Numerical Simulation of Wind Changes after Turning at T-shaped Roadway Intersection

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Abstract. Modeling and numerically simulating the intersection of semicircular arch and rectangular cross-section under different air inlet directions, studying the law of wind flow and the location of the average wind speed point, and providing a basis for the deployment of wind speed sensors. Through simulation, it is found that the influence of wind speed on wind flow change is very small. The law of wind flow change under different wind speeds is consistent, and the distance between the average wind speed point and the tunnel wall is also consistent. Along the direction of wind flow, the flow field near the roof and the side with larger air volume is relatively stable, which is suitable for the arrangement of wind speed sensors.

1. Introduction
With the development and application of intelligent mine ventilation, wind speed sensors, as underground monitoring equipment, can monitor data 24 hours a day, providing a powerful guarantee for dynamic monitoring of the ventilation system. However, the placement of sensors is not standardized and unreasonable, which leads to large errors in wind measurement results. In order to make full use of the advantages of automated and efficient wind measurement provided by the wind speed sensor, it is of great significance to improve the wind measurement accuracy.

The average wind speed point is the location of the wind speed sensor we want to study. Many scholars have conducted modeling or experimental research, all of which take straight roadways as the research object, ignoring the intricate actual situation of underground roadways. Therefore, we don't know where the wind current will reach a stable state after turning, and where the average wind speed point is. So, this article creates a model and numerically simulates the intersection of T-shaped roadway to study the wind flow law and the location of the average wind speed point.

2. Create models and parameter settings
Based on a mine roadway as a reference, two most common semicircular arch and rectangular roadway models were established. The schematic diagram of the air flow direction and roadway model is shown in Figure 1: The two outlets of the first model are symmetrical, and the second model is asymmetrical. In order to make the wind flow more stable and study the average wind speed point more accurately, the...
length of the inlet roadway is 100m and the length of the outlet roadway is 200m. The cross-sectional dimensions of the roadway are shown in Table 1.

The roadway model includes one air inlet and two air outlets, and the remaining surfaces are all wall surfaces. Choose SIMPLE for the solution method; k-epison for the solver. The air inlet type is velocity-inlet, and the wind speed is 1, 2, 3, 4, 5 m/s; the outlet type is pressure-outlet, and the relative pressure value is 0. The wall surface adopts no-slip boundary conditions, assuming that the wall surface is insulated, and the friction resistance coefficient in the roadway does not change.

Table 1. Sectional dimensions of roadway model

| Number | Roadway section shape   | Section size | Width/m | High/m |
|--------|-------------------------|--------------|---------|--------|
| 1      | Semicircular arch       |              | 3.4     | 3.4    |
| 2      | rectangle               |              | 3.4     | 3.0    |

Figure 1. Two roadwayl models with different air inlet directions

3. Analysis of simulation results

Through Fluent's numerical simulation of the roadway models in 4 different situations, the average wind speed point analysis is performed every 10m at the wind flow outlet, and the velocity cloud image is intercepted for analysis. Due to the limited space, only a part is selected for display, as shown in Figure 2.

Figure 2. Cross-section cloud image of semicircular arch roadway
3.1. Definition of average wind speed point
The average wind speed point is theoretically a collection of several points. In order to facilitate the determination of the location of the average wind speed point, along the wind flow direction, the analysis is carried out on the roof of the tunnel and near the left and right tunnel walls. We define the distances from the average wind speed point to the roadway roof, to the left roadway wall, and to the right roadway wall as $a$, $b$, and $c$, respectively, as shown in Figure 3.

![Figure 3. Schematic diagram of roadway section](image)

3.2. Analysis of the position law of the average wind speed point
Use CFD-Post to process and analyze the simulation results. Analyze and record the change rule of $a$, $b$, $c$ every 10m along the wind flow direction at the outlet (10~190m), and connect the data into a smooth curve.

Figure 4 is drawn based on the distance from the average wind speed point to the wall of the roadway for the semi-circular arch of the symmetrical roadway model in Figure 1. According to Figure 4, within 10-30m after turning, the distance between the average wind speed point and the roof, because the wind flow has just split, the flow field is unstable, and its value varies between 0.31~0.38m. After 30m, the wind flow tends to stabilize and gradually stable at 0.59m.

Within 10-50m after the turn, the distance from the average wind speed point to the roadway wall on the left is within 0.91~2.68m and changes greatly. Within 60-110m after the turn, the flow field is relatively stable and changes within 0.61~0.77m. After 110m, it is stable at 0.52m. Within 10-30m after the turn, the distance from the average wind speed point to the wall of the right side tunnel varies between 0.29~0.41m, and after 30m, it stabilizes at 0.4m.

![Figure 4. The law of the average wind speed point of semicircular arch roadway](image)

Figure 5 is drawn based on the distance from the average wind speed point to the wall of the rectangular roadway for the symmetrical roadway model in figure 1. According to Figure 5: Within 10-100m after the turn, the distance from the average wind speed point to the roof varies within 0.29~0.32m,
after 100m, as the wind flow stabilizes, it gradually stabilizes at 0.33m; Within 10-140m after the turn, the distance from the average wind speed point to the left side roadway wall changes within 0.53~2.69m, and after 140m, it stabilizes at 0.48m; Within 10-140m after the turn, the distance from the average wind speed point to the right side roadway wall changes within 0.29~0.43m, and after 140m, it stabilizes at 0.48m after the wind flow stabilizes.

**Figure 5.** The law of the average wind speed point of rectangular roadway

For the asymmetric semi-circular arch roadway in Figure 1, this roadway model has one air inlet and two air outlets, so the location of the average wind speed point of the two outlets will be analyzed separately, as shown in Figure 6. According to the first picture of Figure 6: The outlet with the same direction as the air inlet within 10-80m, the distance from the average wind speed point to the roof varies within 0.60~0.73m. After 80m, it stabilizes at 0.58m; Within 10-110m, the distance from the average wind speed point to the left side roadway wall changes within 0.62~0.81m, after 110m, it stabilizes at 0.51m; Within 10-80m, the distance from the average wind speed point to the right side roadway wall changes within 0.33~0.36m, after 80m, it stabilizes at 0.38m.

According to the second picture of Figure 6: Within 10-120m after the turn, the distance from the average wind speed point to the roof varies within 0.58~2.27m, after 120m, as the wind flow stabilizes, it gradually stabilizes at 0.52m; Within 10-170m after the turn, the distance from the average wind speed point to the left side roadway wall changes within 0.2~0.44m, and after 170m, it stabilizes at 0.52m; Within 10-150m after the turn, the distance from the average wind speed point to the right side roadway wall changes within 0.58~2.06m, and after 150m, it stabilizes at 0.45m.

**Figure 6.** The law of the average wind speed point of the asymmetric semicircular arch roadway
As above, we analyze the two asymmetric outlet of the rectangle separately, as shown in Figure 7. According to the first picture of Figure 7: The outlet with the same direction as the air inlet within 10-20m after split, the distance from the average wind speed point to the roof varies within 0.39–0.45m, and after 20m, it stabilizes at 0.33m; Within 10-160m, the distance from the average wind speed point to the left side roadway wall changes within 0.58–1.29m, after 160m, it stabilizes at 0.55m; Within 10-80m, the distance from the average wind speed point to the right side roadway wall changes within 0.32–0.33m, after 80m, it stabilizes at 0.37m.

According to the second picture of Figure 7: Within 10-130m after the turn, the distance from the average wind speed point to the roof varies within 0.23–0.36m, after 130m, as the wind flow stabilizes, it gradually stabilizes at 0.38m; Within 10-120m after the turn, the distance from the average wind speed point to the left side roadway wall changes within 0.15–0.36m, and after 120m, it stabilizes at 0.38m; Within 10-120m after the turn, the distance from the average wind speed point to the right side roadway wall changes within 0.69–1.91m, and after 120m, it stabilizes at 0.56m.

4. Conclusion

Through numerical simulation of the model in 4 different situations, it is found that the distance between the average wind speed point and the roadway does not change with the change of wind speed. And when arranging the wind speed sensor, try to choose near the roof, and secondly choose the side with larger air volume in the wind flow direction.

The specific location rules of wind speed sensors are as follows.

(1) Semi-circular arch roadway. For the symmetrical intersection of Figure 1, within 40-190m after turning left, the sensor can be arranged at a distance of 0.59m from the roof. And within 40-150m, the sensor is arranged at a distance of 0.37m from the right side roadway wall along the wind flow direction. According to the symmetry, the wind flow law of the roadway after turning to the right can be known.

For the asymmetrical intersection, the outlet with the same direction as the air inlet within 50-190m after split, the sensor can be arranged at a distance of 0.58m from the roof. And within 40-190m, the sensor can be arranged at a distance of 0.38m from the right side roadway wall. Within 100-190m after the turn, the sensor can be arranged at a distance of 0.52m from the roof, and within 60-190m, the sensor is arranged at a distance of 0.38m from the left side roadway wall.

(2) Rectangular roadway. For the symmetrical intersection of Figure 1, within 40-190m after turning left, the sensor can be arranged at a distance of 0.33m from the roof. And within 40-140m, the sensor is arranged at a distance of 0.37m from the right side roadway wall along the wind flow direction, after 140m, the distance is 0.49m.
For the asymmetrical intersection, the outlet with the same direction as the air inlet within 30-190m after split, the sensor can be arranged at a distance of 0.33m from the roof. And within 50-190m, the sensor can be arranged at a distance of 0.36m from the right side roadway wall. Within 50-190m after the turn, the sensor can be arranged at a distance of 0.38m from the roof, and within 70-190m, the sensor is arranged at a distance of 0.38m from the left side roadway wall.

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