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Space systems — Lunar simulants

Systèmes spatiaux — Simulation de la poussiére lunaire

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Contents

Page

Foreword

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The committee responsible for this document is ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Introduction

This International Standard provides lunar systems developers and operators with a specific quantitative measure for lunar regolith simulants in comparison to other simulants and with relation to sampled lunar materials from Apollo and Lunakhod missions. Developers of lunar systems will use simulants as test materials. This International Standard is a reference for quantitative measures of lunar simulants finer than 10 cm. It describes four properties (composition, size, shape, and density) which are the minimum number of properties needed for such uses as comparative testing involving simulants or civil engineering. The quantitative measures of lunar dust simulants are based on the quantitative measures of lunar regolith samples collected at multiple lunar landing sites of the Apollo missions.

This International Standard provides communication of the geological quality of the simulant between developing organizations and systems operations organizations.

Space systems — Lunar simulants

1 Scope

This International Standard is a reference for quantitative measures of lunar simulants.

2 Terms and definitions and abbreviated terms

2.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1.1
agglutinate
vesiculated glass bonded particle containing other particles (lithic fragments), of which the bonding glass contains spherical particles of iron

Note 1 to entry: The lunar spherules are typically 3 – 100 nanometers in diameter and formed contemporaneous with the glass.

Note 2 to entry: Six features characterize lunar agglutinates: size, surface area with relation to volume, composition, nanophase iron content, flow banding, and multiple generations.

2.1.2
angularity
an expression of roundness

EXAMPLE A poorly rounded grain is described as angular.

Note 1 to entry: This definition has been taken from the *Glossary of Geology* (see Reference [5]).

2.1.3
aspect ratio
ratio of the maximum Feret diameter divided into the orthogonal Feret diameter

Note 1 to entry: Values range from > 0 to 1 and equal to 1 for a circle.

2.1.4
Feret diameter
distance between two parallel lines which are tangent to the perimeter of a particle

Note 1 to entry: The maximum Feret diameter is defined as the greatest distance between two parallel lines which are still tangent to the perimeter of the particle.

2.1.5
figure of merit
degree to which a sample matches a reference

Note 1 to entry: Scaling (normalization) forces the norm of the difference of two composition vectors to lie between 0 and 1, and subtraction from unity results in a figure of merit of 1 for a perfect match and 0 for not match at all.

2.1.6
Heywood circularity factor
expression of the complexity of a particle's perimeter

Note 1 to entry: Formally, the Heywood circularity factor is equal to 1 divided by particle perimeter divided by the circumference of a circle with the same area as the particle. This is numerically equal to the "circularity" defined by Waddell (1933). It is expressed in this manner to make it apparent that the Heywood factor is the inverse of a common definition of "circularity", another common measure.

Note 2 to entry: Values range from > 0 to 1 and equal 1 for a circle.

2.1.7
lithic fragments
physically discrete solids of any rock type whose normative composition is within the range of the target terrain

Note 1 to entry: Lithic fragments have texture and mineralogy. Texture is a more important feature than mineralogy for lithic fragments. Texture describes the grain to grain connectivity boundary. Lunar textures cannot be replicated on Earth.

2.1.8
lunar terrains
mare and highlands

2.1.9
regolith
all particulate surface material including rocks, soils, and dust

Note 1 to entry: As stated in the Introduction, this International Standard is limited in scope to regolith 10 cm and smaller. Rocks, soils, and dust are not differentiated on the basis of size.

2.1.10
re-use
after a simulant volume is used (any sequence of events in which a simulant volume is removed from a storage container) then placed back into storage, any future use constitutes re-use

2.1.11
sphericity
degree to which the shape of a particle approaches a sphere

2.2 Abbreviated terms

c_x concentration or portion of a sample for the x^{th} item in the sample

FoM Figure of Merit

RFD Relative Frequency Distribution

w_i weighting factor. w is a value between one and zero. i is an index which refers to the characteristic being weighted, such as glass (a grain type)

3 Characteristics of lunar regolith previously defined in the Lunar Sourcebook©

3.1 Minerologies

The lunar surface mineralogy is variable across major terrain. These properties are qualitative; they cannot be described in a quantitative manner related to any known spatial distribution across the lunar surface. The listing of the primary minerologies in Reference [3] includes

— Silicate minerals such as Pyroxene, Plagioclase Feldspar, Olivine (Fo_{80}), and Silica minerals,

— Oxide minerals such as Ilmenite, Spinels, and Armalcolite,

— Sulfide Minerals such as Troilite,

— Native Fe, and

— Phosphate Minerals.

3.2 Physical and chemical properties

3.2.1 General

Reference [3] provided a compilation of properties from Apollo and Lunakhod lunar samples of use to the scientific community. These properties are listed since a large amount of data exists for lunar regolith characterization using these properties. As demanded by scientific definitions, these properties are qualitative and quantitative. This means some properties can be measured directly while others are descriptive and are not readily measurable. While these properties are of value to planetary or lunar scientists, they do not address the needs of lunar systems developers and operators with a specific quantitative measure for lunar regolith simulants in comparison to other simulants and with relation to sampled lunar materials.

3.2.2 Physical properties

3.2.2.1 Geotechnical properties

a) particle size distribution;

b) particle shapes;

c) specific gravity;

d) bulk density;

e) porosity;

f) relative density;

g) compressibility;

h) shear strength;

i) permeability and diffusivity;

j) bearing capability;

k) slope stability;

l) trafficability.

3.2.2.2 Electrical and electromagnetic properties

a) electrical conductivity;

b) photoconductivity;

c) electrostatic charging;

d) dielectric permittivity.