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SKIING TURNS

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ABSTRACT

1. Introduction

We have developed a multibody model for a skier who performs successive turns on compacted snow. The skier consists of five rigid segments: trunk, left and right thighs and shanks. The segment are connected by joints. The hip joint is a ball socket joint, where the rotation is blocked, the knee joints and the ankle joints are rotational joints. We consider real skis with side cut, camber and given flexural and torsional stiffness. A ski is modeled by 19 rigid segments. The segments are connected by joints with rotational springs to model flexural and torsional stiffness. To model the ski-snow interaction we use a hypoplastic constitutive equation for the normal forces and metal cutting theory for shear forces. The equations of motion are established and solved by Vitual.Lab [LMS]. For each degree of freedom of a joint one has to provide a suitable driving constraint. We are interested in the behavior of forces and torques and especially on the pressure between ski and snow for varying velocities and snow hardness.

2. Method

In Fig. 1 the model of the skier is given. For each segment, one has to provide the position of the center of gravity, the position of the joints, the mass and the inertia tensor. Further, one has to provide driving constraints for the rotational joints modeling both ankle and knee joints as well as for the ball and socket joints modeling the hip joints. The turning is initiated by edging. The edging is controlled by choosing suitable functions for flexion/extension in all joints and a suitable angulation determined by abduction/extension in the hip joints. The skier must have an inward position such that the resultant force from gravity and centrifugal force is directed to the area between the skis. If the lateral component of the resultant force exceeds the ultimate shear force skidding occurs. We have have chosen a reference travel consisting of 3 turns. The first turn is not a complete turn, it serves just for starting. Then, we have computed solutions for softer and harder snow conditions as well as for lower and higher velocities.

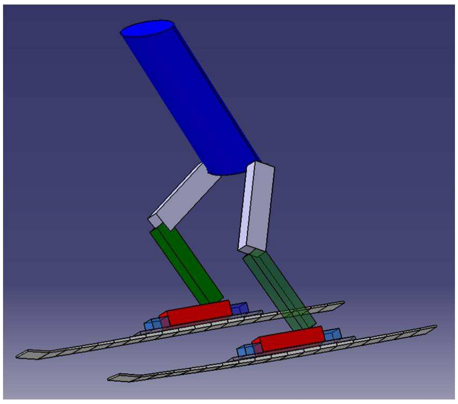

Fig. 1: Model of skier

3. Results

We are interested in forces and torques acting on the body segments. Here, we focus on the pressure between ski and snow. We present the results of the outer ski for three positions in a turn, at traverse angles of $45°$ in the beginning, $90°$ in the center and $135°$ in the end of a turn, see Fig. 2. In Fig. 3 the normal pressure between ski and snow is given. The top of the ski is on the left side, the end on the right side. Because of the vibrations of the ski segments mean values are plotted. At $45°$ the change in edging from one turn to the other is not yet completely finished. The centrifugal force and the lateral component of the weight have an opposite direction. Thus, the pressure is minimal. At the end of a turn the pressure maximum is reached, since then the centrifugal force and the lateral component of the weight have the same direction. For hard snow the penetration depth of the ski into the snow is considerably smaller than for soft snow. Thus, a smaller part of the ski has snow contact. Consequently, the pressure is maximal for hard snow.
The velocity in the reference configuration is about 10 [m/s], the larger velocity is about 12 [m/s]. Skidding occurs for the larger velocity. The skier can use the same inward lean angle as in the reference configuration. It is remarkable that at the rear part of the ski the penetration depth is larger and the pressure is smaller for a hypoplastic constitutive equation compared to an elastic.

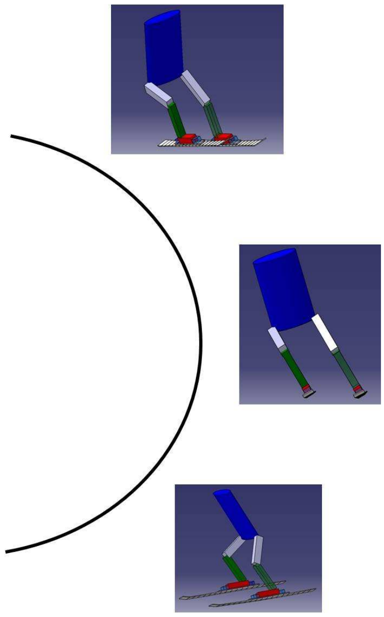

Fig. 2: Position of skier in turn

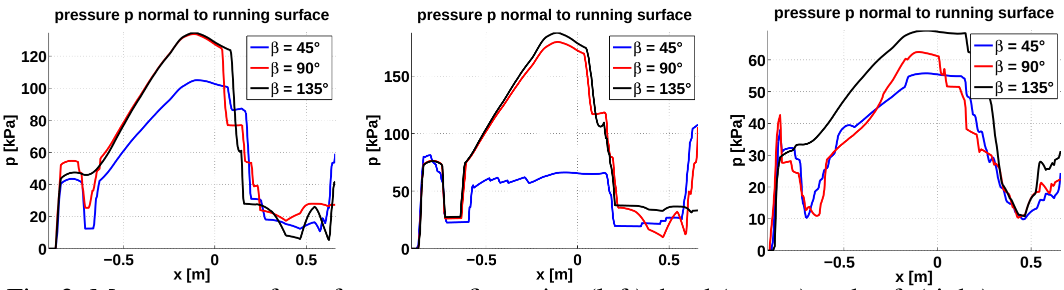

Fig. 3: Mean pressure for reference configuration (left), hard (center) and soft (right) snow conditions

4. Conclusions

The multibody model of a skier provides a substantial contribution to the basic understanding of skiing.

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