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The PTV image processing algorithm of rebounding sand particles over Gobi surface

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Abstract

With the rapid development of detection methods, the recent researches of sand flow are focused on characteristics of macroscopic sediment transport and microscopic motion of particles. The study on the characteristics of moving sand near earth surface is the theoretical basis for well understanding and controlling the process of sand-related disaster. To obtain particle microscopic motion information regarded as a prerequisite for accurately describing sand flow, the PIV(Particle Image Velocimetry) and PTV(Particle Tracking Velocimetry) methods are generally employed.
Because of the special gravels and clay layers covered over Gobi surface, the sediment transport flux and structural characteristics for moving sand are significantly different from the case of sand surface. So, the previous sand transport models suitable for sand surface are no longer applicable for Gobi. However, there are little researches for Gobi wind-sand movement. In order to obtain the transport model of Gobi wind-sand movement, the process of sand-bed interaction should be studied, and the research on collision recovery coefficient of Gobi surface is the core component of sand-bed process.
In this paper, the collision process between actual Gobi surface and natural sand was experimentally researched by PTV and the collision recovery coefficient of Gobi surface was focused on. Due to the existing PTV image processing technologies could not accurately capture the particle trajectories of the collision process on bed, we proposed a new algorithm to deal with this problem. The core innovation of this algorithm is to match two trajectories in the forward and reverse directions of the collision particle trajectory, and then it can solve the problem that the particle trajectory matching was inaccurate due to the huge change of angle after particle collision. After the image processing completed, the accurate Gobi surface collision recovery coefficient had been obtained, which provides support for Gobi wind-sand modeling in future.

1 Introduction

Due to the emergence of gravel and clay layers, the material properties of Gobi surface have changed fundamentally compared with desert surface, and the complexity of its surface is also quite different. Therefore, the previous sand-bed splash model on the desert cannot describe the sand-bed interaction process on the Gobi surface. Preceding studies on sand flow in the Gobi area have not paid enough attention to the sand-bed interaction. But the sand-bed interaction process is an important aspect of the near-surface wind-sand saltation movement:Anderson R S et al.(1988), the study of the interaction between sand particles and the Gobi surface is a key step in the study of wind-sand flow on the Gobi surface. The main reason is that compared with the desert, most of the surface of the Gobi are covered with gravel and clay. It is necessary in order to measure its physical properties and integrate its effects into the sand-bed interaction model, so as to establish a wind-sand movement model suitable for Gobi surface. At the same time, experts and scholars have also devoted a lot of energy to the collision model:Gillette D A et al.(1997). Gravel and clay layers are part of the most prominent characteristics in the Gobi area. Sand particles may collide with gravel or clay (crust) before landing, which has a significant effect on the trajectory of sand particles. Therefore, the collision between sand particles and Gobi should not be simply defined as a model, but be decomposed into the collision between sand particles and crust (clay layer) and the conflict between sand particles and gravel.

2 Experimental materials and methods

The interaction between sand particles and bed surface is an important part of describing the mechanism of aeolian sand movement. It is also the core work to understand the mechanism of aeolian sand flow initiation and development, and to establish the precise relationship between the micro-movement of sand particles and the macro-process of aeolian sand flow. In this experiment, the image data are obtained by PTV photographing the collision process between sand grains and Gobi bed surface, and then the restoration coefficient of Gobi surface and other parameters are obtained by PTV image processing algorithm.

2.1 Experimental Scheme

In the actual sampling process, it is found that the surface of the Gobi is mainly composed of crust and gravel

2.2 Experimental Equipment

The instrument of the laboratory consists of two parts: one is a natural particle launcher capable of launching sand grains,. Other is an image acquisition system used to acquire images, that is, a high-speed photography system. This paper uses high-speed camera for image shooting.

2.3 Layout of experiment

The experimental device is shown in Figure 1. The light source is 532nm green lasers. The high-speed photography frequency is 1000HZ, and the resolution is 1024 x 1024.

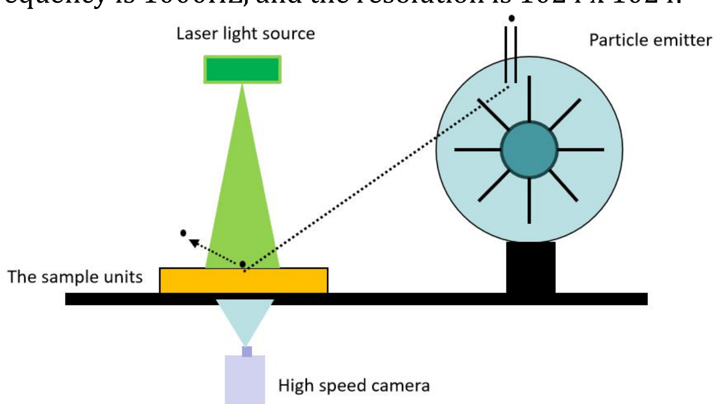

Figure 1: experimental layout

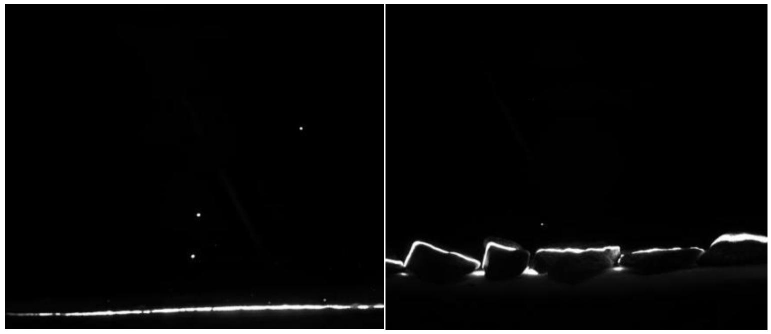

Figure 2: high-speed photographic image : a) clay (crust) ;b) gravel

3 Image Processing

In this paper, the collision recovery coefficient of Gobi surface is studied by means of PTV photography of the collision experiment between actual Gobi surface and natural sand grains. After using high-speed photography to obtain pictures, because the existing PTV image processing technologies, such as DT image processing methods proposed by X. Song et al. (1999), ABL image processing methods proposed by Wang et al. (2008), can not accurately capture the particle trajectory in the process of particle collision bed, this paper proposes a new algorithm to deal with this problem, the core innovation of this algorithm. The problem of inaccurate particle trajectory matching can be well solved by matching the two trajectories after the collision particle trajectory is matched in both positive and negative directions, and then the two trajectories are matched. After the image processing is completed, the accurate Gobi surface conflict recovery coefficient can be obtained, which provides support for the establishment of the Gobi wind-sand splash function.
Using matlab 2016b to write a program :
(1) Reading pictures in batches and converting them into gray and binary images; (2) Setting a picture with fewer particles as background image and calculating the surface boundary; (3) Computing the connected domain and giving the coordinates of each center of mass; (4) Eliminating noise points; (5) Calculating the number of particles in the air; _Calculate the coordinates of the center of mass and speed vectors of each particle. _Calculating particle trajectory in core matching algorithm; Extract the particle attributes of rebound and output data (incident speed, incident angle, rebound speed, rebound angle, recovery coefficient).
Core Matching Algorithms: The trajectory of particles is determined in both positive and negative directions by two judging conditions of distance and angle. Firstly, a particle in the first frame is taken as No.1 particle and its centroid coordinates are read. Then, the centroid coordinates of No.2 particle in the second frame are read from the original point. The initial displacement vector and the sum of the centroid coordinates of particles can be obtained by connecting lines. speed vector, and then read the centroid coordinates of the third picture with No.3 particle as the origin. Connect No.2 particle and No.3 particle to get the second speed vector and the displacement vector. If the above two displacement vectors and speed vectors satisfy the conditions (distance and angle), the incident trajectory of the particle can be obtained, and the trajectory can be determined in turn until it is on the brink of the edge of the surface. No. 7 particle, and No.14 particle are matched inversely from No.9 particle. The distance and time of No. 14 particles are matched, and the positive and negative two-way trajectories of the same particle comply with the conditions. So far, the whole trajectory of particles has been captured, as showed in Figure 3 (literal description and different

positions of No.1 ~ No.14 particles in the figure are the same particle). For image processing, the process is as follows:

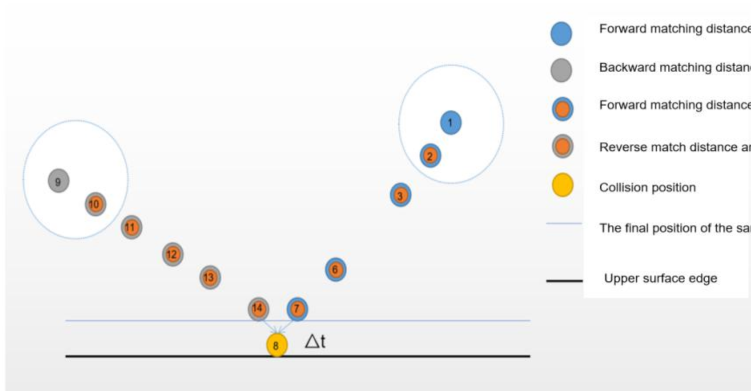

Figure 3: core matching algorithm

The collision matching particle trajectories of sand grains and gobi bed surface are shown in the following figure 4 :

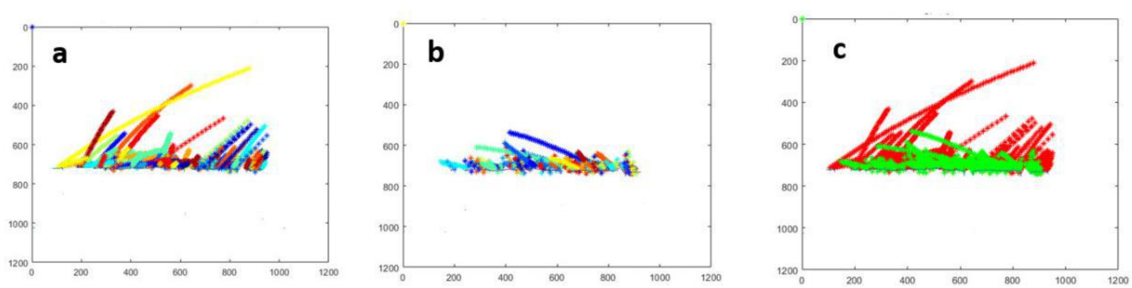

Figure 4: Particle trajectory (Pixel coordinates): a) Incident particles; b) Rebound particle; c) All particles

4 Experimental results

4.1 Sand - gravel collision

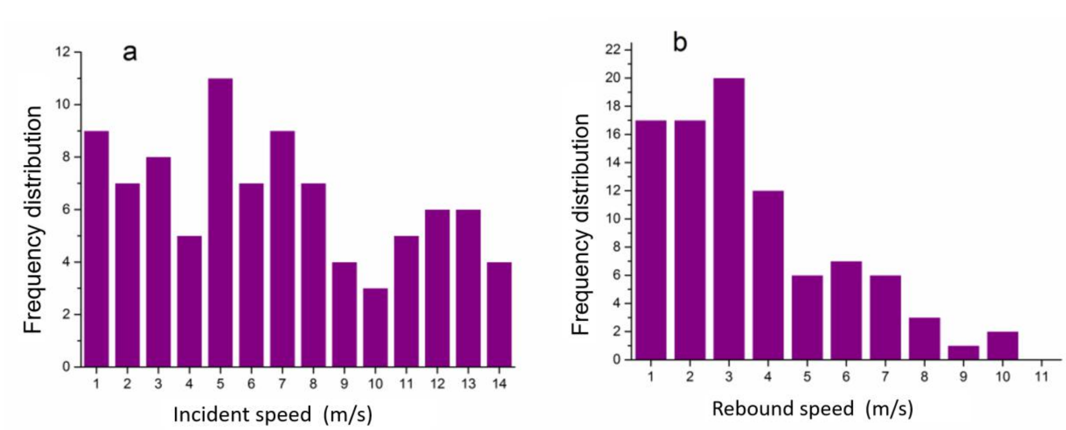

Figure 5: collision speed distribution of sand and gravel: a) incident speed;b) rebound speed

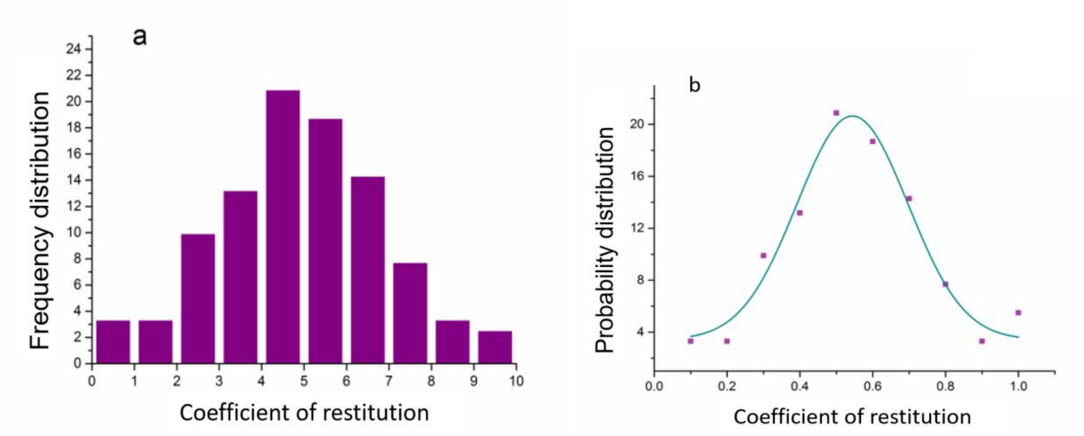

Figure 6: collision recovery coefficient of sand and gravel: a) probability distribution;b) fitting curve

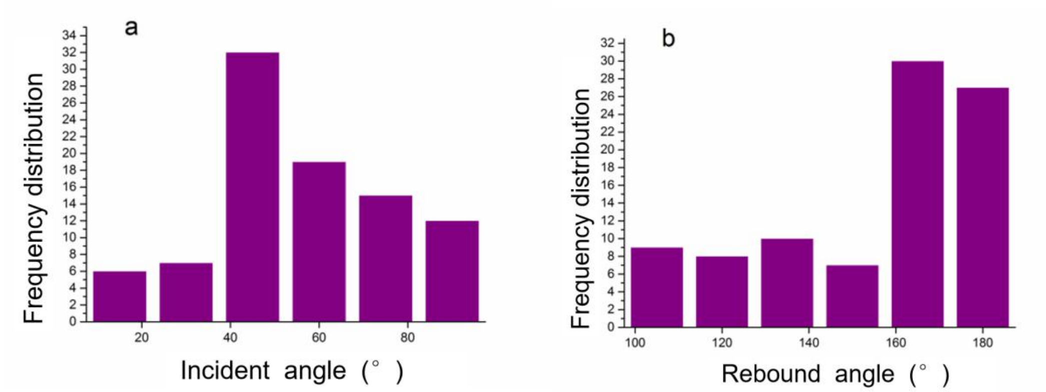

Figure 7:collision Angle distribution of sand and gravel: a) incidence angle;b) rebound angle

Figure. 5, 6 and 7, it can be concluded that in the collision between sand and gravel, the incident speed is mainly between 4m/s and 8m/s, and the rebound speed is mainly below 4m/s. The incident angle is mainly between 40 and 60 and the ejection angle is mainly between 155 and 180 respectively. The coefficient of recovery is mainly distributed in the range of 0.5 to 0.6, which satisfies the lognormal distribution. The fitting degree R^2 is 0.96 and the peak value is 0.55. Incident speed and incident angle are controlled by the speed of the fan in the native particle launcher and the collision position between the particle and the fan. The rebound speed is checked by the recovery coefficient of the material. The rebound angle is linked to the surface roughness of the material.

4.2 Sand - crust (clay layer) collision

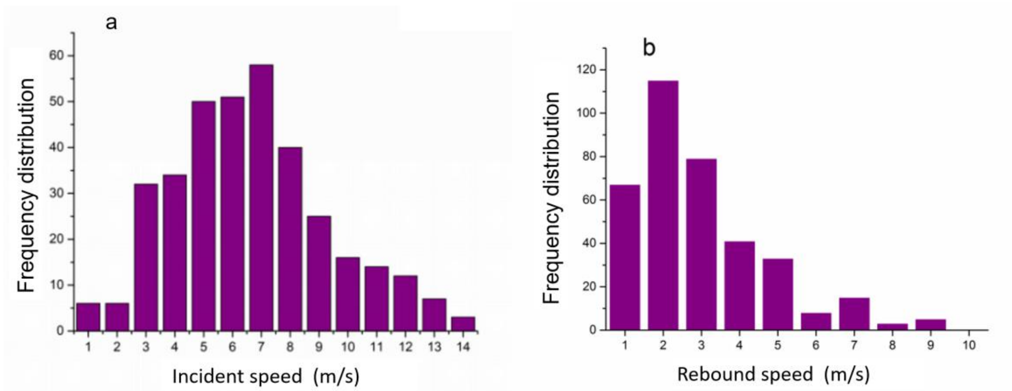

Figure 8: collision speed distribution between sand grains and skinning (clay layer) : a) incident speed;b) rebound speed

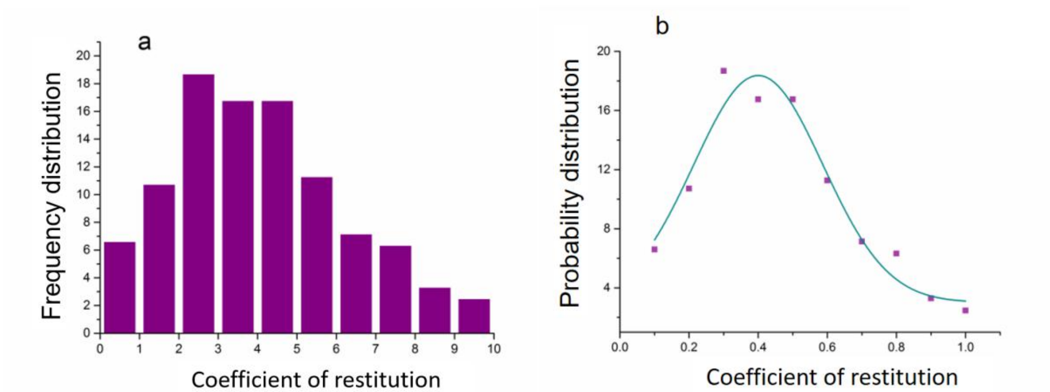

Figure 9: collision recovery coefficient between sand grains and crust (clay layer) : a) probability distribution;b) fitting curve

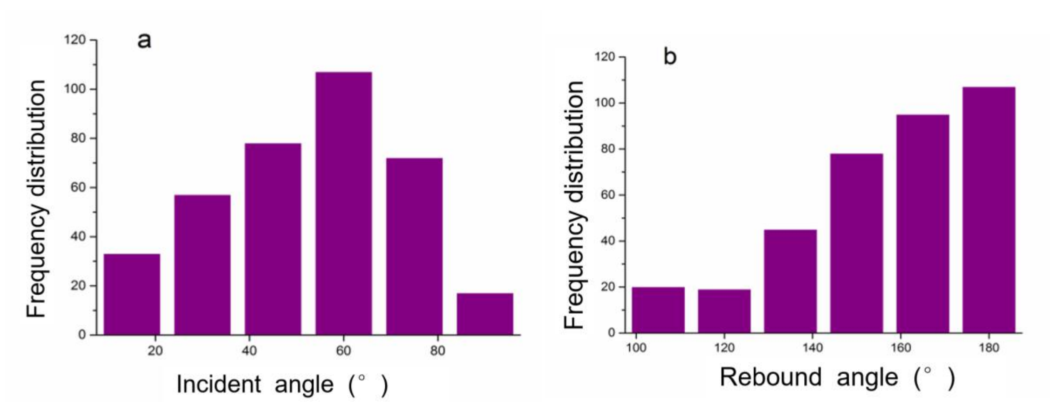

Figure 10: collision Angle distribution between sand grains and crust (clay layer) : a) incidence angle;b) rebound angle

Figure 8, 9and 10, it can be concluded that in the collision between sand particles and crust (clay layer), the incident speed is mainly between 4m/s and 8m/s, and the rebound speed is mainly below 5m/s. The incident angle is mainly between 45 and 60 and the rebound angle is mainly between 135 and 180 respectively. The recovery coefficient obtained is mainly distributed in the range of 0.3 to 0.5, which satisfies the lognormal distribution with a peak value of 0.4 and a fitting degree of R^2=0.98. The control factors of incident speed, incident angle, rebound speed and rebound angle are equal to 4.1.

In conclusion, recovery coefficients of sand-gravel and crust collisions obey lognormal distribution, and the main distribution ranges are 0.5-0.6 (gravel) and 0.3-0.5 (crust), respectively.

5 Conclusion

Due to the lack of research on the collision process between sand particles and Gobi bed, an experimental method for simulating the collision between natural sand particles and Gobi bed is designed in this paper. Based on analysis of 2500 effective collisions, the recovery coefficient of the Gobi surface is given.

Acknowledgements

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