Plastic Creep Design & Long-Term Deformation Validation

ENGINEERING GUIDE | Material data - calculations - part testing - acceptance

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A practical, evidence-led workflow to quantify time-dependent deformation under sustained loads while preventing unsupported life claims.

Included workbooks

WORKBOOK	PURPOSE
Creep Data and Deformation Calculator.xlsx	Measured tensile raw-data arithmetic, article geometry sensitivity example, and formula audit.
Long-Term Creep Validation and Acceptance.xlsx	Test plans, specimen register, actual measurements, requirement-by-requirement acceptance and human release.

Important limitation

The Delrin 500P NC010 cantilever example is an explicitly illustrative sensitivity calculation based on assumed time-dependent equivalent bending moduli. The values are not a manufacturer creep curve at 40 degrees C and are not an approval for use.

This toolkit is educational and intended to support competent engineering review. It does not reproduce copyrighted normative test standards.

Start with requirements, then identify condition-matched test evidence, calculate only within suitable data and geometry assumptions, validate the actual part, and sign off explicitly.

1 Quick-start workflow

Keep measured evidence, model estimates and acceptance decisions separate.

STAGE	ENGINEERING OUTPUT	WHERE
1. Define	Material identity, service load, temperature, humidity, life and acceptance limit.	Material & Source; Service Conditions
2. Acquire	Document method edition, sample direction, conditioning, data origin and reporting.	Test Series Setup; Test Planning Matrix
3. Analyze	Compute tensile engineering stress, gauge strain, creep modulus and compliance.	Raw Creep Data; Creep Curve Analysis
4. Screen	Use dimensionally correct geometry with applicable time-dependent properties.	Part Deformation; Clearance & Sensitivity
5. Verify	Test actual part, document tolerances, environment, contact and response.	Part-Level Measurements; Inspection
6. Release	Check reviewed evidence and obtain named, dated human approval.	Engineering Release

Cell conventions: pale yellow cells are user inputs; calculated results are formula cells. Blank measurements are intentional. The two files do not require cross-file formula links.

Decision states: MODEL ONLY, INSUFFICIENT DATA, PENDING EVIDENCE, FAIL, or human-approved release. A favorable model displacement margin does not become a verified PASS.

2 Material identity and test comparability

A commercial polymer family is not a complete specification.

Record polymer family, full commercial grade, manufacturer, color, reinforcement type and weight fraction, nominal lot/production batch, processing route and specimen orientation. Also record moisture conditioning, annealing, molding flow or additive manufacturing build direction.

MUST DOCUMENT	WHY IT MATTERS
Grade + reinforcement wt%	Unfilled and reinforced grades can creep differently; fiber orientation matters.
Specimen manufacturing path	Molded, extruded, machined and printed specimens may not be transferable.
Conditioning / RH / moisture	Water uptake and thermal history can change long-term response.
Measured mode and orientation	Tensile, compressive and flexural conditions are not interchangeable.
Report number + version	Enables audit and prevents replacing verified data with generic web values.

Mandatory validation gate: If grade identity, source, specimen condition, mode or temperature is unknown, label the data unqualified for part-level prediction.

A published short-term tensile modulus or strength can support initial material screening, but cannot replace duration-specific creep test data.

3 Service condition definition

The acceptance limit should precede the material choice.

List the real sustained load, constant force or constant displacement control, load path, local nominal stress, temperature and humidity profiles, time under load, allowable displacement, clearance, sealing or force-retention limit. Identify cyclic overloads separately.

INPUT	EXAMPLE / UNIT	REVIEW
Force / displacement	N / mm	Direction, load eccentricity, restraint and fixture flexibility
Exposure duration	hours	Continuous load, dwell and inspection moments
Environment	degrees C, %RH	Steady vs cycling; conditioning
Geometry	mm	Effective length, cross-section, notch and contact area
Acceptance	mm, N, %, depending on function	Trace to drawing and inspection method

For a constant-force flexural beam, a bending modulus based on an appropriate creep response may support a simplified elastic-correspondence sensitivity model. A joint held at fixed displacement is a relaxation problem requiring different evidence.

Failure modes to check separately: excessive motion, loss of fit, local contact indentation, buckling, cracking, creep rupture, loss of bolt preload or snap-fit retention.

4 Verified technical standards

Official published scopes; do not substitute summaries for test text.

STANDARD / EDITION	CONFIRMED SCOPE / IMPLEMENTATION NOTE
ASTM D2990-17(2025)	Tensile, compressive and flexural creep and creep-rupture of plastics; 3-point flexure, 4-point option described.
ISO 899-1:2017	Tensile creep of appropriate standard specimens with specified temperature, humidity and pretreatment.
ISO 899-2:2024	Flexural creep of a freely supported beam under three-point midspan loading.

Important: ASTM states its D2990 and ISO 899 results cannot be directly compared because technical content differs. ISO 899-2 is NOT a cantilever test standard. A part-level cantilever load-hold test is a separate application-specific validation.

The governing material specification may impose specimen preparation, conditioning, reporting and testing requirements. Use the full purchased revision of the method and the actual specification when writing a formal test plan.

Source register (publisher page descriptions, checked November 2026): ASTM International, D2990-17(2025), official active standard listing; ISO, ISO 899-1:2017, official standard abstract; ISO, ISO 899-2:2024, official standard abstract. No external web links are embedded in this guide.

5 Test plan and traceable raw measurements

A curve should identify a particular material state and environment.

Create one Test Series ID for a single specimen population, stress level, temperature, humidity and orientation. Define specimen count and sampling plan based on project risk and the applicable standard, not a fixed invented universal minimum.

A raw reading should contain elapsed time (h), applied force (N), undeformed area (mm2), original gauge length (mm), measured extension (mm), temperature (degrees C), RH (%), individual specimen ID, measurement instrument and report reference.

Gauge extension is not grip separation. In tensile creep, strain inferred from grip movement may include fixture slip or other effects. Record the measurement convention. The calculator accepts physical tensile gauge quantities and explicitly flags modes that cannot use its tensile equations.

Missing test reports or nonexistent raw readings must remain BLANK, not replaced by generated synthetic measurements.

A nominal applied stress is calculated from undeformed area and force; make sure the stress convention matches the test data and model.

6 Tensile creep arithmetic

Use dimensionless strain rather than a percentage directly.

OUTPUT	EQUATION	UNITS
Engineering stress	sigma = F / A0	N/mm2 = MPa
Tensile gauge strain	epsilon(t) = DeltaL(t) / L0	mm/mm
Strain percentage	epsilon_percent = 100 x epsilon	%
Apparent creep modulus	Ec(t) = sigma / epsilon(t)	MPa
Apparent compliance	J(t) = epsilon(t) / sigma	MPa^-1
Finite-difference creep rate	[epsilon2 - epsilon1]/[time2 - time1]	h^-1

Use positive area, length, force, and nonnegative elapsed time. The calculator only computes valid numerical rows. A zero-strain reading has no finite modulus via sigma/epsilon and remains blank for that result.

The modulus and compliance expressions are nominal, uniaxial engineering quantities for a specified loading history, not universal material constants. Nonlinear creep depends on stress.

Never apply these tensile formulas automatically to a flexural deflection, compression geometry, stress relaxation or creep-rupture record.

7 Curve handling and isochronous comparisons

Trace every curve to its source and do not invent intermediate results.

Plot individual valid tensile creep series as strain versus time; consider a log time axis when positive times span several decades. Keep 0 h as a separate initial datum rather than forcing log(0).

A valid isochronous comparison samples **measured** strain at one common duration across multiple stress levels for compatible grade, processing state, conditioning and temperature. If data are missing at the requested time, mark that point unavailable until an explicitly supported interpolation policy is approved.

Permissible calculations: within-domain interpolation with documented interpolation method, uncertainty and datum identifiers, once justified for the selected model. **Not automatically permissible:** converting room-temperature curves into 40 C curves, mixing tensile and flexural modes, fitting a one-stress data set and claiming a ten-year life.

Do not classify an arbitrary polymer curve into all three classical creep stages unless the observed curve actually supports those stages.

8 Long-term geometry screening

Simple beam theory is a screening model, not an automatic part rating.

TERM	RELATION / CONDITION
Rectangular second moment	I = b t^3 / 12; b and t in mm
Cantilever tip displacement	delta(t) = F L^3 / [3 E_b(t) I]
Nominal root bending stress	sigma_root = 6 F L / (b t^2)
Creep displacement increment	delta(t) - delta(0)

Assumptions: small deflection, ideally fixed root, prismatic rectangular beam, end point force, and a compatible effective flexural response at the relevant stress, temperature and time. If these assumptions fail, use qualified nonlinear analysis and part testing.

The model does not capture stress concentration at the root fillet, out-of-plane deformation, load redistribution, section change, constraint slip, temperature drift, nonlinear polymer creep or contact compliance.

Cross-mode rule: a tensile creep modulus cannot be silently treated as a flexural modulus. ISO 899-2 is three-point loading, not this cantilever geometry.

9 Clearance budget and acceptance definitions

Use the functional fit as the criterion, not only material strength.

Define the as-built initial functional clearance and all effects consuming the fit budget. Example: remaining nominal clearance = initial clearance - predicted end movement. A conservative project-specific fit budget may additionally subtract tolerance stack, thermal expansion, contact indentation, fixture shift and alignment allowances.

CHECK	REQUIRED EVIDENCE
Allowable tip motion	Drawing or design specification and inspection method
Initial fit / clearance	Manufacturing and assembly measurement
Tolerance accumulation	Worst-case or justified statistical approach with correlated inputs addressed
Environment effects	Temperature, moisture expansion and test conditions
Contact or fixture movement	Representative part-level measurements or validated mechanics

Do not assume that a positive nominal computed clearance establishes release. The calculator deliberately leaves adjusted clearance blank until the user enters the reserve terms.

For preload-sensitive bolted parts and fixed-deflection snap fits, measured stress relaxation or force retention may be needed; a deflection calculation does not determine retained force.

10 Temperature, humidity and processing history

Condition matching is an engineering requirement, not a cosmetic note.

Creep depends on temperature, humidity or moisture state, stress, specimen geometry, loading duration, crystallinity, filler direction, processing, thermal history and actual material grade.

PROCESS	IDENTITY / STATE TO PRESERVE
Injection molding	Resin grade, drying, gate / flow, wall orientation, processing history
Machined stock	Rod / sheet source, machining direction, internal stress, annealing / conditioning
Additive manufacturing	Process, build orientation, infill, layer height, raster and post-treatment

Where service temperature changes, record the time-temperature exposure and use measured properties or independently validated constitutive models covering the window. Time-temperature superposition is material- and condition-dependent; it is not a universal Excel shortcut.

For moisture-sensitive grades, record conditioning and use the appropriate environmental test state. Comparative material rankings should not be inferred from unmatched catalog figures.

11 Model validity and extrapolation

A curve fit is not evidence of out-of-range service life.

Every model must report calibration data origin, stress range, temperature and humidity window, strain convention, elapsed-time range, specimen conditions, fitting method, diagnostic residuals and independent validation.

Recommended explicit classifications: VERIFIED MEASUREMENT; SUPPLIER DATA - CONDITIONS CHECKED; INTERPOLATED WITHIN VALIDATED RANGE; MODEL SENSITIVITY ONLY; OUT OF VALIDATED RANGE; INSUFFICIENT DATA.

The provided workbooks intentionally do not run automated power-law, Prony-series or time-temperature extrapolation. Adding an advanced fit requires multiple stress and environmental histories plus independent checks, particularly for nonlinear polymers.

A 1,000-hour test is not direct evidence of ten-year performance. If service life lies outside the reliable measured/model domain, plan longer duration tests, validate a constitutive model independently, or review service-return parts.

Use explicit uncertainty margins and document engineering sign-off for any extension beyond measured conditions.

12 Creep, stress relaxation and unloading recovery

Choose the test mode from the actual controlled variable.

BEHAVIOR	CONTROL / OBSERVATION	SUGGESTED EVIDENCE
Creep	Hold stress or force; watch strain / displacement grow	Constant-force sustained-load record
Stress relaxation	Hold strain or displacement; watch reaction force / stress decline	Fixed-deflection force retention record
Recovery	Unload and watch strain or displacement decline with time	Measured before / after load-off readings
Residual movement	Remaining offset after defined recovery period	Baseline, sign convention and observation window

A measured decrease in force for a fixed displacement cannot be entered as an ordinary constant-force tensile creep curve. Similarly, creep observations alone do not determine remaining clamp preload.

Recovery may contain instantaneous and delayed parts; a nonzero residual displacement at one chosen observation time is not proof of permanent plastic strain.

The validation workbook makes recovery readings a separate record and does not conflate them with tensile creep modulus.

13 Article case: geometry and nominal stress

Published Delrin 500P NC010 positioning bracket; values from the article.

PARAMETER	VALUE
Material	Delrin 500P NC010, natural, unreinforced POM-H
Process / orientation	Injection molded; mold flow along cantilever length
Cantilever length / width / thickness	40.0 / 20.0 / 8.0 mm
Root fillet radius	2.0 mm
Lateral tip force	30.0 N
Test environment / duration	40 deg C / 50% RH / 0-1,000 h
Bending moment F L	1,200 N mm
I = b t^3 / 12	853.3333 mm4
Nominal root stress = 6 F L / (b t^2)	5.625 MPa

This is not a tested creep coupon. The root radius and actual restraint can raise local stresses beyond the nominal beam stress. The 5.625 MPa calculation is not a validated allowable-stress check.

Reference: EPOC CRAFTER published article Plastic Creep: Deformation, Testing, Curves, and Long-Term Design, section 8.1.

14 Article case: time-dependent sensitivity

Input moduli are assumed, illustrative values and are NOT a manufacturer 40 C creep curve.

ELAPSED h	ASSUMED E_b(t) MPa	PREDICTED TIP mm
0	3,100	0.242
1	2,500	0.300
100	2,100	0.357
500	1,900	0.395
1,000	1,800	0.417

Independent beam arithmetic: I = 20 x 8^3 / 12 = 853.333 mm4. At 1,000 h, delta = 30 x 40^3 / (3 x 1800 x 853.333) = 0.41667 mm. At 0 h, delta = 0.24194 mm. Additional modeled movement = 0.17473 mm.

Against the article 0.450 mm limit, nominal margin at 1,000 h is 0.03333 mm. Against a 0.500 mm starting side clearance, nominal remaining clearance is 0.08333 mm, BEFORE tolerance, temperature, contact or assembly offsets.

Outcome: MODEL SENSITIVITY ONLY - VALIDATION REQUIRED. A numeric screening margin is not a physical-test acceptance or a production release.

15 Validation plan for real components

Use part-level tests to verify the actual load path and failure criterion.

PLAN ITEM	MINIMUM RECORD
Samples and traceability	Actual lot, process, direction, replicate IDs and relevant drawings
Applied loading	Force/displacement control, fixture, duration, transients, alignment
Environment	Actual temperature, humidity, preconditioning and operating cycles
Response	Instrument ID, measurement location, zero reference, time history
Acceptance criteria	Upper/lower dimensions, force retention and functional limits
Evidence	Original data, calibration, report ID, deviations and human reviewer

Select test standards according to specimen type and measurement. The specific cantilever part-level load-hold test is not equivalent to an ISO 899-2 standard three-point flexural coupon test.

Also consider creep rupture, local contact damage, chemical exposure, cyclic stress, moisture or thermal dimensional drift when relevant to the part function.

16 Inspection and evidence-based acceptance

Record numeric limits, measured results, method and independent review.

For each characteristic, record requirement ID, part revision, location, measurement instrument, method, specimen or part ID, environment, time, numerical lower/upper limits, result, evidence ID and reviewer.

The acceptance workbook generates a per-characteristic PASS only if the measured value, at least one numerical bound, measurement method, evidence ID and reviewer are present. Otherwise it returns PENDING. Missing, unverified or unsuitable evidence must not be converted to PASS.

A failed characteristic should block release until investigated and formally dispositioned. Record nonconformity, root cause, engineering impact, corrective action and any retest evidence.

The Engineering Release sheet requires actual inspection evidence, an accepted report, identification of a reviewed plan and separate technical reviewer and approval names. Its output is a workflow summary, NOT a digital signature.

17 Workbook field map and independent checks

Suggested end-to-end validation before using results for any project.

FUNCTION	WHERE / VALIDATION CHECK
Tensile stress / strain	Raw Creep Data / requires valid force, area, gauge and extension
Compliance / modulus	Creep Curve Analysis / no percentage-to-fraction confusion
Article example	Part Deformation / values are explicitly illustrative
Independent reference arithmetic	Calculation Audit / section moment, stress, 0 h and 1,000 h deflection
Clearance margin	Clearance & Sensitivity / tolerances excluded unless separately input
Physical acceptance	Inspection & Acceptance / measured + limit + source + reviewer
Release	Engineering Release / evidence, fails, named human sign-offs

Baseline checks for the unchanged article example: I = 853.333333 mm4; nominal root stress = 5.625 MPa; delta(0) = 0.241935 mm; delta(1000h) = 0.416667 mm; nominal margin = 0.033333 mm; remaining side clearance = 0.083333 mm.

Input changes necessarily change calculated values. The reference comparison is a regression check for the original case inputs, not a universal property specification.

18 Release checklist and source record

Do not issue long-term creep certification from this template alone.

Required before an engineering release: commercial resin grade and lot verified; relevant test mode selected; measured grade- and condition-matched creep evidence available; raw data traceable; model assumptions documented; geometry/contact failure modes evaluated; time-temperature-moisture effects addressed; drawing limits linked to measured results; unresolved deviations closed; reviewer and approver identified.

Official standards verified for this guide (publisher records checked November 2026):

ASTM International. ASTM D2990-17(2025), Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics.

International Organization for Standardization. ISO 899-1:2017, Plastics - Determination of creep behaviour - Part 1: Tensile creep.

International Organization for Standardization. ISO 899-2:2024, Plastics - Determination of creep behaviour - Part 2: Flexural creep by three-point loading.

Article alignment: EPOC CRAFTER, Plastic Creep: Deformation, Testing, Curves, and Long-Term Design, published article section 8. All article example moduli are assumed sensitivity inputs, not measured manufacturer data.

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