SKI LOAD DURING PARALLEL AND CARVING TURN PERFORMANCE

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We were focused on parallel and carving turn comparison in terms of force field between ski and surface. Nine skiing lectors performance was observed using a special measuring and data recording device developed for this purpose at the Technical University of Liberec. At this stage, we were focused on ski load analysis during the turns, especially during the initiation and steering phase of the turn. The measurements revealed that it is very difficult, although essential for proper turn performance, to initiate a carving turn using equal edging on both skis. Furthermore, we found out that the maximal load level is higher and lasts shorter in parallel turn compared to the carving one. Despite the differences we state that, on our opinion, the skier has to practise both parallel and carving turns in a manner that enables adaptation of the riding technique to the overall conditions.

KEY WORDS: skis load, turn phase, force factor.

INTRODUCTION: A lot of analyses concerning ski ride technique evaluation have been performed in the recent time. Japanese theoretician Fukuoka (1971) was the first who used new knowledge and technical equipment in the area of wireless data transfer for biomechanical analysis of the skiing turns. Müller (1984) was focused on ski trajectory and their load manner. In the Czech Republic, the first was Čepelák (1955-1957) and later on Novák (1967). Hellebrandt (1997) dealt with legs laterality and its influence on skiing turns technique. Nachbauer & Rauch (1991) split the turn into three stages: initiation phase, steering phase and turn finish phase.

Remarkable changes especially in the ski construction and ski boots along with the shift to the carving skiing appeared in the recent years. The new construction enables ride on the ski edge for skiers of all skill levels. It leads mainly to changes in terms of trajectory and speed. New trends in biomechanics of alpine skiing were followed by Nachbauer & Kaps (2000), Müller (2004) and other authors. Results of the above mentioned authors show that use of a strain gage approach in combination with synchronous kinematical or time record of the ride can be a great advantage. We were focused mainly on description of important differences in terms of ski load during parallel and carving turns.

METHOD: To measure the force field representing interaction between ski and ground we used a specialised device capable of measurement of three forces and three torque values on each ski. The principle of the measurement, device mounting is described by Vodičková, Lufinka, Zůbek et al. (2003). The force measurement is based on specially-shaped element deformation measurement by strain gages. During the measurement, all the data are stored on a Compact Flash Disc at the rate of 100 Hz. The data recorder is placed in a small bag on the skier's back, thus the ride is not influenced by the equipment. The recorded data can be synchronized with the video-record using a set of LED diodes.

The measurement was preceded by four pilot studies which evaluated the developed device. The measurement was performed in December 2004 on an Italian glacier at very good conditions. Nine skiing lectors in total were measured performing three types of medium turns, i.e. basic turn, parallel turn and carving turn. The data were recorded at 100 Hz sampling rate and subsequently filtered by a low pass filter with cut-off frequency 10 Hz. In order to transform the recorded data to proper scales of SI units we created specialized software.

Nowadays we have evaluated 145 parallel and 135 carving turns in total. Subsequent data processing has been performed using statistic methods (Microsoft Excel) and the results are shown in the next section.

RESULTS AND DISCUSSION: Based on x-axis torque correlation with the video-record we defined every turn timing, while positive values represent right turn and negative left one. Fig. 1 shows the used coordinates system.

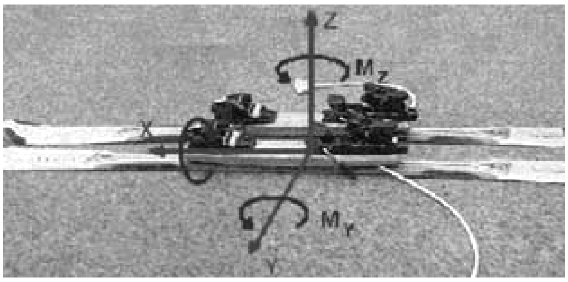

Figure 1: Coordinates system

We analysed 135 carving (out of that 68 left) and 145 parallel (74 left) turns. According to the M_x torque, average time for the carving and parallel turn is 0.791 $\pm$ 0.275 s and 0.901 $\pm$ 0.275 s, respectively. It means that carving turns are 0.11 s shorter than parallel ones in terms of time duration (for the same turn length) which represents 13.9 % change. This comparison reveals faster turn ride-through when the turn is performed using edges, which is typical for carving turns. The first two turns lasted longest time in all analysed cases. This can be explained by a low velocity shortly after start. On the other hand, the shortest turn (0.27 s) was performed as a result of external conditions change. M_x values on the left ski varied in range of -57 to 83 Nm during carving turn and -50 to 85 Nm during parallel turn. The values for the right ski were in range -80 to 69 Nm and -90 to 50 Nm for carving and parallel turn, respectively. These values correspond with edge position of the skis, while positive M_x values are typical for a right turn, negative for the left one.

During the carving turn, both knees move inwards the arch and both skis are gradually edged since the initiation phase, while absolute value of M_x is rising (both skis). This is typical for carving turn during which the lectors try to use equal edging of both skis using distinctive side cut of the skis. Remark: the equal edging for both inner and outer ski was not fully achievable using older ski construction; comparison made e.g. by Nachbauer & Kaps (2000). The torque values varied in range -80 to 83 Nm. Taller skiers display higher absolute values of the M_x. This is in correlation with lever ratio conditions of each skier.

During the parallel turn, consecutive edging of both skis rises since the initiation phase. Unlike the carving turns, the absolute M_x value is not rising equally on both skis. The inner ski is edged before the outer ski. Then the inner ski M_x change rate gets lower while the outer ski edging is continuously rising. Maximal absolute values of the M_x can be observed during the turn always on the outer ski. It is necessary for required edge rebounding at compensation body slope. The outer ski returns to the flat position ($M_x \cong 0$ Nm) before the inner one. This phenomenon can not be observed in the carving turn.

As we denoted in the introduction, the ski load changes during the turn, mainly because of skier's body position change. While comparing parallel and carving turn, it is essential to perceive the way (what time instant) the centre of gravity of the skier's body changes. In parallel turn, the ski unloading is ensured by the centre of gravity movement upwards, while the ground reaction rises before the skis are unloaded. The vertical movement is remarkably lower in carving turn compared to the parallel one and the carving turn is performed using centre of gravity movement downwards, while skis are unloaded just right after the movement start. The evaluation revealed that the maximal load of the skis during the parallel turn lasts shorter time and reaches higher value than during the carving turn (Table 1).

Table 1: Fz values during medium turns

	m [kg]	parallel				carving			
		$_L$Fz max[N]	$_L$Fz min[N]	$_P$Fz max[N]	$_P$Fz min[N]	$_L$Fz max[N]	$_L$Fz min[N]	$_P$Fz max[N]	$_P$Fz min[N]
1.	97	-93	-1454	-95	-1107	-153	-1480	-146	-1254
2.	100	-94	-1811	-102	-1423	-149	-1754	-153	-1306
3.	80	-50	-1422	-53	-1154	-124	-1315	-120	-1068
4.	80	-53	-714	-52	-550	-108	-694	-102	-502
5.	108	-104	-1523	-96	-1309	-151	-1406	-136	-1215
6.	82	-60	-817	-53	-638	-96	-721	-112	-495
7.	70	-50	-648	-51	-552	-82	-556	-78	-409
8.	85	-61	-1350	-72	-1106	-150	-1410	-142	-1128
9.	83	-69	-1059	-76	-730	-81	-802	-71	-740
Me	83	-61	-1350	-72	-1106	-124	-1315	-120	-1068

Legend: m- skier's weight including equipment, $_L$Fz – vertical force component – left ski, $_P$Fz – vertical force component – right ski, Me - median

For the carving turns, the curve of the F_z time-course can be approximated by a sinusoidal curve oscillating around -700 N value (skier weighting 100 kg). It can not be found in the parallel turn. The continuous changing of the load and unload is typical for the carving turn and can be considered as optimal performance of the edge-ride turn (cut turn). Unlike the carving turn, the parallel one includes very fast unload of the ski after the maximal load making the skis to turn and skid. This is the fundamental difference between parallel and carving turn.

CONCLUSION:

Based on our evaluation we conclude the following:

- medium parallel turns last longer than the medium carving ones (13.9%);
- not all the evaluated skiers were able to initiate carving turn using outer edge of the inner ski and inner edge of the outer ski simultaneously;
- the right skis position on their edges and simultaneous load during the initiation phase is crucial for subsequent steering phase and for resulting shape of the carving turn;
- maximal load of the skis during the parallel turns lasts shorter time and the values are higher than during the carving turns

Practise recommendations:

- while training carving turns it is important to apply special attention to the initiation phase to ensure movement of both knees inwards the arch and loading both inner edge of the outer ski and outer edge of the inner ski
- aside carving turns training it is important to train also parallel turns which, thanks to skid participation, can prove useful in all terrains mainly by skiing public.

We were focused on M_x and F_z evaluation during carving and parallel turns which we consider crucial in terms of training of skiing and turning. Other forces and torques analysis is, for its complexity, subject to further processing. We are also aware of the fact that such studies are usually made including a spatial video-analysis to ensure complex view on the problem. We used our observation using only one camera to confront the recorded data with picture. An observation of racers group was performed using a 3D video-analysis which is currently being evaluated and the results will be published later.

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