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Numerical Analysis of Particle Motion and Collision of Surround U-clevis in Windy and Sandy Environment

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Abstract

The collision and accumulation of sand on the U-Clevis will greatly affect the wear of U-Clevis in windy and sandy area. The numerical simulation of the movement and collision of sand around the U-Clevis used in the overhead transmission lines under strong wind environment are studied by using Euler two-phase model. The different moving features, such as the variation of the sand volume fraction of the U-clevis surface with the time, and the trajectory of the sand in different speed of wind are further investigated. The influence of wind speed on the sand movement around the U-clevis is analyzed to provide the basis for optimizing the design of U-clevis.

Introduction

The terrain of the Xinjiang region in China is highly complex. Gales are frequent, readily mixing with a large amount of sand due to the Taklimakan desert, thus forming sand and dust storm weather patterns. According to data provided by weather stations, combined with meteorological research [7,10] on wind speed of the Xinjiang region, the maximum wind speed in Xinjiang can reach 56.5 m/s. Xinjiang's 750-kilovolt Urumqi-Turpan-Hami transmission line project achieved fully electrified operation in October 2010. However, only after several months, its overhaul in March 2011 showed that there was serious wear detected on the tower ground wire and the connected hardware fittings (U-clevis) of the hanging point of the cable located in an area with wind speed up to 42 m/s.

The hardwire fittings are key components for connection and protection of the entire transmission line. Failure of these fittings will compromise function of the transmission line. The U-clevises are mainly used for the straight tension string of the rod and the connection between the upper end of the cable and the hoop. The inevitable wear will be produced in the pairs of U-clevis, but such serious wear in a short period is very uncommon. Some researchers have analyzed the causes of wear of the fittings [2], and done some related wear tests [11], but did not consider the impact of sands. There are researchers[1,3-6,8-9,12] using a two-phase flow model to do much research while taking the sand into consideration, but no one investigated the turbulent flow and collision with the U-clevis. Therefore, it is of great urgency to make a deep study on the collision of sand on the fittings under the sandstorm environment.

Numerical simulation model and analysis

The Euler model can be used to simulate the movement of multiple phases of a mixture of solids, liquids, and gases that are separated from each other yet interact by solving the momentum equation and the continuity equation for each phase. For the flow-solid particle flow, the statistical kinematics theory is used to obtain the characteristics of the system, and the exchange of the inter-phase momentum is achieved depends on the type of mixture. In this paper, the Euler model is used to determine the variation of the volume fraction of sand with the time on the U-clevis, and the collision of the sand at different positions of the U-clevis.

The wind speeds of 10 m/s, 20 m/s, 30 m/s and 40 m/s are simulated respectively, which are the cases of the high Reynolds number. The 3D rectangular fluid domain is selected as the calculation area. Define that the initial coordinate origin coincides the centroid of a U-clevis, and Y direction is the flow direction. To meet the requirements of the blocking rate, the upstream of the computational domain model is 5D (D is the reference length of the U-clevis) away from the centre of the U-clevis and the downstream boundary is 15D, and the boundaries at upper and lower sides are 5D away from the U-clevis, as shown in Figure 1.

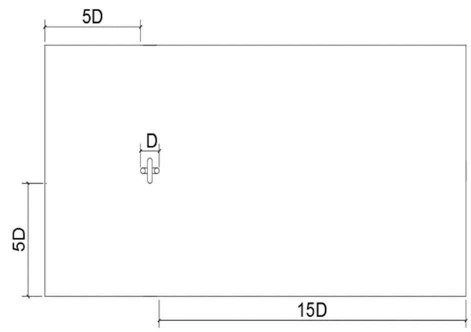

Figure 1 The computational domain of the flow field

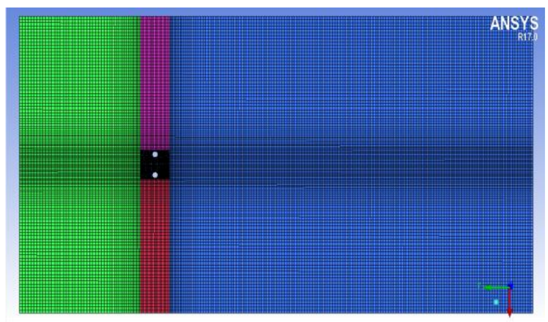

Figure 2 Mesh on X-Y plane

Due to such complex climatic conditions surrounding the transmission line and the principles of the transmission sector, it is impossible to monitor the concentration of sand near the transmission line in real time on site. Therefore, accurate sandstorm concentrations cannot be measured. The available data show that the sand concentration within one meter of visibility will not exceed 1000mg/m^3. Therefore, the sand concentration of inlet injection in the following numerical calculations is set as 1000 mg/m^3 with the wind speeds of 10 m/s, 20 m/s, 30 m/s and 40 m/s. All faces are set as a wall surface with a roughness of 0.5 considering the roughness influence.

Sandstorm accumulation and collision analysis

In the literature[9], the influence of the frictional velocities on the volume fraction of the particles was studied. The results showed that with the increase of the friction wind speed, it will take less time for the sand flow to achieve steadiness. The larger the flow velocity, the greater the volume fraction of the sand at the same position in the sand flow layer will be. The simulation results shown in the next section are in positive compliance with this conclusion.

The sand density is 2600kg/m^3, with air density of 1.225 kg/m^3 and sand concentration of 1000 kg/m^3. Comparison of the calculated results of different wind speeds as seen in Figure 3.

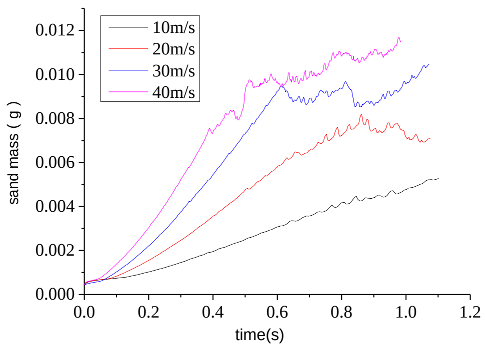

Figure 3 Variation of sand mass with time on the U-clevis surface

The variation of sand mass with the time on the U-clevis in 1.1s is taken, as shown in Figure 3. It can be seen that the mass of the sand collision increases with the increase of the wind speed. The collision mass is stable at about 0.0056mg, 0.0073 mg, 0.0093 mg and 0.0115 mg when the wind speed is 10 m/s, 20 m/s,30 m/s and 40 m/s respectively.

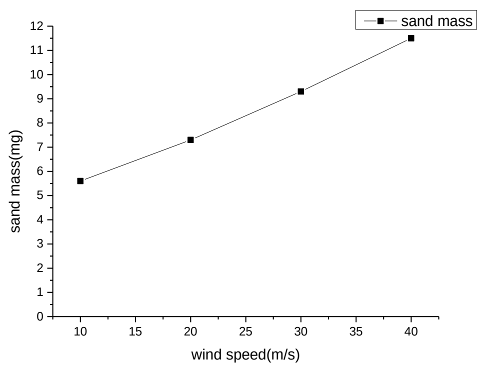

Figure 4 Relationship between sand mass and wind speed

The greater the wind speed, the faster the mass of sand collision remains stable of the U-clevis. It starts to stabilize at about 1.3s,0.8s,0.6s and 0.5s with the wind speed is 10 m/s, 20 m/s, 30 m/s and 40 m/s, separately. It can be found by summarizing the characteristics of sand collision at different wind speeds that the mass of the sand particles on the U-clevis is in linear relationship with the wind speed, as shown in Figure 4.

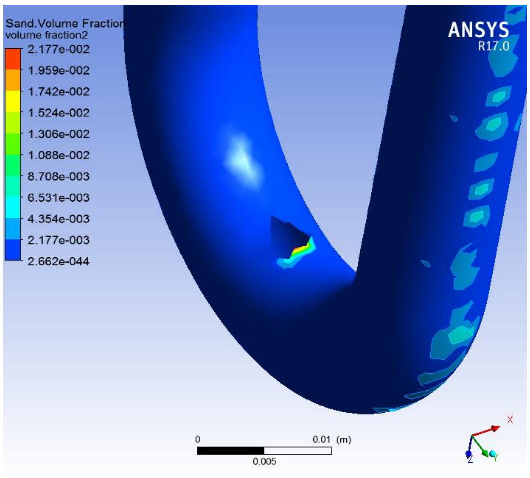

Figure 5 Then local collision of upper U-clevis

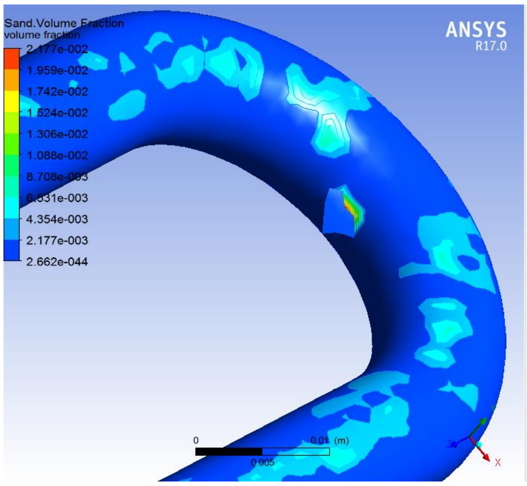

Figure 6 Then local collision of lower U-clevis

Fig. 5 and Fig. 6 show that the sand most frequently collides at the contact of the upper and lower U-clevis, and that is the most seriously wore part of the U-clevis. The numerical simulation analysis shows that the reason U-clevis wear in the Xinjiang region is more serious than that of the Three Gorges region in China is that the sandstorms in Xinjiang are greater and the sand easily collides at the contact of the upper and lower U-clevis when passing through the U-clevis.

The data of the volume fraction of the different position points on the U-clevis are extracted, as shown in Figure 7. The Z-direction of the U-clevis is taken as the x-coordinate and the volume fraction of the sand on the U-clevis is regarded as the Y-coordinate. It is clear that the position of the largest volume fraction is located at 0, which is the contact of the upper and lower U-clevis.

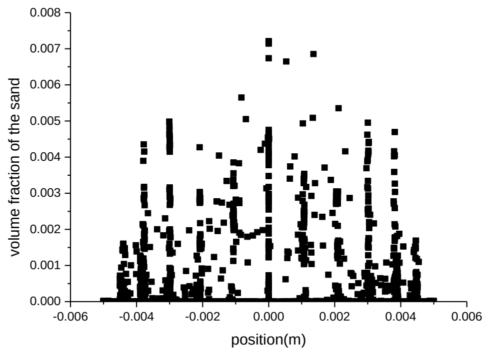

Figure 7 Volume fraction of the sand at different positions for the upper U-clevis

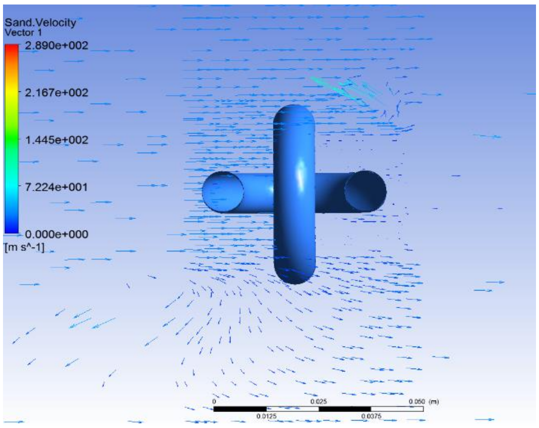

Figure 8 Diagram of sand velocity vector

Figure 8 shows the velocity vector of the sand, which can well reflect the trajectory of the sand at that moment. That is, when the sand makes contact with the U-clevis, some particles will change the trajectory and some particles will rebound.

Conclusions and Prospective

The Euler model is used to simulate the variation of volume fraction of the sand with the time on the U-clevis and the collision of the sand at the different positions of the U-clevis with the wind speeds as 10 m/s, 20 m/s, 30 m/s and 40 m/s respectively. The numerical simulation data shows that the reason for U-clevis wear in the Xinjiang region is more serious than other regions is that the sandstorms in Xinjiang are greater and the sand easily collides at the contact of the upper and lower U-clevis when passing through the U-clevis. The mass of the sand collision increases with the increase of the wind speed. Besides, the greater the wind speed the quicker the sand mass become stable on the U-clevis. The sand most frequently collides at the contact of the upper and lower U-clevis. Furthermore, the collision of sand will aggravate wear. This conclusion will provide the basis for optimal U-clevis design.

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