Glossary
with special emphasis put on composites

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References

[1] CMH-17 (Military Handbook 17): *Composite Materials Handbook.* US Department of defense

[2] HSB 40100-01: *Buckling - General Remarks and Terms.* Issue A, 2010

[3] HSB 01501-01: *Essential Topics in the Determination of a Reliable Reserve Factor.* Issue A (not yet issued)

[4] VDI-2014: German Guideline, Sheet 3 *Development of Fibre-Reinforced Plastic Components - Analysis.* Beuth Verlag, 2006

[5] Tsai, S.W. (editor): *Strength & Life of Composites.* JEC Composites, 2010 (contact: compositesdesign.stanford.edu)

[6] Diestel, O.: Personal note on textile terms, 2008

[7] MMPDS-06: *Metallic Materials Properties Development and Standardization.* April 2011

1 General

This sheet includes terms, definitions and abbreviations applied in structural mechanics. Special emphasis is put on composite materials.
The sheet is seen as a living document. Its content should be checked, monitored and is still open for definitions provided by IASB members.

The definitions for commonly used terms have been compiled from several sources. A specific glossary of terms related to composite testing and material property generation is presented in CMH-17 (Ref. [1]). Other information has been obtained from websites of

General Composite Inc. Glossary (http://www.generalcomposites.com/),
Trans Tech Composites Glossary,
Composites-By-Design Glossary (http://clev11.com/~composi1/?page_id=21),
Composite Resources Terminology
(http://composite-resources.com/composite-technology/composite-terminology/index.php) and
Wikipedia - the free encyclopedia (http://www.wikipedia.org/).

More detailed buckling terms are provided in HSB 40100-01 (Ref. [2]) and safety concept terms in HSB 01501-01 (Ref. [3]).

2 Abbreviations

AIMS	Airbus material specification
AMS	aerospace material specification
ASTM	American society for testing and materials
BVID	barely visible impact damage
CDF	cumulative density function
CDM	continuum damage mechanics
CDR	critical design review
CDS	characteristic damage state
CF	carbon fiber
CFRP	carbon fiber-reinforced plastic
CLT	classical laminate theory
CMC	ceramic-matrix composites
COD	crack-opening displacement
CoG, CG	center of gravity
COS	coordinate system
CoV	coefficient of variation
CT	compact tension (specimen)
CTE	coefficient of thermal expansion
DCB	double cantilever beam
DLL	design limit load (spacecraft terminus technicus)
DMA	dynamic mechanical analysis (T_g determination)

DoD	department of defense
DoE	design of experiments
DoF	degrees of freedom
DSC	differential scanning calorimetry (T_g determination)
DTA	damage tolerance analysis
DUL	design ultimate load
Eff	material stressing effort
EC	elasticity center
ENF	end-notched flexure
EP	epoxy
EPFM	elastic-plastic fracture mechanics
ERR	energy release rate (fracture mechanics)
ESA	European space agency
F	failure function
FAA	federal aviation authority
FEA	finite element analysis
FEM	finite element method
FF	fiber failure
FGM	functionally graded material
FMECA	failure mode effect and criticality analysis
FoS	(design) factor of safety
FPP	fiber patch placement
FPF	first-ply-failure
FRP	fiber-reinforced plastic
FSDT	first-order-shear-deformation theory
GFRP	glass fiber-reinforced plastic
GMT	glass mat-reinforced thermoplastics
HM	high modulus C-fiber
HPRTP	high pressure resin transfer molding
HRR	Hutchinson, Rice, Rosengren (HRR) singular crack tip field (stress and strain) for elastic-plastic material response
HST	high strength C-fiber
HT	high tenancy
IFF	inter-fiber failure
ILS	inter-laminar stresses ($\tau_{23}, \tau_{13}, \sigma_3$ of a UD lamina)

ILSS	inter-laminar shear strength
IM	intermediate modulus C-fiber
LC	load case
KDF	knock-down factor
LBA	Luftfahrtbundesamt
LCM	liquid composite moulding
LEFM	linear elastic fracture mechanics
MDO	multi-disciplinary optimization
MKF	multi-axially (reinforced flat bed) weft knitted fabrics
MMC	metal-matrix composites
MMPDS	Metallic Materials Properties Development and Standardization (predecessor was MIL-HDBK 5)
MRO	maintenance, repair, overhaul
MS	(MoS) margin of safety
NCF	non-crimp fabric
NDE	non-destructive evaluation (broadly considered synonymous with NDI)
NDI	non-destructive inspection
NDT	non-destructive testing (considered synonymously with NDI), nil-ductility transition temperature
NF	normal fracture (σ-based)
OHS	open hole strength (tensile, compressive)
PDF	probability density function
PDR	preliminary design review
QL	qualification test load
R	strength, resistance
RF	reserve factor
RIM	reaction injection moulding
RT	room temperature
RSM	response surface method
RTM	resin transfer moulding
RVE	representative volume element
SAE	standard american equivalent, society of automotive engineers
SC	center of shear
SCF	stress concentration factor
SENB	single-edge-notch bend (three-point bend specimen)
SERR	strain energy release rate

SF	shear fracture (τ-based)
SIF	stress intensity factor
SHM	structural health monitoring
SMC	sheet moulding compounding
SY	shear yielding(τ-based)
TCD	theory of critical distances
TFP	tailored fiber placement
TMA	thermal mechanical analysis (initiation of glass transition)
TUS	tensile ultimate stress (also used is UTS)
UD	uni-directional
UHM	ultra-high modulus C-fiber
VAP	vacuum assisted process
VCCT	virtual crack closure technique
WF	lamina with woven-fabric reinforcement
WWFE	World-Wide-Failure-Exercise
1D	one-dimensional, uni-axial
2D	two-dimensional, bi-axial
3D	three-dimensional, tri-axial
2K	two matrix components, 2000 filaments

3 Terms

A-Basis Design_Allowable (or "A"-Value): statistically-based material property, above which at least 99 % of the population of values is expected to fall, with a confidence level of 95 %.
Note 1: Definition in MMPDS (Ref. [7]): The lower of either a statistically calculated T_{99} value, or the specification minimum (S-Basis). The T_{99} value indicates that at least 99 % of the population is expected to equal or exceed it, with a confidence of 95 %.
Note_2: There is no other property addressed than strength or resistance.
Note 3: The use of the lower value of T_{99}-value and specification minimum shall protect the design value against a potential drift of the material quality.

A-Stage: early stage in the reaction of thermosetting resins in which the material is still soluble in certain liquids and may be liquid or capable of becoming liquid upon heating

Absorption: process in which one material (the absorbent) takes in or absorbs another material (the absorbate)

Absorption: process in which one material (the absorbent) takes in or absorbs another material (the absorbate)

Accelerator: material which, when mixed with a catalyzed resin, will speed up the chemical reaction between the catalyst and the resin

Action: loading applied in design.
Examples: axial load, external differential pressure, line load, stress state, suction, patch or local load, friction load, hygro-thermal loading, hydrostatic loading

Accumulation: here, summing-up of damaging portions during a material damage process

Adhesion: state in which two surfaces are held together at an interface by forces or interlocking action or both

Adhesive: substance capable of holding two materials together by surface attachment.
Note: the term is used specifically to designate structural adhesives, those which produce attachments capable of transmitting significant structural loads

Aging: process of exposing materials to an environment for an interval of time.
Example: degradation of polymers by environmental effects

Ambient: surrounding environmental conditions such as pressure, temperature, moisture

Amorphous: polymers with no crystalline component

Angle-ply: balanced laminate consisting of plies at arbitrary angles of plus and minus Θ, where Θ is the angle of the fibers with the principal laminate axis

Anisotropic: not isotropic, having mechanical or physical properties which vary with the direction relative to the natural reference axes inherent in the material.
Note: special cases are transversely-isotropic (UD), orthotropic, monotropic

Aramid: manufactured fiber in which the fiber-forming substance consists of a long-chain synthetic aromatic polyamide

Areal Weight of Fiber: weight of fiber per unit area of prepreg.
Note: this is often expressed as grams per square meter

Artificial Weathering: exposure to laboratory conditions.
Note: conditions may be cyclic, involving changes in temperature, relative humidity, radiant energy and any other elements found in the atmosphere in various geographical areas. Closely related to aging

Assembly: combination of assembled units which form a functional part

Availability: aptitude of a product to be - at a certain time or during a certain time - in a position to provide the functions, expressed in terms of probability

Autoclave: closed vessel for producing an environment of fluid pressure, with or without heat, to an enclosed object which is undergoing a chemical reaction or other operation

Autoclave Molding: curing process in an autoclave.
Note: the lay-up is covered by a pressure bag, and the entire assembly is placed in an autoclave capable of providing heat and pressure for curing the part. The pressure bag is normally vented to the outside

Average Strength: typical strength $\bar{R}$, utilized in test data mapping.
Note: it is the statistical mean strength in case enough test data are available

Average Stress (here): stress in a lamina, smeared over a length that includes some micro-cracks generated after the onset of IFF until final failure of the laminate

B-Basis Design Allowable (or "B"-Value): statistically-based material property, above which at least 90 % of the population of values is expected to fall, with a confidence level of 95 %.
Note 1: Definition in MMPDS (Ref. [7]): Based on the calculated T_{90}, at least 90 % of the population of values are expected to equal or exceed the B-Basis mechanical property allowable with a confidence of 95 %.
Note 2: These values are used in case of resistance (strength) properties.
Note 3: If the A-Basis value is lower than the specification minimum, the B-Basis value is often reduced as well, to keep the ratio between A- and B-Basis the same as the ratio between T_{99} and T_{90}. Having in mind the protection of the A-value against potential drift, it is unlikely that the T_{90}-value would remain stable if the T_{99}-value is decreasing. However, such a B-value reduction is not a requirement.

B-Stage: intermediate stage in the reaction of a thermosetting resin in which the material softens when heated and swells when in contact with certain liquids but does not entirely fuse or dissolve.
Note: materials are usually precured to this stage to facilitate handling and processing prior to final cure

Bag Molding: method of molding or laminating which involves the application of fluid pressure to a flexible material which transmits the pressure to the material being molded or bonded. Fluid pressure usually is applied by means of air, steam, water or vacuum

Balanced Laminate: composite laminate in which all laminae at angles other than 0° and 0° occur only in $\pm$ pairs (not necessarily adjacent).
Note: balanced laminates, necessarily are not symmetric. They do not exhibit in-plane shear coupling.

Basic Lamina: model lamina used as calculation element in the analysis of fabrics

Batch (or Lot):
1. for fibers and resins, a quantity of material formed during the same process and having identical characteristics throughout.
2. for prepregs, laminae, and laminates, material made from one batch of fiber and one batch of resin

Beam: uni-axial structural element with cross section dimensions small compared to its length, subjected to loadings that include bending and shear besides a normal force being tensile or compressive.
Note 1: its cross section is not necessarily constant along the length x. A beam may be straight or curved.
Note 2: in the framework of structural analysis, a beam is usually reduced to its longitudinal axis in a mathematical sense, using effective cross section properties such as cross section area or moments of inertia (exception: deep beam).
Note 3: if a load parallel to the beam axis is applied that does not invoke any bending reaction, a beam is also referred to as a rod or strut (the latter in the case of a compressive load).
deep beam: a high beam structure where the bending stiffness lateral to the vertical z-axis is much lower than about the y-axis. The beam theory can be only approximately applied
short beam: beam with dimensions where the classical stress distribution derived by beam theory cannot evolve
homogeneous beam: one-dimensional structural member built up from one material, only
Note: the material may be isotropic, UD, or orthotropic.

Beam Column: beam under lateral and axial compressive loading

Bearing Load: compressive load on a curved or plane interface (surface)

Bearing, by-pass Interaction: interaction of bearing stress and by-pass stress in the case of bolted joints

Bearing Yield Strength: strength equal to a bearing stress at which a material exhibits a specified limiting deviation from the proportionality of bearing stress to bearing strain

Bend Test: test of ductility by bending or folding, usually with steadily applied forces.
Note: in some instances the test may involve blows to a specimen having a cross section that is essentially uniform over a length several times as great as the largest dimension of the cross section.

Bifurcation Point: point in a load-displacement space where two equilibrium paths intersect. Bifurcation buckling is a type of instability which is accompanied with a sudden change of shape of the structure.
Note: beyond this point the primary equilibrium path becomes unstable while the secondary path emanating from this point is stable

Binder: bonding resin used to hold strands together in a mat or preform during manufacture of a molded object.

Bleeder Cloth: nonstructural layer of material used in the manufacture of composite parts.
Note: allows the escape of excess gas and resin during cure. The bleeder cloth is removed after the curing process and is not part of the final composite

Bond: adhesion of one surface to another, with or without the use of an adhesive as a bonding agent

Braid: system of three or more yarns which are interwoven in such a way that no two yarns are twisted around each other

Braid Angle: angle measured from the axis of braiding

Braid, Two-Dimensional: braided fabric with no braiding yarns in the through-thickness direction

Braid, Three-Dimensional: braided fabric with one or more braiding yarns in the through-thickness direction

Braid, tri-axial: bi-axial braided fabric with laid in yarns running in the axis of braiding

Braiding: textile process where two or more strands, yarns or tapes are intertwined in the bias direction to form an integrated structure

Buckling: response of a structural system where more than one state of system equilibrium is possible under the present loading and where the structural system tends to change into the stable equilibrium state (see HSB 40100-01 Ref. [2], too).
global buckling (also general buckling): buckling mode which affects the structural system as a whole
local buckling: buckling mode which affects the structural system only locally (e.g. inter-rivet buckling, wrinkling, crimping (also named: crippling))
postbuckling: denotation, if the structural element operates in a regime where the applied load is beyond the critical buckling resistance

Buckling Factor: factor to obtain the critical buckling resistance of the investigated structural system from a generic problem characterizing quantity.
Note 1: includes the effects of different support conditions, different cross section properties and non-uniformly distributed applied stresses.
Note 2: also applicable for prediction of the critical buckling stress
modified buckling factor: combination of the buckling factor with other factors such as mathematical constants and scaling factors.
Note: The aim of the modified buckling factor is to simplify the utilization of the respective formulas, diagrams and tables

Buckling Load: load level at which buckling occurs (used as a resistance property)
design buckling load: statistically-based resistance property used in design

Buckling Resistance: Resistance of the structure equal to the smallest load under which the structure can respond in more than one system equilibrium state.
characteristic buckling resistance: buckling resistance determined under the prerequisite of possible inelastic material response, geometrical and structural imperfections, follower load effects and residual stresses.
critical buckling resistance: Buckling resistance determined with a model under the prerequisite of idealized conditions
design buckling resistance: Design value of the buckling resistance taking into account the uncertainties of model-based predictions.

Buckling Stress: Key value of a stress field associated with the buckling resistance in the non-buckled equilibrium state.
Note 1: the buckling stress is utilized to characterize a strength property of a structural system. Thereby, the term buckling stress is used as synonym for buckling strength.
Note 2: characteristic buckling stress is the buckling stress associated with the characteristic buckling resistance:
Note 3: the critical buckling resistance is a system property; the stress at a distinct location predicted for the considered state of equilibrium is used as a vehicle to quantify this system property

Bundle: general term for a collection of essentially parallel filaments or yarns

Butt Joint: joint in which parts are joined with no overlap

C-Stage: final stage of the curing reaction of a thermosetting resin in which the material has become practically infusable and insoluble.
Note: normally considered to be fully cured

Carbon Fiber: fiber produced by the pyrolysis of an organic precursor fiber, such as PAN (polyacrylonitrile), rayon or pitch, in an inert atmosphere at temperatures above $982^{\circ}C \triangleq 1800^{\circ}F$.
Note: the term carbon is often used interchangeably with the term graphite, but the fibers differ. Carbon fibers are typically carbonized at about $1315^{\circ}C$ and contain 93 to 95 % carbon. Carbon fibers can be converted to graphite fibers by graphitization at $1900^{\circ}C$ to $2480^{\circ}C$, after which they contain more than 99 % elemental carbon. Carbon fibers are known for their light weight, high strength and high stiffness

Caul Plate: smooth metal plate, free of surface defects, to transmit normal pressure and to provide a smooth surface on the finished laminate.
Note: plate of the same size and shape as the composite lay-up, used immediately in contact with the lay-up during the curing process

Certification: written declaration stating that the structural product complies with requirements.

Chain-Growth Polymerization: one of the two principal polymerization mechanisms.
Note: In chain-growth polymerization, the reactive groups are continuously regenerated during the growth process. Once started, the polymer molecule grows rapidly by a chain of reactions emanating from a particular reactive initiator which may be a free radical, cation or anion

Classical Laminate Theory: 2D continuum theory used in laminate composites analysis.
Note: the CLT bases on Kirchhoff's classical plate theory (normal hypothesis, transverse shear deformations neglected)

Cloth: kind of woven fabric

Co-curing: act of curing a composite laminate and simultaneously bonding it to some other prepared surface during the same cure cycle

Coefficient of Thermal Expansion (one-dimensional, linear): change in length per unit length and unit temperature

Coefficient of Variation: ratio of the full population (or of the sample) standard deviation to the population mean (or sample mean)

Cohesion Strength: stress level when a brittle behaving material breaks

Collapse: final fracture of the structure after hazardous deformation and degradation progress.
Note 1: plastic collapse is a material (instability) failure due to rupture (yielding failure mode), whereas structural instability collapse is a structural stiffness loss caused failure.
Note 2: material failure (material instability) triggers structural instability

Collective: loading cycle distribution.
Note: essential are the levels of the cycles and their magnitudes

Commingled Yarn: hybrid yarn made with two types of materials intermingled in a single yarn.
Example: thermoplastic filaments intermingled with carbon filaments to form a single yarn

Compatible: ability of different resin systems to be processed in contact with each other without degradation of end product properties

Component: major section of the structure that can be tested as a complete unit to qualify the structure

Composite Class: major subdivision of a composite construction in which the class is defined by the fiber system and the matrix class.
Example: organic-matrix filamentary laminate.

Composite Material: combinations of materials differing in composition or form on a macro-scale.
Note 1: composite materials can be metallic, non-metallic or a combination thereof. The constituents retain their identities in the composite; that is, they do not dissolve or otherwise merge completely into each other although they commonly act.
Note 2: composite materials often provide improved characteristics not obtainable by any of the original constituents acting alone
Note 3: a lamina (ply) of fiber-reinforced polymer consists of the fibers, an embedding polymer matrix.and an inter-phase material at the interface of both the constituents
Note 4: Composites include fibrous layers (composed of fibers, usually in a matrix) or include fabrics, laminar layers of materials, and hybrids (combinations of any of the above)

Composite Structure: structure, fully or partially made of composite materials

Compound: mixture of polymer or polymers with all the materials necessary for the finished product

Condensation Polymerization: special type of step-growth polymerization characterized by the formation of water or other simple molecules during the stepwise addition of reactive groups

Conditioning: process of exposure of a material to a property-altering environment prior to subsequent testing (Ref. [1], paragraph 6.3.1). Applied are equilibrium conditioning and fixed-time conditioning

Confidence Level (C): interval estimate of a population parameter used to indicate the reliability of an estimate. How frequently the observed interval contains the parameter is determined by the confidence level or confidence coefficient.

Compression strength-after-impact (CAI): residual strength of composite laminates after being damaged by an impact.

Consolidation: strengthening

Constant Amplitude Loading: fatigue loading of a test specimen where the amplitude remains constant.
Note: basis of S-N curves

Constituent: element of a composite.
Note 1: in advanced composites, the principal constituents are filaments (fibers) and matrix.
Note 2: The inter-phase is an essential but difficult to fix third material part

Continuous Filament: yarn or strand in which the individual filaments are substantially of the same length as the strand

Coordinate Systems: system which uses one or more numbers, or coordinates, to uniquely determine the position of a point or other geometric element.
Note: Several coordinate systems are used such as global, local, reference, lamina (related to the principal material axis of the lamina), principal, path

Core: central component of a sandwich construction to which the sandwich faces or skins are attached.
Note: see also Sandwich. Also part of a complex mold that forms undercut parts

Crazing: apparent fine micro-cracks at or under the surface of an organic matrix

Creep: time dependent (inelastic) part of deformation resulting from an applied stress

Creep Rate: slope of the creep-time curve at a given time

Crimp: fiber waviness, which determines the effectivity of the filament

Critical Length: minimum length of a filament necessary for load transfer at tips by matrix shear loading to make the maximum lamina strength possible

Cross-ply: angle-ply laminate that only contains layers with right angles to one another.
Note: examples are stacks such as [0/90], $[0_2/90_2/90_2/0_2]$

Cross section: intersection of a body with a plane.
Here: area of a load-carrying structural element

Cross linking: polymerization reactions that branch out from the main molecular chain to form a networked pattern of chemical links

Crystallinity: quality of having a molecular structure with atoms arranged in an orderly, three-dimensional pattern.

Cure: change of properties of a thermosetting resin irreversibly by chemical reaction.
Example: condensation, ring closure, or addition. Cure may be accomplished by addition of curing (cross linking) agents, with or without catalyst, and with or without heat. Cure may occur also by addition, such as it occurs with an-hydride cures for epoxy resin systems

Cure (curing) Cycle: schedule of time periods at specified conditions to which a reacting thermosetting material is subjected in order to reach a specified property level

Cure Stress: residual internal stress produced during the curing cycle of composite structures. Normally, these stresses originate when different components of a lay-up have different coefficients of thermal expansion

Cure Temperature: temperature at which a material attains final cure.

Curing Agent: catalytic or reactive agent that brings about polymerization when it is added to a resin

Cyclic Load: alternating load

Cyclic Load Modeling: manner to model load spectra
Example: block modeling, cycle-by cycle modeling and analysis, cycle jump strategy

Damage: result of a damaging process.
AMC 20-29: structural anomaly caused by manufacturing (processing, fabrication, assembly or handling) or service usage
damaging portion (German: Schädigung): portion of a damaging process represented by multiple crazes, micro-void cavities, micro-flaws.
damage (German: Schaden): result of a damaging process after judgment, represented by macro-cracks, technical cracks, delamination.
Note 1: in English the term damage is used, both, for the *damaging portion* (German: Schädigung), generated during damaging and for the 'large' discrete damage (German: Schaden) as well. The latter term is used as a technical crack quantity in 'Damage Tolerance Design' in case of cracks, delamination). In general: a damage (crack, delamination, leakage, deformation, etc.) becomes essential - if in the actual failure case - a usability limit is exceeded
Note 2: for fiber-reinforced composite, micro-damaging usually corresponds to diffuse damaging, that ends with a small number of localized macro-damages
Note 3: the result of the damaging process may be a tolerable or a non-tolerable damage (for FRP-composites e.g. IFF-caused)

Damage Accumulation: summation of cycling-caused damaging portions

Damage Entity: physical quantity that helps to measure the increasing damage

Damage Portion (in composite usually): cycling-caused increase of degradation until IFF and beyond.
Note: in cases where damaging of fibers is not significant

Damage Process (material): gradual enlargement of micro-voids, and micro-cracks which leads to macro-voids and macro-cracks and finally to brittle (no slip system present in material) or ductile failure (slipping in matrix material)

Damage Tolerance: capability of a structure to resist failure caused by the presence of flaws or other damage for a specified period of non-repaired usage without inspection or repair

Damage Variable: variable that is used to describe and quantify the damage

Debond: deliberate separation of a bonded joint or interface, usually for repair or rework purposes

Decohesion Element: finite element that pr edicts both onset and propagation of delamination without previous knowledge of the crack location and propagation direction .
Note: singularity at the crack tip is removed

Deflection: term to describe the magnitude to which a structural element deforms laterally (bends) under a load

Deformation: change in shape of a structural part caused by the application of a load or force or the hygrothermal environment

Degradation: result of a deleterious process in the material or in a structural element.
Note: The result of the finalized degradation process (deleterious change in chemical structure, physical properties or appearance) is a degraded property

Delamination: separation of the layers in a laminate.
Note: the delamination may be local or may cover a large area of the laminate. It may occur at any time in the cure or subsequent life of the laminate and may arise from a wide variety of causes

Denier: numbering system for yarn and filament in which yarn number is equal to weight in grams of 9000 meters of yarn

Density: mass per unit volume

Design Allowable: statistically based strength capability with respect to a failure mode.
Note: in terms of resistance to a loading such as a strength R, or also to a deformation limit. With respect to a failure mode such as fracture, rupture, collapse, detrimental deformation or to a load in some buckling cases.
Examples: A-, B-value as strength design allowables (at stress or material level), at flux or load level statistically-based 'strength' property value (e.g. in terms of load resistance, buckling resistance, strength, or limit strain) with respect to a failure mode (e.g. rupture, detrimental deformation). statistically based 'strength' capability of a structure (e.g. in terms of load resistance, stress resistance (which is equal to strength), or strain limit) with respect to a failure mode (e.g. rupture, collapse, detrimental deformation or unacceptable defect growth).

Desorption: phenomenon whereby a substance, an absorbed or adsorbed material, is released from another material.
Note: desorption is the reverse of absorption, or adsorption, or both

Design Factor (spacecraft): multiplying factor to be applied to the limit load that takes the uncertainty in the determination of the design limit load into account
Note: it is defined as the product of several factors: the model factor which takes into account the representativeness of the mathematical model for the derivation of the limit load, the project factor which accounts for the maturity of the design, and the margin policy factor

Design Life: project-defined life the structure has to survive according to the given design requirements

Design Load: factorized or non-factorized load used in design.
Examples: aircraft limit load ($\ell\ell$), design limit load (DLL) in spacecraft, design ultimate load (DUL) or design buckling load (DBL) in aerospace.
Note: analogous in case of pressure loading

Design Point: point in structural reliability hyperspace which represents or includes the nominal values of the design variables calculated in the stochastic analysis

Design Policy: realization manner in the design of the structure project that reflects special safety margins, test and inspection procedures, etc.

Design Principle: design of a structure is the result of the design principle chosen. Such design principles are 'fail safe', 'safe life', 'damage tolerant'

Design Ultimate Load (DUL): limit load ($\ell\ell$) in aircraft or Design Limit Load (DLL) in spacecraft multiplied by the respective ultimate safety factor.
Note: The reader is referred to Ultimate Load and to the HSB sheet 'Essential topics for the development of a reliable reserve factor' (Ref. [3]).

Design Value: value of a property used in design input which is assumed to respect its uncertainty. Value of a design variable which is used in a design verification

Design Variable (parameter): physical feature which influences the design performances.
Note: According to the nature of the design variables, linked to loading, geometry, tolerances, and material properties, different design problems can be identified such as structural sizing for the dimensioning of beams, shells, plates; shape optimization; material selection; structural topology

Design Verification: process whereby a structural design is comprehensively examined and qualification-tested to ensure that it will perform in the required way, before and during operational use.
Note: demonstration that the design fulfills the requirements

Design Ultimate Stress: mechanical stress caused by the design ultimate load.
Note: According to this definition no relation exists with ultimate strength

Detrimental Deformation: structural deformation, deflection or displacement that prevents any portion of a structure from performing its intended function or that reduces the probability of successful completion of the mission.
Example: excessive plastic deformation as a deformation that prevents proper functioning or usability

Deviation: variation from a specified dimension or requirement, usually defining the upper and lower limits

Diffuse Damaging in composites: damaging, occurring from onset of micro-cracking until onset of discrete local macro-cracks indicated by whitening (for ductile thermoplastics connected to void initiation and void growth).
Note: linked to the termination of the linear elastic stress-strain curve, and then to the damaging, that occurs at the begin of the non-linear stress-strain curve domain

Diffusion Coefficient: temperature and micro-cracking dependent value that is defined in case of
1. Heat Transfer: thermal diffusivity is thermal conductivity k divided by the volumetric heat storage capacity c_p;
2. Moisture Transfer in porous media such as e.g. epoxy molding compounds: moisture diffusivity is moisture conductivity divided by the volumetric moisture capacity

Diffusivity: rate of transfer of the solute in a given fluid under the driving force of a concentration gradient

Discrete Damaging: localization of diffuse damaging sometimes ending with a CDS

Discrete Necking: localized necking following diffuse necking at onset of the final ductile rupture

Dimensioning Load Case: design driving load case

Disbond: area within a bonded interface between two adherends in which an adhesion failure or separation has occurred. It may occur at any time during the life of the structure and may arise from a wide variety of causes. Also, colloquially, an area of separation between two laminae in the finished laminate (in this case the term delamination is normally preferred)

Disk: structural element that is subjected to an in-plane stress state.
Example: rotating hard disk

Displacement: vector extending from initial to final positions of a material particle and deformation in the direction of a length coordinate

Distribution: statistical model which gives the probability that a value will fall within prescribed limits.
Note: distributions are not only linked to statistical modeling, they may be also measured

Drape: ability of e.g. a prepreg to conform to the shape of a contoured surface

Dry: material condition of moisture equilibrium with a surrounding environment at 5% or lower relative humidity

Dry Fiber Area: area of fiber not totally encapsulated by resin

Ductile-to-Brittle Transition Temperature: temperature, where below ductile behaving material can become brittle

Ductility: ability of a material to deform plastically before rupture

Dynamic Load: fast time varying load (shock, impact) with a deterministic or stochastic distribution

Effectivity: ratio of the achieved value to the defined value.
effective value: value that considers the usable size of a property or its effectiveness.
Examples: effective stress, effective column length in buckling, effective moduli in damage analysis.
effective stress: stress that considers a reduced load-carrying cross section

Effort: see material stressing effort

Elasticity: ability of a material to return to its previous shape after stress is released.
Note: In many materials, the relation between applied stress and the resulting strain is directly proportional (up to a certain limit), and a graph representing those two quantities is a straight line. Such a material is referred to as being linear-elastic. The slope of this line is known as the (tangent) Modulus of Elasticity, or Young's modulus. It is used to determine stress-strain relationships in the linear-elastic portion of the stress-strain curve which is engineering-like taken between 0 and 0.2 % strain, and is defined for ductile behaving metals as that region of strain in which practically no yielding (permanent deformation) occurs

Elongation: increase in gage length or extension of a specimen during a tension test.
Note: usually expressed as a percentage of the original gage length

End (here): single fiber, strand, roving or yarn in textile industry.
Note: an end may be an individual warp yarn or cord in a woven fabric. In referring to aramid and glass fibers, an end is usually an untwisted bundle of continuous filaments

Energy Release Rate (G): energy dissipated during fracture per unit of newly created fracture surface area.

Engineering Stress: ratio of acting load and initial or non-deformed area.
Note: compare difference to True Stress

Envelope Life Cycle: envelope of partial operational lives

Epoxy Equivalent Weight: number of grams of resin which contain one chemical equivalent of the epoxy group

Epoxy Resin: thermo-setting resin which is characterized by the presence of the epoxy group
Note: epoxy resins are often used in polymer composites

Equivalent Sub-layer: equivalent idealized UD lamina that sufficiently well models a textile layer.
Example: Non-crimp fabric (NCF)

Equivalent Stress: stress value combining effects of those stresses which are active in a failure mode.
Examples: von Mises equivalent stress σ_{eq}^{Mises} in case of the shear yielding failure mode (SY); maximum principal stress in case of a brittle tensile fracture failure mode $\sigma_{eq}^{NF} = \sigma_I$ (NF)

Extensometer: device for measuring linear strain

Fabric, non-woven: composite material formed from fibers or yarns without interlacing.

Fabric, woven (German: Gewebe): composite material constructed of interlaced yarns or fibers.
Note: specifically, a cloth woven in an established weave pattern from advanced fiber yarns and used as the fibrous constituent in an advanced composite lamina. In a fabric lamina, the warp direction is considered the longitudinal direction, analogous to the filament direction in a UD lamina.
weaves or woven fabric: types are plain, twill, satin. The weave may be UD, tri-axial plain, near-net shape, polar or a spacer weave, 3D
warp knitted fabric: types are available with more or less straight reinforcing fibers (of high interest in structural modeling). Weft inserted is equivalent to warp knitted fabrics
non-crimp fabric NCF: uni-axial, bi-axial, multi-axial straight ply lay-up
weft knitted fabric (German: Gestricke): UD, bi-axial, multi-axial, multi-layer
braided fabric (German: Geflecht): flat, circular, 3D

Face Sheet: cover sheet of a sandwich

Factor of Safety (FoS): deterministic factor j for the design that increases the level of the given loading for safety reasons in order to account for (uncertainties in the statistical distribution of loads, not always), uncertainties in manufacturing process, material properties and failure conditions for purposes of analytical assessment or test verification of design
Note 1: factor of safety is synonym of safety factor. The additive (design) makes clear that a FoS for the design is addressed
Note 2: the FoS is often a combination of factors according to various sources of uncertainties. Its magnitude is based on proven processes and verification methods for analyses, tests and manufacturing. To account for uncertainties of analysis, higher values of factor of safety are normally used for verification by analysis only. Higher values of factors of safety are also used if higher reliability is desired than was taken in the limit load determination.
Note 3: applicable FoS, specified by the procurement authority, are for yield, ultimate, buckling, local buckling, burst and for the design life. The value of the FoS is most often denoted$j$ in the mathematical expressions.
Note 4: a FoS ensures reliability of the structural part
Note 5: a FoS cannot be calculated! It is required from authorities for a safe design
Note 6: a FoS cannot cover basic error sources. FoS are minimum values specified on the assumption that manufacturing process, analysis tools, modeling, etc. are qualified. Further, the buckling FoS does not cover the effect of dimensional tolerances and misalignment

Failure (German: Versagen): state of inability of an item to perform a required function (limit state)
Examples: stability, ductile tearing, (brittle) cleavage fracture, onset of yielding, deformation limit, leaking, shear crimping, face dimpling. Material failure (e.g. strength failure mode) or a structural failure (e.g. stability failure).

Fail-Safe Structure: structure designed with sufficient redundancy to ensure that the failure of one structural element does not cause failure of the entire structure.
Note: a factor of safety $j = 1$ is 'applied' to loads in case of a structural failure, if the failure is readily detectable

Failure Condition: mathematical formulation of the failure surface $F = 1 = 100\,\%$.

Failure Criterion: formulation that takes the form $F > 1,\ F = 1,\ F < 1$

Failure Index: value of the failure function F.
Note: it corresponds to the accurate 'material stress effort' or to Puck's 'exposure' only in cases where the stress terms are linear

Failure Initiation: event that is initiates a certain (defined) failure

Failure Load: load level where failure occurs.
Note: physical test value or theoretical, model-based predicted value (often, as computational failure load the maximum load achieved when computation stops is taken due to numerical stability problems in non-linear analysis)

Failure Mechanism: underlying phenomenon that determines the mode of failure

Failure Mode: observable effect of the mechanism through which the failure occurs.
Examples: initiation of yielding, rupture, collapse, buckling, degradation, excessive wear, normal fracture and shear fracture, local or global buckling, leakage, eigenfrequency limitation, deformation beyond a given limit, fiber-fracture, inter-fiber-fracture, delamination, and any other phenomenon resulting in an inability to sustain environmental 'loadings'
Note 1: above examples involve failure modes of a material failure type (shear yielding, normal fracture, etc.) or a structural failure type (buckling, dimpling, etc.).
Note 2: number of strength failure modes for isotropic materials is 2 for brittle behaving isotropic materials; tensile ultimate strength (TUS) governs the mode NF and compressive strength the mode SF. For ductile behaving materials the yield strength is to be addressed and the tensile strength (a real compressive strength does not exist)
Note 3: number of strength failure modes for transversely-isotropic UD materials: five for these usually brittle behaving composites; 2 FF and 3 IFF, with each of these failure modes 'governed' by one strength, only

Failure Surface: graphical representation of a failure condition $F = 1$ (envelope that contains the non-failed domain $F < 1$ or the non-failure body).
Note: mathematical description by a failure condition, $F = 1 = 100\,\%$

Failure Theory: theory that intends to predict failure.
Examples: the strength failure theory, and failure theories based on notch mechanics, on fracture mechanics, and on continuum damage mechanics
Note: often understood to include:
1. a failure condition to assess multi-axial states of stress,
2. non-linear stress-strain curve(s) of the material as analysis input, and
3. a non-linear code in structural analysis.

Failure Type: denotation of a failure for a ductile or brittle behaving material.
Note: ductile means a gradually occurring and brittle a rapidly occurring failure

Far-field Stress: stress far away from a notch or a crack.
Note: hypothetical stress in the structure if the stress raiser was not present

Fatigue: damaging process in which repeated cycles of increasing and decreasing stress finally may lead to the development of a fatigue damage
Note: principally, fatigue life captures the phases crack initiation and crack propagation. Progressive and localized structural damage that occurs when a material is subjected to cyclic loading.

Fatigue Strength: measure of the strength of a material or a component under cyclic loading

Fiber: term used to refer to filamentary materials.
Note: often, fiber is synonymously used for the filament but also in production for a bundle of filaments or, respectively, for a strand consisting of thousands of filaments.
(short fiber: $< 2\,\text{mm}$, long fiber: $< 20\,\text{mm}$, endless fiber: $> 20\,\text{mm}$)

Fiber Architecture: fibrous preform or part in which the fibers are arranged in a particular way to achieve a desired result
Note: mats and braided, stitched and woven fabrics are common forms of fiber architecture

Fiber Bridging: reinforcing fiber material bridging layers

Fiber Content: amount of fibers present in a composite expressed either as percent by volume or percent by weight.
Note: Also sometimes referred to as fiber volume fraction (e.g., a 60:40 fiber-to-resin ratio denotes a composite with 60 % fiber content and 40 % resin content

Fiber Count: number of fibers per unit width of ply present in a specified section of a composite

Fiber Direction (orientation): alignment of the longitudinal axis of the fiber with respect to a stated reference axis

Fiber Orientation: direction of fiber alignment
Note: convention for the fiber orientation angle is from coordinate x to coordinate $x_{||}$ (with $x_{||} \equiv x_1$)

Fiber Patch Placement: technique to place patches of reinforced fibers just there where the structure 'needs' it

Fiber Placement: continuous process for fabricating composite shapes with complex contours or cutouts by means of a device that lays preimpregnated fibers (in tow form) onto a nonuniform mandrel or tool. It differs from filament winding (below) in several ways: there is no limit on fiber angles; compaction takes place on-line via heat, pressure, or both; and fibers can be added and dropped as necessary. The process produces more complex shapes and permits a faster put-down rate than filament winding

Fiber sizing: process to handle fibers during processing and how they perform as part of a composite.
Note: sizing is essential to glass fiber manufacture and critical to several key fiber characteristics

Fiber System: type and arrangement of fibrous material which comprises the fiber constituent of an advanced composite.
Examples: collimated filaments or filament yarns, woven fabric, randomly oriented short-fiber ribbons, random fiber mats, whiskers, etc.

Fiber volume fraction: content of fibers in a unit volume of fiber-reinforced materials

Filament: individual endless fiber (here used as single spun endless fiber).
Note: The basic unit of a fibrous material. The use of this term provides more clarity in some descriptions

Film Adhesive: adhesive in the form of a thin, dry, resin film with or without a carrier, commonly used for adhesion between layers of laminates

Filament Winding: process for fabricating composites.
Note: process in which continuous reinforcing fibers, either preimpregnated with resin or drawn through a resin bath, are wound around a rotating, removable mandrel of predetermined geometry under controlled tension

Filamentary Composites: major form of advanced composites in which the fiber constituent consists of continuous filaments. Specifically, a filamentary composite is a laminate comprised of a number of laminae, each of which consists of a non-woven, parallel, uni-axial, planar array of filaments (or filament yarns) embedded in the selected matrix material. Individual laminae are directionally oriented and combined into specific multi-axial laminates for application to specific envelopes of strength and stiffness requirements.

Filament Wound: pertaining to an object created by the filament winding method of fabrication

Fill (weft): yarn in a woven fabric running from selvage to selvage at right angles to the warp.
Note: replaces the more often used term weft but avoids the letter conflict with the identical first letter of warp when sub-scripting

Filler: relatively inert substance added to a material to alter its physical, mechanical, thermal, electrical, and other properties or to lower cost. Sometimes the term is used specifically to mean particulate additives

Finish: material applied to fibers, after sizing is removed, to improve matrix-to-fiber coupling.
Note: material with which filaments are treated, which contains a coupling agent to improve the bond between the filament surface and the resin matrix in a composite material. In addition, finishes often contain ingredients which provide lubricity to the filament surface, preventing abrasive damage during handling, and a binder which promotes strand integrity and facilitates packing of the filaments

First-Order-Shear-Deformation Theory (FSDT): basic higher order laminate theory that does not use normal hypothesis anymore.
Note 1: out-of-plane stresses are considered. In particular, the shear stress profile is represented either by independent piecewise quadratic functions in the thickness or by satisfying the three-dimensional equilibrium equations written in terms of mid-plane strains and curvatures. Application is often necessary in case of thick-walled laminates. The FSDT is the counterpart of the classical Reissner-Mindlin theory for isotropic plates.
Note 2: second and third order shear deformation theories are available with which inter-laminar stresses and transverse shear deformations can be determined

First-Ply-Failure: first failure that occurs in a ply (lamina) of a laminate.
Note: It does not address whether it is an IFF (often termed matrix failure) or an FF

Flash: excess material which forms at the parting line of a mold or die, or which is extruded from a closed mold

Flaw: local discontinuity in a structural material.
Example: Scratch, notch, crack, void or pore, inclusion, delamination and porosity in case of composite laminates.
Note: a flaw is not a defect

Fracture: separation of a whole into parts
Note: in case of laminates separation with and without complete separation

Fracture Ductility: true plastic strain at fracture

Fracture Mechanics: mechanics of fracture mechanisms.
Note: Nowadays, primarily applied as a theory describing the behaviour of a crack in a solid

Fracture Mechanics Modes: the three ways of crack propagation used in Irwin's model (mode I opening, mode II sliding, mode III tearing)

Fracture Toughness K_{Ic}: measure of the damage tolerance of a material containing initial flaws or cracks, delamination
Note: property in materials science which describes the ability of a material containing a crack to resist fracture

Friction: here addressed is the material internal behaviour (often termed pressure-dependent material behaviour) that is to be considered in the respective strength failure function for compression

Gel: initial jelly-like solid phase that develops during formation of a resin from a liquid. Also, a semi-solid system consisting of a network of solid aggregates in which liquid is held

Gel Coat: quick-setting resin used in molding processes to provide an improved surface for the composite; it is the first resin applied to the mold after the mold-release agent

Gel Point: stage at which a liquid begins to exhibit pseudo-elastic properties. (This can be seen from the inflection point on a viscosity-time plot)

Gel Time: period of time from a pre-determined starting point to the onset of gelation (gel point) as defined by a specific test method

Glass Cloth: conventionally-woven glass fiber material

Glass Fibers: fiber spun from an inorganic product of fusion which has cooled to a rigid condition without crystallizing
E-glass: alumina-calcium-borosilicate glass where strength and high electrical resistivity are required
R-glass: calcium-alumino-silicate glass where strength temperature resistance is required
S-glass: magnesium-alumino-silicate glass where high strength, modulus and durability under high temperature and in corrosive media are required

Glass Transition: reversible change in an amorphous polymer or in amorphous regions of a partially crystalline polymer from (or to) a viscous or rubbery condition to (or from) a hard and relatively brittle one

Glass Transition Temperature T_g: approximate midpoint of the temperature range over which the glass transition takes place (transformation of a glass-forming liquid into a glass)

Graded Material: material that possesses a change in its properties over a domain

Gradual: denotes slow successive change of stress or stiffness o r another feature

Graphite Fibers: see Carbon Fibers.

Hand Lay-up: process in which components are applied either to a mold or a working surface, and the successive plies are built up and worked by hand

Hardener: substance used to promote or control curing action

Hardening: consolidation of composites during curing.
Note: see also Strain Hardening

Heterogeneous: descriptive term for a material consisting of dissimilar constituents separately identifiable (a medium consisting of regions of unlike properties separated by internal boundaries).
Note: Having more than one phase (solid, liquid, gas) present in a system or process. All non-homogeneous materials are not necessarily heterogeneous

Homogeneous: descriptive term for a material of uniform composition.
Note 1: medium that has no internal physical boundaries; a material whose properties are identical at every point.
Example: distribution of filaments in a lamina
Note 2: in the context of a beam 'homogeneous' means that is built up from one material, only.

Honeycomb: distance material formed into hexagonal cells.
Note: usually manufactured in hexagonal cells that serves as a core material in sandwich constructions. Honeycomb may also be metallic or polymer materials in a rigid, open-cell structure

Hoop layer: ply laid onto a rotating mandrel at a 90° angle to the axis of the mandrel

Humidity, relative: ratio of the pressure of water vapor present to the pressure of saturated water vapor at the same temperature

Hybrid Laminate: composite laminate comprised of laminae of two or more materials.
Examples: CFRP with metal, Glare, Arall, organo-sheets

Hydrostatic Pressure: absolute value of hydrostatic compression stress

Hygroscopy: material's readiness to absorb or retain moisture

Idealized Bi-directional Lamina (layer): virtual decomposition of a woven fabric model used in analysis of textile composites with non-crimp reinforcement (NCFs)

IFF modes: 3 different Inter Fiber Fracture modes known from fractography. Each of these modes is governed by an associated strength.
Note: the term IFF mode may be differently used

Impact Strength: capability of the material in withstanding dynamically applied loads (in terms of energy, Joules)

Imperfection: state or an instance of being imperfect, or a shortcoming.
Note: Structural examples: from production usually defined by a value for the deviations from nominal values: flaws, out-of-roundness (deviation from circularity), eccentricities (deviations from a continuous mid-surface), local dimples (local normal deviations from the nominal middle surface, non-straightness, misalignment of loads (point of 'attack'), fiber waviness, etc.

Imperfection Sensitivity: sensitive response of a structure to the presence and magnitude of an imperfection

Impregnation: saturation of the voids and interstices of a reinforcement with a resin

Inclusion: discontinuity within a material or part.
Note: usually consisting of solid, encapsulated foreign material. Inclusions are often capable of transmitting some structural stresses, but in a noticeably different manner from the parent material. They are often the source of stress concentrations

Infiltration of a polymer composite: impregnation of fibers with resin

Infusion of a polymer composite: impregnation of fibers with resin under a pressure less than 1 bar

Injection of a polymer composite: impregnation of fibers with resin under a pressure higher than 1 bar

Initial Buckling Load: transition point between pre-buckling and post-buckling state for structures providing significant post-buckling load carrying capacity (e.g. plates, stiffened shells)
Note: the term 'initial buckling resistance' should be preferred.

Initial Failure (composite laminate): 'practical' onset of degradation.
Note: Initial failure is usually indicated by the occurrence of a slope change (knee) in the stress-strain curve of a laminate, and this is determined by the first IFF.

In-situ Strength: here, strength capacity of the built-in composite material
Example: strength of a UD layer within a laminate is different (redundant due to embedding, following a parallel failure system) to the strength values from the usual 'isolated' material test specimens (weakest link behaviour, following a series failure system)
Note: the in-situ strength might be termed an effective mode strength

Integral Composite Structure: composite structure in which several structural elements, which would conventionally be assembled by bonding or with mechanical fasteners after separate fabrication, are instead laid up and cured as a single, complex, continuous structure.
Examples: spars, ribs, and one stiffened cover of a wing box fabricated as a single integral part.

Interaction: here, a process of a combined action of stresses, or loadings, or failure modes

Interface: boundary or surface between the individual, physically distinguishable constituents of a composite.
Note: also used for the surface (2D) that separates two parts o r laminate layers

Intra-lamina (in-plane) shear stress: shear stress τ_{21} in the ply plane

Inter-laminar: descriptive term pertaining to some object (e.g., voids), event (e.g., fracture), or potential field (e.g. stress field) referenced as existing or occurring between two or more adjacent laminae in perpendicular direction to the laminate plane

Inter-laminar shear stresses (ILS): in a uni-directional ply the shear stresses τ_{23}, τ_{13} acting perpendicular (thickness direction) to the lamina plane

Inter-laminar shear strength (ILSS): maximum shear stress reached in the respective ILSS laminate test specimen

Inter-laminar stresses: in a uni-directional ply the normal stress σ_3 and the shear stresses τ_{23}, τ_{13}

Inter-phase: material (3D), that physically and probably chemically joins filament and matrix.
Note: often modeled as gradual because properties are merely determinable

Intra-laminar: descriptive term pertaining to some object (e.g., voids), event (e.g., fracture), or potential field (e.g., temperature gradient) existing entirely within a single lamina

Invariant: combination of stresses or strains the value of which does not change when altering the coordinate system .
Note: The stresses in the invariants may be powered or not powered. Invariants are advantageous when formulating the usually desired scalar failure conditions. Such material-associated invariants are utilized for isotropic and composite materials

Isotropic: material with identical properties in all directions

J-integral: path-independent line-integral which is based on Irwin's principle of (strain) energy release rates .
Note: value, based on an energy conserving calculation to find the strain energy release rate for crack propagation. Helpful in case of small plastic zones at the crack tip (localized plasticity) where it may be also applied for non-linear elastic situations

Knitting (German: Stricken): method of constructing a fabric by interlocking series of loops of one or more yarns

Knock-Down Factor: reduction factor that takes into account
1. change of mechanical properties due to environmental exposure and
2. imperfection sensitivity (KDF used to predict the characteristic buckling resistance from the value gained with a model treated under a classic theory)

Lamina: sub-unit of a laminate .
Note 1: here the designation of the calculation element as numerical building block of the laminate
Note 2: laminae is plural of lamina. The term laminas is also used
Note 3: the term lamina does not necessarily mean the physical single layer as it is realized in the laminate. The single layer of a non-crimped fabric layer, e.g. [0/90/45], is often modeled using three distinct laminae with orientation angles 0°, 90° and 45°
Note 4: M lamina is a lamina with random reinforcement (mat)
isolated lamina properties: properties obtained from traditional isolated test specimens.
Note: Values used in analysis despite of the fact that they cannot consider the effect of embedding which may improve but also sometimes deteriorate the property values
embedded lamina properties: properties obtained from special sub-laminate test specimens where the test ply is embedded between other plies (laminas) that are destroyed at higher load levels than the test ply

Laminate: designation of a stack of several laminae which are bonded together

Lap joint: joint made by bonding overlapped portions of two adherends

Layer: here, physical sub-unit of the laminate.
(basic layer: see above)

Lay-up: process of fabrication involving the assembly of successive layers

Lifetime: span of time during a material or a structural component functions
Note: this definition is specified in the actual projects

Limiting Conditions: conditions which are applied to define a limit of the structural part on basis of its functional requirements

Limit Load: in aircraft the maximum load to be expected in service
Note: the specified load is expressed in terms of aerodynamic forces, inertia forces, or ground or water reactions. For aerospace see further HSB 01501-01, Ref. [3].

Limit Point: point along the equilibrium path where the stiffness is zero

Limit State: state in which a structure or a material comes to a limit
plastic limit: structure develops zones of yielding in a pattern such that its ability to resist increased loading is deemed to be exhausted. It is closely related to small deflection theory plastic limit load and plastic collapse mechanism
tensile rupture: e.g. a plate experiences gross section failure due to tension

cyclic plasticity: repeated yielding, caused by cycles of loading and unloading, leading to a low cycle fatigue failure where the energy absorption capacity of the material is exhausted
buckling: structure suddenly loses its stability under membrane compression or shear. It leads either to large displacements or to the structure being unable to support the applied loads
fatigue: cycles of loading initiate cracks or a delamination

Linear Elastic Fracture Mechanics: fracture mechanics assuming linear material response

Liquid-crystal Polymers: melt processable, newer type of thermoplastic.
Note: thermoplastic with high orientation in molding, improved tensile strength, and high-temperature capability

Load Collective: 'shape' of the load spectrum.
Note: marked by number of cycles as (n), number of cycles to failure as (N)

Load Cycle: closed alteration of load change

Load Factor: multiplying factor, termed$n$, of inertial weights of an aircraft.
Note: in spacecraft, at prime level, the term *(system) load factor* is also used in the margin policy for uncertainty consideration reasons

Load History: loadings experienced in life

Load Spectrum: spectrum of loads used in fatigue analysis

Loading: load (including normal and shear forces, moments, torques), or pressure, temperature and moisture applied to the structural system

Loop Joint: joint used in composite engineering to transfer loads

Lot: see batch

Macaulay brackets: $\{\}$ or $f(x) = \max(x, 0)$.
Note: notation used to describe the ramp function ($x = 0$, if $x < 0$; $x = x$, if $x \geqq 0$)

Macro-scale: physical scale having a characteristic dimension above 1 mm.
Note: in the analysis of composites originally used when denoting characteristics and when modeling composite laminas and laminates. In the early days the thicker fibers (boron) caused ply thicknesses larger than a mm. Therefore the homogenized ply or lamina was addressed as macro (Refs. [4, 5]) which is not always kept any more in literature and FE code manuals

Maintainability: probability that the product can be kept in or returned to a state in which it can provide its functions, when maintenance is applied. Maintenance comprises adequate storage, controls, preventive actions, e.g. repair of surface protection

Mandrel: form fixture or male mold used for the base in the production of a part by lay-up, filament winding or braiding

Margin of Safety: ratio of the design resistance and the design load minus 1

Mat: fibrous material consisting of randomly oriented chopped or swirled filaments loosely held together with a binder

(structural) Material: here, model of the homogenized (smeared) solid with effective properties.
Note: a laminate may be modeled as a homogenized material or as a structural entity

Material Acceptance: testing of incoming material to ensure that it meets requirements.

Material Qualification: procedures used to accept a material by a company or organization for production use

Material Stressing Effort *Eff*: exertion, a material experiences under a stress state generated by external loading and residual stresses(material).
Note: percentage (portion) of 'load' carrying capacity of the material (metal, lamina, etc.). See the terms Stress and Resistance, too. The material stressing effort caused by a stress state in a distinct failure mode is the ratio $Eff^{mode} = \sigma_e^{mode}/R^{mode}$, that is equivalent stress over strength

Material System Class: group consisting of material systems categorized by the same generic constituent materials, but without defining the constituents uniquely; e.g., the carbon or epoxy class

Material Variability: source of variability due to the spatial and consistency variations of the material itself and due to variation in its processing

Matrix: essentially homogeneous material
Note: it may be a plastic (e.g. a cured result of a mixture of resin and hardener in which the fiber system of a composite is embedded), a metal, ceramic, or glass

Mechanical Properties: properties of a material that are associated with elastic and inelastic reaction when a force is applied, or the properties describing the relationship between stress and strain

Membrane Forces: normal and shear section forces (forces per unit width)

Meso-scale: 'something' between scales
Note 1: it is not a scale or level, but often used as a model characterizing term at different length levels such as the micro-scale defined below. It has to be clearly defined in each application case
Note 2: with composites the term meso is referred to the fiber architecture within a textile lamina. Unfortunately, since some time it is also sometimes applied when citing lamina characteristics

Micro-scale: physical scale having a characteristic dimension typically ranging from 1 to 999 µm (below 1 mm)
Note: term is not always used as above. In case of composites it addresses the constituents matrix, fiber, inter-phase and small flaws such as pores, inclusions etc.

Middle Surface (mid-plane, if flat): surface that lies midway between the inside and outside surfaces of a shell or plate.
Note 1: where the shell is stiffened on either one or both surfaces, the reference middle surface is still taken as the middle surface of the curved shell or the plate. The middle surface is the reference surface for analysis, and can be discontinuous at changes of thickness or at shell junctions, leading to eccentricities that may be important for structural behaviour of the shell.
Note2: The middle surface is a strictly geometric quantity and should not be confused with symmetry plane

Mixed-Mode-Fracture: interaction of at least two fracture modes in fracture mechanics

Model Validation: proof of a theoretical model by a number of (reliable) physical test results

Modulus, chord: slope of the chord drawn between any two specified points on the stress-strain curve

Modulus of elasticity (Young's Modulus): slope of the initial straight portion of a stress-strain curve

Moisture Content: amount of moisture in a material determined under prescribed condition and expressed as a percentage of the mass of the moist specimen, i.e., the mass of the dry substance plus the moisture present

Moisture Equilibrium: condition reached by a material when it no longer takes up moisture from or releases moisture into the surrounding environment

Mold Release Agent: lubricant applied to mold surfaces to facilitate release of the molded structural component

Molding: forming of a polymer or composite into a solid mass of prescribed shape and size by the application of pressure and heat

Mono-layer: basic laminate unit from which laminates are constructed

Monomer: compound consisting of molecules each of which can provide one or more constitutional units

Multifold Strength Failure: failure when a distinct failure occurs multifold under a multi-axial state of stresses in strength mechanics.
Example: under a bi-axial tensile stress state the fracture failure type 'normal fracture' is in two orthogonal directions activated

Multi-Scale Analysis: analysis which is executed on several levels.
Example composites: e.g. micro-scale and macro-scale using meso modeling of the fiber architecture. In the associated analyses a bottom-up approach (micro to macro (i.e. the lamina)) combined with top-down approach is mandatory. A closed system is necessary: the micro-mechanical data in the HSB can be only used with the micro-mechanical formulas that have been utilized at their determination

NDI: non-destructive inspection process or procedure for determining the quality or characteristics of a material, part, or assembly without permanently altering the subject or its properties.
Note: often synonymously applied are the other techniques NDT (non-destructive testing) and NDE (non-destructive evaluation)

Necking: process by which a ductile material deforms under tension forming a neck
1. diffuse necking: feature before reaching maximum load (TUS) in a load-controlled test of a tensile ductile specimen
2. localized (discrete) necking: situation in the specimen in the following softening branch (strain-controlled) until ductile rupture will occur

Net Shape: fabrication to final dimensions that do not require machining or cutting

Netting Theory Analysis: analysis where the fibers are assumed to take all the load.
Note: can not be used for inelastic analyses that need the real stiffness

Nominal Life: life span from release via transport to the termination of use.
Note: project specific differently formulated

Nominal Specimen Thickness: summation over the thickness of nominal plies multiplied by the associated number of plies

Nominal Value: value assigned for the purpose of a convenient designation.
Note: a nominal value exists in name only

Non-crimp Fabrics: laminate composed of stitch-bonded (z-threads) UD laminas

Non-laminar Composite: textile composite (3D textile) containing a'high' portion of z-threads

Non-redundant and Redundant Structures: types of structural behaviour: non-redundant (single load path) and redundant (multiple load path) structures:
non-redundant: applied loads are distributed through a single member within an assembly, the failure of which would result in the loss of structural integrity of the component involved. Has to sustain DUL until exchange of the critical part or until end of service life
redundant: applied loads are safely distributed to other load-carrying members in case of failure. A new load path can be generated that has to sustain in case of failure of one path the aircraft *limit load* $\ell\ell$.
Note: for multiple load path structural parts B-values may be used

Non-woven Roving: reinforcement composed of continuous rovings loosely gathered together

Normalization: mathematical procedure for adjusting raw test values for fiber-dominated properties to a single (specified) fiber volume content

Off-axis Laminate: laminate whose principal axis is oriented at an angle to the load direction.
Note: application as off-axis lamina test specimens

Open-hole strength (OHS): tensile strength and compressive strength of a composite laminate containing a hole or notch. Note: value depends on absolute hole size

Orthotropic: orthogonal-anisotropic material having three mutually perpendicular planes of elastic symmetry.
Note: requires the knowledge of 9 independent stiffness properties

Out-gassing: release of solvents and moisture from composite parts under a vacuum

Oven Dry: condition of a material that has been heated under prescribed conditions of temperature and humidity until there is no further significant change in its mass

PAN Fibers: reinforcement fiber derived from the controlled pyrolysis of polyacrylonitrile fiber

Panel: flat or curved thin-walled structural component that may be reinforced.
Note: may be a stiffener-reinforced part (barrel) of a fuselage section

Parameter Identification: determination of model parameters from physical test results

Part Consolidation: design-and-fabrication process in which a number of previously discrete parts are combined in a single component to reduce or eliminate assembly operations and associated costs

Peel Ply: layer of material applied to a prepreg lay-up surface that is removed from the cured laminate prior to bonding operations and leaves a clean resin-rich surface ready for bonding

Pitch Fibers: reinforcement fiber manufactured from petroleum or coal tar pitch

Planar: type of fiber winding or tape placing

Plastic: material that contains one or more organic polymers of large molecular weight
Note: is solid in its finished state, and, at some state in its manufacture or processing into finished articles, can be shaped by flow

Plastic Hinge: hinge, formed when plastic yielding of a cross section of a structural member occurs.
Note: cross section is unable to additionally transmit bending moments

Plastic Strain at the End of Uniform Elongation (uniform strain): plastic strain in % at onset of necking which is marked by the maximum tensile load, in the case of ductile behaviour

Plasticizer: material of lower molecular weight added to a polymer to separate the molecular chains.
Note: application results in a depression of the glass transition temperature, reduced stiffness and brittleness, and improved processability. Many polymeric materials do not need a plasticizer

Plate: thin-walled, flat smooth structural element of almost uniform thickness

Ply: number of single yarns twisted together to form a plied yarn.
Note: designation of the layers that make up a stack or laminate

Ply-by-ply analysis: term used in laminate analysis if each ply (lamina) is analysed

Ply-discounting Approach: degradation model of the ply

Poisson's Ratio: ratio of transverse strain and longitudinal strain of a uni-axially tensioned test specimen.
Note: In the early days indexing of Poisson's ratio followed 'location' before 'cause'. This makes more sense and -in addition- follows the convention for the load quantities. This is the reason why - after many discussions and extensive literature work of the working group - the VDI 2014 guideline (Ref. [4]) still sticks to the 'old' sequencing $\nu_{21}$for the larger Poisson's ratio. However, in the last two decades more and more - for the larger Poisson's ratio ν_{12} - has been used, especially in the FE codes. Of course, there is no objective reason to write ν_{21} or ν_{12}. This might have been the reason for the change. In the HSB ν_{12} is used for the larger Poisson's ratio.
Note: Meanwhile Stephen Tsai turned back in his newest book 'Strength and Life of Composites', 2011 (Ref. [**?**]), to the old sequencing ν_{21}

Polymer: organic material composed of large molecules characterized by the repetition of one or more types of (smaller) monomeric molecules

Polymerization: chemical reaction in which the molecules of monomers are linked together to form polymers.
Note: two principal reaction mechanisms work,.addition polymerization proceed by chain growth and most condensation polymerization through step growth

Porosity: volume fraction of pores, voids
condition of trapped pockets of air, gas, fluid, or vacuum within a solid material, usually expressed as a percentage of the total non-solid volume to the total volume (solid plus non-solid) of a unit quantity of material

Post-buckling: see Buckling

Post-cure: additional elevated temperature cure, usually without pressure, to increase the glass transition temperature, to improve final properties, or to complete the cure

Pot Life: period of time during which a reacting thermosetting composition remains suitable for its intended processing after mixing with a reaction initiating agent

Precursor (for carbon fibers): either the PAN or pitch fibers from which carbon fibers are derived

Preform: assembly of dry fabric and fibers which has been prepared for one of several different wet resin injection processes.
Note: a preform may be stitched or stabilized in some other way to hold its shape. A commingled preform may contain thermoplastic fibers and may be consolidated by elevated temperature and pressure without resin injection

Preply: layers of prepreg material, which have been assembled according to a user specified stacking sequence

Prepreg: semi-finished fiber product such as a resin-impregnated cloth, mat or tape in flat form that can be stored for later use.
Note: ready to mold or cure material in sheet form. The resin is often partially cured to a tack-free state called B-staging

Pressure: normal force or load per unit area acting normally to the loaded area

Primary Stresses: stress system required for equilibrium with the imposed loading.

Primary Structure: part of the structure that carries the main loads and defines the overall stiffness.
Note: In AMC20-29 the structure which carries flight, ground, or pressurisation loads, and whose failure would reduce the structural integrity of the aircraft.

Principal Axis (laminate): coordinate axis that coincides with the direction of maximum in-plane Young's modulus

Principal Axis (lamina): coordinate axis that coincides with the fiber direction

Principal Stress: components of the stress tensor when the basis is transformed in such a way that the shear stresses become zero

Progressive Failure (FRP composites): progressive series of failure events.
Note: This is the term describing the condition when different parts of a failure surface reach failure at different times. Failure often starts as a tiny crack between the fibers and matrix. Continued loading leads to the formation of multiple micro-cracks in the lamina. These cracks decrease the stiffness of the matrix causing the fibers or surrounding plies to carry a higher stress than they normally would carry. Capturing stress redistribution is the key to realistic simulation of composite structures' progressive failure

Proof Load: load applied during a proof test

Proof Test: test of a flight hardware under proof load or pressure to give evidence of satisfactory workmanship and material quality or to establish the initial crack sizes in the hardware

Pultrusion: continuous process for manufacturing composites in rods, tubes, and structural shapes having a constant cross section.
Note: after the reinforcement is passed through the resin-impregnation bath, it is drawn through a shaping die to form the desired cross section; curing takes place before the laminate can depart from that cross section

Quasi-isotropic Laminate: laminate approximating isotropy by orientation of plies in several directions.
Note: laminate possessing an in-plane or membrane quasi-isotropy but still exhibits flexural anisotropy

Quasi-laminar Composite: denotation for a textile composite which basically behaves like a 2D laminate

Quasi-static Load: load independent of time or which varies slowly, so that the response time of the structure is not significant
Note: (quasi-) static loads comprise static, cyclic and dynamic (impact) loads and are applied at a frequency sufficiently below the natural frequency of the considered part thus being equivalent to static loads for the structure

Rainflow Counting: counting method, used in the analysis of fatigue data in order to reduce a spectrum of varying stress into a set of simple stress reversals

R-curve (crack extension resistance curve): curve of strain-energy release rate G versus crack length a.
Note: a positive slope indicates unstable crack propagation and a negative that the crack growth is stable

Reinforced Plastic: plastic with relatively high stiffness or very high strength fibers embedded in the composition.
Note: reinforcement improves some mechanical properties over that of the base resin

Release Agent: material that is used to prevent cured matrix material from bonding to tools

Reliability: aptitude of a product to perform the required functions at certain performance levels under specific conditions and for a given period of time, expressed in terms of probability

Reserve factor (RF): load-defined factor as ratio of a resistance value and an action value.
Note: similar to the definition of the FoS, RFs are referred to loads and not to stresses

Residual Stress: stress that remains in an unloaded structure after processing, fabrication, assembly, testing, or operation

Residual Strength: strength of a material after being damaged

Resilience: property of a material which is able to do work against restraining forces during return from a deformed condition

Resin: organic polymer or prepolymer used as a matrix to contain the fibrous reinforcement in a composite material or as an adhesive.
Note: this organic matrix may be a thermoset or a thermoplastic, and may contain a wide variety of components or additives to influence handability, processing behavior and ultimate properties.

Resin Content: amount of matrix present in a composite either by percent weight or percent volume

Resin Rich Area: localized area filled with resin but lacking reinforcing fibers

Resin Starved Area: area of composite part where the resin has a non-continuous smooth coverage of the fiber

Resin System: mixture of resin, with ingredients such as catalyst, initiator, diluents, etc. required for the intended processing and final product

Resistance: material property or structural property counteracting the applied loadings or capacity to withstand environmental loadings.
Examples: load resistance and buckling resistance (as structural resistances, at load level), strength (as material resistance, at stress level), or a limiting strain.
Note: One should not mix up an increase of strength with an increase of resistance. Both these increases lead to a reduced material stress effort, that determines the danger to fail. According to the strength condition, the resistance may become also bigger by a reduced equivalent stress. This can take place under a superimposed hydrostatic stressing.

Rib: local reinforcing member of a shell

Room Temperature Ambient (RTA):

1. an environmental condition of $73 \pm 5^{\circ}F$ $(23 \pm 3^{\circ}C)$ at ambient laboratory relative humidity;
2. a material condition where, immediately following consolidation or cure, the material is stored at $73 \pm 5^{\circ}F$ $(23 \pm 3^{\circ}C)$ and at a maximum relative humidity of 60 %

Resin-transfer molding (RTM): molding process in which catalyzed resin is transferred into an enclosed mold into which the fiber reinforcement has been placed
Note: cure normally is accomplished without external heat. RTM combines relatively low tooling and equipment costs with the ability to mold large structural parts

Risk: probability of an incident (event) times severity of its consequences

Robust Design: design that performs optimally under the variable operating conditions during lifetime.
Note: Ontonix defines robustness as 1/ (uncertainty x complexity) = 1/ fragility

Roving: collection of bundles of continuous filaments either as untwisted strands or as twisted yarns

R-ratio: ratio of minimum stress and maximum stress or load

Rupture: fracture of the final cross section area of a ductile behaving tensile test specimen.
Note: the term rupture, where e.g. a tension rod experiences gross section failure due to tension, should be not confused with fracture, This is when the maximum load of this specimen at onset of necking is reached

S-Basis (or S-Value): mechanical property value which is usually the value of the appropriate specification.
Note 1: Definition in MMPDS (Ref. [7]): The S-value represents or is based on the specification minimum value specified by the governing industry specification. For certain products heat treated by the user (for example, steels hardened and tempered to a designated tensile ultimate strength), the S-Basis value may reflect a specified quality-control requirement. Traditionally, the statistical assurance of S-Basis values has not been known. However, the statistical assurance associated with S-Basis values established since 1975 is known within the limitations of the qualification sample and the analysis method used to evaluate the data. Within those constraints S-Basis values established since 1975 may be viewed as estimated A-Basis values.
Note 2: MMPDS (Ref. [7]): Traditionally, the statistical assurance of S-Basis values has not been known. However, the statistical assurance associated with S-Basis values established since 1975 is known within the limitations of the qualification sample and the analysis method used to evaluate the data. Within those constraints S-Basis values established since 1975 may be viewed as estimated A-Basis values.
Note 3: MMPDS (Ref. [7]): For properties which do not have a specification minimum, the designated S-basis represents either the calculated minimums using the normal S-basis equation or (in most cases for compression, shear, and bearing properties) the derived properties which get their basis from the denominator (see Indirect Analysis). In cases where the primary test direction (specification minimum) is an A- and B-basis, but the derived property is an S-basis, it indicates that the reduced ratios were questionable, most likely due to insufficient data according to current guidelines.
Note 4: MMPDS (Ref. [7]): In the opposite (and fortunately infrequent) situation where the more rigorous A-Basis property falls well below the S-Basis value, the repercussions may be greater for both the user and producer. Actual design margins (as compared to originally perceived design margins) on primary structure may be reduced below desirable levels if the S-Basis value must be downgraded to a lower A-Basis value. The perceived adequacy of a material for a particular application may be reduced if the S-Basis value is reduced to match a lower A-Basis value. However, under most circumstances, the S-Basis value should be reduced to match the A-Basis value if process improvements cannot be instituted to raise the A-Basis value to the level of the original S-Basis value.

Safe Life: period during which the structure is predicted not to fail in the expected service life environment

Note: newly used too as fracture control design policy, for which the largest undetected defect that can exist in the part does not grow to failure when subjected to the cyclic and sustained loads and environments encountered in the service life

Safety: defined as 'absence of circumstances liable to cause death, or degradation or loss of equipment within limits of probability of occurrence' of these events.
Note: safety is - in contrast to structural design - related to human being

Safety Concept: deterministic or probabilistic concept or format, respectively, that considers the parameter uncertainties (see Ref. [3])
Note 1: concept that implements structural reliability (safety is a wrong term) in design by application of the FoS.
Note 2: Two formats are available for considering design uncertainties:
1. The deterministic format accounts for design uncertainties in a lumped manner by enlarging the design limit loads by multiplication with FoS.
2. The probabilistic format maps each single design parameter's uncertainty into a probability density function. Thereby, the joint probability of failure, caused by a combination of design parameters, can be considered. The joint probability of failure respects the combination of all scatter-caused varying design parameters

Safety Factor (factor of safety FoS): see FoS

Sample: collection of observations or of measurements taken from a specified population of a small portion of a material or product intended to be representative of the whole.

Sandwich Construction: structural panel concept consisting in its simplest form of two relatively thin, parallel sheets of structural material bonded to, and separated by, a relatively thick, light-weight core

Saturation: equilibrium condition in which the rate of absorption under prescribed conditions practically falls to zero (essential for conditioning of polymer matrix composites before testing).
Note: MIL-HDBK 17 (Ref. [1]), paragraph 2.2.7.2 formulation is: saturisation content is the largest value of moisture equilibrium content for a given material under humid conditions at 100 % relative humidity (RH)

Scarf joint: bonded joint in which similar segments of adherends are cut away, with cut areas overlapped and bonded

Scatter Factor: factor which indicates the variation of a property.
Note: In fatigue analysis the factor by which the number of cycles or life time is multiplied in fatigue, fracture and thermal cycling analysis and test in order to account for uncertainties in the statistical distribution of loads and cycles; factor by which the number of cycles or life time is multiplied in order to account for uncertainties in the statistical distribution of loads and cycles as well as uncertainties in fatigue analysis, manufacturing processes and material properties are considered. Term is reserved for the lifetime ratio $T50\,\%$ over $T90\,\%$, data which stem from s-n curves.

Scrim (also called Glass Cloth, Carrier): low cost fabric woven into an open mesh construction, used in the processing of tape or other B-stage material to facilitate handling

Secant Modulus: ratio of stress to strain at any point of a stress-strain curve (tension, compression, torsion, shear).
Note: slope of a line from the origin to any point of the curve

Section Force (German: Schnittkraft): force acting at a distinct cross section

Section Quantities: forces and moments acting at a cross section, at a node

Service Life: life of a structural component which starts with the manufacture of the structure and continues through all acceptance testing, handling, storage, transportation, service, repair, re-testing, re-use
Note: interval, beginning with the last item inspection or flaw screening proof test after manufacturing, and ending with completion of its specified life (completion of the mission)

Secondary Stresses: stresses induced by needs of internal compatibility or by compatibility with the boundary conditions
Note: Secondary stresses are associated with imposed loading or imposed displacements (temperature, pre-stressing, settlement, shrinkage). These stresses are not required to achieve equilibrium between an internal stress state and the external loading

Secondary Structure: structure attached to the primary structure with low participation in the main load transfer and overall stiffness

Section: station at a distinct length coordinate x of the structure.
Note: In practical application, the term section is unfortunately used as well as for an extruded beam (e.g. a product form such as a fabricated steel angle section or a channel section), and the cross section.
section forces and **section moments:** section quantities at a section cut at the coordinate x and dedicated to a distinct cross section (see stress resultants, too)

Selvage (selvedge): narrow edge of woven fabric that runs parallel to the warp
Note: It is made with stronger yarns in a tighter construction than the body of the fabric to prevent raveling

Sequential Loading: Loading sequences in fatigue loading

Singularity (point): point where a variable reaches an unmeasurable value or infinite value

Shear Center: point at a cross section, where a shear force can be applied without inducing any torsion.
Note: in general, the shear center is not the centroid. For cross section areas having one axis of symmetry, the shear center is located on the axis of symmetry. For those having two axes of symmetry, the shear center lies on the centroid of the cross section. The shear center is also known as the elastic axis or torsional axis

Shear Deformation Theories: see First.Order-Shear-Deformation Theory

Shear Flow: here: flow of shear stress given in dimensions of force per length.

Shear Modulus (secant): ratio of shear stress to shear strain

Shelf Life: length of time a material, substance, product, or reagent can be stored under specified environmental conditions and continue to meet all applicable specification requirements or remain suitable for its intended function

Shell: two-dimensional, curved structural element the thickness of which is small in comparison to the other dimensions.
shallow shell: slightly curved shell where a simplified theory may be used
Examples: cylindrical, spherical, conical, etc.
Note: a shell may buckle under loadings causing compressive stresses or shear stresses

Sizing: assessment of dimensions of a structure and term for fiber treatment.
Note: for compounds applied to yarns to bind the fiber together and stiffen the yarn to provide abrasion-resistance during weaving. Starch, gelatin, oil, wax, and man-made polymers such as polyvinyl alcohol, polystyrene, polyacrylic acid, and polyacetatates are employed

Sleeving: common name for tubular braided fabric

Slenderness Ratio: ratio of the effective length of a column to the least radius of gyration of its cross section is called the slenderness ratio (stability analysis)

Small-Scale Yielding: yielding of a material at a small spot of the structural component.
Note: term used in fracture mechanics indicating whether linear-elastic fracture mechanics is applicable

Solidification: process when a material becomes a solid quantity that describes the stress situation in the crack tip vicinity used to estimate whether the crack will grow or not
Note: It is a theoretical construct applicable to a homogeneous elastic material and is useful for providing a failure criterion for cracked brittle materials

Solute: dissolved material

Specific Gravity: ratio of the weight of any volume of a substance to the weight of an equal volume of another substance taken as standard at a constant or stated temperature. Solids and liquids are usually compared with water at $4^{\circ}C$

Specific Heat Storage Capacity: heat per unit mass a substance can store.
Note: 'specific heat' is an abbreviation commonly used

Specimen: piece or portion of a sample or other material taken to be tested. Specimens normally are prepared to conform with the applicable test method

Stacking Sequence: arrangement of ply orientations and material components in a laminate specified with respect to some reference direction

Staple: either naturally occurring fibers or lengths cut from filaments

State of the Art: highest level of development, as of a device, technique, or scientific field, achieved at a particular time

Statically Determinate Structure: structure where all of the unknowns can be found from equilibrium considerations alone.

Statically Indeterminate Structure: structure where not all of the unknowns can be found from equilibrium considerations alone, compatibility equations must also be used.
Note: a structure is said to be redundant if it provides more load paths than are necessary to satisfy equilibrium

Stiffness: rigidity of a structure, and elasticity of a material.
extensional stiffness: here, normal stiffness of an isotropic or laminated wall.
Note: also termed membrane stiffness in the case of plates and shells

Storage Life: amount of time a material can be stored and remain suitable for use

Strain: Length change per unit length due to force, temperature, moisture.
Note: Strain is frequently expressed in inches per inch, meters per meter, or percent.change in the metric properties of a continuous body in the displacement from an initial placement to a final placement

Strain after Rupture: remaining plastic or permanent strain after rupture.
Note: permanent increase in gage length due to tension loading, measured after fraction of the specimen, commonly expressed as a percentage of the original gage length, (in %). A subscript 5 in A_5 refers to a gage length L of 5 times the diameter for round bar specimens

Strain Energy Release Rate G_c: change in strain energy due to the creation of a new crack surface
The rate is reckoned with respect to the change in crack area, so if we use U for strain energy, the strain energy release rate is numerically dU/dA, elastic energy released is equal to surface energy plus plastic deformation energy

(Strain-) Hardening: stress increase, in relation to the non-linear stress-strain curve

(Strain-) Softening: material non-linear behaviour where the elasticity modulus reduces with continuous development of degradation by plastic shear strains or micro-cracks

Strand: normally an untwisted bundle or assembly of continuous filaments used as a unit.
Note: includes slivers, tow, ends, yarn, etc. Sometimes a single fiber or filament is called a strand

Strength: material resistance equal to the maximum stress the material is capable of sustaining.
Note 1: in structural design should be demonstrated material strength (applying strength conditions) and structural strength (applying buckling resistance conditions).
Note 2: strength is linked to a failure mode such as NF, SF, SY, FF, IFF

Strength Analysis: assessment of the resistance of a structure in a given mechanical environment that demonstrates the structure is able to sustain the applied loadings without unacceptable behaviour such as rupture, detrimental deformation, buckling.
Note: strength analysis bases on models. It leads to design verification, on the basis of computed MoS

Strength Property Types, composites: weakest link data (e.g. 'isolated' UD test specimen) and redundant behaviour data (e.g. in-situ values of the 'embedded' lamina)

Stress: force per unit cross section area of a surface.
Note: denotations used for stresses are primary stresses (external loadings caused), secondary stresses (self-equilibrating stresses, residual stresses, constraint-dependent stresses), and so-called tertiary stresses (stress *gradients* at stress concentrations, but these are not stresses) .
principal stress: stresses which are the components of the stress tensor when the basis is changed in such a way that the shear stress components become zero
mean stress: average of the principal stresses (invariant formulation: $\sigma_{eq} = I_1/3$)
v. Mises stress: equivalent stress that is responsible for the shear deformation of the material element (invariant formulation: $\sigma_{eq}^{Mises} = \sqrt{3 \cdot J_2}$)
true stress: force per unit actual cross section area
engineering stress: force per unit initial (nominal) cross section area

Stress Analysis: computation of stresses in a structure, due to loadings carried by the structure in a given mechanical environment

Stress Concentration: convergent theoretical stress

Stress Intensity: infinite theoretical stress (different grades of singularity)
Note: the term used in fracture mechanics to describe the stress singularity (intensity state) near the tip of a crack caused by a remote load or residual stresses. It is directly proportional to the applied loading.

Stress Intensity Factor (SIF) K: LEFM quantity that describes the stress singularity at the crack tip
Note: It can be used in crack propagation analyses to predict crack growth.

Stress Concentration (stress raiser, stress riser): converging theoretical stress
Note: phenomenon at a location in a structure where stress is concentrated

Stress Concentration Factor K_t: ratio of peak value of the non-uniformly distributed stress over nominal stress.
Note: quantifies the local stress increase at notches

Stress Redistribution: change of the stress distribution due to non-reversible (inelastic) material response in the structural element.
Note 1: stress redistribution lowers stress peaks and may improve the fitness to use. As a temperature treatment means utilized in the production for metallic and composite materials.
Note 2: stress redistribution within the thickness of a laminated structure. This redistribution lowers, due to micro-cracking, the matrix-dominated stress level including the residual stresses

Stress Resultants: system of forces which is statically equivalent to a stress distribution over an area

Stress Singularity: description of infinite stresses at locations of geometric (point, edge line) or material discontinuity.
Note: singularities are generally an artefact of the underlying assumptions of linear elasticity and the associated simplifications when developing an engineering model. Stresses tend to infinite values with decreasing distance from the discontinuity

Stress-strain Curve: graphical representation of the strain-response of a material subjected to a stress.
Note: Usually to be used as an average property like other physical quantities (such as α_T)

Stress Tensor: multi-dimensional mathematical formulation of the full stress state in a solid, σ_{ij}.
Note 1: The 9 stress tensor components or 9 stresses may be organized in a matrix (3×3). The first subscript of a stress denotes the direction of the surface normal upon which the stress acts. The second subscript denotes the direction of the stress.
Note 2: The stress state is a second order tensor since it is a quantity associated with two directions. As a result, stresses have 2 subscripts. A surface traction is a first order tensor (i.e. vector) since it a quantity associated with only one direction. Vector components therefore require only 1 subscript. Mass would be an example of a zero-order tensor (i.e. scalars), which have no relationships with directions (and no subscripts).

Stress Vector: acting vector σ_i or $\{\sigma\}$ on an internal surface in a continuum, involving the normal and shear stresses (vector components) on that surface
Note: first order tensor (3 x 1), that is also often termed t, from traction

Structural Element: generic element of a more complex structure ('standard structural elements' are column, plate, shell, stringer, shear panel, sandwich panel)

Structural Health Monitoring: process of implementing a damage detection and characterization strategy for engineering structures

Structure (structural) Integrity: characteristic of a structural element that enables it to withstand the load environment and the usage imposed during service

Structure Reliability ($\Re$): ability of a structure to fulfill the functional requirements during a distinct lifetime with a distinct reliability

Structural Risk: defined here arbitrarily as amount of costs (incurred in the case of later failure) times the probability P that the distinct failure occurs in the structural part

Sub-laminate: part of a laminate that is used for simplifying ply-wise modeling

Sub-cycle sequence (German: Teilfolge): selected loading in fatigue life predictions

Support (boundary) Condition: refers to the kind of support of a structural element, e.g. for a beam, plate or shell being simply supported or pinned (S), free (F), clamped (C) fixed, guided, elastically supported, stiffened edges.

Surfacing Mat: thin mat of fine fibers used primarily to produce a smooth surface on an organic matrix composite

Symmetrical Laminate: composite laminate in which the sequence of plies below the laminate mid-plane is a mirror image of the stacking sequence above the mid-plane.
Note: mid-plane and symmetry plane coincide for a symmetric laminate

Symmetry Plane: plane if the geometry and loading on one side of the structure is mirrored on the other side of the plane

T-90: Statistically based lower tolerance bound for a mechanical property such that at least 90 % of the population is expected to exceed T_{90} with 95 % confidence (Ref. [7])

T-99: Statistically based lower tolerance bound for a mechanical property such that at least 99 % of the population is expected to exceed T_{99} with 95 % confidence (Ref. [7])

T-Stress: additional, higher term in the definition of the stress intensity factor K

Tack: stickiness of the prepreg.
Note: qualitative quantity, difficult to measure and quantify

Tailored Fiber Placement (TFP): reinforcement process (embroidery technology) by which the lay up is produced by using a single roving.
Note: This roving is fixed by stitching to the base material. The base material can be a 2D-textile such as a woven fabric or for thermoplastic composites a matrix-compatible foil material. During the process, the stitching unit is stationary and the base material is moved using numerical control. Enables to realize fiber arrangements that optimally meet the calculated requirements concerning direction and accumulation of fibers in preforms

Tailor-made Blanks: application-optimized, two or more joined metal sheets that differ in thickness or material composition or condition, before the forming operations

Tangent Modulus: elasticity modulus defined as slope of the stress-strain curve at any specified stress or strain.

Tangential Stiffness: in non-linear problems the slope of the load-deflection curve for the current solution position

Tape: UD prepreg, usually fabricated in widths up to 12 inches wide for carbon fibers.
Note: cross stitched carbon tapes up to 60 inches wide are available commercially in some cases

Tape Laying: fabrication process in which prepreg tape is laid side by side or overlapped to form a structure

Tex: mass description of the used yarn in g/km

Textiles: woven, or knitted or braided, etc. or even non-woven products

Thermal Conductivity: ability of a material to conduct heat, measured in heat, times unit length per unit time, unit area and unit temperature.
Note: synonym for heat conductivity

Thermoplastic (Thermoplast): plastic that repeatedly can be softened by heating and hardened by cooling.
Note: can be shaped in the softened stage by molding or extrusion

Thermoset (Duromer): plastic that is substantially in-fusible and insoluble after having been cured by heat or other means

Titer: measure of concentration.
Note: titer is an important characteristic of the used yarn. It defines its fineness which is expressed in the unit called tex that means in g/km

Tolerance: total amount by which a quantity is allowed to vary.

Tolerance Limit: lower (upper) confidence limit on a specified percentile of a statistical distribution.
Example: the B-basis value is a 95 % lower confidence limit on the tenth percentile of a distribution

Tolerance in Strength Design Verification: One-sided (static and fatigue strength), and two-sided tolerance bands (thickness, elasticity properties) have to be considered

Tolerance Limit Factor: factor which is multiplied by the estimate of variability in computing the tolerance limit

Tool: mold, either one- or two-sided and either open or closed, in or upon which composite material is placed in order to make a part

Toughness: capability of a material to absorb work, or the actual work per unit volume or unit mass of material that is required to rupture it
Note: toughness is defined as the load-deformation integral (area under the load-elongation curve from the origin to the breaking point)

Tow: untwisted bundle of continuous filaments
Note: it is commonly used in referring to man-made fibers, particularly carbon and graphite fibers. It is designated by a number followed by K, indicating multiplication by $1,000$; for example, a $12K$ tow has $12,000$ filaments. Unfortunately, the capital letter K is used here for $1,000$ instead of the normally used k

Tow placement: see fiber placement

Transient Load: deterministic load whose magnitude or direction varies with time and for which the response of the structure is significant

Transversely-isotropic: descriptive term for a material exhibiting a special case of orthotropy in which properties are identical in two orthotropic dimensions, but not the third.
Note 1: material possesses identical properties in all transverse directions but not in the longitudinal or principal direction, where superior properties are usually encountered.
Note 2: typical assumption for uni-directional material

Traveler: small piece of the same product (panel, tube, etc.) as the test specimen, used for example to measure moisture content as a result of conditioning

Tri-axial Fabric: fabric with three non-interwoven layers, oriented at $+45°$, $-45°$ and either $0°$ or $90°$, which are bonded together, usually by through-the-thickness stitching, to form a single sheet of fabric

Tri-axiality Factor: factor that marks a 2D- or 3D-stress state that has a fundamental effect on ductile and brittle failure behaviour

True Stress: see Stress

Twist: measure of the number of turns per unit length that a fiber bundle makes around its axis

Typical Basis: typical property value used if statistical significance is unknown.
Note 1: Definition in MMPDS (Ref. [7]): A typical property value is an average value and has no statistical assurance associated with it
Note 2: the typical value becomes a so-called mean value, if it is the simple arithmetic mean which has a statistical of 50 % reliability with 50 % confidence

UD-lamina: lamina (ply) with unidirectional reinforcement

Unbond: area within a bonded interface between two adherends in which the intended bonding action failed to take place.
Note: Also used to denote specific areas deliberately prevented from bonding in order to simulate a defective bond, such as in the generation of quality standards specimens

Ultimate Failure: fracture failure at the physical failure loading

Ultimate Load: physical fracture load.
Note: unfortunately used in aircraft-regulations as limit load multiplied by the prescribed ultimate factor of safety

Ultimate Strength: resistance of a material equal to the load the material specimen can withstand without incurring fracture divided by the associated initial cross section area.
Note: It is implied that the condition of stress represents uni-axial tension, uni-axial compression (just in case of brittle behaviour given), or pure shear. (rupture or collapse are differently used limits)

Uncertainty: 'unclearness' or fuzziness in loadings, strengths, stiffness and other design parameters such as geometrical parameters, applied engineering models.
Note: structural reliability will be increased if the uncertainty can be transferred into a stochastic uncertainty, because a quantitative assessment is then possible. However, this requires measurement or assessment of the scatter of the design parameters

Uni-directional Laminate: lamina or laminate with non-woven reinforcements and all layers laid up in the same direction

Unit Cell: basic model in continuum analysis of composites, assumed to represent all features of the considered material

Undulation: waviness of yarns

Vacuum Bag Molding: process in which the lay-up is cured under pressure generated by drawing a vacuum in the space between the lay-up and a flexible sheet placed over it and sealed at the edges

Validation: demonstration or providing evidence that something is correct or conforms to a certain standard.
Note1: In data collection or data entry, it is the process of ensuring that the data fall within the accepted boundaries of the application collecting the data.
Note 2: means 'solving the right equations', to be proven by tests. Design validation: Testing aimed at ensuring that a product or system fulfills the defined user needs and specified requirements, under specified operating conditions.
Note 3: a model can be validated only if sufficient physical test data are available. Otherwise it can be 'just' verified. The same is with a design.

Variance: measure of the average distance between each of a set of data points and their mean value; equal to the sum of the squares of the deviation from the mean value

Verification: use of supplementary tests, to ensure the accuracy, correctness, or truth of the information.
Note: Means 'solving the equation right', benchmark check in case of design models and theories. Virtual tests accompanied by benchmarks lead to verification not validation. See also Design Verification

Virtual Crack Closure Technique: method which uses a single finite element solution to obtain a value for the strain energy release rate for a crack (delamination) propagated over a pre-determined length

Viscosity: a fluid's property of resistance to flow.
Example: honey has a higher viscosity value than water

Void: pockets of entrapped gas, fluid that have been cured into a laminate.
Note: a physical and mechanical discontinuity occurring within a material or part which may be two-dimensional (e.g. thin flat dis-bonds, delamination) or three-dimensional (e.g., vacuum-, air-, or gas-filled pockets). Voids are essentially incapable of transmitting structural stresses or non-radiative energy fields. Porosity is an aggregation of micro-voids and may decrease stiffness and strength

Volume Fraction: portion of a constituent (V) within 100 % total volume

Warp: longitudinally oriented yarn in a woven fabric.
Note: a group of yarns in long lengths and approximately parallel

Warpage: out-of-plane deformation of a cross section

Weave: pattern by which a fabric is formed from interlacing yarns
Note: in plain weave, the warp and fill fibers alternate to make both fabric faces identical; in satin weave, the pattern produces a satin appearance, with the warp tow over several fill tows and under the next one (for example, eight-harness satin would have warp tow over seven fill tows and under the eighth).

Weft (German: Schuss): 'filling' material of the fabric or transversely oriented yarn, respectively
Note: for a weft property (i.e. a fill property) the letter F is used to separate it from warp

Wet Lay-up: method of making a reinforced product by applying a liquid resin system while the reinforcement is put in place

Wet Strength: strength of an organic matrix composite when the matrix resin is saturated with absorbed moisture (see saturation)

Wind Angle: angle between the fiber direction and an established reference axis

Winding Pattern: regularly recurring pattern of the filament path in a filament winding after a certain number of mandrel revolutions

Work Life: period during which a compound, after mixing with a catalyst, solvent, or other compounding ingredient, remains suitable for its intended use

Wrinkle: imperfection in the surface of a laminate that looks like a crease or fold in one of the outer layers

Woven Fabric Composite: major form of advanced composites in which the fiber constituent consists of woven fabric.
Note: a woven fabric composite normally is a laminate comprised of a number of laminae, each of which consists of one layer of fabric embedded in the selected matrix material. Individual fabric laminae are directionally oriented and combined into specific multi-axial laminates for application to specific envelopes of strength and stiffness requirements

Yarn: continuous assembly of twisted filaments or strands suitable in textile fabrication.
Note: generic term for strands or bundles of continuous filaments or fibers, usually twisted and suitable for making textile fabric

Yield Strength: material resistance equal to the stress when reaching $0.2\,\%$ permanent strain.
Note: The yield strength value is usually determined by measuring the departure of the actual stress-strain relationship from the initial, proportional relationship. The specified value is usually taken as a unit strain of 0.002. For very ductile metals both yield strengths (tensile and compressive) become equal.

Yield Stress Domains Specifics:
Local:
1. in a material 'point', the vicinity of which will take over loading by stress redistribution,
2. at a constraint edge of a shell loaded by a bending moment (however, the cross section possesses redundancy in case of ductile behaviour);

Global:
distributed in the structural component (usual design requirements do not permit global yielding)

Young's Modulus: see modulus of elasticity

x**-Axis:** in composite laminates, an axis in the plane of the laminate which is used as the 0° reference for designating the angle of a lamina.

x-y**-Plane:** in composite laminates, the reference plane coinciding with the middle plane of the laminate

y**-Axis:** in composite laminates, the axis in the plane of the laminate which is perpendicular to the x-axis

z**-Axis:** in composite laminates, the reference axis normal to the plane of the laminate.
Note: often referred to as thickness direction

Z-thread: thread, used to fix (when draping) and sometimes also to reinforce a laminate stack in thickness direction.

Dictionary English-German (for a number of technical terms)

absorption	Aufsaugen
adsorption	Anlagerung
aileron	Querruder
braided fabric	Geflecht
cohesion	Trennfestigkeit
cloth	Tuch, Stoff
curved shallow shell	schwach gekrümmte Schale
cross section	Querschnitt
damage	Schaden (leider auch Schädigung)
damage accumulation	Schädigungsakkumulation
damaging portion	Schädigung
deep beam	gedrungener Balken
desorption	Austreiben
embroider	sticken
fabric, woven	Gewebe
failure	Versagen
failure surface	Versagensoberfläche
fiber	Faser
filament	Einzelfaser
filament-wound structure	Wickelkörper
fracture toughness	Bruchzähigkeit
fuzziness	Unschärfe
knitting	Stricken
layer-wise fracture analysis	schichtweise Bruchanalyse
loop-joint	Schlaufenanschluß
material stress effort	Werkstoffanstrengung
non-crimp fabric	Gelege
plain weave	Leinwandgewebe
pot life	Topfzeit
pitch	Teilung
satin	Atlasgewebe
section force	Schnittkraft
section quantities	Schnittgrössen (generell)
shear flow	Schubfluss
spacer weave	Abstandsgewebe
specific heat	spezifische Wärme
stress resultants	Schnittgrössen (Balken, Platte)
taileron	Höhenruder
sub-sequence	Teilfolge
thermoset	Duromer
twill	Köpergewebe
warp	Kette
warp-knitted fabric	Gewirke
weft (fill)	Schuss
weft-inserted	schussverstärkt
weft-knitted fabric	Gestrick

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