ANALYSIS OF VIBRATIONS AND SHOCKS DURING THE PARALLEL TURN IN ALPINE SKIING

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INTRODUCTION: In downhill skiing a skier is exposed to shocks and vibrations caused by the interaction of skis and snow (Muller and Hautz, 1991; Hull and Mote, 1978; Wunderley et al., 1988). This interaction is directed by the controlled and reflex action of a skier's muscles. In this paper we present results on measurements of forces normal to the ski during downhill skiing and evaluate their effect on skiing safety. The main goal of the research is to the develop a tool for the evaluation of vibration isolators inserted between skis and ski bindings.

METHODS: Forces during downhill skiing on well packed snow using parallel technique were measured. Forces were measured at the contact point between the ski boot sole and the ski, using four force transducers per each leg (Nemec, 1997). Forces on both skis were measured simultaneously at the rate of 50 measurements per second. Force measurement was synchronized with the video image. Filtered data, using a low-pass filter with the cut-off frequency at 20 Hz, were then analyzed using power spectrum density in the frequency domain.

RESULTS: Measured signals were typical for parallel skiing technique, indicating clearly the loading and unloading phase in a turn. Sequential right and left giant slalom parallel turns, performed on carving skis, were analyzed. Video clips with the time marks of the analyzed turns are outlined in Figs. 1 and 2, respectively.

Fig. 1: Right turn

Fig. 2: Left turn

The measured reaction forces for the left and right turn and the motion of the force application point along the skis are presented in Fig. 3. The loading and unloadingphase for each turn can be distinguished from the force diagram.

(Fig. 3 is not printable).

Fig 3: Measured ground reaction forces and force application point for right and left turn

First we analyze the power spectrum density of both left and run parallel turn. From Fig. 4 it can be seen that the major part of the power spectrum is portioned for frequencies up to 3 Hz, and the power spectrum vanishes for frequencies above 9 Hz. The peak at low frequencies below 1Hz is due to the loading and unloading phase during the parallel turn. The spectrum for frequencies above 3Hz is due to terrain irregularities, since human musculature cannot produce frequencies higher than 3 Hz (Wunderly et al., 1988). If we compare power spectrums for the right and left turn in Figs. 5 and 6, we note a peak at low frequencies for the outer (loaded) leg regarding the parallel ski turn, which is due to the loading and unloading phase of the ski turn.

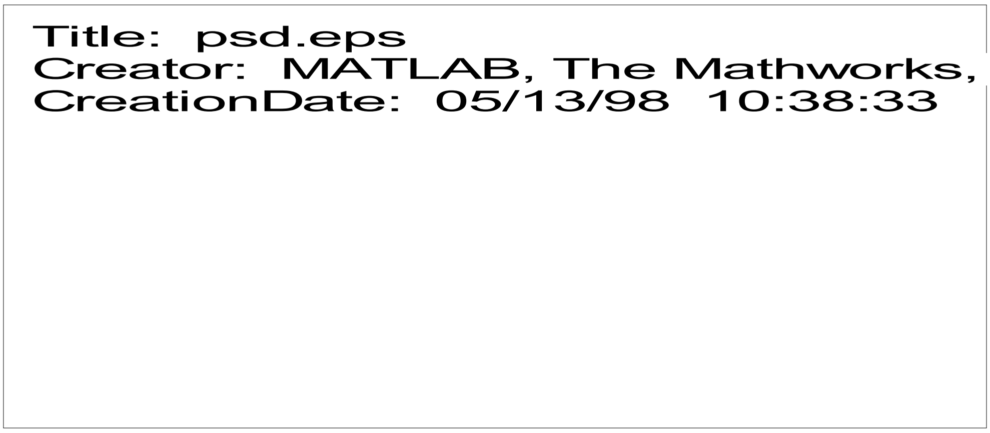

Fig 5: Power spectrum density for right and left turn

Observing power spectrum for frequencies above 2Hz it can be seen that in a parallel turn vibration magnitude on the outer (loaded) ski are greater than those acting on the inner (unloaded) one, which is an accepted result. Both legs are loaded with impulses with a typical duration of 0.05 sec. The average magnitude on the inner (unloaded) ski is about 0.3 times the weight of the skier, while the magnitude of the force pulses on outer (loaded) ski is up to the weight of the skier.

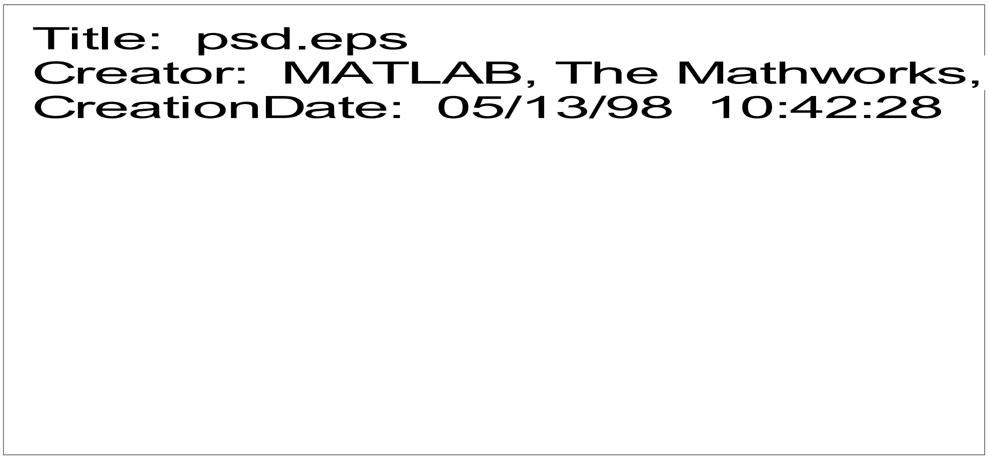

Fig 6: Power spectrum density for right turn

We repeated the analyses for over than 100 ski turns using the parallel technique with different skiers and different snow conditions, but we always got nearly the same results. We found out also that the skidding causes large vibrations, where the magnitude and frequency depends mainly on the type of snow. Consequently, skis with normal side cut produce larger vibrations comparing to the carving skis with short sidecut.

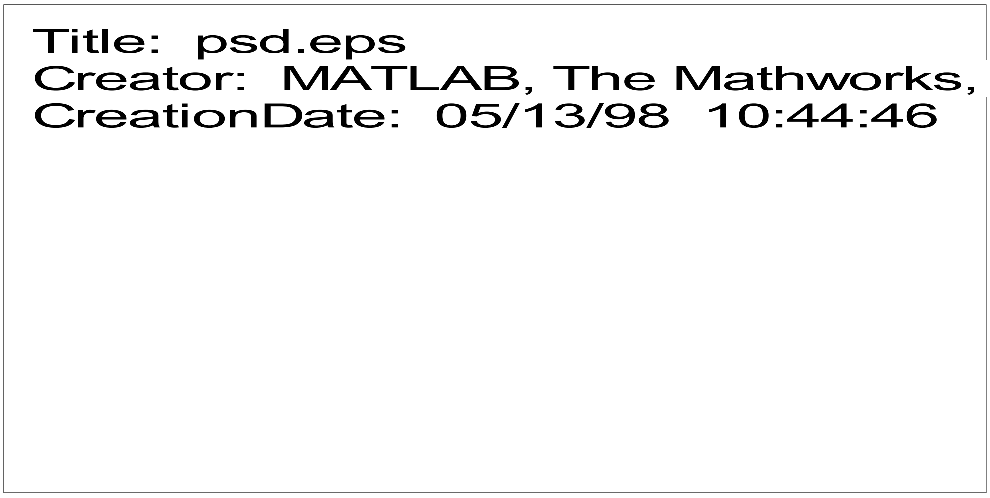

Fig 7: Power spectrum density for left turn

CONCLUSION: The analysis shows that for the parallel turn the outer (loaded) ski is more exposed to unfavorable loads than the inner one. The duration of impulses is estimated to be shorter then the time necessary for the voluntary and reflex action of the skier. These loads could damage the skier’s muscles and in particular knee ligaments. The developed methodology for vibration analyses will serve as an evaluation tool for the development of new vibration isolators between skis and ski bindings.

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