MINIMUM AEOLIAN PARTICLE THRESHOLD ON MARS; B. R. White, University of California, Davis, CA; 95616, R. Greeley, Arizona State University, Tempe, AZ 85287

Summary. Dust storms on Mars have long been known to exist [1]. Theoretical predictions [2] and previous wind-tunnel tests [3] conducted at equivalent Martian pressure predict higher threshold wind speeds than were observed by the Viking Landers [1, 4-7]. We have carried out new preliminary wind-tunnel tests that suggest 10 micron-sized silt particles' threshold is strongly a function of aerodynamic “conditioning” of the surface and the state of the atmospheric stability (i.e., unstable or stable). The threshold wind speeds at a height of one meter ranged from a low of 34 m/s (U_T = 1.5 m/s) for an unconditioned surface and unstable atmosphere to a high of 85 m/s (U_T = 3.8 m/s) for a “conditioned” surface and neutral atmosphere. The conditioning refers to the level of compaction the surface has obtained. An “unconditioned” surface represents newly deposited particles that have aerodynamically settled onto an existing surface. A conditioned surface is one that has undergone several cycles of wind speed above and below threshold condition without having additional particles settling on the surface.

Introduction. The previous threshold theory predicts a minimum value of threshold friction speed, U_T, of about 2 m/s for 115 micron-sized particles [2]. Previous wind-tunnel minimum threshold data acquired at martian-equivalent pressure and extended to Mars' conditions by gravity adjustment was about 85 m/s with a U_T of 1.7 m/s [7]. More importantly, this condition was thought to be an absolute minimum with increases in threshold friction speeds for either larger or smaller sized particles (i.e., for a 10 micron-sized particle, theory predicts U_T = 7.5 m/s). These previously derived curves were based upon very limited data for small sized particles. Also, the extrapolation of wind-tunnel data to 10 micron-sized particles predicted a U_T of 3 m/s [7]. Additionally, these previous threshold curves were extended to the less than 20 micron-sized particle range on the assumption that threshold speeds would increase with decreasing particle size as predicted by the theory [2]. The present results suggest that this situation may not be the case and in fact the threshold may “flatten out” in the smaller-sized particle range less than 100 microns.

Experiments. Figures 1 and 2 display the results of experiments conducted in the Mars Surface Wind-Tunnel (MARSWIT) located at NASA Ames Research Center, Moffett Field, California. For Figure 1, experiments were performed for five different sized particle distributions: 11, 53, 78, 93 and 125 microns mean diameters. Each particle size tested was carefully sieved such that there was little, if any, overlap of the other size distribution, i.e., less than 5% overlap. The test procedure was as follows: a bed of these nearly uniform-sized particles was placed in the wind-tunnel test section and the surface smoothed. For each test, a minimum three meter long bed of material was used, as previous tests showed that a bed of this length would give nearly the same results as an infinitely long bed [8]. Shorter bed lengths may give incorrect threshold values. The tunnel which is located inside a large vacuum chamber was evacuated to 10, 15, 20 or 40 mb pressure using “Earth” air. The tunnel was then started and wind speed gradually increased until saltation threshold was reached. The tunnel was stopped and started several times at each test condition to obtain a number of data points which were averaged to produce a single final value. Two separate methods were used to determine saltation threshold: i) a high-resolution closed-circuit television system was used to observe the particle movement directly; and, ii) an electrostatic detector measured the current produced by saltating particles impinging on the detector element. For all experiments, both systems were used concurrently to detect saltation, with the electrostatic system being more sensitive for small particles and the television system more sensitive for larger particles.

Unstable atmosphere experiments were performed by heating the surface of the tunnel floor. Heating of the floor models solar radiation which affects vertical turbulent structure of the near-surface boundary layer. On Mars, solar surface heating is expected to produce a minimum difference of surface and wind temperature of at least 25C and a maximum of 100C. For MARSWIT simulation, the greater the temperature difference the more closely Richardson number similitude was met. The material was placed on the tunnel’s floor by aerodynamic settling, to model the natural placement of the silt.

Vertical temperature profiles were measured under several heating conditions. The typical thermal boundary layer was 20 cm high, with a 100C temperature difference over the lowest 5 cm, which produced a martian-equivalent Richardson number. Presumably minimum threshold would occur on Mars when the temperature difference between the surface and air above it is a maximum, and this condition is estimated to correspond to a minimum bulk Richardson number of about -0.002 on Mars. Wind-tunnel results showed minimum particle movement occurs in the bulk Richardson number range of -0.001 to -0.002, when scaled to Mars.
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Results. Figure 1 shows four curves for the four ambient pressures tested. The data display a “flattened” trend in the 50 to 120 micron-sized particle range for values of threshold wind speed. All results were the same for both neutral and unstable atmospheric conditions except for the 11 micron-sized material at 10 mb ambient pressure. Figure 2 shows the 11 micron-sized particle results for four different surface-stability test conditions. Specifically, for conditioned surfaces, threshold was substantially greater than unconditioned ones; and, for unstable conditions, threshold was reduced for both conditioned or unconditioned surfaces. Note, all other thresholds (Figure 1) were unaffected by stability condition, i.e., accept for 11 micron particles at 10 mb pressure.

Figures 1 and 2 illustrate the unique characteristics of 11 micron silt as opposed to larger particles. The 11 micron silt threshold was affected by varying parameters such as surface heating and conditioning; whereas, larger sized particles appeared unaffected by these parameters. This effect was probably due to an increased dependence on interparticle forces among these smaller particles. As particles become smaller, interparticle forces such as cohesion have stronger influence on the physics of the particle’s behavior. Figure 2 suggests that an unstable environment may increase surface stress thus enhancing particle motion. Accordingly, threshold is achieved at lower wind speeds than neutral or unheated surfaces. Understanding the behavior of 11 micron-sized silt in a simulated Martian environment provides important insight about behavior of smaller sized particle motion on Mars.


Fig. 1. Threshold as function of surface pressure and particle size from MARSWIT experiments

Fig. 2. Surface condition-stability effects on 11 micron particles at 10 mb. Viking range from [4-6].