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Lunar electrostatic effects and protection

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Abstract. The space environment and features on the moon surface are factors in strong electrostatic electrification. Static electricity will be produced in upon friction between lunar soil and detectors or astronauts on the lunar surface. Lunar electrostatic environment effects from lunar exploration equipment are very harmful. Lunar dust with electrostatic charge may enter the equipment or even cover the instruments. It can affect the normal performance of moon detectors. Owing to the huge environmental differences between the moon and the earth, the electrostatic protection technology on the earth can not be applied. In this paper, we review the electrostatic characteristics of lunar dust, its effects on aerospace equipment and moon static elimination technologies. It was concluded that the effect of charged lunar dust on detectors and astronauts should be completely researched as soon as possible.

1. Introduction

All of the moon detector activities, such as exploring the appearance of the moon, investigating the lunar resource material, detecting the moon's space environment and deepening the knowledge of the lunar soil, will face one of the major challenges that is the impact of lunar dust. Lunar surface is covered by a layer of lunar soil which contains a variety of lunar rock and mineral debris. The lunar soil records the lunar surface's impacted history and the solar activity. It is the main sources of studying the lunar resources, material composition and the evolution of the moon. And it is also one of the most important research content on lunar exploration. The lunar soil is a floating layer which consisted of a large number of fine particles, and it is about a few meters thick. It is the fission products by the rock and lunar crust in the role of meteorite impact, mainly composed by solidification or glass fragments and fragments. Below 100 microns, it is usually called lunar dust. The average diameter of the lunar dust is 20 microns, but the majority is less than 5 microns. The lunar dust has a high specific surface area and insulation. Due to the space environmental effects, the lunar dust is easy to get static electricity [1-3]. It is also static floating and has strong adsorption capacity due to the interaction among electrostatic lunar dust electrostatic. Floating lunar dust will block the probe line of sight, adsorb on the surface of the detection equipment or enter the equipment contained in the lunar probe, and even affect the working state of the moon detector optical system, power systems, thermal control system, and even the astronaut system, resulting in blurred vision, reading errors, sealing failure, materials wearing, and reducing the power efficiency of the system, astronauts inhalation and

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allergy problems [4-6]. For example, a mirror of the "measurement on the 3rd (Surveyor3) lander dust pollution, 25 % of the area of the camera filters lunar dust pollution, resulting in decreasing the amount of light to reduce the image contrast. If the moon detector solar system is covered with lunar dust or leads to electrostatic discharge with electrostatic role of lunar dust, it will cause the performance degradation or the function loss, and most likely to make the detection task fail.

2. Electrostatic properties of the lunar dust

Dust particles usually have electrostatic. There are generally three factors accounting for the phenomenon: firstly, when the Moon goes through the Earth's magnetosphere, charged particles would generate static electricity; secondly, when solar storms occur, a high-speed stream of particles is formed by a large number of charged particles. The ray will be launched to the moon, the electrostatic charge of the lunar surface will be gathered to the highest when the solar activity reaches the highest peak; thirdly, when the moon detectors move on the lunar surface, the friction of the lunar surface will generate static electricity. The moon charges positively in the day, while the moon charges negatively in the night, which caused by solar ultraviolet and X-ray photoelectron charge dominant.

In 1968, NASA's Surveyor 7 (Surveyor7) lander photographed a lunar horizon after dark issued a strange light, which is shown in figure 1. A static dust particles floating on the surface of the moon, and the light is scattered when the sun light goes across the charged lunar dust surface. The phenomenon is consistent with the data sent back by NASA's Lunar Prospector "(Lunar Prospector) with this phenomenon lunar Prospector moon running around in 1998-1999. During the period of the moon and the Earth's magnetic tail phase cross, lunar Prospector recorded the significant voltage changes in the lunar surface.

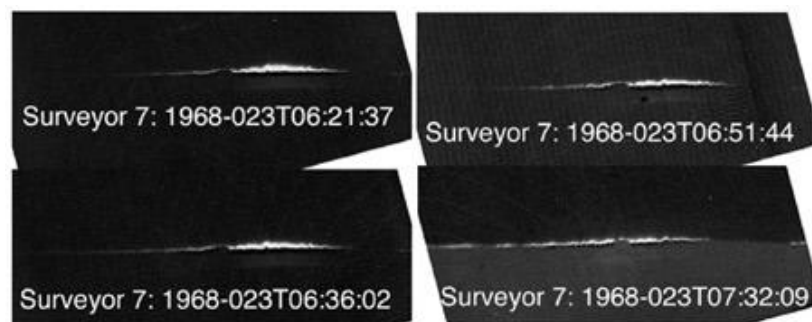


Figure 1. The moon dust scattering of Surveyor7.

Tim-Stubbs, working in Goddard Space Flight Centre, found that the earth's magnetic tail extend far, even cross the earth's orbit. The moon passes through the earth's magnetic tail once a month (full moon), forming a series of phenomena, from the lunar 'dust storms' to electrostatic discharge (Figure 2). The moon moves through the plasma which formed by electric particles during a full moon. The moon charged negative because of the lightest and the most mobile particles, which spreads over the surface of the moon. Positive side of the moon, this effect is offset by sunlight—the photon to hit the electronic bouncing back from the lunar surface, releasing the negative charge. On the other hand, in the back side of the moon, the effect will make the negative potential up to several kilovolts. After analysed the "lunar probe" probe's returned data and the lunar lander photographs for the period 1998-1999, Jasper Halekas, from University of California, found that the charge of the lunar surface is up to 4500 volts. These extreme differences in charge may make the negatively charged dust from the night side of the moon fly to the smooth side, and the strongest particle stream will be formed in the region of the sun rising or falling. The conductivity of the moon surface is low, so the lunar dust particles will maintain charged.

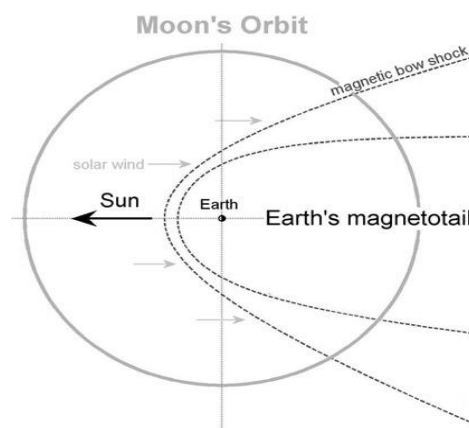


Figure 2. The moon through the Earth's magnetosphere in the full moon.

On the moon, except for the space environment, the environment of triboelectrification is also harsh to make the lunar soil charged. The dry environment of the lunar surface and the low conductivity make the electrical properties of lunar soil to be an insulator. When the moon probe or astronauts land on the lunar surface, lunar soil and the moon probe, as well as the most parts of the space suits material (such as aluminized polyester film, the diene coated nylon, polyester, polyurethane coated nylon, warp knitting fabrics, as well as stainless steel) will produce static electricity in the process of friction with grit and dust. As the lunar soil is insulated, there is no path leading to the ground. The lunar probe and spacesuits surface would accumulate huge amounts of electrostatic charges. Charged lunar dust has a strong adsorption friction which can easily adsorbs on any surface. It can enter into the equipment contained in the lunar rover, no matter the lander, rover or the suit, even in the aluminium surface and the coating surface. It would be no use to remove the lunar dust, even if surface drier, vibration and wiping were used. Large numbers of charged lunar dust may affect the normal working state of the circuit system, thermal control systems, and solar energy power supply system. All of these impacts would lead to communication failure, discharge breakdown, solar panels covering, and other electronic equipments failure and even form an irreversible damage. For example, the moon has no atmosphere, and the temperature varies greatly between days and nights. If the probe's thermal control system is impacted by the lunar dust, and the dust adsorbed on the surface would increase the absorption of radiation and the visible light, which would lead to the radiator deterioration. Studies found that the impact of the lunar dust on absorption ratio is nonlinear, 11 % of the lunar dust coverage area will lead to doubling solar energy absorption ratio.

Static lunar dust would also harmful to spacesuit and human health either. Since the Apollo 11 lunar mission, most of the astronauts considered that lunar dust is one of the main problems encountered after landing on the lunar surface. December 13, 1972, the Apollo 17 spacecraft Astronauts Eugene Cernan and Harrison Schmitt made an investigation of the Taurus-Littrow valley on the moon surface. The spacesuit surface covered with gray dust, and there were also numerous scratches appeared on the goggles. The dust also crept into the suit though the mechanical joints, and even the lunar module was covered with fine dust. After walking on the moon, Schmitt breathed some dust, appeared similar allergic reaction; Cernan reported that his eyes and throat were irritated by static lunar dust. The American space suits manufacturers Hamilton Standard and ILC-Dover engineers believed that the spacesuit providing for "Apollo" missions would make its wearer in serious danger because of these dust. Preliminary studies have shown that astronauts may cause health hazards, including iron poisoning through inhalation of lunar dust. For example, Taylor, a member of the NASA lunar air dust toxicity advisory group, carried out the study of lunar dust's influence on the respiratory system, and planed to develop the standard of touching lunar dust in 2010.

3. Lunar electrostatic environment simulation and static electricity protection research

The moon's atmosphere is very thin, about 12 to 14 orders of magnitude smaller than the density of the Earth's. The atmosphere of the moon's surface is made of neon, hydrogen, helium and argon. Neon, hydrogen, and most of the helium is brought from the solar wind, about 10 % of the helium is produced by the heavy nuclear radioactive decay of the moon itself. Because there is no atmosphere on the moon, the temperature of the lunar surface is determined by the sun directly, ranging from -150 °C to 130 °C, thus high requirements on the efficiency of the lunar probe thermal control system is proposed. The moon rotates a cycle for 27.322 days; a night on the moon is as long as 14 days on the earth. If detect the moon on the moonlit night, the lunar probe has a great demand for solar power system. As the major equipment of the observation of the lunar environment, the lunar probe high-precision optical detection system must always remain in good condition, these equipments are most likely to be effected by the electrostatic lunar. There is no evidence for the existence of the water on the moon, so the grounding system for neutralizing the moon electrostatic would not work. The mature technology of static electricity protection on Earth can't be applied on the moon, because of the different environment between the Moon and the Earth. The lunar probe is completely exposed in a multi kind of cosmic rays, the acceleration of gravity on the moon is about 1.62 m s^{-2} , which is one sixth of the Earth's. These conditions limit the development of the lunar electrostatic protection technology significantly, and Moon static elimination technology is a new technology.

NASA has been very concerned about the effects of static electricity, the lunar dust on astronauts and the moon detectors. A large number of lunar electrostatic environment simulations and researches about the elimination technical are done. As part of the plan, NASA Glenn Research Center developed lunar dust simulation test equipment, which includes lunar dust, vacuum, temperature, solar electromagnetic irradiation and other environmental factors. Lunar dust simulation is one of the most important parts of the equipment. In order to prevent the expansion of the simulated lunar dust explosion, the pumping speed of the vacuum pump should be reasonably controlled; the lunar dust should be stirred constantly at the same time. The degree of vacuum should be achieved 10^{-6} Pa , and before the experiment, more than three times of temperature cycling treatment in the range of -150-200 °C should be done until the residual gas analyzer measurement data remained stable. For the interaction of dust particles with a payload in the vacuum environment, which will be inspected in the following ways: in a temperature-controlled vacuum experimental area, near-ultraviolet irradiation could be produced with the mercury-xenon lamp while far-ultraviolet irradiation could be produced by deuterium lamp. The analogy inputs are from the laboratory and the theoretical analysis and observation of the lunar surface. NASA also built a laboratory, which would be used to simulate the voltage change caused by the interaction of solar radiation and plasma. From these, we can understand how to control the surface voltage to resist or attract month dust, thereby reducing or eliminating the effect of static electricity lunar dust on the moon aerospace equipment. For the electrostatic problem, NASA Glenn Centre studied in the Pathfinder space vehicle. They made a tip in the bottom of the antenna, which is made of sharpened tungsten, one inch long and 2.5 microns in diameter. The tip can produce a strong field, and charges gathered on the device which is released into the thin air. Landis, university of California, believed that we can use a extremely thin air on the moon as a common electrode and put a small radioactive source connected to the space suit and the ground, the low-energy alpha particles will fly into the thin atmosphere and impact the gas molecules, then ionize them. The gas around the moon equipment and the astronauts will become a conductor, so any extra charge will be counteracted. NASA plans to build an ion gun, laser technology will be used to regulate the voltage of the conductive surface. This self-cleaning device is a combination of devices based on electronic or ion beams, which is used for cleaning the lunar dust. The quality and power consumption are limited to a few kilograms and a few watts level, respectively. The application of electric curtain to eliminate the lunar dust is also actively developing. In order to prevent electrostatic breakdown, transparent parallel electrodes are covered by a polyester film of electric curtain, which are connected to the multi-phase or single AC power, forming an alternating electric field. Lunar dust deposited on the electrode will be lifted and moved along the direction perpendicular to the electrode axis under the

electric field, so as to achieve the purpose of lunar dust removal. This method has been used to prototype demonstration; removal efficiency can reach to 80-90 %. But there are lots of further researches should be done in the future, such as optimum conditions chosen including AC voltage, frequency, electrode spacing and electrode width.

The lunar dust seminar convened by NASA in 2007, discussed four issues of the lunar dust: the basic theory of the lunar dust, the effect of lunar dust on the mechanical systems, the impact of lunar dust on medicine/ health and the life support system. These studies cover the lunar plasma environmental studies, the lunar dust data, and the existing analogue lunar soil analysis to see if it is sufficient to describe the characteristics of the real lunar dust. According to the Apollo mission's knowledge, the lunar dust seminar studied the lunar dust reduction and cancellation technology, designed a mechanical device in the lunar dust environment guide, and developed the correct simulated lunar soil to design, and tested the performance of the lunar dust elimination devices. The standard testing techniques and improved technology were also used to study the sensitivity of the mechanical systems on the lunar dust.

4. Conclusion

To the long-term development of China's lunar exploration mission, the impact of lunar dust is a problem that can not be ignored. So the exploration of the moon must be carried on the basis of fully studying the problem. Considering the status and trends of the technology development of China's lunar exploration project, the effect of charged lunar dust on the detector and the astronauts should be completely researched as soon as possible.

Acknowledgments

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