A MECHANICAL APPARATUS (SKIING MODEL) EXECUTING TURNS ON CARVER SKIS

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INTRODUCTION: The use of carver skis has for years been the topic of discussions and new concepts of optimal skiing technique, assuming that realizing curves should be possible only by canting the skis on their edges without the necessity of lateral sliding or turning skis (carving). Investigations objectifying the real effect of mechanical factors on the beginning (release) and trajectory of curves are generally interfered with by the 'biological system' of the subject (skier). Therefore, a mechanical apparatus (called: skiing model; see Fig. 1) was constructed which is able to pitch from one side to the other, can 'lean' forward or backward (to alter the center of gravity relative to the skis), and can be varied with respect to the angle of canting the skis (to alter the effect of the edges). Thus, the skiing model allows us to isolate the influence of different factors on carving (side cut of the ski, canting, center of force, etc.).

THEORETICAL BASIS: When the skiing model is positioned on the slope, it is possible to split the force taking effect parallel to the slope (F_H) into the perpendicular components F_V und F_Q (see Fig. 1). It is taken for granted that the further relations and influences of these forces are known (HOWE 1983).

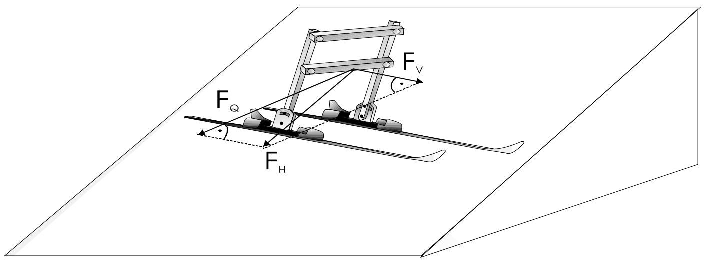
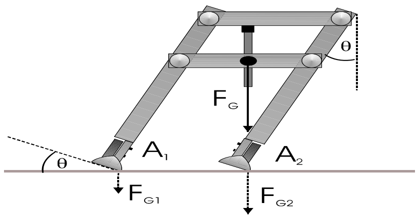


Fig. 1: Skiing model with defined angle of canting on the slope

In the neutral position both skis are loaded by equal forces (each one with half of the skiing model's weight). Leaning to one side, that is, taking a canting position, the center of gravity of the model (CG) changes its position: it is drawn down and shifted to the side to which the model leans. This change of CG produces a moment of rotation (torque; see Fig. 2). The effect of this torque is a load shift from one ski to the other (from A_1 to A_2). Canting the model as shown in Fig. 2a, one ski is loaded more than the other because the leverage *a* is increasing (Fig. 2b).

The relation between the angle of canting θ and F_{G1} to F_{G2} is calculated with the torque at A_1. E.g., the force distribution between A_1 and A_2 (F_{G1} vs. F_{G2}) with θ = 25° is approx. 1/3 vs. 2/3, so the "inner" ski's load (F_{G2}) is twice the load on the "outer" ski (F_{G1}).



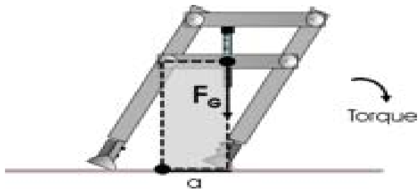


Fig. 2a: The model with defined angle of canting θ shown on the plane

Fig. 2b: Visualization of the torque

The carver skis are edged by taking a certain "angle of canting", which is a basic supposition for skiing a curve. However, not only the angle of canting, but also the "slope angle" (slant) α, and the "radius angle" δ, influence the curving behavior of the model. Depending on the position of the model on the slope, represented by the radius angle δ, there is a resulting "leaning angle" ε. The influence of the slope angle α on the leaning angle ε of the model is: $\varepsilon = \alpha \cdot \cos\delta$

To illustrate this relation, ε is shown in three major positions on the slope (Fig. 3).

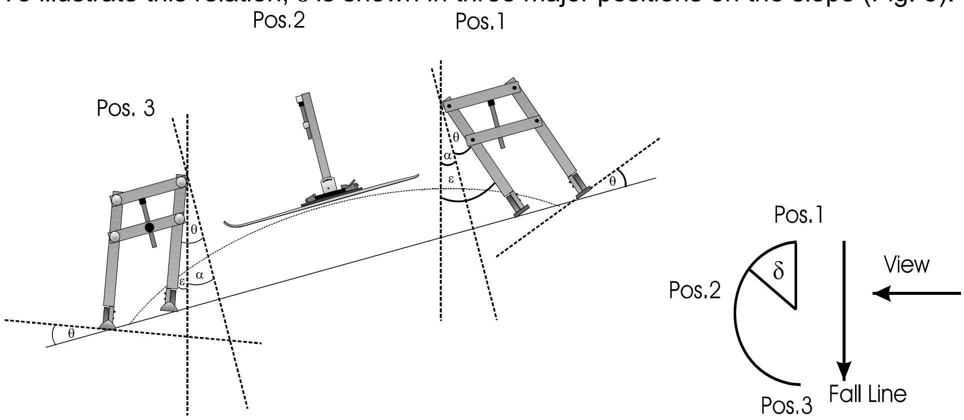


Fig. 3: Three basic positions of the model during a turn

The geometrical relations are given in the table below:

Position 1: starting point with δ = 0°	$\varepsilon = \theta + \alpha \cdot \cos\delta$ $\varepsilon = \theta + \alpha$	The slope angle α and the angle of canting θ complement one another with the effect of a maximum downhill leaning of the model.
Position 2: turning point related to the fall line with δ=90°	$\varepsilon = \theta + \alpha \cdot \cos\delta$ $\varepsilon = \theta$	The slope angle has no influence, so the relation between the angle of canting and the resultant leaning angle are the same as on the plane.
Position 3: final point with δ=180°:	$\varepsilon = \theta + \alpha \cdot \cos\delta$ $\varepsilon = \theta - \alpha$	The angle of canting θ is reduced by the slope angle α, so the resultant leaning angle assumes a minimum value.

The force to accelerate mass (F_H) in the direction of trajectory and its components F_V and F_Q, and the normal force F_N (which bends the skis and presses them into the snow) are taking effect on the ski edges (see Fig. 4). When both skis are edged, the force F_V determines the amount of effective force in the pointed direction. Using parallel side cut, the trajectory follows a straight line, because the force works in the same direction as the parallel edges of the skis.

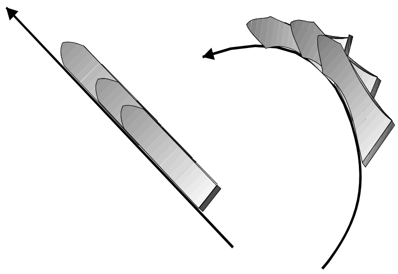


Fig. 4: Trajectory of canted skis with parallel and carver side cut

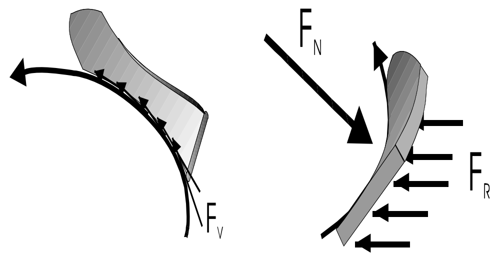


Fig. 5: The effect of forces on the carver ski

However, skis with carver side cut react in a different way: F_V is tangential at every point on the bent edge of the ski. Uniting the separate points of the edge gives the curved ski's trajectory, which is identical to the ski's side cut. In order to accomplish this movement of the ski, two additional forces must be effective:

Firstly, the ski has to be bent and pressed down with the load of F_N. Secondly, there must exist sufficient snow resistance (friction). So, the produced radial force F_R "compels" the ski to follow the curve given by the ski's side cut, without sliding.

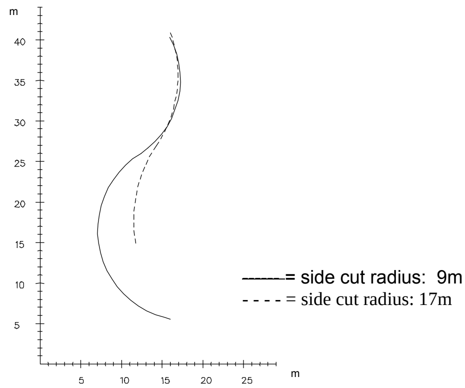
The effect of these conditions is that the skiing model mounted on carver skis should pitch from one side to the other while running only by establishing the proper angles, and thus execute consecutive turns. Depending on the side cut of ski, the result should be smaller or larger curve radiuses, respectively.

METHOD: To test these assumptions an exploratory study was realized on a prepared slope inside a ski hall. To collect cinematographic data, the runs of the skiing model, using two different carver skis under controlled conditions and slightly pushed to start running, were filmed by two synchronized Hi8-video-cameras. The carver's trajectory was evaluated and compared.

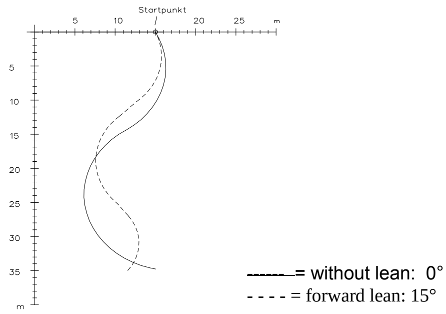
RESULTS:

- *Skiing Model executes curves:* Only edging and bending the carver skis causes the model to execute curves. This experiment proves the importance of the ski's side cut.
- *The skiing model shows constant curving:* Changing the "inner" and "outer" characteristics of the model, it is possible to alter the curve radius. Repeated runs under same conditions show constant trajectories.

- *Direct relation between side cut and ski trajectory:* the larger the side cut's radius the larger the curve's radius.



- *Direct relation between forward lean and ski trajectory:* the more the model leans forward, the smaller the radius.
Exemplary result: The increase of the angle of forward lean from 0° to 15° resulted in a decrease in the first curve's radius from approx. 13m to 12m (ski's side cut: turn radius 9m; inclination of hill: 9°, angle of forward lean: 0°; start velocity: 0 m/s; angle of canting 20°).



- *Direct relation between canting angle of the skis and the curve radius:* the larger the angle of canting, the smaller the curve radius.
Exemplary result: An increase in the angle of canting from 20° to 25° produced a decrease in the first curve radius from approx. 13m to 11m (other conditions as before).

CONCLUSION: Exclusively controlled by external forces in combination with the internal geometry of the skiing model, this mechanical apparatus is able to realize different turns. There is no need for muscular force and biological regulation for carving if the moving system provides the proper mechanical conditions. These results should influence the discussion of how to teach, learn and optimize skiing with carver skis.

REFERENCE:

Howe, J. G. (1982). Skiing Mechanics. Colorado.