6061 Aluminum Anodizing

Critical Fits, Machining Allowances & Dimensional Acceptance | Engineering Toolkit

Purpose

A practical workflow to transfer anodizing requirements into controlled machining dimensions, supplier requirements, and traceable final-part inspection. Companion workbook: 12 linked engineering sheets.

Who should use this toolkit?

- Mechanical / design engineers defining finished dimensions and fit requirements.
- Purchasing and NPI teams writing unambiguous anodizing and RFQ specifications.
- Quality engineers assessing feature measurements, coating evidence and lot release.

Five-stage workflow

01 REQUIRE	02 MODEL	03 CONTROL	04 MEASURE	05 REVIEW
Specify type, zone and tolerances	Estimate or validate net surface change	Set pre-size, masking and RFQ notes	Inspect finished parts and film	Review evidence and authorize release

Important boundary

This resource is a planning and verification aid. It is not a coating process specification, substitute for purchased standards, certificate of conformity, or independent authority to release product.

Files delivered

PDF: engineering logic, accepted terminology, decision rules and three labeled illustrative examples.
Excel: blank templates for real projects, numerical model, fit stack-up, process controls, inspection, RFQ text and readiness dashboard.

01 | Quick Start

Start from drawing requirements, not a guessed anodize thickness or growth factor.

Order	Workbook worksheet	Action / minimum information
1	02 PROJECT SPEC	Part, revision, temper, product form, material lot, anodize lot, supplier.
2	03 ANODIZE REQ	Identify the applicable standard/edition; type, class, color where applicable, thickness range, sealing, masking and rack zones.
3	04 COATING MODEL	Choose Estimated or Validated; identify net surface-change range per coated surface.
4	05 / 06 / 07	Enter functional dimension limits, special features, paired fits, and thread gauging.
5	08 / 09	Build supplier RFQ and confirm pre-clean, rack, masking and inspection controls.
6	10 / 11 / 12	Record real measurements and evidence; review the final decision.

Workbook conventions

- Dimensional values and acceptance limits: millimeters (mm). Film thickness and surface change: micrometers (um).
- Editable cells have pale orange shading; calculated outputs have pale blue shading. Blank inputs are intentional.
- MODEL WITHIN LIMITS is only a numerical screening result; it is not PASS or lot approval.
- Actual test results use PASS / FAIL / INCOMPLETE; dashboard requires a separate documented QA sign-off.

Before calculation

Confirm whether drawing tolerances apply before or after anodizing, which surfaces are coated or masked, and which inspection methods can reach the feature.

02 | Process Selection

Select Type II or Type III for function and contractual requirements, not only for expected appearance.

Decision	Conventional Type II	Hard Type III
Primary function	Common protective and decorative anodic finish	Hard anodic coating for wear-oriented applications
Specification references	MIL-PRF-8625F with Amendment 2; ISO 7599:2018 where contractually used	MIL-PRF-8625F with Amendment 2; ISO 10074:2021 where contractually used
Film thickness	Define the contractual minimum/maximum; do not infer a default from this guide	Specify exact project thickness; thick films increase dimensional risk
Color / seal	Document class, color and sealing as required by selected specification	Wear versus corrosion/sealing trade-off requires approval
Design action	List cosmetic and critical tolerance surfaces	Review bores, threads, thin edges, contact and fit zones

6061 condition must be traceable

Identify 6061 alloy, exact temper (for example T6, T651 or T6511), stock form, material specification, heat/lot and the machining and anodizing lots. Film behavior and visual appearance can depend on the substrate and preparatory operations.

Standard selection

Type, class, minimum coating thickness, optional testing, sealing, sampling and acceptance criteria shall follow the selected governing standard and purchase contract. This workbook does not prescribe universal Type II or Type III limits.

03 | What Grows, What Does Not

Total anodic film thickness is not the outward displacement of the finished surface.

Define the measurable stages

Symbol	Meaning	Measured from
t	Total anodic oxide thickness	Film thickness test, per project method
f	Outward growth fraction in a simplified estimate	Process-specific assumption, not universal
e	Additional preparatory substrate removal per surface	Pre-machining versus post-cleaning baseline; process evidence
g	Net change of the exposed outer surface	From a consistent reference condition; can be negative
Delta D	Resulting dimension change for two exposed opposed surfaces	Actual features and coating distribution

Screening model - all surface terms in um

Net surface change

Estimated g_min = t_min x f_min - e_max; estimated g_max = t_max x f_max - e_min. Inputs require evidence and physical consistency. This is a sensitivity model, not a guaranteed process capability.

The optional f = 0.5 example describes a common engineering allowance, not a blanket acceptance guarantee. MIL-PRF-8625F w/Amendment 2, section 6.10.1, provides design guidance on an increase near one-half film thickness per exposed surface; section 6.10.1.1 warns that film in small holes can range from none to normal thickness.

Measure what matters

- A film thickness gauge quantifies coating thickness, not finished-part growth directly.
- For process qualification, capture consistent before/after dimension data for each relevant feature family.
- Masked areas need explicit keep-out and post-process inspection. Masking does not prove zero change without checking.

04 | Dimensional Equations

Use a worst-case interval, not a single nominal correction, for dimensional acceptance planning.

Feature	Predicted minimum finished value	Predicted maximum finished value
External dia	Pre_min + 2 x g_min / 1000	Pre_max + 2 x g_max / 1000
Internal dia	Pre_min - 2 x g_max / 1000	Pre_max - 2 x g_min / 1000
External thickness (both sides)	Pre_min + 2 x g_min / 1000	Pre_max + 2 x g_max / 1000
Fully masked feature	Pre_min, subject to verification	Pre_max, subject to verification

Variables Pre_min/Pre_max are measured or specified pre-process dimension bounds in mm. g_min/g_max are surface net-change bounds in um. The factor 1000 converts um to mm. The formulas assume both opposed surfaces follow the same bounded change and no later changes occur.

Machining limits that protect the final drawing

Geometry	Allowable pre-process lower	Allowable pre-process upper
External	Final_LSL - 2 x g_min/1000	Final_USL - 2 x g_max/1000
Internal bore	Final_LSL + 2 x g_max/1000	Final_USL + 2 x g_min/1000

Infeasible process window

If the allowable pre-machining minimum exceeds its maximum, the surface-change range cannot be absorbed by the current final tolerance. Rework the finish, thickness, masking plan, geometry or acceptance strategy.

05 | Critical Fit Evaluation

Analyze both mating members at their extreme post-finish dimensions.

A dimensionally acceptable hole and shaft may still fail the intended clearance, insertion force, sealing or wear requirement. Capture the required final fit window independently from each component tolerance.

Worst-case diametral clearance

Fit calculation

C_min = hole_finished_min - shaft_finished_max.
C_max = hole_finished_max - shaft_finished_min. Positive clearance and negative interference are different functional conditions.

Required input	Why it matters
Hole feature ID / shaft feature ID	Links each mating feature to a traceable coating group and finished-dimension prediction.
Permitted C_min and C_max	Functional design acceptance window; cannot be taken from this resource as a default.
Finish state of both partners	Either or both mating surfaces may be coated, masked or finished by an alternate method.
Assembly test evidence	A tolerance screen cannot replace required practical assembly / contact validation.

The workbook rejects treating a special thread feature as a standard cylinder in the fit screen and flags incompatible or missing dimensional data for review.

Interference is not automatically defective

An intentional press-fit may require a negative clearance interval. Enter the actual functional requirement before interpreting results; brittle anodic coatings may make forced assembly unsuitable.

06 | Bores, Threads & Special Features

Small internal features require process confirmation rather than generic two-surface geometry.

Feature	Risk	Required engineering action
Small bore / blind bore	Coating accessibility and thickness may vary, including uncoated regions	Ask anodizer to establish feasibility; inspect actual functional diameter.
Tapped hole	Internal thread geometry and oxide buildup can affect gauge acceptance	Specify coated or masked state; check correct thread standard and actual calibrated gauges.
External thread	Crest/flank growth affects effective pitch diameter	Verify finished thread by specified gauge and fit checks.
Sharp edges	Electrical field and oxide formation vary locally	Review edge condition, edge break and coverage requirements.
Partial mask	Boundary and leakage are not captured in simple model	Agree marked surfaces, masking tolerance, and inspection coverage.

Why the workbook does not calculate thread pitch diameter

Anodic coatings on V-threads affect functional fit differently from growth on a smooth cylindrical diameter. MIL-PRF-8625F w/Amendment 2, section 6.10.2 addresses thread dimension effects. No thread-specific numerical allowance is entered without its geometry, tolerance class and applicable method.

Final thread acceptance

Record thread designation, internal/external state, process exposure, gauge identification, calibration, measured gauge result and evidence reference. A missing item produces INCOMPLETE, not PASS.

07 | Masking and Electrical Contact

The mask plan and racking scheme are controlled drawing requirements, not finishing afterthoughts.

Drawing callout	Reviewer checks
No-coat / masked surfaces	Which exact features must remain uncoated? Are boundaries dimensioned?
Thread plugging	Are the thread entry, counterbore and blind-hole constraints identified?
Electrical rack contact zones	Where are contact marks acceptable without interfering with fits or appearance?
Cosmetic classification	Which A/B/C surfaces have appearance expectations?
Exposed part handling	Can the supplier clean and inspect all critical surfaces after coating?
Special sealing / plugging	Are the selected process and sealing requirements mutually compatible?

Approval sequence

- Design defines coated, non-coated and critical functional zones on a revision-controlled drawing.
- Anodizer confirms achievable masking, contact locations, film specification and process capability.
- Machining and quality teams agree which features are cut to pre-size and which are checked after finishing.
- First article must check mask leakage, contact marks and final dimensions where applicable.

No assumption of perfect masking

The prediction engine only passes pre-process values through for a fully masked feature and always triggers engineering review. Dimensional and surface verification are still required.

08 | Drawing Notes and Supplier RFQ

Specify process and acceptance criteria in a format that can be bid and inspected.

Drawing / purchase order fields

Field	Minimum project decision
Applicable document	Exact standard identifier and revision or approved customer process specification.
Anodizing type and class	Required type; dyed/undyed class as applicable.
Thickness requirement	Numerical minimum/maximum; measurement zones and methods where necessary.
Color, sealing, appearance	Only where specified and technically appropriate to the selected type.
Masking, contact, holes	Drawing-defined zones and special features.
Dimensional acceptance	Finished drawing and tolerances; inspection stage; sampling and measurement method.
Release evidence	Lot traceability, test records, gauge records, first article and corrective action.

Copy-ready worksheet

Use sheet 08 DRAWING RFQ. Enter each controlled requirement first; the generated sentence deliberately remains INCOMPLETE when any mandatory field is missing. Always review the resulting text with the supplier before issue.

For MIL-PRF-8625F with Amendment 2, section 6.2 identifies procurement information including the specification/date, coating type/class, special requirements, color where applicable, thickness for Type III, sealing, contact marks and acceptance terms. Do not interpret an unmentioned option as silently approved.

09 | Coating Thickness & Measurement

Coating verification and dimensional inspection serve different purposes.

Check	Procedure selection	Evidence to retain
Anodic film thickness	Appropriate method and accessible, representative measurement zone	Numerical readings, location, lot, instrument/calibration, method.
Eddy-current thickness	ASTM B244-09(2021), within its applicability and measurement limitations	Instrument ID; calibration/zero reference; base material and geometry review.
Cross-section thickness	ASTM B487-24, where destructive sampling is approved	Preparation, location, micrograph, measurement record and traceability.
Appearance	Controlled reference / drawing-defined visual acceptance	Zone, lighting or viewing criteria if specified, defect observations.
Sealing quality	Test only if applicable to coating and governing requirement	Test method, acceptance limit, specimen, actual result.

Interpreting measurement results

- A thickness reading alone cannot establish the finished bore or shaft dimension.
- Specify which critical features require final dimensional inspection and their instruments.
- If access, curvature or surface roughness makes a method unsuitable, record the issue and approved alternate method.
- Do not apply ASTM B680-24 as a generic hardcoat seal test; applicability must be checked before selecting it.

No inferred performance

A measured coating thickness does not establish wear resistance, corrosion performance, adhesion, fatigue performance or seal quality without the separately applicable evidence and requirements.

10 | First Article & Acceptance

Record actual data and compare with explicit final drawing and contract limits.

Data field	Required content
Identity	Part number, drawing revision, sample / serial, material lot, anodize lot.
Feature definition	Feature ID, finish stage, specification and drawing limit.
Dimensional measurement	Actual result, units, instrument/calibration, method and inspector.
Coating verification	Actual film thickness, measurement site, method suitability, record reference.
Threads / masking	Applicable gauge result, masking condition, contact and cosmetic observations.
Disposition	PASS / FAIL / INCOMPLETE with record reference and reviewer.

Acceptance decision rules

- FAIL: measured value breaches a known specified upper or lower limit.
- INCOMPLETE: a required record, measurement, specification or evidence is missing.
- PASS: measurement is within both final limits and required traceability and verification fields are completed.
- REVIEW REQUIRED: model uncertainty, special geometry, unverified process or technical conflict remains unresolved.

The workbook FAI and coating-verification results are per recorded measurement row. Project release also requires lot-wide review of the approved sample plan, all critical surfaces and controlled exceptions.

Do not backfill evidence

Do not populate measurement cells with model predictions. Never convert a missing physical test into PASS or use a supplier claim without the required supporting document.

11 | Worked Example A - External Diameter

Illustrative arithmetic only. These are hypothetical inputs, NOT measured 6061 production values.

Illustrative inputs

Input	Assumed example value	Notes
Pre-anodize external diameter	20.000 to 20.010 mm	Hypothetical machining control interval
Net outward change per surface	+5 to +8 um	Hypothetical bounded process change
Final diameter specification	20.005 to 20.030 mm	Hypothetical drawing acceptance window

Worst-case results

Predicted minimum = 20.000 + 2 x 5 / 1000 = 20.010 mm.
Predicted maximum = 20.010 + 2 x 8 / 1000 = 20.026 mm.

Analytical interval [20.010, 20.026] lies inside the hypothetical finished limit [20.005, 20.030] mm. This is MODEL WITHIN LIMITS, not a pass of a physical anodized part.

Pre-process window to meet that final specification

Allowable pre-size lower = 20.005 - 0.010 = 19.995 mm.
Allowable pre-size upper = 20.030 - 0.016 = 20.014 mm.

Interpretation

The model has a feasible pre-size window, contingent on a validated surface-change range, correct two-sided exposure, representative geometry and final inspection.

12 | Worked Example B - Internal Bore

Illustrative arithmetic only; uniform internal-wall coating is assumed for this numerical example.

Input	Assumed example value
Pre-anodize bore	10.020 to 10.030 mm
Net inward change at each exposed wall	+4 to +7 um (magnitude of inward wall growth)
Final bore specification	10.000 to 10.025 mm

Calculated worst-case bore interval

Predicted bore minimum = 10.020 - 2 x 7 / 1000 = 10.006 mm.
Predicted bore maximum = 10.030 - 2 x 4 / 1000 = 10.022 mm.

Analytical interval [10.006, 10.022] lies within [10.000, 10.025] mm; therefore the hypothetical numerical test is within limits.

Permissible bore machining interval

Allowable lower = 10.000 + 2 x 7 / 1000 = 10.014 mm.
Allowable upper = 10.025 + 2 x 4 / 1000 = 10.033 mm.

Critical limitation

In real small bores, blind bores, threads and restricted access, local film deposition may differ strongly from an exposed flat surface. Qualify the actual feature or mask it; verify finished bore dimensions and fit.

13 | Worked Example C - Mating Clearance

Illustrative interval arithmetic; no real tolerance capability or product verification is claimed.

Characteristic	Hypothetical predicted final interval
Bore diameter	10.006 - 10.022 mm
Mating shaft diameter	9.995 - 10.005 mm
Permitted diametral clearance	0.000 - 0.030 mm

Worst-case clearance

Minimum clearance = 10.006 - 10.005 = 0.001 mm.
Maximum clearance = 10.022 - 9.995 = 0.027 mm.

The hypothetical analytical clearance range [0.001, 0.027] mm falls within the entered functional window. This is not a substitute for mating assembly, wear, leakage or force testing.

Fit review checklist

- Are both components finished and dimensioned in the same unit system?
- Are the coating groups and source change-ranges appropriate to their different geometries?
- Are internal and external features correctly paired with the right part and revision?
- Is functional verification specified where needed for the service condition?

If one member is masked

The model can copy its pre-size limits for screening, but masking requires evidence. If either feature is a thread, use actual thread gauging rather than generic diametral compensation.

14 | Supplier Workflow & Decision Gate

An engineering toolkit only helps when its assumptions and required verification reach the actual process owner.

Phase	Supplier / buyer action	Required record
RFQ	Confirm standard/edition, type/class, film limits, masking, rack zones, inspection criteria.	Reviewed quote and drawing clarification.
NPI review	Identify critical dimensions and model assumptions; qualify net change from actual features.	Dimensional sample plan and process qualification data.
Machining	Apply pre-process control dimensions only after approved model and drawings.	Pre-finish inspection where contractually required.
Anodizing	Operate according to approved controls; retain lot and test traceability.	Process/inspection records and supplier certificate.
First article	Measure finished key features, coating, thread, masking and cosmetic requirements.	Actual FAI and coating report with limits.
Disposition	Separate failed, incomplete and engineering-review cases; obtain QA authorization.	Signed approval and exceptions register.

Stop conditions

- No accepted supplier capability for the specified coating and dimensions.
- Predicted interval extends outside the final tolerance or machining window is infeasible.
- Measurement method or required inspection location is inaccessible or unqualified.
- Failed finished dimensions, coating thickness, thread gauges or other required verification.
- Lot, drawing revision, process source or approval evidence cannot be traced.

Release principle

Only authorized personnel may make the formal batch/product disposition under the applicable quality system and contract. The dashboard reports readiness, not certification.

15 | References & Scope of Use

Standard identifiers and high-level applicability verified against the respective issuing organizations as of 20 Nov 2026. No external links are embedded.

Standard / edition	Relevance / caution
MIL-PRF-8625F with Amendment 2 (23 Nov 2020)	Types/classes, coating tests, ordering information; sections 6.10.1-6.10.2 contain nonmandatory dimensional design guidance.
ISO 7599:2018	How to specify decorative and protective anodic oxidation coatings; excludes engineering hard anodizing covered by ISO 10074.
ISO 10074:2021	Requirements and test methods for hard anodic oxidation coatings on aluminum alloys.
ASTM B244-09(2021)	Eddy-current measurement of anodic coating thickness; geometry and calibration limits apply.
ASTM B487-24	Cross-sectional microscopic determination of oxide/coating thickness.
ASTM B680-24	Seal-quality acid-dissolution method; applicability depends on coating and sealing process.

Document boundaries

- Standards are normative only to the extent invoked by contract/drawing; the current authorized edition and full requirements control.
- No universal coating thickness, outgrowth ratio, etch loss, thread allowance, measurement uncertainty or acceptance criterion is supplied.
- Published vendor examples must not be substituted for process-specific capability evidence.
- Brittleness, local film variation, surface roughness, substrate and chemical pretreatment can alter functional results.

RFQ & engineering support

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