A Review Article on Lunar Dust Levitation Modeling

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***Abstract*— The lunar surface is electrostatically charged by space plasma currents and ultraviolet portion of sunlight to certain potential. Due to the surface charging phenomena, the dust particles which are resting on the surface get charged and levitated in the lunar environment. The levitation of dust particles involves consideration of some parameters like density, charge, potential and electric field. Here we studied few research papers which are related on this area. These papers give the idea about different levitation parameters at different Sun elevation angle, surface topography etc.**

***Index Terms*— Particle-in-cell; Sun Elevation Angle; Lunar; Levitation etc.**

I. INTRODUCTION

Around the Moon it has plasma environment, which refers to the electric fields, magnetic fields and distribution of charged particles such as electrons and ions. The lunar surface electrically charged during the day due to the ambient plasma, the emission of photoelectrons under sunlight and secondary electrons, and the collection of backscattered electrons [1]. When sunlight fall on the lunar surface that time due to the photoelectrons emission process electrons are knocked out and the day-side region positively charged [2]. At night-side region where sunlight is not present, electrons are come faster than the positive ions because of ions have heavier weight than the electrons. So, electrons attract the positive ions and overall at the night-side region it negatively charged due to the recombination process of electrons and positive ions [1]. So, we can say that lunar surface is electrostatically charged are provided. The formatter will need to create these components, incorporating the applicable criteria that follow.

II. LITERATURE REVIEW

A. *Dust Levitation Modeling* [3]

The lunar surface is electrostatically charged so, the dust particles which are resting on the lunar surface is also charged because of several mechanisms like charging by contact potential difference and photoelectron emission [3]. This charged dust particles are levitated if the repulsive electrostatic force between dust and surface is sufficiently large to overcome the gravitational force and the cohesive force on the dust grain which is like as [3]

$$Q_d E_s \geq F_g + F_c \tag{1}$$

Where, Q_d is the charge of dust particle, E_s is the electric field of surface, F_g is the gravitational force, F_c is the cohesive force between particles. Here Fc is very small so we can neglect it.

Near the Lunar surface electric field is complicated due to the transition from photoelectron sheath to plasma sheath and ambient plasma flow; it is significantly change even for small changes in the sun elevation angle [3]. Here authors take a charge dust model and simulate it into a MATLAB using particle-in-cell method which is used for simulation of motion of charged particles. As par the sun elevation angle dust levitation height is change that we can show in Table-1 [3].

TABLE I: Sun elevation angle Vs. Levitation height [3]

Sun Elevation Angle	Levitation Height (m)
0°	2.46
2°	1.63
8°	28.92

Sun elevation angle increase means that day is converting into a night. Here when solar elevation angle is 0° that time levitation height is 2.46 meter and when change the elevation angle 8° that time levitation height is 28.92 meter [3]. From that table we can say that at the 8° elevation angle the electric field is very high if we consider the charge of particle is 1.6×10^{-19} C as per the (1). Electric field magnitude increase means gradient of the potential increases as per equation (2) which is given below

$$\vec{E} = -\nabla\emptyset \tag{2}$$

A potential increase negatively means that negative charged particles are more than the positive charged particles. Sun elevation angle changes 10° that time levitation height is decreases. Sun elevation angle is angle with respect to the local horizontal plane so; the flow of solar light is measure dependent on the levitation height. At the negative charged region the electric field magnitude is increases with solar zenith angle (which is 90 °- sun elevation angles). But, the electric field direction is negative [4]. When solar zenith angle is 0° that time we get maximum electric field magnitude and get minimum electric field magnitude at 75° solar zenith angle [4].

Moon surface is not plain at every side that has some craters and boulders which are create a complex plasma environment because crater has some shadow region which has negative potential at other side region work as a positive side region. So, inside the crater the electric field is in negative direction and the outside the crater the electric field is in positive direction [4]. At the edges and rim of the crater has maximum electric field than the outer side and inside region [4].

B. *Lunar Dust Fountain Model* [5]

A dynamic "Fountain" model is presented which is shown in fig.1, which can explain how submicron dust is able to reach altitudes of up to approximately 100 km above the lunar surface [5]. The static dust levitation models are most applicable to the heavier micron-sized grains in close approximately to the surface but they can't explain the availability of light grains at higher altitudes show fig.1 [5]. In the dynamic fountain model, if the dust grain has sufficient charge to overcome lunar gravity F_g and cohesive force F_c then it leaves the lunar surface. The dust grain is small so, the gravitational force acting on it is so small in comparison with the initial electrostatic acceleration [5]. The grain leaves the sheath region with an upward velocity and follows a near parabolic trajectory back toward the lunar surface since the main force acting on it now is gravity [5].

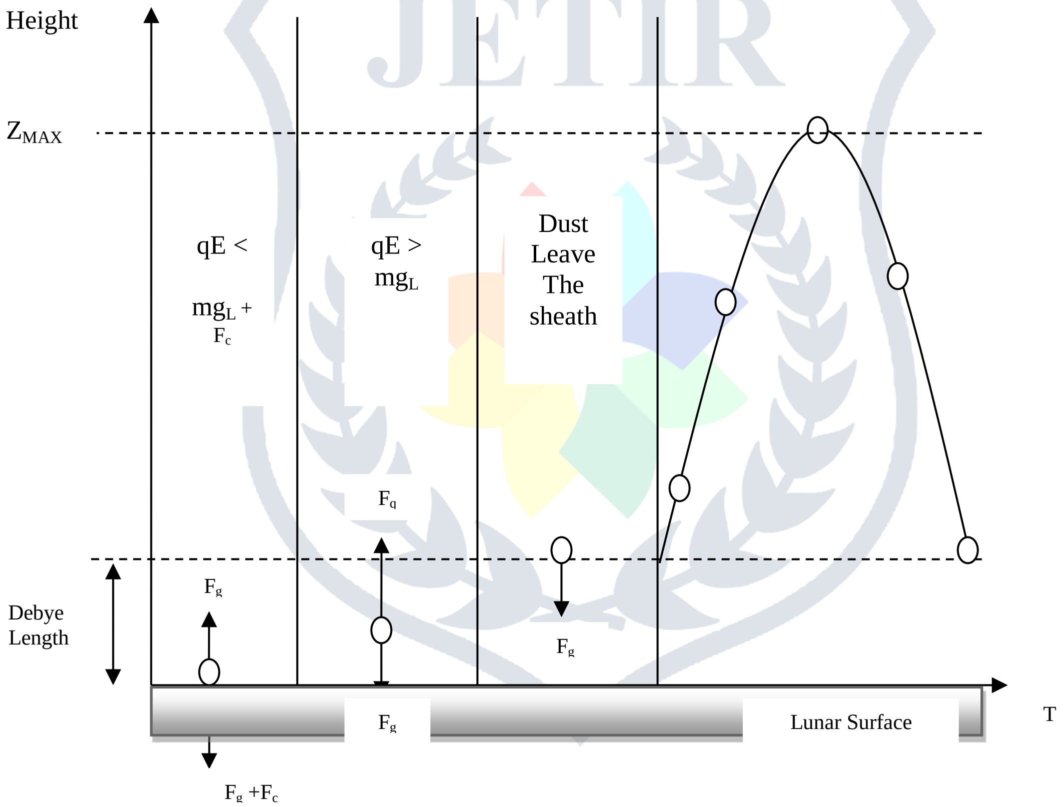

Fig.1: Dust Fountain Model [5]

Table-II: Dust Fountain Model data for maximum height with different sub-solar point [5]

Sub Solar point	Maximum Height Z_{MAX} (m)	Dust grain radius size range (μm)
0°	0.5-1000	1.0-0.01
60°	5-900	0.4-0.01
90°	10-5000	1.0-0.01
100°	15-100000	1.0-0.01

Here Table-II shows Z_{MAX} as a function of r_d, which reveals that dust, may be lifted by the fountain effect at most locations on the lunar surface [5]. At the sunward of the terminator where θ≈80° this region is called "Dead Zone" because there has not presence of lofted dust [5].

This model predicts that a very small (<<0.01 μm) positively charged grains above the day-side, a region in the Dead Zone where no detection occurs, and larger (0.01-0.1 μm) negatively charged grains around the terminator region [5].

C. *Surface Effect on Lunar Dust* [6 and 7]

The two electric fields are interact with each other at the terminator and the surface may cause a stream of particles moving as fountains of dust from one side to the other as per Fountain model [5]. The scattered solar radiation becomes clearly visible against the dark sky of the moon. Science the sky of the moon is always dark, during day and night because of the lack of atmosphere, the presence of micro sized particles transported b electrostatic field [6]. The maximum charge limit for each particle on the surface by the solar wind or by the earth's magneto-tail will depend upon the equilibrium surface potential or the electric field reached by the negative charging [6].

The dust can be mobilized and transported on a surface exposed to a plasma environment [7]. A circular patch of the non-conducting dust particles is observed to spread to form a dust ring on a surface that repels the electrons and collects the ions [7]. This condition may be created near the ion wake boundary on the night-side of the lunar surface when the moon enters the earth's plasma sheet [7].

III. Summary And Future Work Plan

The dust transport on lunar surface is basically depend on the levitation parameter and accordingly that parameter dust changes that characteristics like solar zenith angle, sun elevation angle. The craters and boulders also create a complex plasma environment due to this parameter. The dust follows the ballistic characteristic up to the Debye length limitation and at some region where that has no lofting charged dust particles due to the force that region is called dead-zone region. Dust particle lofting height is depends on the radius of the dust grain. At the negative charged region dust particle has higher lofting height than the positive charged region dust particles.

Our project work involves comparison of a few landing sites consideration of actual lunar terrain data. For the modeling of charge particles we use the particle-in-cell method. Particle-in-cell (PIC) is a method which is used to simulate the motion of charged particles, or plasma [8]. The PIC method can provide the information about density, potential, electric field etc.

We will use Particle-in-cell method for the lunar surface charged particles modeling and develop different possibility of lunar surface cases and simulate those models into a MATLAB. We will take out some specific results which give the idea of self lunar are landing site and it may be useful in mission planar. We will also compare those models with lunar plain site and also take the particles motion and velocity results and we will also derive levitation parameters like density, potential, electric field, force etc. The particle-in-cell code in MATLAB to study scenario at a landing site on the Moon and this research work may be helpful to the mission planner.

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