Numerical Simulation of Wind Field Based on Topography of Lanzhou Zhongchuan Airport

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Abstract. Lanzhou Zhongchuan Airport is one of the Northwest's largest aviation hubs, and it is greatly affected by the wind shear. Due to the low-lying terrain of the airport and the terraced terrain, the wind field around the airport is closely related to its topography. This paper set up the digital elevation model of the terrain near the runway with an area of 6KM*6KM*2KM, and wind field numerical simulation is solved by Fluent software. The wind speed and pressure distribution characteristics of the simulated wind field are obtained by iterative computation. Using the method of horizontal plane at mountain area, the local influence of topographic factors on the wind field is analyzed. The results show that when the wind flows through the surrounding mountain area, due to the ups and downs of the mountain, the wind speed has a big difference in different height layers, and it is easy to cause crosswind shear, which has an impact on the flight safety. The results have important reference value for the research and low-level wind shear forming factors of wind field caused by complex terrain, and it is of great significance to deeply understand the mechanism of wind shear.

Introduction

Located in the southeast end of the Qin Chuan basin in Yongdeng County, Lanzhou Zhongchuan Airport is one of the Northwest's largest air hubs, surrounded by mountains around the airport. The northern part of the airport lies on the lee side of the Wushao Mountain, and the west side is the Qilian Mountains. The complicated geometry features of the complex terrain make the environment of the wind field very unstable. The fluctuation of regional underlying surface \cite{1} is one of the important factors that affect the upper air field. Air flow through rough surface is more likely to generate turbulence, thus increasing the instability of wind field in the whole region. This situation has increased the likelihood of meteorological conditions affecting aviation safety, such as wind shear and turbulence.

The rough surface layer to wind field distribution is non-uniform height, the observation data obtained by wind rod has certain limitations, and it can not fully represent the local wind field changes. Therefore, the refined wind field distribution in complex terrain is obtained by numerical simulation, and the data are more reliable. The application of computational fluid dynamics CFD \cite{2-3} (Computational Fluid Dynamics) model, which is commonly used in the computation of aerodynamic fine flow field, has attracted more and more attention in the field of Meteorology, especially from the beginning of the world in 80s. CFD is penetrated into the research field of meteorological factors of wind gradually. Wood et al. studied the changes in wind speed of the storm surge over the top of the mountain \cite{4}. Hangan used CFD to study the characteristics of the wind field in the lower storm surge wind \cite{5}, Paterson and Apelt discussed the k-\varepsilon model of turbulence, they considered this model to be a simple, efficient and accurate method for computing the flow past a 3D rectangular body surface, and this method has been widely used in later generations \cite{6}; Li Lei selected the k-\varepsilon epsilon model to verify the feasibility of applying FLUENT to meticulous simulation of complex terrain \cite{7}.
According to the Lanzhou Zhongchuan Airport and the surrounding terrain, establish a wind field model of the 6KM*6KM*2KM range, and through the FLUENT software on the wind field model with full wave model for simulation, analysis of the local terrain wind field. In this paper, the analysis of the wind speed variation in different height layers is of great significance for the further study of the factors affecting the aviation safety factors, such as the possibility of low-level wind shear.

The Establishment of Zhongchuan Airport Digital Elevation Model

According to the latitude and longitude of the airport coordinates and the terrain conditions around Zhongchuan airport rolling hills and basin [8], the corresponding terrain data file are downloaded from the website, importing Global Mapper software for coordinate conversion. The coordinate system of longitude and latitude in data is converted to Universal Transverse Mercator Grid System (UTM) plane Cartesian coordinate system. In the software, the selected coordinate method is used to obtain the target range region. Extracting the terrain data from the Digital Elevation Model (DEM) file [9], and converting the grid coordinate representation to point coordinate representation and imports vertical height Z coordinates for each point. Finally, the destination region terrain data file is derived. As the original data, using the MATLAB software to generate fixed format instruction files, loading Gambit can automatically run the background to generate undulating terrain surface [10].

Design of Experiment Scheme

In this paper, using the model of non-uniform method of mesh grid points and the distribution of the definition of line, of which the grid spacing with 30m boundary in the grid area in the main generation of tetrahedral mesh, but the area which are far away from the boundary can be tapered hexahedron, and wedge grid contains. Air as a fluid has viscous characteristics, and without the addition of external energy, the motion of fluid will stop gradually, and the Maher number of the air flow determines that it is incompressible, therefore, there is no need to choose the energy equation. Considering the range of simulated regional scales of 6KM, the Coriolis force has also been ignored [11]. The optimal convergence speed and accuracy are achieved by using a variety of Fluent software solutions and multigrid accelerated convergence techniques. In order to facilitate the observation of the iterative process, a residual monitor is set up to observe the convergence of the curve, and the number of iterations is increased to 50 times. The dominant wind direction at Lanzhou Zhongchuan Airport is influenced by the topography of the northwest, mainly westerly winds from the mountains. In view of this situation, the boundary conditions of this simulation are set as the inlet side of the wind field as the inlet wind speed surface, and the wind velocity 6.7m/s as the inlet flow parameter value is taken into account. A full wavelength model [12] is used for numerical simulation of crosswind as follows:
\[
\begin{aligned}
V_w &= 0 & x < 0 \\
V_w &= \frac{V_{w0}}{2} (1 - \cos \frac{\pi x}{d_m}) & 0 \leq x \leq 2d_m \\
V_w &= 0 & x > 2d_m
\end{aligned}
\]

The renormalization group model is chosen as the turbulence model. The renormalization group model is a model derived from the mathematical method of renormalization group for the instantaneous Navier-Stokes equation \[^{[13]}\]. The turbulent kinetic energy and dissipation equation are as follows:

\[
\rho \frac{Dk}{Dt} = \frac{\partial}{\partial x_i} \left( \left( \alpha_{k} u_{i} \right) \frac{\partial k}{\partial x_i} \right) + G_k + C_{b} - \rho \varepsilon - Y_{m}
\]  \hspace{1cm} (2)

\[
\rho \frac{D\varepsilon}{Dt} = \frac{\partial}{\partial x_i} \left( \left( \alpha_{\varepsilon} u_{i} \right) \frac{\partial \varepsilon}{\partial x_i} \right) + C_{t2} \frac{\varepsilon}{k} (G_k + C_{3e} G_\varepsilon) - C_{2e} \rho \frac{\varepsilon^2}{k} - R
\]  \hspace{1cm} (3)

The non-equilibrium wall function is chosen as the experimental standard in the near wall region. In the solver setting, the SIMPLEC algorithm is used to solve the coupling of the pressure field and the velocity field for the flow control RANS equation. In the solver settings, for solving the coupling pressure field and velocity field of the SIMPLEC algorithm by solving RANS flow control equations, discretization of the convective term by two order upwind scheme, convergence standard calculation RMS.

**Experimental Result Analysis**

Fig.2 shows the modeling processing of the research area, in which the left graph is extracted from the actual terrain after coordinate extraction, and then the terrain reconstruction results are obtained by using gambit software. In the selected terrain, the altitude of the highest point is 1905.313m. In order to get refined wind field, the terrain is meshed and the distance between the grids is 30 meters. The right picture is the final wind field.

![Figure 2. Tectonic relief map.](image)

Fig. 3 shows the wind speed vector diagram at the entrance of the wind field, where the left plane is the inlet plane of the wind field, and the initial wind speed of the entrance is 6.7m/s. From the change of the surface wind speed, it can be seen that when the wind flows through the uneven terrain, due to the uneven terrain, resulting in changes in wind speed. In the region where the color is deeper, the wind speed increases, which indicates that the wind speed increases with the increase of altitude, and also brings hidden danger to the safety of the flight.
Fig. 4 and Fig. 5 represent the pressure distribution height of 200 meters and 400 meters high layer layer, as in Figure two below the level of pressure difference generated, due to a height of 200 meters layer close to the ground, so affected larger gully terrain, along with the increase of height, the affected range decreased gradually, it can be concluded that the possibility of wind shear in the mountains near.

The vertical profile of the wind field is as follows. From the speed of the graph can be seen in the wind field with mountains rolling fluctuations, including 200 m, 400 m height due to terrain partition effects, so many wind speed greater volatility, more prone to wind shear; and in the 600 m height, wind speed undulating tends to be stable.
It can be seen from the fig.7 that with the increase of distance y, the horizontal wind speed increases first and then decreases. After processing the data, it is concluded that the variation trend of the horizontal wind speed accords with the full wavelength model.

Summary
In this paper, Lanzhou Zhongchuan Airport area is selected as the research target, and combined with the terrain characteristics in the airport area under complex terrain conditions, a numerical simulation method using fluid dynamics software Fluent is proposed. Through the establishment of airport terrain model under complex terrain, the airport wind field was numerically simulated, and the refined wind field with a resolution of 30 meters was obtained. Drawn from the simulation results, the CFD software can reflect the airport wind field distribution and topography on the wind field of the mountains, the effect of wind speed near the top of the hill is large, low air pressure. It can reflect the height layer of wind shear from the simulated wind distribution map, which provides a new idea for airport location, airport safety operation and wind shear warning.

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