Studies on skier’s ski control and ski’s motion

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Introduction
Many studies on a skier’s ski control have been reported and its effects on a skiing have been discussed frequently. It is axiomatic that the shape and mechanical properties of the ski effect on a skiing. However, in most reports, their effects on the skiing have not been considered since there is no approach for estimating their effects except for the approach developed by the authors. First, the authors have proposed a numerical approach for the analysis of the motion of the ski lying on an elastic foundation when a vertical force acts on the shoe center of the ski\(^{(1)}\). Next, they have developed a numerical approach for estimating a ski turn. By using the approach, one can discuss the effects of skier’s ski control, the shape and mechanical properties of the ski and the property of a slope on the ski turn\(^{(2)}\). Although many useful results for a design of the ski and interesting results for the skiing were obtained by using the approach, the approach has some points being necessary to be improved. One of them is the model of the skier’s ski control. Although the skier’s ski control is modeled by a force from the skier to the ski and the displacement of the skier’s center of gravity, the force and the displacement are given by very simple functions of a time variable because the skier is modeled by a particle of which mass equals to the skier’s whole mass.

The purpose of the present study is to develop a better model of the skier’s ski control for studying more precisely the effect of the skier’s ski control on the skiing. The skier is modeled by a multibody system consisting of a head, a body, two arms and so on. The force acting from the skier to the ski is attempted to estimate from the motion of the skier. The skier’s motion is videotaped and the picture is analyzed by an image processing technique. From the obtained results, the force acting to the ski from the skier is estimated and it is used for the calculation of the ski’s motion. The ski’s motion caused by the skier’s motion (the skier’s ski control) is measured experimentally. Numerical and experimental results of the ski’s motion are compared.

Experimental and Numerical studies
Experimental setup:
Experimental setup is shown in Figure 1. The urethane sheet of 0.04m thickness is used as an elastic foundation instead of a snow slope. The ski lies on the urethane sheet placed on a horizontal surface plate. To measure a force \(q\) acting on the ski from the skier, four load cells are put around a shoe center of each ski and they support the skier through binding plates and ski boots. Two video cameras were used to measure the skier’s motion. The motion of the ski was measured by four laser displacement sensors \((L_1, L_2, L_3, L_4)\).

Skier’s ski control:
As a skier’s ski control “Up-weighting” and “Down-unweighting” actions were studied. The motion of the skier was videotaped. The skier is modeled by a multibody system consisting of nine kinds of part as shown in Figure 2. The mass of each part is estimated from the standard distribution of mass of human body\(^{(3)}\) (see Table 1) and the skier’s whole mass. The skier’s motion, that is the skier’s ski control, was analyzed from the videotaped picture by using an image processing technique, and the displacement of each part of the skier’s body was obtained. From
the displacement and mass of the each part, the displacement of the gravity center of skier’s whole body was estimated. Next, the vertical force $q$ acting on the ski from the skier was calculated from the whole mass of the skier and the acceleration estimated from the vertical displacement of the skier’s gravity center. Furthermore, the vertical force $q$ was measured by four load cells put between the ski and binding plate for the comparison of numerical and experimental results. Figure 3 shows an example of the comparison. The vertical force $q$ estimated numerically agreed well with that obtained experimentally.

Ski’s motion:
The ski’s displacement $d$ caused by the skier’s ski control was measured by laser displacement sensors at the positions ($L_1, L_2, L_3, L_4$) shown in Figure 1, and they were estimated numerically, too. As the skier’s ski control, the vertical force $q_s$ estimated from the vertical force $q$ measured experimentally was used. The ski sold in the market was used in this study. The ski was assumed to be a non-homogeneous orthotropic plate for a numerical calculation. The shape (width $B$ and camber height $A$) and mechanical properties of the ski (mass per unit area $\gamma$ and flexural rigidities $D_5, D_n, H$ and $D_1$) are shown in Figure 4. The axis of abscissa, $\xi$, in Figure 4 shows the distance from the shoe center in the longitudinal direction of the ski. The urethane sheet was assumed to be an elastic material of which force per unit area $P(N/m^2)$-displacement $\delta(m)$ relationship is given by $P=2.21E6\delta-1.09E4$. The numerically estimated displacement $d$ at the point $L_2$ apart 0.232(m) from the shoe center of ski agreed well with that obtained experimentally as shown in Figure 5.
Conclusions

The motion of the ski caused by the skier’s actions was measured when the skier did “Down-unweighting” and “Up-weighting” actions. The motion of the skier which is called as the skier’s ski control was videotaped at the same time. The videotaped picture was analyzed by the image processing technique and the force acting to the ski from the skier was estimated. Using the estimated force the motion of the ski caused by the skier’s action also was calculated numerically. The motion of the ski calculated agreed well with that measured experimentally. Since the skier was modeled by the multibody system in the present study, we can discuss the effect of each part of the skier on the ski turn by using the numerical approach proposed by the authors. A part of the work was supported by the Grant-in-Aid for Scientific Research (C) No.12650237 of the Japan Society for the Promotion of Science.

References