Lunar Surface Charging Process with Solar Elevation Angle

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***Abstract*—The Lunar surface is electrostatically charged by several mechanisms. The dust particles which are resting on the lunar surface are also charged and levitated. We have taken study model and simulate the model with different Solar Elevation Angles. The Lunar surface charging is depends on the solar elevation angle. When solar elevation angle increases, surface potential also increases with 5.2 V up to the 90^0, after 90^0 its start to decreases with -60.31 V up to the 180^0. The Electric Field and Electrostatic Force are change with the solar elevation angle, as same as surface potential characteristic. If electric field or potential increases then surface particles are levitated higher. So, applying concept of solar elevation angle on study model we can easily say at which solar elevation angle the surface potential and electric field is Minimum for safe landing at lunar site for future mission.**

***Index Terms*— Levitation; Lunar; Solar Elevation Angle; Surface Charging.**

I. INTRODUCTION (HEADING 1)

During the Apollo 17 astronauts observed dust particles which are reaching from 10 to 100 km above the lunar surface [1]. During the day when UV lights and Solar Wind are exposed on to the lunar surface; lunar surface is charged positively and during the night lunar surface is charged negatively due to the Plasma [2] as shown in Fig.1. The dust particles which are resting on the lunar surface are also charged by surface electric field, contact potential difference etc [2]. The dust particles are not levitated that region is called “Dead-Zone” region [3], which is very interesting region for the planetary science because we can choose this region as a lunar landing site for future mission.

This paper presents simulation of relation between Potential, Electric Field and Electrostatic Force with different solar elevation angle on lunar surface. At the lunar surface the dust particles are levitated with higher velocity so, these particles may be puncture or stuck the Lander or the lunar spacecraft. So, a region may be choosing where dust particles are not levitated is calculated through the solar elevation angle because this angle has relation with potential. So, knowing the relation between solar elevation angle and potential relation is important for choosing lunar landing site.

Here, we consider a study model for calculating the lunar surface charging. In this study model we are applying the standard analytical calculations.

In this paper, Particle-In-Cell (PIC) simulation based study model is developed for lunar environment. The surface potential, electric field and electrostatic force between dust and lunar surface are obtained from PIC simulation. These simulations are used to study dust levitation. Section II discusses the simulation models for lunar charging. Section III presents calculated results for surface potential, electric field and electrostatic force different solar elevation angle. Section IV contains a summary and conclusions.

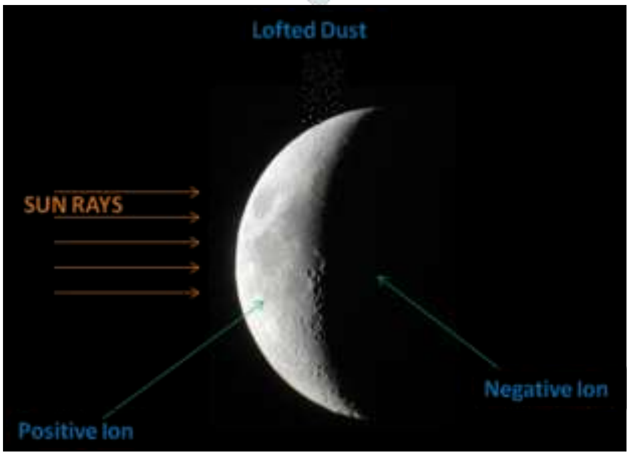


Fig.1. Concept of Lunar Surface Charging

II. Formation And Approach

We consider lunar dust particles which are initially resting on the lunar surface. Here some particles are inserted when the solar winds are coming. This problem is simulated using the Particle-In-Cell (PIC) code in MATLAB. This section discusses the interaction characteristics with changes in Solar Elevation Angle. Fig.2 shows the model setup and Fig.3 shows the solar elevation angle on the lunar surface. In this paper, Particle-In-Cell (PIC) simulation based study model is developed for lunar environment.

A. Lunar surface Charging

We take some Lunar Prospector data for lunar surface charging which are shown in Table I. These parameters are applied for the model. We are calculating some plasma parameters like photoelectron current, ion current, electron current etc which are used in our computation. We have used the current balance Equation (1) which is taken from [5, 6].

$$Ie + Ii + Iph + Is = 0 \qquad (1)$$

where, I_e is the electron current, I_i is the ion current, I_{ph} is the photoelectron current, I_s is the secondary electron current which we are ignoring because its value is very less compare to other.

$$I_e = I_{0e}$$

$$I_i = I_{0i}\, e^{\frac{-e\phi}{kT_i}}$$

$$I_{ph} = I_{0ph}\, e^{\frac{-e\phi}{kT_{ph}}}$$

where, I_{0e} is the electron density, I_{0i} is the ion density and I_{0ph} is the photoelectron density which is derived from Equation (2)

$$\left.\begin{array}{l} I_{0e} = -ne\sqrt{\frac{kT_e}{2\pi m_e}} \\ I_{0i} = -ne\sqrt{\frac{kT_i}{2\pi m_i}} \\ I_{0ph} = 4.5 \times 10-6 \times \cos(90-\alpha) \end{array}\right\} \qquad (2)$$

where, α is the Solar Elevation Angle at the lunar surface.
We take Debye length is

$$\lambda_D = 6.9 \times 10^{-2}\sqrt{\frac{T}{n}} \qquad (3)$$

where, $n = n_e = n_i$, density and $T = T_e = T_i$, Temperature.

TABLE I: Solar Characteristics which are apply for the Model [6]

Parameters	Value
Mass of electron m_e, kg	9.1×10^{-31}
Mass of ion m_i, kg	1.67×10^{-27}
Temperature T, eV	Day - 10, Night - 16
Photoelectron Temperature T_p, eV	2.2
Electron Density n, #/cm^3	Day - 5, Night - 0.8

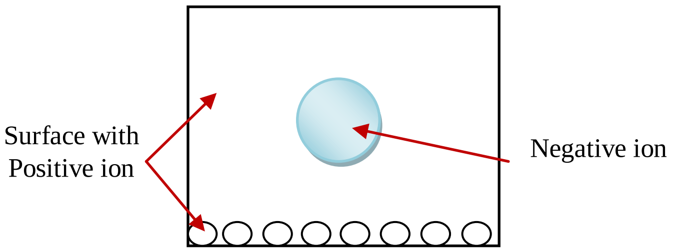


Fig.2. Study model for lunar surface charging

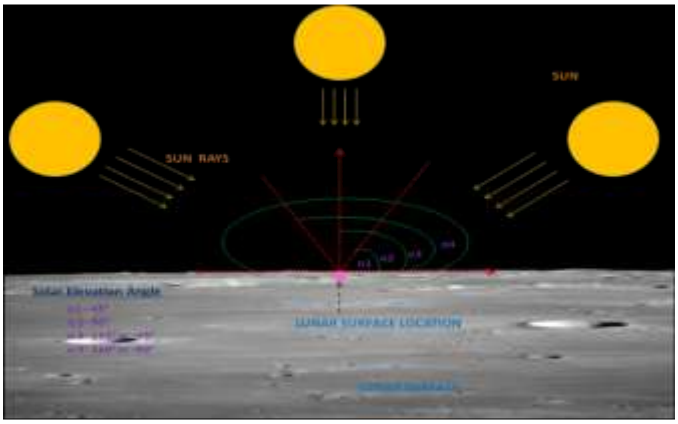


Fig.3. Solar Elevation Angle on Lunar Surface

Surface Potential for day- side is founded by [6]

$$\phi_s = \frac{kT_p}{e} \times ln\left(\frac{I_{oph}}{I_{oe}}\right) \quad (4)$$

and night-side Surface potential is founded by [6]

$$\phi_s = -\frac{kT_e}{e} \times ln\left(\frac{I_{oe}}{I_{oi}}\right) \quad (5)$$

B. Model for Levitation parameter

In this, Particle-In-Cell simulations are carried out by applying boundary condition [7]. Initially we take surface potential $\phi_s = 0$ V. For founding the surface potential with different solar elevation angle we have used equation 4 & 5. Electric Field at lunar surface is obtain from the Potential which is shown in equation (6) which is taken from [6]

$$E = \frac{\phi_s}{\lambda_D} \quad (6)$$

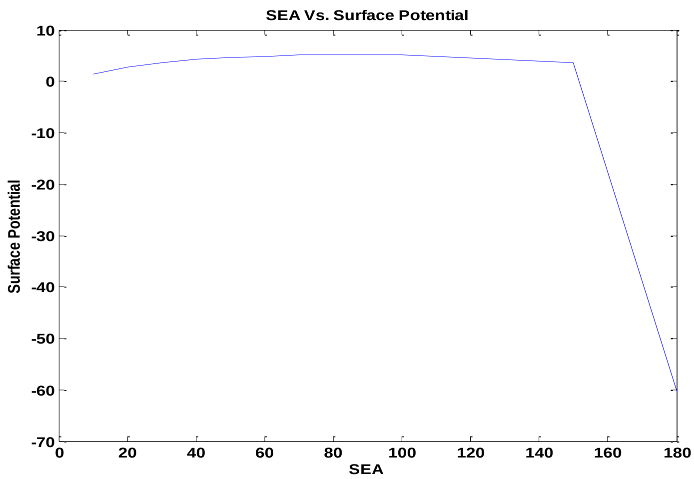
If the potential increases than the Electric Field is also increases. Electrostatic Force on the lunar surface can be founded by the equation (7)

$$F = q * E \quad (7)$$

where, q is the electronic charge

These all equations are applying for lunar surface charging simulations in the next section. During the initial dust charging process, the single dust grain charging model does not change the dust charge significantly [2].

III. Results And Discussions



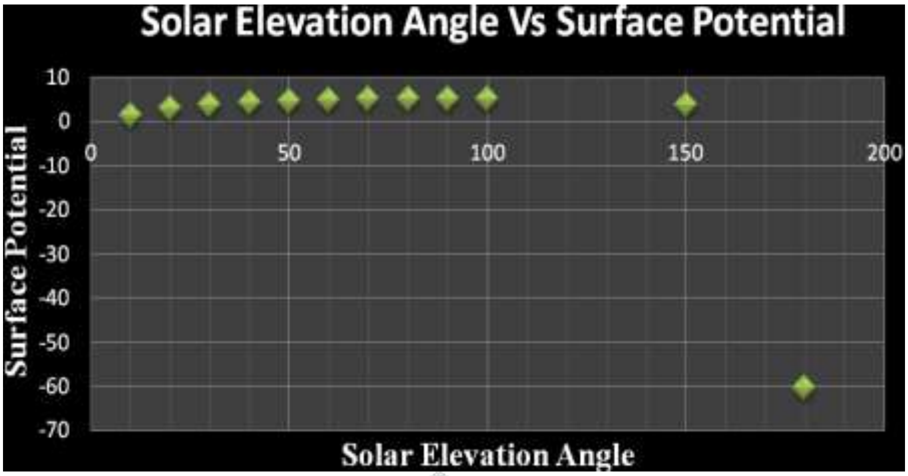


Fig.4. Relation graph of Solar Elevation Angle and Surface Potential

This section presents PIC simulations of lunar surface charging with different solar characteristics. The parameters used in the simulation shown in Table I. In Fig.1. A circle is created on the study model which has negative potential, (means that it can be considered as a night-side region), and the rest of the region in study model has positive potential, (means that it can be considered as a day-side region). As per the Equation (5) surface potential in the night-side region doesn't change with the Solar Elevation Angle. So, the surface Potential and Electric Field is fixed for the circular object, the values are -60.30 V and -5.73 V/m respectively.

For the region in the study model without the circle object, surface potential changes with different solar elevation angle as shown in Fig.4. When sun elevation angle increases the surface potential starts to increase up to 90^0, because morning is eventually transferred in afternoon. After 90^0 solar elevation angle, surface potential decreases because the afternoon is eventually transferred in evening and tends to night. During the day, surface potential has maximum value 5.2 V at the solar elevation angle 90^0. At the solar elevation angle 180^0, we get higher surface potential but in the negative which is -60.31 V. So, the electrostatic force is also high as shown in Table II. As Electrostatic force increases, the acceleration also increases so, levitation height of dust particles is very high at the night-side region.

TABLE II: Levitation Parameters with Solar Elevation Angle

Solar Elevation Angle	Surface Electric Field (E), V/m	Electrostatic Force (F_d) × 10^{-20}, N
10^0	0.1284	2.05
20^0	0.2703	4.32
30^0	0.3498	5.597
40^0	0.4024	6.439
50^0	0.4392	7.026
60^0	0.4649	7.43
70^0	0.4820	7.711
80^0	0.4918	7.864
90^0	0.4950	7.919
100^0	0.4918	7.86
150^0	0.3498	5.59
180^0	-5.7395	-91.8

As per the Equation (6) and (7) when surface potential increases, electric field and electrostatic force also increases. We get value of Debye length as 10.50 m. So, here value of electric field and electrostatic force depends only on the solar elevation angle as shown in Table II. The electric field and electrostatic force increases in the positive direction up to 90^0 with 0.495 V/m and 7.919×10^{-20} N respectively. At the solar elevation Angle 180^0, electric field and electrostatic force are in the negative direction with -5.74 V/m and -91.8×10^{-20} N respectively, but the electric field magnitude and electrostatic force magnitude increases after the 90^0.

IV. Summary And Conclusion

The Particle-In-Cell method is used for the lunar surface environment and simulation results are carried out. When solar elevation angle increases the surface potential and electric field increases up to 90^0 with 5.2 V and 0.495 V/m respectively. After 90^0, the surface potential and electric field are decreases up to 180^0 with -60.31 V and -5.74 V/m respectively. The nature of variation in electrostatic force is same as electric field. Surface potential magnitude and electric field magnitude increases then levitation height of dust particles are also increases. So, if we want to choose lunar landing site then the day side region is prefer with the Solar Elevation Angle between 0^0-10^0, because at that solar elevation angle surface potential and electric field both are lesser as compare to the other solar elevation angle. So, we may be safe our Lander if we choose this range of solar elevation angle.

This paper explain study model to show lunar surface charging with different Solar Elevation Angle and also gives the idea of the lunar landing sites for future planetary mission. More sophisticated dust charging models will needed to be developed in future studies to understand the dust charging characteristics in the surface topography [8, 9].

V. Acknowledgment

The authors would like to thank Dr. Jayesh Pabari, researcher, Physical Research Laboratory, Ahmedabad, India, for the much useful guidance. We are thankful to our family for their continuous encouragement to pursue higher studies and our friends for the help and support.

References

[1] O. Berg, H. Wolf, J. Rhee, “Lunar Soil Movement Registered by the Apollo 17 Cosmic Dust Experiment ”, in *Interplanetary Dust and Zodiacal Light*, H. Elsasser and H. Fechtig, Eds. New York: Springer-Verlag, pp. 233-237, 1976.
[2] J. Wang, X. He, Y. Cao, “Modeling Electrostatic Levitation of Dust Particles on Lunar Surface”, *IEEE Transaction on Plasma Science*, Vol. 36, pp. 2459-2466, 2008.
[3] T. J. Stubbs, R. R. Vondrak, W. M. Farrell, “A Dynamic Fountain Model for Lunar Dust ”, *Advance in Space Research*, Vol. 37, pp. 59-66, 2006.
[4] G. H. Heiken, D. T. Vaniman, B. M. French, “Lunar Sourcebook a User’s Guide to the Moon”, *Cambridge Unoversity Press*, Cambridge, 1991.
[5] J. E. Colwell, A. S. Gulbis, M. Horanyi, S. Robertson, “Dust Transport in Photoelectron Layers and the Formation of Dust Ponds on Eros”, *ICARUS*, Vol. 175, pp. 159-169, 2005.
[6] Robert H. Manka, “Plasma and Potential at the Lunar Surface”, *Astrophysics and Space Science Library*, pp.347-362.
[7] Anonymous-a, February 2015. Online: http://www.particleincell.com/blog/2011/particle-in-cell-example/
[8] Andrew R. Poppe, Marcus Piqette, Alexandre Likhanskii, Mihaly Horanyi, “The Effect of Surface Topography on the Lunar Photoelectron Sheath and Electrostatic Dust Transport”, *ICARUS*, Vol. 221, pp. 135-146, 2012.
[9] M. R. Collier, W. M. Farrell, T. J. Stubbs, “The Lunar Dust Pendulum”, *Advance in Space Research*, Vol. 52, pp. 251-261, 2013.