrometer

1. Main text

According to Foss and Glenne 2007, ‘The dynamic property most responsible for adverse ski behavior at high speeds on hard snow is a highly active torsion mode. Higher torsional vibration of a ski forebody directly affects

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edge control and stability, particularly during turns’. According to Buffinton et al. 2003 ‘Natural frequencies and damping ratios are two of the key parameters characterizing snowboard ride, feel, and performance. In particular, damping ratios as well as the relative values of bending and torsional natural frequencies directly relate to snowboard controllability and handling’. The edge grip of a snowboard is defined as the ‘level of grip exhibited during turns’, according to Subic et al. 2008. In essence, edge grip refers to the ability of the snowboard to hold the arc of a carving turn, i.e. the ability of maintaining carve integrity. Poor edge grip causes the board to break out of the carve.

As there is currently no objective method available for measuring the vibrational movement of the edge of a loaded, tilted and bent board, the aim of this paper is to develop a method for this purpose. The movement of the edge has to be measured against a soft surface, considering that maintaining the properties of snow over the entire edge length, as well as its temperature over time, is difficult under experimental conditions. According to Foss and Glenne 2007, the frequency response functions of skis on hard and soft snow are similar, with ‘responses on hard snow … about one order of magnitude higher than those from soft snow’.

Fig. 1. (a) experimental set-up, 1: load, 2: foam mat, 3: shaker, 4: laser vibrometer, top insert: scanning grid projected on the shovel; (b) frame mounted on board; (c) experimental set-up, 5: weight of load, 6: weight of frame, 7: belt force.

2. Experimental Procedure

Two snowboard decks used in a previous study by Fuss et al. 2010 were analysed. The boards had similar bending stiffness; board A had a higher torsional stiffness than board B analysed by Fuss et al. 2010. In contrast to previous experiments by Fuss et al. 2010 carried out in free-free conditions, the goal of the current study was to analyse the displacement of the edge of a loaded board in contact with a softer surface. The boards were placed on a closed cell polyurethane foam mat (20 mm thick; density: 34 kg/m³; 0.12 MPa stress at 0.5 strain) at an angle of 41 degrees (Figure 1). The boards were loaded with 20 kg through a 0.9 m high triangular frame (11 kg) connected to the holes for the binding screws, such that the boards bent under the added load and the edges were in full contact with the foam surface. The frame-board system had four instant centres, three revolute joints, and the instant centre of the bending board between the binding sites. The frame was connected by a belt to a post behind the board. This method kept the board in a stable position and the belt force simulated the centrifugal force when making a turn. The overall load perpendicular to the board was therefore approximately 400 N, i.e. the resultant of gravitational and belt forces (Figure 1c). In contrast to skis, where the binding is in the centre of the ski, thereby deflecting the ski fully by the bodyweight when carving, snowboards are loaded by both legs and the bindings are located off centre. Therefore, the mid section of the board is not deflected fully by the bodyweight when carving and consequently not in entirely in contact with the supporting surface. When loading the boards with the frame described above, the distance between mid-edge and surface was minimal between 40 and 45 degrees.
Fig. 2. Board A; coherence, average spectrum of displacement, and displacement of last edge point against frequency; 0: rigid body motion, 1,2,3,4,5: segments 1-5 (cf. Results); R: rigid body motion, B₁ & B₂: first and second bending modes, T₁ & T₂: first and second torsional modes, C: combined bending/torsional modes; the inserts on the bottom sub-figure display the node lines (black) and the associated frequencies in Hz.
Fig. 3. Board B; coherence, average spectrum of displacement, and displacement of last edge point against frequency.

The vibrometer used was a PSV 400-1D (Polytec, Waldbronn Germany). The scanning vibrometer measured velocity and displacement based on laser interferometry (Doppler effect). An electro-magnetic shaker (Gearing &
Watson Electronics V4) applied the input force to the board, perpendicular to the shovel. A PCB Piezotronics 221B02 impedance head measured the coherence of the input force and laser vibrometer results. The Polytec system drove and controlled the shaker and laser head while simultaneously processing measurements from the impedance head and the laser head. The shaker was connected to one shovel, whereas the measurements were carried out on the other shovel. This served for preventing displacement artifacts and interference with node lines generated by the movement of the shaker’s stinger.

The boards were excited with a swept sine signal from 5 – 200 Hz. Initial tests were carried out up to 1 kHz with swept sine and white noise signals. The coherence of the white noise signal was inferior to the one of the swept sine signal; and displacements of the shovel beyond 200 Hz proved to be negligible. The laser head scanned 112-115 points on the shovel using a rectangular grid (Figure 1a, insert). The resulting frequency response function (FRF) consisted of 1561 lines with a frequency band from 5 Hz to 200 Hz and a 125 mHz resolution.

The type of mode, i.e. bending or torsional, as well as the displacement of grid points was identified with the Polytec software (Waldbronn Germany), by displaying the motion of the boards at a specific frequency, corresponding to the peaks of the FRFs. The edge point on the measurement grid, which exhibited the maximal displacement range, was the outermost point still in contact with the surface. The node lines of the shovel at each peak frequency were determined from the colour-coded displacement maps. The type of mode, i.e. bending, torsional, or combined, was determined from the shape and position of the node lines. Node lines perpendicular to the longitudinal axis of the board, causing left and right sides of the shovel to move in the same direction, indicate bending modes. Node lines which intersect the end of the shovel longitudinally, causing left and right sides of the shovel to move in opposite directions, indicate torsional modes. Oblique node lines indicate combined bending/torsional modes, i.e. the transition from bending to torsion. The output data for analysis were comprised of the coherence and the displacement-FRF of both the average spectrum and single scan points.

Integration of the area under the displacement curve of the last edge point \((FRF_{pt})\) and normalising it to the frequency range \(\Delta f\) and to 1 nm yields a proposed edge mobility index \(I_{mob}\) for quantifying edge grip:

\[
I_{mob} = \frac{\int_{f}^{f_{max}} FRF_{pt} \; df}{\Delta f \cdot 1 \text{ nm}}
\]

3. Results

The coherence, frequency response function (FRF), and displacement of the last edge point of the shovels of the two boards are shown in Figures 2 and 3. The coherence of all frequency spikes was greater than 0.95. Based on the node lines (Figures 2, 3), the FRF and the displacement of the last edge point can be divided in five segments:

a) segment 1 consists of two spikes of a combined and the first bending mode of the shovel (23-45 Hz);

b) segment 2 encompasses spikes of combined modes (45-95 Hz);

c) segment 3 contains spikes of the first torsional mode of the shovel (95-140&160 Hz [boards B&A]);

d) segment 4 is comprised of spikes related to second torsional mode (140&160-190 Hz); and

e) segment 5 consists of a spike related to second bending mode (190-200 Hz).

The first spike of the FRF at 11 Hz is not a vibration mode per se, but rather rigid body motion of the shovel, rotating about the edge contact line. The greatest displacement of the last edge point is caused by the first torsional mode (segment 3), followed by displacement spikes of segments 1 and 2. The vibration modes of segments 4 and 5 show negligible displacement. Board A exhibited a larger movement range in segment 3 (first torsional mode) and the frequency peak was wider. The shovels of board A had a higher torsional stiffness (segment 3), whereas the ones of board B had a slightly higher bending/combined stiffness (segment 1). The edge mobility index \(I_{mob}\) after integration of the area under the displacement curve of the last edge point (grey areas in Figures 2 and 3) from 21.5 Hz to 200 Hz according to Equation (1) amounted to 86.7 in board A and 56.1 in board B. The last edge point of board A is therefore approximately 1.5 times as mobile as the one of board B.
4. Discussion

Board A had a higher torsional stiffness but also more edge mobility. The anecdotic rule that torsionally softer boards have poor edge grip could not be confirmed in the two boards investigated. According to Foss and Glenne 2007, ‘bending modes can also affect performance, but to a lesser degree’. As seen from the displacement-FRF of the last edge point, bending and combined bending/torsional modes (segments 1 and 2; Figures 2 and 3) affect the edge grip as well. That a highly active torsional mode (segment 3) is responsible for poor edge grip, as outlined by Foss and Glenne 2007, was confirmed by own results. However, it is debatable whether edge movement at a frequency of > 100 Hz (segment 3) really affects the edge grip, compared to lower frequencies of 20-40 Hz (segment 1). At lower frequencies, a turning board has more time to break out of the carve, whereas higher frequencies might be self-correcting. These assumptions need to be researched properly.

In the current study, the loaded boards were placed on soft foam, allowing the edge to move, instead of placing them on snow. Snow has two effects on snowboards: it allows vibrational movements of the edge and it excites vibrations. The latter can only be achieved by using a shaker under laboratory conditions. The former effect can be simulated by any soft surface. Hard snow constrains the edge movement more than soft snow does; hard snow, however, also excites vibrations at a higher energy. Standardised laboratory conditions are required for comparing different boards, and this includes a constant temperature environment, as low temperatures stiffen the boards, as found by Clifton et al. 2009. The overall edge movement (in nanometers, shown on the bottom plots of Figures 2 and 3), however, cannot be compared to the actual movement when riding on snow. The spikes of the vibration nodes are expected to be in the same location at the same temperature, independent of the surface. However, the damping effect of foam surface is expected to broaden the spikes.

In the current study, designed for developing a method for edge grip assessment, the boards were analysed at a tilt angle of 41 degrees. Further work needs to be done in order to compare the edge grip at different tilt angles and also on different soft surfaces.

5. Conclusions

The shovel of a loaded and tilted snowboard exhibits bending, torsional and combined modes. The first torsional mode generates the largest movement of the last edge point. Torsionally softer boards do not necessarily have a better edge grip.

Acknowledgements

The author would like to thank A. Hardy for designing the frame in Catia, and J. Harding for providing the two snowboard decks.

References


