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# StandardTerminology Relating to Wear and Erosion[1]

This standard is issued under the fixed designation G40; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 The terms and their definitions given herein represent terminology relating to wear and erosion of solid bodies due to mechanical interactions such as occur with cavitation, impingement by liquid jets or drops or by solid particles, or relative motion against contacting solid surfaces or fluids. This scope interfaces with but generally excludes those processes where material loss is wholly or principally due to chemical action and other related technical fields as, for instance, lubrication.

1.2 This terminology is not exhaustive; the absence of any particular term from this collection does not necessarily imply that its use within this scope is discouraged. However, the terms given herein are the recommended terms for the concepts they represent unless otherwise noted.

1.3 Certain general terms and definitions may be restricted and interpreted, if necessary, to make them particularly applicable to the scope as defined herein.

1.4 The purpose of this terminology is to encourage uniformity and accuracy in the description of test methods and devices and in the reporting of test results in relation to wear and erosion.

NOTE 1—All terms are listed alphabetically. When a subsidiary term is defined in conjunction with the definition of a more generic term, an alphabetically-listed cross-reference is provided.

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

C242 Terminology of Ceramic Whitewares and Related Products

## 3. Terminology

**abradant,** *n*—a material that is producing, or has produced, abrasive wear.

**abrasion,** *n*—in tribology, the process by which relative motion between a surface and hard particles or protuberances on an opposing surface produces abrasive wear of that surface. (See also **abrasive wear**.)

**abrasive wear,** *n*—wear due to hard particles or hard protuberances forced against and moving along a solid surface.

**abrasion-corrosion,** *n*—a synergistic process involving both abrasive wear and corrosion in which each of these processes is affected by the simultaneous action of the other and, in many cases, is thereby accelerated.

**abrasivity,** *n*—the ability of a material or substance to cause abrasive wear.

*absolute impact velocity*—See **impact velocity**.

**acceleration period,** *n—in cavitation and liquid impingement erosion*, the stage following the incubation period during which the erosion rate increases from near zero to a maximum value. (See also **erosion rate-time pattern.**)

**accumulation period,** *n—in cavitation and liquid impingement erosion*, a less-preferred term for **acceleration period**.

**adhesive wear,** *n*—wear due to localized bonding between contacting solid surfaces leading to material transfer between the two surfaces or loss from either surface.

**angle of attack,** *n—in impingement erosion*, the angle between the direction of motion of an impinging liquid or solid particle and the tangent to the surface at the point of impact.

**angle of incidence,** *n—in impingement erosion*, the angle between the direction of motion of an impinging liquid or solid particle and the normal to the surface at the point of impact.

**apparent area of contact,** *n—in tribology*, the area of contact between two solid surfaces defined by the boundaries of their macroscopic interface. (Contrast with **real area of contact**.)

**asperity,** *n—in tribology*, a protuberance in the small-scale topographical irregularities of a solid surface.

**attenuation period,** *n—in cavitation and liquid impingement erosion*, a less-preferred term for **deceleration period**.

**average erosion rate,** *n*—a less preferred term for **cumulative erosion rate**. (See also **interval erosion rate**.)

[1] This terminology is under the jurisdiction of ASTM Committee G02 on Wear and Erosion and is the direct responsibility of Subcommittee G02.91 on Terminology.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

**Beilby layer,** *n*—an altered surface layer of supposedly amorphous material formed on a crystalline solid during mechanical polishing, whose existence was proposed in Sir George Beilby's writings. The existence of such a layer is not supported by recent research, and the use of this term is therefore considered archaic and is strongly discouraged.

*break-in*, *n*—See **run-in**.

*break in*, *v*—See **run in**.

**brinelling,** *n*—damage to a solid bearing surface characterized by one or more plastically formed indentations caused by static or impulsive overloads, especially as found in rolling contact bearings. (See also **false brinelling**.)

**brittle erosion behavior,** *n*—erosion behavior having characteristic properties that can be associated with brittle fracture of the exposed surface; that is, little or no plastic flow occurs, but cracks form that eventually intersect to create erosion fragments. (See also **ductile erosion behavior**.)

DISCUSSION—In solid impingement an easily observable aspect of erosion helps to distinguish brittle from ductile behavior. This is the manner in which volume removal varies with the angle of attack. With brittle erosion the maximum volume removal occurs at an angle near 90°, in contrast to approximately 25° for ductile erosion behavior.

**carrier fluid,** *n—in impingement or slurry erosion*, fluid medium that transports impinging solid or liquid particles and that gives the particles their momentum relative to the solid surface on which they are impinging.

**catastrophic period,** *n—in cavitation or liquid impingement erosion*, a stage during which the erosion rate increases so drastically that continued exposure threatens or causes gross disintegration of the exposed surface. This stage is not inevitable; it is observed most commonly with some brittle materials. When it does occur, it may begin during any stage of the more common erosion rate-time pattern.

**catastrophic wear,** *n*—rapidly occurring or accelerating surface damage, deterioration, or change of shape caused by wear to such a degree that the service life of a part is appreciably shortened or its function is destroyed.

**cavitating disk device (or apparatus),** *n*—a flow cavitation test device in which cavitating wakes are produced by holes in, or protuberances on, a disk rotating within a liquid-filled chamber. Erosion test specimens are attached flush with the surface of the disk, at the location where the bubbles are presumed to collapse.

**cavitating jet,** *n*—a continuous liquid jet (sometimes submerged) in which cavitation is induced by the nozzle design, or sometimes by an obstruction placed in the center of the flow passage.

*cavitating wake*, *n*—See **flow cavitation**.

**cavitation,** *n*—the formation and subsequent collapse, within a liquid, of cavities or bubbles that contain vapor or a mixture of vapor and gas.

DISCUSSION—Cavitation originates from a local decrease in hydrostatic pressure in the liquid, usually produced by motion of the liquid (see **flow cavitation**) or of a solid boundary (see **vibratory cavitation**). It is distinguished in this way from boiling, which originates from an increase in liquid temperature.

DISCUSSION—The term cavitation, by itself, should *not* be used to denote the damage or erosion of a solid surface that can be caused by it; this effect of cavitation is termed **cavitation damage** or **cavitation erosion**. To erode a solid surface, bubbles or cavities must collapse on or near that surface.

**cavitation cloud,** *n*—a collection of a large number of cavitation bubbles. The bubbles in a cloud are small, typically less than 1 mm (0.04 in.) in cross section. A surface that is being eroded by cavitation is usually obscured by a cavitation cloud.

*cavitation damage*, *n*— See **damage**.

**cavitation erosion,** *n*—progressive loss of original material from a solid surface due to continued exposure to cavitation.

**cavitation erosion test,** *n*—a procedure whereby the surface of a solid is subjected to cavitation attack under specified, or measurable, or at least repeatable conditions.

DISCUSSION—Such tests can be divided into two major classes depending on whether flow cavitation or vibratory cavitation is generated.

**cavitation number, σ,** *n*—a dimensionless number that measures the tendency for cavitation to occur in a flowing stream of liquid, and that is computed from the equation:

$$\sigma = (P_o - P_v)/\frac{1}{2}\rho V_o^2 \quad (1)$$

where:

$P_v$ = vapor pressure,
$P_o$ = static pressure in the stream in an undisturbed state,
$V_o$ = undisturbed stream velocity, and
ρ = liquid density.

DISCUSSION—The cavitation number and the net positive suction head (NPSH) are related by the equation:

$$\text{NPSH} = (\sigma + 1)V_o^2/2g \quad (2)$$

where $g$ is the acceleration due to gravity.

**cavitation tunnel,** *n*—a flow cavitation test facility in which liquid is pumped through a pipe or tunnel, and cavitation is induced in a test section by conducting the flow through a constriction, or around an obstacle, or a combination of these.

**coefficient of friction** *μ or f*, *n—in tribology*, the dimensionless ratio of the friction force ($F$) between two bodies to the normal force ($N$) pressing these bodies together. (See also **static coefficient of friction** and **kinetic coefficient of friction**.)

$$\mu = (F/N) \quad (3)$$

**collection efficiency,** *n—in impingement erosion and particulate flows*, the cross-sectional area of undisturbed fluid containing particles that will all ultimately impinge on a given solid surface, divided by the projected area of the solid surface, where these two areas are perpendicular to the direction of relative motion between the solid surface and the particles in the undisturbed fluid.

DISCUSSION—"Undisturbed fluid" means fluid that is sufficiently ahead of the solid surface to be undisturbed by the flow around the solid surface. For example, the particles could be carried in a stream of fluid moving toward a solid surface that is stationary, or the solid surface could be moving through a suspension of particles. Not all of the particles that move in the direction of the solid surface or lie in its path will impinge upon it, since some will be carried away in the fluid as it flows around the surface.

DISCUSSION—A variety of terms having the same meaning can be found in the literature. These include "collision efficiency," " capture efficiency," "catchment efficiency," " impaction ratio," and others. The term "collection efficiency," being perhaps the most widely used, is preferred.

*continuous jet*, *n*—See **liquid jet**.

**corrosive wear,** *n*—wear in which chemical or electrochemical reaction with the environment is significant.

**cumulative erosion,** *n—in cavitation and impingement erosion*, the total amount of material lost from a solid surface during all exposure periods since it was first exposed to cavitation or impingement as a newly-finished surface. (More specific terms that may be used are *cumulative mass loss, cumulative volume loss*, or *cumulative mean depth of erosion*. See also **cumulative erosion-time curve**.)

DISCUSSION—Unless otherwise indicated by the context, it is implied that the conditions of cavitation or impingement have remained the same throughout all exposure periods, with no intermediate refinishing of the surface.

**cumulative erosion rate,** *n*—the cumulative erosion at a specified point in an erosion test divided by the corresponding cumulative exposure duration; that is, the slope of a line from the origin to the specified point on the cumulative erosion-time curve. (*Synonym:* **average erosion rate**)

**cumulative erosion-time curve,** *n—in cavitation and impingement erosion*, a plot of cumulative erosion versus cumulative exposure duration, usually determined by periodic interruption of the test and weighing of the specimen. This is the primary record of an erosion test. Most other characteristics, such as the incubation period, maximum erosion rate, terminal erosion rate, and erosion rate-time curve, are derived from it.

**cutting wear,** *n— in solid impingement erosion*, the erosive wear associated with the dissipation of kinetic energy of impact arising from the tangential component of the velocity of the impacting particles.

DISCUSSION—Since erosion due to oblique particle impact inevitably involves *deformation wear* as well as cutting wear, the magnitude of the cutting wear can be experimentally determined by conducting a separate test at normal impact to determine the deformation wear, and subtracting that from the total wear at any angle of impact, where both tests are conducted with the same *normal* component of impact velocity and both results are normalized to the mass of impacting particles. See also related terms **deformation wear, ductile erosion behavior**, and **brittle erosion behavior**.

**damage,** *n—in cavitation or impingement*, any effect on a solid body resulting from its exposure to these phenomena. This may include loss of material, surface deformation, or any other changes in microstructure, properties, or appearance.

DISCUSSION—This term as here defined should normally be used with the appropriate modifier, for example, "cavitation damage," "liquid impingement damage," "single-impact damage," and so forth.

**debris,** *n—in tribology*, particles that have become detached in a wear or erosion process.

**deceleration period,** *n—in cavitation or liquid impingement erosion*, the stage following the acceleration period or the maximum rate period (if any) during which the erosion rate has an overall decreasing trend although fluctuations may be superimposed on it. (See also **erosion rate-time pattern.**)

**deformation wear,** *n—in solid impingement erosion*, the erosive wear of a material associated with the dissipation of kinetic energy of impact arising from the normal component of the velocity of the impacting particles. It is therefore the sole component of wear for particles impacting at a 90° angle of attack.

DISCUSSION—This term is used for the erosion of brittle materials, even though plastic deformation is lacking. See also related terms **brittle erosion behavior, ductile erosion behavior**, and **cutting wear**.

**distributed impact test,** *n—in impingement erosion testing*, an apparatus or method that produces a spatial distribution of impacts by liquid or solid bodies over an exposed surface of a specimen.

DISCUSSION—Examples of such tests are those employing liquid sprays or simulated rainfields. If the impacts are distributed uniformly over the surface, the term "uniformly distributed impact test" may be used. (Contrast with **repetitive impact erosion test**.)

**drop, liquid,** *n*—see **liquid drop**.

**drop size,** *n*—the diameter of a liquid drop if it is approximately spherical; otherwise, the approximate shape and appropriate dimensions must be described.

DISCUSSION—In a spray or rainfall, there will normally be a spectrum of drop sizes, which can be presented by distribution curves or histograms, showing either number of drops or combined volume of drops as a function of drop size. A representative drop size for a distribution is afforded by the sauter mean diameter, or else by the size interval containing the largest total volume.

**ductile erosion behavior,** *n*—erosion behavior having characteristic properties that can be associated with ductile fracture of the exposed solid surface; that is, considerable plastic deformation precedes or accompanies material loss from the surface which can occur by gouging or tearing or by eventual embrittlement through work hardening that leads to crack formation. (See also **brittle erosion behavior**.)

DISCUSSION—In solid impingement, two easily observable aspects of erosion help to distinguish ductile erosion behavior. The first is the manner in which volume removal varies with the angle of attack. Ductile materials show maximum volume removal for angles from approximately 20 to 30°, in contrast to near 90° for brittle erosion behavior. A second indication of ductile behavior is the characteristic ripple pattern that forms on the exposed surface at low values of angle of attack.

**erodant,** *n*—a material that is producing, or has produced, erosive wear.

**erosion,** *n—in tribology*, progressive loss of original material from a solid surface due to mechanical interaction between

that surface and a fluid, a multicomponent fluid, or impinging liquid or solid particles.

DISCUSSION—Because of the broad scope of this term, it is recommended that it normally be qualified to indicate the relevant mechanism or context, for example, cavitation erosion, liquid impingement erosion, solid impingement erosion, beach erosion, and so forth.

**erosion-corrosion,** *n*—a synergistic process involving both erosion and corrosion, in which each of these processes is affected by the simultaneous action of the other, and in many cases is thereby accelerated.

**erosion rate,** *n*—any determination of the rate of loss of material (erosion) with exposure duration. (See also **rationalized erosion rate**.)

DISCUSSION—Erosion rate is usually determined as a slope on the cumulative erosion-time curve. Since in cavitation or liquid impingement this curve is generally not a straight line, it is necessary to specify how any particular numerical value was determined from this curve. The following more explicit terms may be used: average erosion rate, instantaneous erosion rate, interval erosion rate, maximum erosion rate, and terminal erosion rate. See individual definitions of these terms.

**erosion rate-time curve,** *n*—a plot of instantaneous erosion rate versus exposure duration, usually obtained by numerical or graphical differentiation of the cumulative erosion-time curve. (See also **erosion rate-time pattern**.)

**erosion rate-time pattern,** *n*—any qualitative description of the shape of the erosion rate-time curve in terms of the several stages of which it may be composed.

DISCUSSION—In cavitation and liquid impingement erosion, a typical pattern may be composed of all or some of the following "periods" or "stages": **incubation period, acceleration period, maximum-rate period, deceleration period, terminal period**, and occasionally **catastrophic period**. The generic term "period" is recommended when associated with quantitative measures of its duration, and so forth; for purely qualitative descriptions the term "stage" is preferred.

**erosion resistance,** *n*—a test and measurement dependent characteristic of a triboelement in a tribosystem that describes the relative amount of erosive wear measured, or to be expected, in a test or application. (See also **normalized erosion rate**.)

DISCUSSION—Erosion resistance is typically reported in relative terms, for example, "Material A is more erosion resistant than Material B," or "Material A is 3.5 times more erosion resistant than Material B."

**exposure duration,** *n—in erosion or wear*, exposure time, or any other appropriate measure of the accumulation of exposure to an erosion or wear environment.

DISCUSSION—For impingement erosion, some alternative duration parameters are the number of impacts that have occurred on a given point, or the mass or volume of particles that have impinged on a unit area of exposed surface. For wear, it may be the sliding distance traveled.

**false brinelling,** *n*—damage to a solid bearing surface characterized by indentations not caused by plastic deformation resulting from overload but thought to be due to other causes such as *fretting corrosion*. (See also **brinelling**.)

**fatigue wear,** *n*—wear of a solid surface caused by fracture arising from material fatigue.

**flow cavitation,** *n*—cavitation caused by a decrease in local pressure induced by changes in velocity of a flowing liquid. Typically, this may be caused by flow around an obstacle or through a constriction, or relative to a blade or foil. A cavitation cloud or "cavitating wake" generally trails from some point adjacent to the obstacle or constriction to some distance downstream, the bubbles being formed at one place and collapsing at another.

**fretting,** *n—in tribology*, small amplitude oscillatory motion, usually tangential, between two solid surfaces in contact.

DISCUSSION—Here the term *fretting* refers only to the nature of the motion without reference to the wear, corrosion, or other damage that may ensue. The term *fretting* is often used to denote *fretting corrosion* and other forms of *fretting wear*. Usage in this sense is discouraged due to the ambiguity that may arise.

**fretting corrosion,** *n*—a form of fretting wear in which corrosion plays a significant role.

**fretting wear,** *n*—wear arising as a result of fretting (see **fretting**).

**friction force,** *n*—the resisting force tangential to the interface between two bodies when, under the action of an external force, one body moves or tends to move relative to the other. (See also **coefficient of friction**.)

**galling,** *n*—a form of surface damage arising between sliding solids, distinguished by macroscopic, usually localized, roughening, and the creation of protrusions above the original surface; it is characterized by plastic flow and may involve material transfer.

**hard particle erosion,** *n*—deprecated term; use the preferred synonyms *solid impingement erosion* or *solid particle erosion.*

**Hertzian contact area,** *n*—the apparent area of contact between two nonconforming solid bodies pressed against each other, as calculated from Hertz' equations of elastic deformation.

**Hertzian contact pressure,** *n*—the magnitude of the pressure at any specified location in a Hertzian contact area, as calculated from Hertz' equations of elastic deformation.

**impact angle,** *n— in impingement erosion*, an angle that could be either the **angle of attack** or the **angle of incidence**, which see. Because of this ambiguity, this term should be specially defined when used or, preferably, used only in contexts where the ambiguity does not matter.

**impact velocity,** *n—in impingement erosion*, the relative velocity between the surface of a solid body and an impinging liquid or solid particle.

DISCUSSION—To describe this velocity completely, it is necessary to specify the direction of motion of the particle relative to the solid surface in addition to the magnitude of the velocity. The following related terms are also in use:

(*1*) **absolute impact velocity**—the magnitude of the impact velocity.

(*2*) **normal impact velocity**—the component of the impact velocity that is perpendicular to the surface of the test solid at the point of impact.