THE ESTABLISHMENT OF MATHEMATICAL MODEL OF THE TAKE-OFF SPEED OF AERIALS OF FREESTYLE SKIING

Wang Xin[1], Fu Yanming[1] and Zhao Le[2]

School of Sports Kinetics, Shenyang Sport University, Shenyang, China1
Sport Science College, Shenyang Sport University, Shenyang, China[2]

The take-off speed of freestyle skiing aerials is one of the key factors which can decide the success. However, the take-off speed depends on snow quality, circumstance condition, in-run slope angle, in-run distance, air resistance and skiers' action. By using sports biomechanics, mathematical model and numerical simulation method and combining theory with experiment, this study sets up a mathematical model of outside circumstance and skiers' self-adjustment, simulates the changes of inside and outside stress in each stage of sliding, calculates the parameters intuitively and then forms into speed values. The setup of this model can provide scientific guidance for ensuring necessary take-off speed for specific actions.

KEY WORDS: freestyle skiing aerials, take-off speed, mathematical model method, calculation software, integral operation.

INTRODUCTION: The movement structure of the freestyle skiing aerials consists of in-run, take-off, soaring and landing[1]. And one of the key factors that determine the success of the action is the control of the soaring height, which involves the control of take-off speed[2]. This paper focuses on the air resistance simulation and skiers' internal regulation, using the simulation technology to reveal the effect of pedaling acceleration and lifting arm of freestyle skiing of aerials skiers on supporting force[3-4]. The simulation technology has been widely applied to the study of sports events at home and abroad for its advantages of fast computation and the reduction of the experiments. This paper also explores methodsby which the reaction force value measured in laboratory is directly loaded on computer software to simplify the simulation calculation process.

METHODS: The research object is Chinese women's freestyle skier Xu Mengtao whose total score ranks the first in the world, and Jia Zongyang, the champion of men's freestyle skiing aerials in the 24th Universiade. We establish three-dimensional solid model of skiers according to the theory of reverse model and 3D laser scan. By adopting the module insert / merge and inherited functions of 3D virtual design in pro/ENGINEER, we establish the space model of skiers' flow around field. Finally, the air resistance and lifting value will be computed in the software ofAdina.By adopting the method of laboratory simulation, we measure the supporting counter force of different stances to pedal and lift arm of skiers. Finally, we select the mathematical calculation software of Matlab to calculate the take-off speed and establish equation of the take-off speed control to calculate the take-off speed.

RESULTS: Forces skiers geton the in-run slope are all written in function that force changes as the location of the in-run slope changes, according to the integral expression of Newton's second law:

$$\frac{dv}{dx} \Rightarrow \int_{x_0}^{x} F_{(x)}\,dx = \int_{v_0}^{v} mv dv \Rightarrow v(x) \text{Formula1}$$

As shown in figure 1, skiers put on weight on the in-run slope. While x is the in-run distance, v is the skiers' running speed, α is the inclination angle of ski track, *G* is gravity, *N* is supporting force, f' is air resistance, *f* is friction force, L is lift force. Skiers do the regulatory action in the sliding process, namely that the change of body stance will be a force on surface, in turn, snow surface also gives human a force *N*, *N* can be decomposed into force N_x which parallels to the snow surface, force N_y which perpendiculars to the snow surface and force N_z along the body axis (influence on in-run speed direction is so small as to ignore).

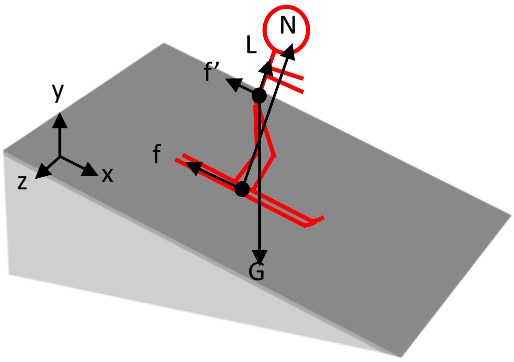

Fig.1The figure of skiers' stress in straight segment

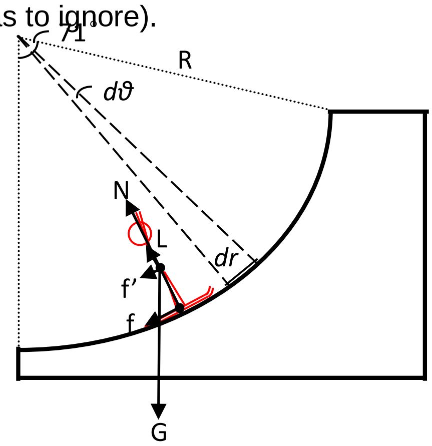

Fig.2The figure of skiers' stress in curve segment

According to Formula 1, the motion equation along the slope on the in-run slope is as follow:

$$\int_0^x (f + f' + G_x + N_x)dx = m\int_{v_0}^{v} vdv \quad \text{Formula2}$$

Bodies of skiers have kept upright before entering the arc zone of platform, and they basically go up onto the platform maintaining this posture. In view of the fact that this posture doesn't get changed, and meanwhile simplifying the calculation, this process ignores the influence that the variation of supporting counter-force of human body has on the speed of leaving platform. Considering skiers always slide on the curving surface, the radius of curvature is regarded as a fixed value, and the equation of velocity of leaving platform adopts the theorem of kinetic energy to calculate. The equation is shown as Figure 2:

$$W_{A-B} = \int_A^B (f + f' + G_x).dr = \int_0^{\alpha} (f + f' + G\sin\alpha).Rd\alpha \quad \text{Formula 3}$$

Air has a huge influence on the action effect of freestyle skiers. The control equation of the flow field around a player is turbulent model, and finite element method can be used to solve this equation. Adopting mesh generation on the established flow field space model (it is divided into more than 8 units), as shown in Figure 3. Considering the relatively large velocity gradient of the boundary layer, which is close to the surface of skiers and complex skiers' surface, the grids of skiers' surface are specially encrypted, as shown in Figure 4.

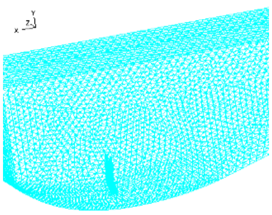

Fig.3Turbulent model of mesh

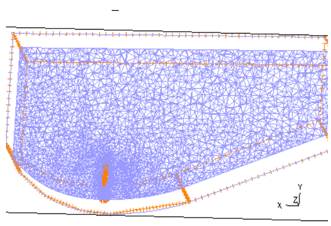

Fig.4 Encrypted grids on skiers' surface

$f' = \frac{1}{2} \rho C_k A(V + V_f \cos\theta)^2$Formula4

$L = \frac{1}{2} \rho C_S A(V + V_f \cos\theta)^2$Formula5

During the whole movement process, due to the windward area of skier's body is variable on the in-run slope, and the sliding speed of human body is variable in the in-run process, the calculation equations according to the resistance and lift force of air are, In this equation, C_k is resistance coefficient, ρ is air density, V_f is wind speed, $\Theta$is wind direction angle, andC_S is lift force coefficient.Regarding the influence of wind on the auxiliary sliding speed, the most important factor is wind speed. Through smoothly simulating calculating software to calculate the resistance coefficient and lift force coefficient of human body in different position, and then calculate the values of the resistance and lift force of the air when skiers slide thrusting against the ground in different wind directions and postures.Regulation force is the force influenced by variable postures of skiers themselves, namely the force that generated by skiers' changing postures. In order to fix the values of supporting counter force in different postures, the fitting function of the value of supporting counter force and the and the size of the joint angle is established according to the joints which have primary influence in different stages.In the software, the calculation of leaving platform speed's control equation uses Euler to do the calculation of two segments' ordinary differential equations.Assuming that f(x,y) in the y'=f(x,y) ($a \leq x \leq b$) is sufficiently smooth, expand y(xi+1) at point x I by Taylor. So we get $\begin{cases} y_{i+1} = y_i + K \\ K = hf(x_I, y_i) \end{cases}$According to figure2, the motion equation of direction which is along the slope of approach is as follows.According to formula1, there is$dv = \frac{\sum F}{mv_i} \cdot dx$, When Δx is very small, there is $dv \approx \Delta v = K \cdot \Delta x$,so $dv = f'(x_i)\Delta x$, $f'(x_i) = \frac{\sum F}{mv_i}$ .According to equation of Taylor expansion, the equation of speed is$\begin{cases} v_{i+1} = v_i + h\frac{\sum F}{mv_i} \\ v_0 = 0.8 \end{cases}$Curve equation's calculation method is the same, here is a little.

CONCLUSION: To sum up, the air resistance, friction coefficient, jumping, sliding distance, posture changes will affect the speed .This paper uses numerical simulation method to demonstrate the whole process of the external environment and skiers' self-regulation, and then to quantitatively simulate the force that skiers get during the whole process, which can help athletes and coaches adjust the body posture and help increase sliding distance. We should ensure a reasonable pace vacated, flight time for different actions and the quality of the ground. Analysed from kinematics, aerial action of freestyle skiing is enable athletes to gain vertical velocity on the air. When the vertical velocity is increased, theflight height is bigger, the movement completed is relatively better, according to the scoring criterion of judgment reflecting the high floating principle. The pre-efficient determined slide aid scheme will help coaches and athletes reduce the number of the venue and get good grades.

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Acknowledgement

This work was financially supported by the National Natural Science Foundation (11102120).