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The features of the landing slope of a ski jumping hill that need to be considered

Kazuya Seo[a]*, Yuji Nihei[b], Ryutaro Watanabe[b], Toshiyuki Shimano[c], Takayuki Sakaguchi[a]

[a]*Yamagata University, 1-4-12 Kojirakawa, Yamagata 990-8560, Japan*
[b] *Yamagata City Office, 2-3-25 Hatagomachi, Yamagata 990-8540, Japan*
[c]*Access Corporation, 2-3-4, Minami-1-jo Higashi, Chuo-ku, Sapporo 060-0051, Japan*

Abstract

This paper describes the features of the landing slope of a ski jumping hill that need to be considered. A ski jumping hill is composed of the in-run, the take-off table, the landing slope and the out-run. The features of the landing slope that we have considered are the construction fee, the safety of the landing slope, the long flight distance for the interesting game and the difficulty for unskilled jumpers. The construction fee was estimated on the basis of the amounts of material that need to be removed from and brought in to the existing Zao jumping hill in Yamagata city. The safety on landing was estimated on the basis of the landing velocity. The landing velocity is the velocity component perpendicular to the landing slope at the instance of landing, and this needs to be small to reduce the impact and make the landing safer. In order to estimate the landing velocity and the flight distance, it is required to simulate the flight trajectory. The difficulty for unskilled jumpers is estimated on the basis of the variance of the flight distance. It is considered that the flight distances for unskilled jumpers are less than for skilled jumpers because they are unable to satisfy the optimal conditions from take-off through to landing. Therefore, a landing slope for which the variance in the flight distance is large is defined as a difficult slope for unskilled jumpers.

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Keywords: Landing slope; Ski jumping; Safety landing; Construction fee; Variety

* Corresponding author. Tel.: +81-23-628-4350; fax: +81-23-628-4454.
E-mail address: seo@e.yamagata-u.ac.jp

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Nomenclature

b	Width of the landing slope
FD_i	Flight distance around FD_L
FD_L	Longest flight distance
g	Gravitational acceleration
D	Drag
I_{yy}	Moment of inertia of the body–ski combination on its y_b –axis
h	Height difference between the old Zao and the new Zao
L	Lift
M	Pitching moment
m	Mass of the body–ski combination
Q	y_b component of the angular velocity vector
(U, W)	(x_b, z_b) components of the velocity vector
$v\perp$	Velocity component perpendicular to the landing slope at the instance of landing
(X_a, Z_a)	(x_b, z_b) components of the aerodynamic force
(x_b, z_b)	Body-fixed coordinate system
α	Angle of attack
β_H	Slope of the landing hill at the landing point
γ	Flight path angle
Θ	Pitch angle

1. Introduction

Since 2012 the Zao jumping hill in Yamagata city has been host to the annual ladies world cup. A ski jumping hill is composed of the in-run, the take-off table, the landing slope and the out-run. The Zao track was renovated to resemble the ski jump at the Sochi Games in 2013, with a take-off table with an angle of 11 degrees downhill. A further renovation related to the landing slope is being planned for 2015. This is the subject of this study. The features of the landing slope that we have considered are the construction fee, the safety of the landing slope, the long flight distance and the difficulty for unskilled jumpers.

In this paper, it will be discussed how to estimate four features of the landing slope, which are the construction fee, the safety of the landing slope, the long flight distance and the difficulty for unskilled jumpers.

2. Construction fee

The construction fee was estimated on the basis of the amounts of material that need to be removed from and brought in to the existing Zao jumping hill. Lower cost is, of course, better.

The inertial coordinate system is shown in Fig.1. The origin is defined as being at the edge of the take-off table, while the X_E-axis is in the horizontal forward direction and the Z_E-axis is vertically downward. The height difference between the old Zao and the new Zao at X_E is denoted by $h(X_E)$ as shown in Fig.1. The width at X_E is denoted by $b(X_E)$. The amounts of material that need to be removed from and brought in to the existing Zao jumping hill are derived by equation (1).

$$Amount\ of\ materials = \int_0^{X_E(tf)} h(X_E)\cdot b(X_E)\, dX_E \tag{1}$$

Here, the flight time is denoted by tf. The construction fee depends on the height at which material needs to be removed from and brought into the existing Zao jumping hill. The greater the height, the more expensive the construction fee. Here, the lowest cost is at Z_U (the lowest height) and this is assumed to be 200 Japanese yen per 1 m^3, while the highest cost is at Z_E=0 (the highest height), which is assumed to be 10,000 yen per 1 m^3 on the basis of