Catena 148 (2017) 138–144

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Turbulence burst over four micro-topographies in the wind tunnel

Wenhai Sun, Ning Huang *, Wei He

Key Laboratory of Mechanics on Disaster and Environment in Western China (Lanzhou University), Ministry of Education of China, Lanzhou 730000, China

ARTICLE INFO

Article history:
Received 28 November 2015
Received in revised form 17 March 2016
Accepted 20 April 2016
Available online 7 May 2016

Keywords:
Wind-blown sand movement
Wind tunnel experiment
Different roughness
Turbulence burst

ABSTRACT

Investigating the mechanisms of wind-sand movement is essential to deeply understand sand storm and desertification process, and further to control the wind-sand hazards. It is considered that turbulence burst may have great influence on the motion of sand particles. But current theoretical and experimental studies mostly concentrate on the turbulence burst over flat surface or in the water. Sand dunes and sand ripples are basic forms of desert landscape, and the slope gradient will inevitably affect the frequency of turbulence burst. In this paper, instantaneous velocities over 4 different sand surfaces, including smooth flat bed, flat sand bed, sand bed with ripples and slope bed, are measured using one-dimensional hot wire detector. The results show that for the slope sand surface, wind field in leeward slope region is a buffering zone, which doesn't obey logarithmic function. On the flat sand surface, the distribution of turbulence intensity and Reynolds normal stress are gradually decreasing along the height of boundary layer. On the slope sand surface, the stronger turbulence behavior happens near the top of slope. Based on Mu-level method analysis, it is found that the turbulence bursts on both flat sand surface and sand ripples mainly occur near the surface, and gradually decrease with the height. Compared to flat sand surface, the burst frequency is 30% ~ 50% higher on the sand ripples surface, which indicates that micro-topography have an influence on the turbulence burst. This work may be helpful in understanding the initiation and transportation of sand storm, as well as the desertification process.

1. Introduction

The hazards caused by wind-sand movement have become one of the most important environmental and ecological issues in the world. It is considered that investigating the mechanisms of wind-sand movement is the key factor to entirely comprehend, and further prevent wind-sand hazards. Thus, the researchers have done many works at this field (Bagnold, 1941). Since this century, the effect of turbulence on particle transportation has drawn more and more attentions (Dupont et al., 2013; Hu et al., 2009). Some scientists argued that the burst of the turbulence strongly dominate the motion of sand particles (Lin, 2008).

Turbulence burst is the coherent structure, including outward event and sweep event, which transport most turbulence energy. Kline et al. (1967) found that turbulence burst has a great influence on the transportation of pollutant, sand particles and sediment, and Leenders et al. (2005) found that higher sand transport rate is along with turbulence burst by experimental investigation. The turbulence burst near surface has a great influence on particles' start-up, and the instant Reynolds stress enable the particles take off to air (Lin, 2008). Nevertheless, most experiments on turbulence burst were carried out in water (Cai, 2008; Wang et al., 1999; Mao, 2003; Shu and Tang, 1989; Lu and Willmarth, 1973; Luchik and Tiederman, 1987). Numerical simulations were carried out to study the turbulence characteristics over smooth flat surface (Jeong et al., 1997; Robinson, 1991; Roberts, 1923).

The aim of this paper is to study turbulence characteristics of air flow over several sand surfaces and provide more insight into the relationship between turbulence burst frequency and surface roughness.

2. Material and methods

2.1. Study site

The experiment was carried out in multi-functional environment wind tunnel of Lanzhou University (Fig. 1). The wind tunnel is DC blowing, with 22 m experimental section, 1.45 m high and 1.3 wide. The roughness on front of wind tunnel was used to accelerate the development of boundary layer thickness, which is about 0.65 m thick in measurement section (Fig. 1).

In this experiment, flow velocities on 4 different bed surfaces, including flat sand bed surface (Fig. 2A), sand ripples bed surface (Fig. 2B), slope bed surface (Fig. 2C) and smooth flat surface (Fig. 2D) were measured using 1-D hot wire in the wind tunnel. We use the 3-dimensional automatic traverse machine to hold detector (Fig. 2D), its minimum displacement is 0.1 mm. The highest measurement point is over 300 mm. But we mainly focus on the vertical region below 100 mm, where the strong turbulence characteristics happen (Crowe, 1993).

* Corresponding author.
E-mail address: huangn@lzu.edu.cn (N. Huang).

http://dx.doi.org/10.1016/j.catena.2016.04.017
0341-8162/

Fig. 1. The wind tunnel with roughness.

We stick sand to the model surface (Fig. 2A, B, C) for strengthening the roughness of surface model. All models are placed in area of 8 m–10 m from roughness (Fig. 3). Natural sand ripple is about 7.5–15 cm length and 0.5–2.0 cm height. So the single sand ripple of model is 15 cm length and 2.0 cm height. The triangle dune model with the angles of 17° and 28° in the windward and leeward slopes, respectively, and height of 0.178 m was used to mimic complex surface.

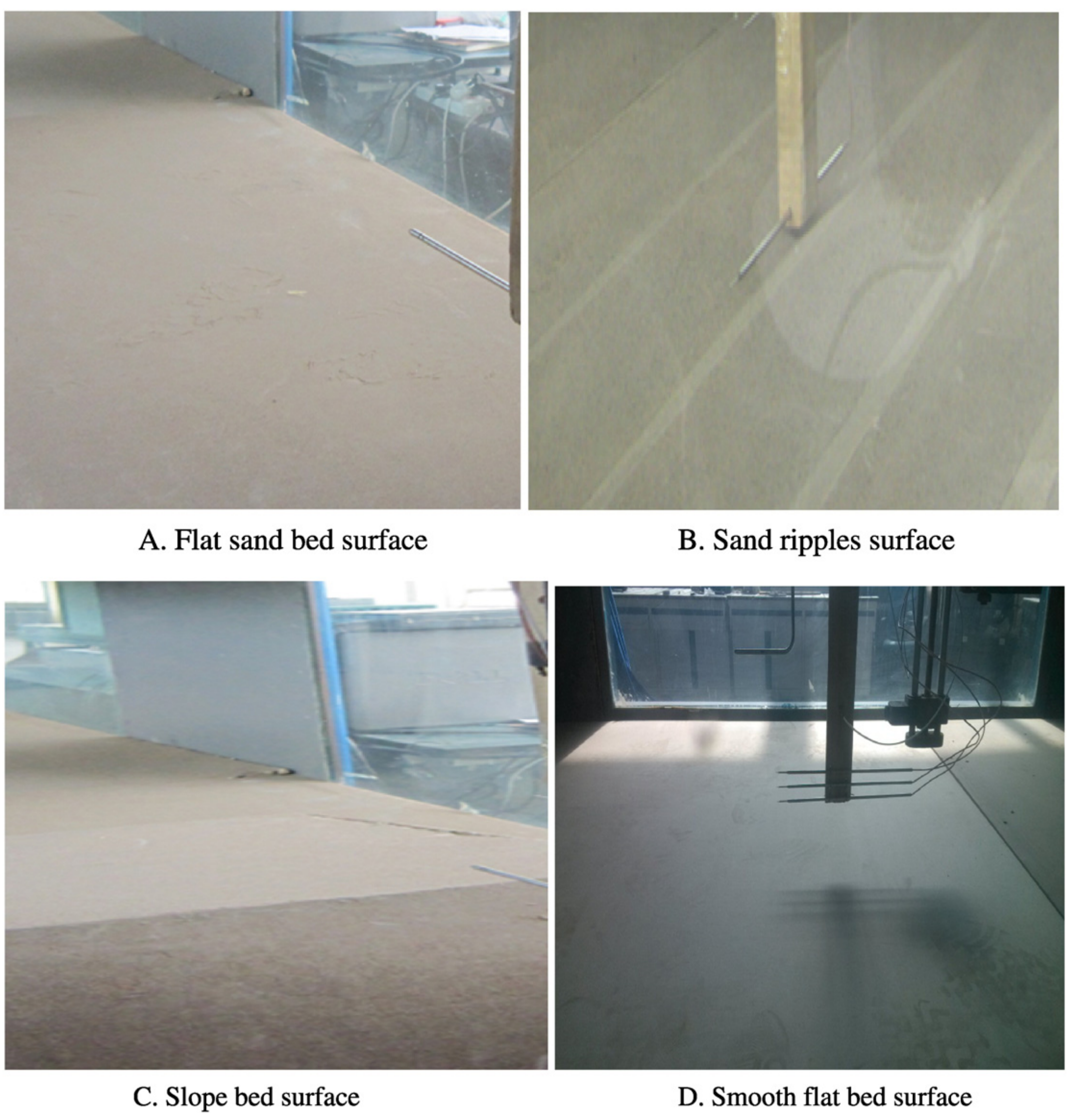

Fig. 2. 4 different bed surfaces.