DFM | CNC MILLING | TURNING

ALUMINUM CNC MACHINING DESIGN GUIDE

Practical design-for-manufacturing guidance for machined parts

Prepared by BAOSONG

baosongprecision.com

Version 1.0 | September 2026 | Metric units

00 How to Use This Guide

For aluminum housings, brackets, fixtures, structural parts and precision components made by milling, turning or multi-axis machining.

CORE PRINCIPLE	Define function and datums first, then allocate tolerances. Confirm cutter access and workholding before refining cosmetic geometry. Every number labeled as a starting point must be checked against the actual part, machine, tool, quantity and supplier capability.

What this guide helps you do

- Select a practical alloy, temper and starting stock form.
- Set defensible starting points for walls, ribs, radii, pockets, holes, threads, tolerances and finishes.
- Prepare a complete RFQ package that supports useful DFM feedback and comparable quotations.

Contents

For application-specific support, visit BAOSONG Engineering Support or send a drawing for review.

01 Design Inputs and Process Route

Treat the part as a combination of functional, machinable and inspectable features.

1.1 Answer six questions first

- What loads, temperatures, corrosion, wear, conductivity or insulation conditions apply?
- Which fits, seals, locating features and cosmetic surfaces are function-critical?
- What are the prototype and production quantities, target cost and validation timing?
- Will stock be plate, bar, extrusion, forging or casting, and is its condition controlled?
- How many setups are acceptable, and are 4-axis, 5-axis or mill-turn routes available?
- How will the part be verified: hand gauges, air gauging, CMM, profilometry or a functional fixture?

1.2 Match geometry to process

PART FORM	LIKELY ROUTE	PRIMARY DESIGN CONCERNS
Shaft, sleeve, disk, revolved form	CNC turning	Functional axis, gripping length, slenderness and interrupted cuts
Housing, plate, bracket, open pocket	3-axis milling	Open directions, cutter access and second-operation datums
Multi-face hole patterns and side features	4-axis or 5-axis	Fewer setups, but rotary envelope and fixture access still matter
Very deep narrow slot or sharp internal corner	Redesign or special process	EDM and custom tooling are not default low-cost choices

ROUTE CHECK

If a feature requires a third or later reorientation, or only an extreme-reach cutter can access it, first consider changing the geometry, splitting the part or selecting a nearer-net stock form.

02 Alloy, Temper and Starting Stock

Do not select aluminum by strength alone. Availability, residual stress, finishing response and product form also drive risk.

ALLOY / TEMPER	RELATIVE CHARACTER	COMMON USE	DESIGN NOTE
6061-T6 / T651	Balanced strength, corrosion resistance, machining and anodizing	Housings, brackets, fixtures	Consider stress-relieved T651 plate for heavy pocketing
6082-T6	Common structural alloy in Europe and Asia	Loaded brackets and machine parts	Align the product standard and section with the supplier
7075-T6 / T651	High strength and good cutting behavior	Weight-sensitive loaded parts	Review corrosion, stress corrosion and anodized appearance
2024-T3 / T351	High strength and established fatigue applications	Aerospace-type structures	Copper content makes corrosion and anodizing more sensitive
5052-H32	Good corrosion resistance and formability	Formed sheet with local machining	Not a drop-in precision plate for stiff machined housings

2.1 Stock form matters

- For thick plate with extensive pocketing, discuss stress-relieved plate, balanced roughing and an intermediate stabilization step.
- Extrusion can reduce chip volume for repeated sections, but extrusion radii, wall variation, straightness and section availability must be accepted explicitly.
- State alloy, temper, product form and governing material specification on both the drawing and purchase order.

MATERIAL RELEASE	Lock the material certificate and substitution workflow for critical parts. Explore BAOSONG aluminum extrusion services when a repeated section could reduce billet removal.

03 Walls, Ribs and Section Transitions

Thin-wall risk is governed by height, span, support, cutter direction and stock-removal sequence - not thickness alone.

3.1 Early DFM starting points

FEATURE	ROBUST START	RISK RISES	DESIGN RESPONSE
General wall	1.5 mm or more	About 0.8-1.5 mm	Shorten the wall, add support, step down and leave finish stock
Short local wall	About 1.0 mm or more	Below about 0.8 mm	Use only with low height, good support and supplier review
Broad floor	2.0-3.0 mm or more	Thin with a large unsupported span	Add shallow ribs or curvature; avoid one-sided bulk removal
Tall rib	Width at least about one-third of height	Height-to-width above about 6	Reduce height, add root radius or change cutting direction

These ranges are review triggers, not capability guarantees. Geometry, tool access, stock condition, finish and batch repeatability can move the practical limit.

3.2 Stabilize the section

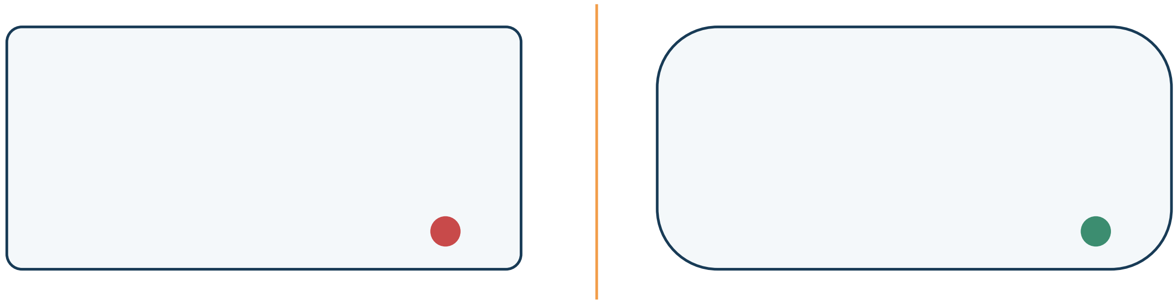
- Prefer uniform walls and blend abrupt stiffness changes with radii or gradual transitions.
- Use islands, ribs or cellular pockets when function allows; removing every gram can increase both cycle time and distortion.
- Add sacrificial tabs, rails or bridges for thin frames, then remove them in a controlled final operation.

BETTER QUESTION	Ask: What wall is repeatable at this height, span, workholding condition and cosmetic requirement? That is more useful than asking for a universal minimum thickness.

04 Internal Radii, Pockets and Cutter Access

Internal radius selects cutter diameter. Pocket depth selects tool reach and stiffness. Together they often dominate cycle time.

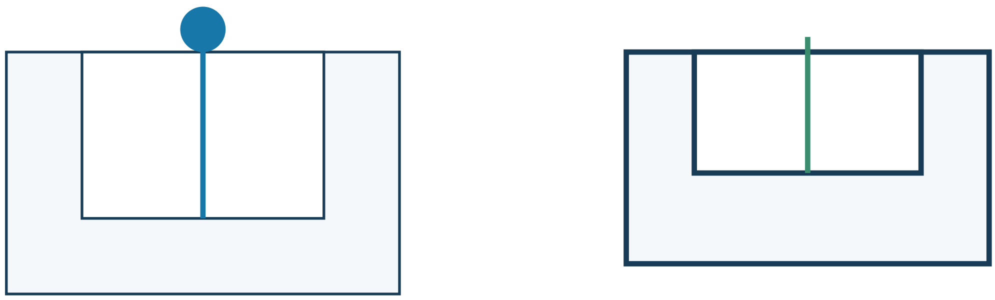
4.1 Internal corners



Small radius / high cutter engagement   Larger radius / smoother cutter load

- Every milled internal corner has a radius. Make the design radius larger than the cutter radius and leave roughly 0.2-0.5 mm, or the supplier's preferred margin, to avoid full engagement.
- Standardize radii within each depth zone to reduce tool changes. Deeper pockets deserve larger radii.
- If a mating part needs square relief, chamfer the mating part or use a dog-bone / T-bone relief instead of defaulting to EDM.

4.2 Pocket depth and narrow slots



Deep pocket: long reach, lower stiffness, harder chip evacuation   Shallower or split geometry: faster and more stable

DEPTH / TOOL DIA.	DFM ASSESSMENT	ACTION
Up to 3D	Usually robust	Prefer standard flute length and short reach
3D-5D	Watch reach and chip evacuation	Increase radius, reduce engagement, check holder clearance
5D-8D	Materially higher risk	Split the depth, widen the slot, machine from both sides or use special tooling
Above 8D	Special-process territory	Require drawing-specific supplier validation

05 Holes, Threads and Slots

Define diameter, depth, entrance, bottom condition, precision, finish and inspection - not just a hole symbol.

5.1 Hole design

ITEM	RECOMMENDED PRACTICE	COMMON FAILURE
Diameter	Prefer standard drill and reamer sizes	A nonstandard diameter forces interpolation, special tools or extra inspection
Blind bottom	Separate usable depth from total drilled depth	A CAD-flat bottom is mistaken for a normal drill point
Deep hole	Use 6D or less as an initial conventional-drilling discussion point	Chip packing, drift, inadequate coolant and drill breakage
Cross hole	Provide deburring access and define internal-burr acceptance	Hidden burrs remain in the flow path or assembly
Precision bore	Control size and position separately; consider reaming or boring	Size, position and finish are all over-tightened

5.2 Thread design

- Prefer standard metric coarse threads. Use fine pitch only when wall, adjustment or locking needs justify it.
- For aluminum internal threads, about 1.0-1.5 times nominal diameter is a reasonable engagement discussion range. Calculate high-load, fatigue or repeated-service joints and consider thread inserts.
- Add lead, tap chamfer, chip space and runout beyond the required full thread in a blind hole.
- Define masking, plugging, pre-compensation or post-finish chasing when anodizing affects the thread.

5.3 Slot and marking

Slot width sets tool diameter. Avoid deep closed narrow slots when an open, wider or two-sided feature works. For engraving, specify a single-line font, stroke width, depth and protected location.

HOLE TABLE	For a hole-dense part, issue a hole table with ID, specification, depth, quantity, position tolerance, finish condition and notes.

06 Tolerances, Datums and Surface Texture

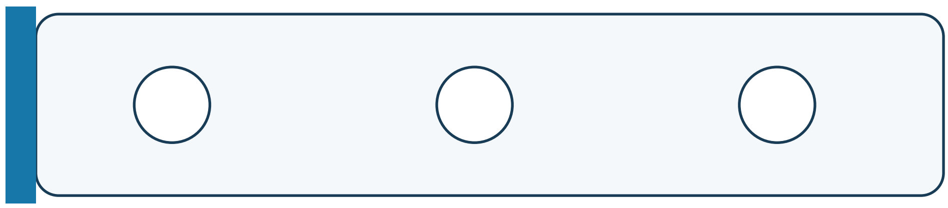
Tolerance should close a functional loop. Blanket precision increases machining, metrology and rejection cost.

6.1 Practical tolerance tiers

TIER	DISCUSSION START	TYPICAL FEATURES	PROCESS IMPLICATION
General	+/- 0.10 mm or supplier default	Clearance, nonmating outline, ordinary holes	Routine machining and general gauges
Controlled	+/- 0.05 mm	Locating steps and secondary fits	Stable workholding, finish pass and temperature awareness
Precision	+/- 0.02 mm	Critical fits, hole spacing, selected thin-wall features	Process capability, tool compensation and dedicated inspection
Special	+/- 0.01 mm or tighter	Very few function-critical characteristics	May require grinding, honing, controlled metrology and statistics

These are not universal shop defaults. Part size, geometry, finish, inspection temperature, quantity and supplier capability all matter.

6.2 Build a functional datum system



Datum A stabilizes the part; B and C orient it. Locate critical holes from one functional datum system.

- Choose a stable primary plane that is repeatable in assembly, machining and inspection.
- Reference critical hole patterns, locating steps and sealing faces from the same functional datum system where possible.
- Avoid using raw stock or flexible cosmetic walls as precision datums unless function truly requires it.

MORE DETAIL	See BAOSONG's aluminum CNC tolerance guide for feature-level tolerance planning and inspection questions.

06 Avoiding Redundant Controls

Size, geometric tolerance and surface texture control different aspects of the part. Combine them only when function requires it.

6.3 Select geometric controls by function

FUNCTION	COMMON CONTROL	DESIGN QUESTION
Stable mounting or sealing	Flatness	What region contacts, and is the part inspected free or restrained?
Locate a hole from datums	Position	What assembly clearance and material-boundary rule apply?
Relate cylindrical axes	Position or runout	What is the functional axis and how will it be established?
Orient two surfaces	Parallelism or perpendicularity	Is an angle dimension already creating a redundant control?
Fit a complex surface	Profile of a surface	What datums and inspection sampling support the functional envelope?

6.4 Surface roughness starting points

Ra	PROCESS LEVEL	COMMON APPLICATION	NOTE
3.2 um	Routine machined surface	General structure and nonsealing contact	Do not apply it indiscriminately to every surface
1.6 um	Controlled finish pass	Sliding, locating and many sealing interfaces	State lay direction only when it matters
0.8 um	Fine machining	Precision sliding or sealing	Tool path and inspection cost increase
0.4 um or finer	Special finishing	Demanding seals and friction pairs	Grinding, lapping or polishing may be required

6.5 Thermal and measurement effects

At tens of micrometers, aluminum temperature, gauge temperature, measurement force and datum cleanliness can become part of the result. Agree on measurement temperature, stabilization and restraint for critical characteristics.

COST CONTROL

Concentrate tight limits on a small CTQ set. Give each CTQ a datum, finished-state definition, inspection method and acceptance rule.

07 Workholding, Distortion and Residual Stress

The part must remain secure while clamped, recover predictably when released, and leave room for cutters and probes.

7.1 Design for gripping and location

- Provide parallel, sufficiently wide gripping regions that do not damage functional surfaces.
- Do not finish every outside surface in operation one and leave operation two without a repeatable datum.
- Remember that 5-axis machining still needs a base, vise, zero-point fixture or dedicated workholding interface.
- Route clamping force through stiff structure, not through a cantilever, seal lip or cosmetic wall.

7.2 Pair design and process controls

RISK SOURCE	DESIGN RESPONSE	PROCESS RESPONSE
One-sided bulk removal	Use balanced geometry or nearer-net stock	Rough both sides symmetrically and leave finish stock
Thin-wall force	Add ribs, shorten spans or add sacrificial bridges	Use staged cuts, small engagement and controlled clamping
Thermal accumulation	Avoid abrupt thick-to-thin transitions	Use effective coolant, distributed cutting and stabilized inspection
Stock residual stress	Specify an appropriate material condition	Separate rough and finish machining; re-establish datums

7.3 Burr and edge classification

Classify edges as functional sharp, safely broken or cosmetic touch edges. A generic 'deburr and break sharp edges' note is ambiguous. Give an allowable range on ordinary edges and identify seals, cutting edges or measurement datums that must not be rounded.

HIDDEN RISK	Cross holes, deep slots, internal flow paths and hand-contact edges require explicit deburring and inspection planning.

08 Finishing and Size Compensation

Finish requirements must close the loop across size, tolerance, masking, electrical contact, color and cosmetic inspection.

FINISH	PURPOSE	PRIMARY RISK	WHAT TO SPECIFY
Type II sulfuric anodize	Corrosion, appearance, insulation	Bores and fits change; alloy and lot influence color	Coating, color, sealing, masking and limit sample
Type III hardcoat	Wear and thicker oxide	Greater size change, edge burning and fatigue sensitivity	Thickness capability, protected bores and post-machining
Chemical conversion	Thin protection or conductive pretreatment	Limited wear; regulatory and system requirements	Governing standard, class and conductivity requirement
Blast / brush plus anodize	Controlled texture and appearance	Tool marks, edge condition and color variation become visible	Direction, texture, rack marks and visual sample
Paint or powder coat	Color, weathering and insulation	Thicker film closes holes and fits	Coating system, color, gloss and masking drawing

8.1 Anodizing size logic

The anodic layer consumes some substrate and grows partly outward. A commonly cited AAC rule of thumb is about two-thirds inward and one-third outward for conventional Type II, and about half inward and half outward for Type III. A bore changes on two sides, so use the finisher's actual process data rather than adding nominal single-side thickness blindly.

8.2 Cosmetic control

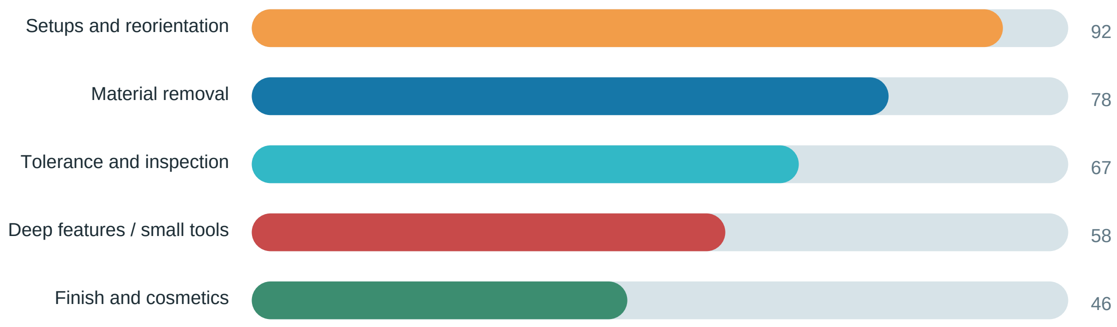
- Mark Class A, non-cosmetic and permitted rack-contact areas in the product definition.
- Agree on a physical limit sample and viewing conditions for color, gloss, texture, scratches and tool marks.
- Keep alloy, temper, pretreatment and finishing batch consistent for matched assemblies.

FINISH RESOURCES

Review BAOSONG surface finishing and anodizing for precision aluminum parts before releasing precision bores, threads, ground contacts, bond surfaces or Class A faces.

09 Cost and Production-Volume Strategy

Setup, inspection, scrap risk and supply uncertainty can outweigh pure cutting time.



Relative influence illustration only - not a quotation model.

9.1 Five high-leverage cost actions

- Reduce setups and reorientation by clustering features into accessible directions.
- Reduce chip volume with appropriate plate, bar, extrusion or other near-net stock.
- Increase internal radii, widen deep slots and reduce pocket depth to enable shorter, stiffer tools.
- Limit CTQs, fine texture and 100 percent inspection to features that protect function.
- Standardize holes, threads, counterbores, countersinks and radii around common tooling.

9.2 Design evolves with volume

STAGE	PRIMARY GOAL	PRACTICAL EMPHASIS
Prototype 1-10	Validate function quickly	Stock material, modular workholding and room for revision
Low volume 10-500	Stable cycle and repeatability	Dedicated soft jaws, process consolidation and first-article control
Production 500+	Capability and automation	Near-net stock, dedicated fixtures, probing, SPC and mistake-proofing

RELATED GUIDE

See Lower-Cost CNC Machined Aluminum Parts for drawing-level value engineering, then request a drawing-based review before changing a functional requirement.

10 Drawing and Inspection Handoff

A manufacturable design must also be purchasable, machinable, measurable and acceptably packaged without guesswork.

10.1 Minimum drawing information

- Part number, revision, units, projection, general tolerance and the authority of the 3D model versus 2D drawing.
- Alloy, temper, stock form, standard, certificate requirement and substitution workflow.
- Datum system, CTQs, geometric controls, roughness and inspection methods.
- Finish standard, thickness or class, color, sealing, masking, rack points and cosmetic zones.
- Burr, edge, cleanliness, marking, packaging, preservation and traceability requirements.

10.2 Inspection tiers

FEATURE CLASS	SUGGESTED CONTROL	RECORD
CTQ / safety critical	First article plus risk-based sampling or 100 percent	Measured value, equipment, temperature and traceability
Important fit	First article plus AQL or capability plan	Trend, offset history and nonconformance disposition
General dimension	First article confirmation plus sampling	Acceptance result or selected measured values
Finish / cosmetic	Limit sample plus specified lighting and distance	Batch, sample, coating thickness and defect record

10.3 Cutting data: method, not a universal answer

For milling, spindle speed n = Vc x 1000 / (pi x D), and table feed Vf = fz x Z x n. For drilling, Vf = fn x n. Use the cutting-tool supplier's starting data and correct for machine power, spindle limit, tool reach, coolant, alloy condition, radial engagement and axial depth.

RELEASE GATE

If a critical feature lacks an unambiguous datum, finished-state definition or executable inspection method, the drawing is not complete. BAOSONG's quality overview describes useful planning inputs.

11 DFM Example: From CAD-Complete to Production-Ready

A representative milled housing shows how small design changes reduce tool, fixture and inspection risk.

ORIGINAL DESIGN	MANUFACTURING CONSEQUENCE	IMPROVED DESIGN
R0.5 internal corners in a 35 mm pocket	Long-reach small tool and high corner engagement	Use R4 in the pocket; add local relief only where assembly needs it
1.0 mm floor across 120 mm	Clamping and free-state distortion	Use a 2.5 mm floor with shallow ribs and balanced stock removal
M3 full thread drawn to blind-hole bottom	No tap lead or chip space	Separate drilled depth and full-thread depth; add bottom allowance
Features on six faces with no gripping zone	Repeated setups and datum drift	Add a removable rail; reorient side holes or use a rotary route
Every dimension at +/- 0.02 mm	High CMM burden and unnecessary rejection risk	Keep only locating bores and the seal step as CTQs
Black anodize everywhere with no rack point	Unclear appearance and size acceptance	Define Class A faces, rack zone, coating, plugging and color sample

A more stable route

1 STOCK	2 ROUGH	3 STABILIZE	4 FINISH	5 TREAT / VERIFY
6061-T651 plate	Balanced two-side roughing	Release or re-establish datums	Complete CTQs from a common datum	Anodize compensation and CMM

FIRST-ARTICLE DATA

Record free-state flatness, clamped dimensions, pre- and post-finish bores, and cosmetic results. Use the evidence to set tool offsets, SPC and sampling as volume grows.

12 Release Checklist

Complete this with design, manufacturing, quality and finishing stakeholders.

MODULE	RELEASE CONDITION
Function	[ ] CTQs and safety-critical features identified [ ] Load, environment and life limits defined
Material	[ ] Alloy, temper, form and standard complete [ ] Certificate and substitution rules defined
Geometry	[ ] Walls and ribs stable [ ] Radii match tools [ ] Deep pockets and narrow slots reviewed
Holes	[ ] Usable and total depth separated [ ] Deep-hole evacuation reviewed [ ] Blind-thread runout added
Workholding	[ ] Every operation has a datum and grip zone [ ] Holder, fixture and probe access checked
Tolerance	[ ] Tight limits protect function [ ] Datum system complete [ ] No redundant controls
Texture	[ ] Specified only where useful [ ] Lay and seal needs defined [ ] Inspection is executable
Finish	[ ] Coating, color and seal defined [ ] Bores, threads, contacts and bonds masked or compensated
Cosmetic	[ ] Class A faces and rack points shown [ ] Scratch, color and texture sample agreed
Inspection	[ ] CTQ equipment and condition defined [ ] Sampling level matches risk
Handoff	[ ] 3D and 2D revisions match [ ] Packaging, marking and traceability are defined

FINAL QUESTION

Can a supplier quote, program, machine and inspect the part without guessing the design intent? If not, complete the product definition before release.

Fast red flags

Small corner radius plus deep pocket; large one-sided material removal; tall unsupported wall; blind thread to the bottom; blanket tight tolerances; anodizing without bore compensation; six-face features without a gripping zone; cosmetic surfaces without rack points; CTQs without inspection methods.

13 RFQ Package and Contact BAOSONG

Send a controlled drawing package so engineering review can focus on manufacturability, evidence and production risk.

13.1 Include these RFQ inputs

INPUT	WHAT TO PROVIDE
Product definition	Indexed 3D model and 2D drawing with the same revision
Material	Alloy, temper, stock form, material standard and approved substitutions
Demand	Prototype and production quantity breaks, target dates and expected annual volume
CTQs	Functional datums, fits, seals, load features and required inspection evidence
Finish	Process, standard, color, thickness or class, masking, rack zone and cosmetic sample
Quality and logistics	Certificates, FAI, CMM report, sampling, marking, packaging and delivery location

REQUEST A REVIEW

Use the BAOSONG contact and RFQ page to send drawings and production requirements. For process preparation, browse aluminum CNC machining services and engineering support.

13.2 Sales and project enquiries

CHANNEL	CLICK TO CONTACT
Website	baosongprecision.com
RFQ / contact	baosongprecision.com/contact-us/
Email	info@aagintr.com
Telephone	+86-757 8556 3891
Mobile	+86-133 2675 8535
WhatsApp	+86 189 3431 1334

Foshan office and supply-chain hub

Room 305, Floor 3, Building A, Fengdong Nanfang Commercial Center, Fengchi, Dali, Nanhai District, Foshan, Guangdong 528231, China.

Contact details and URLs verified against the BAOSONG website on 11 September 2026.

APPENDIX References

Use the current contract edition of every standard. Web content and standard status may change.

SOURCE	REFERENCE	LINK
ISO	ISO 2768 - general specification of linear and angular sizes	Open source
The Aluminum Association	Aluminum Standards & Data 2024	Open source
Aluminum Anodizers Council	Anodized Aluminum FAQ - dimensional change and masking	Open source
Aluminum Anodizers Council	Specifying Anodized Aluminum	Open source
Protolabs	CNC Milling Design Guidelines	Open source
Protolabs	Designing for Machinability	Open source
Haas Automation	Mill - Speeds and Feeds Formulas	Open source
Sandvik Coromant	CoroPlus ToolGuide - tool and cutting-data recommendations	Open source

Terms and limitations

D means nominal tool or hole diameter in context. CTQ means Critical to Quality. Ra is arithmetic average surface roughness. Numerical values in this guide are design-review starting points, not guarantees of any machine, supplier or production lot. Approved drawings, contracts, industry requirements and supplier process documents take precedence.

BAOSONG	For a drawing-specific manufacturability review, submit your RFQ and project requirements.