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Multibody Simulation of Carved Turns in Alpine Skiing

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Abstract. Carved turns with Alpine Skis were investigated using a computer simulation model. Varied input data to the model were snow conditions, edging of the skis, and the velocity of the skier. Results include the pressure distribution along the running surface of the skis and the trajectory of the skier.

Keywords: Alpine skiing, turns, pressure distribution, numerical simulation

1. Introduction

In Alpine skiing turns of a skier depend on several factors such as properties of the skis, properties of the snow and actions of the skier like loading and unloading or edging the ski. Furthermore the pressure distribution between ski and snow is an important factor describing the interaction between ski and snow (Kaps et al., 2001; Federolf, 2005). In the last few years a multibody model has been developed in order to study carved turns of a skier on two skis. The model was validated in the case of a single turn by Mössner et al. (2006). The aim of the present study was to compute the pressure distribution and the trajectory of the skier during two consecutive turns including a further developed model of the skier. Additionally the influence of edging and speed of the skier as well as snow conditions should be quantified.

2. Method

2.1. Skier and skis

The skier and the skis are modelled as a multibody system in the multibody system software LMS Virtual.Lab (Fig.1). For the skier a 7 segment model is used consisting of a trunk and two legs (shank, thigh, foot). Concerning the geometry of the segments the trunk is represented by an elliptic cylinder, thighs, shanks and feet are represented by cuboids. Mass properties are set accordingly to an average male skier. The ankle and knee joints are modelled by hinge joints allowing flexion and extension. The hip joint is modelled by a ball and socket joint. The body of the ski is divided into 19 segments along its longitudinal axis. Adjacent segments are connected by two revolute joints in order to model bending and torsion of the ski. Stiffness and damping properties of the ski are represented by spring-damper elements integrated in the revolute joints. In order to get realistic input parameters for the skis experiments in the laboratory were conducted.

2.2. Contact between skis and snow

In order to model the contact between the skis and snow three types of forces are used: penetration force, shear force and kinetic friction force. For a precise description of the contact between the skis and the snow, ski segments are further divided into 16 sub-segments. The penetration force is determined using a hypoplastic force-penetration relationship (Fellin 2000). This relationship is considered in order to describe the local loading and unloading behaviour of snow. In other words it can be used to describe the idea that in a carving turn the front part of the ski digs the track and the rear part of the ski follows this track. Shear force is modelled based on metal cutting theory (Shaw 1984). Friction between the ski and the snow is modelled using Coulomb friction and a friction coefficient μ = 0.07. Details concerning the implementation of the contact between ski and snow are described in Mössner et al. (2006).

2.3. Simulation of turns

A reference simulation was established consisting of two consecutive turns. Afterwards edging angles, speed of the skier and snow conditions were varied in the simulation.

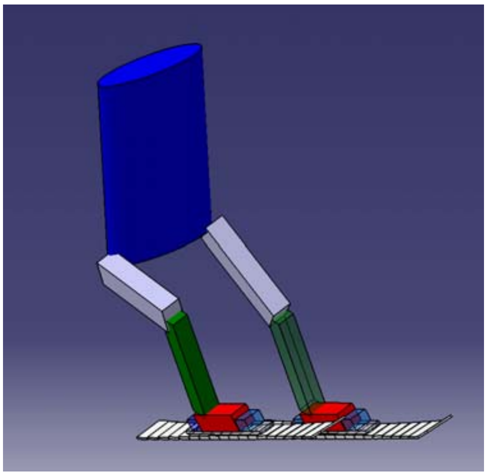

Fig.1: Multibody model of the skier and the skis.

3. Results

3.1. Pressure distribution

The results of the reference simulation showed that during the turn pressure shifted continuously from the inner to the outer ski. Most of the pressure was concentrated in the middle of the ski. This became more accentuated as load increased. At higher edging angles pressure shifted from the middle of the ski to the shovel and the tail.

3.2. Trajectory of the skier

In the simulation edging of the skier resulted in a significant effect on the trajectory of the skier. With raising speed of the skier skidding became more and more dominant and turns became wider. Snow conditions showed a significant influence on the trajectory of the skier at increased speed and low edging angles.

4. Discussion

This study quantifies the influence of the edging angle, the speed and the snow conditions on the pressure distribution between the skis and snow and as a consequence on the trajectory of the skier. Sharp pressure peaks and zones with little penetration depth should be avoided, because these factors lead to an increased risk of skidding. Here ski manufacturer and the skier are challenged. The strong influence of the edging angle of the skis indicated that actions of the skier were an important factor in order to perform carved turns. Especially at high speed and hard snow conditions edging gained additional importance.

5. Acknowlegement

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