FREE ENGINEERING REFERENCE GUIDE · RAPID MACHINED INSERTS

THE STEEL GRADE SELECTION GUIDE

for Injection Mold Inserts

→ Grade-by-grade: P20 · H13 · 420SS · NAK80 · STAVAX · S7 · D2 · 718 · 1.2316

→ Insert type matrix — core inserts, sliders, heels, cavities, multi-cavity sets

→ Surface treatment reference: nitriding, PVD, DLC, hard chrome, TiCN

→ 9 common failure modes and the material decisions that prevent them

→ 18-point material selection checklist for every new tooling project

9	4	18+	18
Steel Grades Covered	Industry Sectors	Years Experience	Point Checklist

ABOUT THIS GUIDE

This guide distils 18+ years of hands-on experience producing precision mold inserts for automotive, medical, consumer electronics, and industrial programs. It covers every major steel grade used in core inserts, sliders, heels, lifters, and multi-cavity tools — with grade-specific property ratings, application matrices, surface treatment guidance, failure mode analysis, and a printable 18-point material selection checklist.

RAPID MACHINED INSERTS

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Introduction

Why Steel Grade Selection Determines Program Outcome

Every injection mold insert failure — premature wear, dimensional drift, surface degradation, cracking under thermal cycling — traces back to one of two root causes: **an inadequate steel grade for the application**, or **inadequate heat treatment for the grade specified**. Material selection is not a secondary consideration. It is the first engineering decision on every tooling project, and it determines everything downstream: machining cost, tool life, surface finish, FAI outcomes, and long-run production yield.

The consequences of wrong grade selection compound through the program. A P20 core insert in a glass-filled PA66 application will show measurable wear within 50,000 cycles — causing dimensional nonconformance that forces rework or replacement. A STAVAX cavity specified for an industrial structural part that never required corrosion resistance costs 40–60% more than H13 with no performance benefit.

THE FOUR CONSEQUENCES OF WRONG GRADE SPECIFICATION

Premature wear failure	Soft grades in abrasive resin applications — inserts wear out of tolerance within tens of thousands of cycles instead of millions.
Thermal cracking	Grades without thermal fatigue resistance at hot-runner gates develop heat-check cracking that propagates through the insert.
Corrosion degradation	Standard tool steels (P20, H13) in PVC, fluoropolymer, or humid environments corrode over months — cavity surface roughens, producing defective parts.
Over-specification cost	Using STAVAX or H13 where P20 suffices adds 30–80% material cost with no production benefit.

THE CORE TRADEOFFS

Hardness vs. Toughness	**Polishability vs. Wear Resistance**
Higher hardness improves wear resistance but reduces impact toughness. A slider needs toughness to survive cyclic lateral loading — D2 at 60 HRC in a slider application will result in chipping or brittle fracture.	The steels that achieve the finest mirror finishes (NAK80, STAVAX) are not the hardest grades. Optical cavities require grain uniformity and ESR cleanliness over raw hardness.
Corrosion Resistance vs. Machinability	**Pre-hardened vs. Heat-treated**
Stainless grades (420SS, STAVAX, 1.2316) resist aggressive resins but are harder to machine and more expensive. Standard grades oxidise faster in the wrong application.	Pre-hardened grades (P20, 718, NAK80) avoid heat treatment distortion. Heat-treated grades require rough machining, heat treatment, and finish machining — adding lead time that must be scheduled.

HOW TO USE THIS GUIDE

Each grade section includes properties at a glance, application guidance, and specific use / avoid callouts. The application matrix (Ch. 2) is the one-page quick reference. Use the 18-point checklist at the end to validate every new tooling project before steel is ordered.

Chapter 1

Grade-by-Grade Reference

The nine grades below account for more than 95% of insert steel specifications seen across automotive, medical, consumer electronics, and industrial programs. Property bars show a 0–100 index relative to each property. Grades are ordered from most commonly specified to most specialised.

P20 / 1.2311

Pre-Hardened Tool Steel

AISI P20 · DIN 1.2311 · Also: 1.2738

P20 is the most widely used mold steel in the world. Supplied pre-hardened to 28–34 HRC, eliminating post-machining heat treatment. Default choice for large cavity blocks, core inserts, and structural components in medium-volume programs. Excellent machinability means lower cost and faster lead times.

HARDNESS (SUPPLIED)	28–34 HRC
MACHINABILITY	Excellent
POLISHABILITY	Good / A-series
WELDABILITY	Good
WEAR RESISTANCE	Moderate
TOUGHNESS	Good

Composition	0.35% C, 1.9% Cr, 0.2% Mo. 1.2738 adds ~1% Ni for improved through-hardening in thick sections.
Best for	Medium-volume (<500k shots), non-abrasive resins (PP, ABS, PC, HDPE), cavity blocks, core inserts, stripper plates, runner systems, support pillars.
Avoid for	Glass-filled or mineral-filled resins. High-volume >1M shots. Mirror finish requirements. PVC, fluoropolymers.
Heat treat	Pre-hardened — no post-machining heat treatment. Can be nitrided for surface wear resistance without distortion.
Applications	Core inserts (general), cavity blocks, stripper rings/plates, runner inserts, bolster plates, heel blocks (lower duty).

RMI SOURCING NOTE

P20/1.2311 sourced from Finkl Steel (USA) or Böhler (EU). Mill certificate with heat number supplied as standard. Available in standard stock; delivery to machining 2–3 days.

H13 / 1.2344

Hot Work Tool Steel

AISI H13 · DIN 1.2344 · Trade: Assab 8407, Orvar Supreme

H13 is the premier high-performance insert grade. Its Cr-Mo-V composition delivers outstanding toughness and thermal fatigue resistance — the cyclic stress from injection-cooling that cracks lower-grade steels. Standard specification for automotive Tier 1 programs. ESR variants (Assab 8407, Orvar Supreme) deliver 20–40% longer life than standard H13 in high-cycle applications due to finer, more uniform microstructure.

HARDNESS (HT)	44–52 HRC
TOUGHNESS	Excellent
THERMAL FATIGUE RESIST.	Outstanding
WEAR RESISTANCE	Very Good
POLISHABILITY	Good / B-grade
MACHINABILITY (PRE-HT)	Moderate

Composition	0.38% C, 5.2% Cr, 1.3% Mo, 1.0% V. ESR variants (Assab 8407, Orvar Supreme) have higher purity.
Best for	Sliders, lifters, side-actions, hot-runner gates; core inserts for glass/mineral-filled resins; automotive structural parts; high-cycle industrial programs.
Avoid for	Optical/mirror surface requirements (use NAK80 or STAVAX). Corrosion-critical environments (use 420SS/STAVAX). Very large sections where through-hardening uniformity is difficult.
Heat treat	Rough machine → stress relieve → harden 1020–1050°C (air/N_2 quench) → double temper to target HRC. Finish machine after HT. Allow 0.05–0.15% dimensional growth.
Applications	Sliders and side-actions; lifters; core inserts (abrasive resins); hot-runner gate inserts; cam drivers; automotive cavity inserts.

ESR vs. Standard H13: For automotive and medical programs, always specify ESR H13 — Assab 8407 Supreme or Uddeholm Orvar Supreme. ESR processing removes non-metallic inclusions and produces a finer, more uniform microstructure, typically achieving 20–40% longer service life in high-cycle applications.

RMI SOURCING NOTE

H13 sourced from Assab (8407) or Uddeholm (Orvar Supreme) for automotive programs requiring named mill certificates. Assab certificate with heat number, composition, and hardness confirmation supplied as standard. HT at Assab-accredited facility.

420 SS / 1.2083

Martensitic Stainless Steel

AISI 420 · DIN 1.2083

420SS is the standard corrosion-resistant tool steel for medical, food-contact, and PVC/fluoropolymer applications. Its 12–14% Cr provides genuine stainless corrosion resistance — unlike H13, which oxidises in humid environments or under PVC acid off-gassing. Achieves 48–54 HRC after heat treatment, with good polishability.

HARDNESS (HT)	48–54 HRC
CORROSION RESISTANCE	Excellent
POLISHABILITY	Very Good / A2
WEAR RESISTANCE	Good
MACHINABILITY	Moderate
TOUGHNESS	Moderate

Composition	0.35% C, 13% Cr, 0.3% Mo. Higher-C variant (1.2083) optimised for tool steel hardness vs. standard 420 bar.
Best for	Medical device components; food-contact parts; PVC, fluoropolymer, FR resin tooling; core inserts where corrosion in transit/storage is a concern; heel blocks in humid environments.
Avoid for	High-impact loading (lower toughness than H13). Mirror-finish on textured parts (use STAVAX). Programs where cost is primary and corrosion resistance is not required.
Heat treat	Harden 1020–1050°C, oil or forced-air quench, double temper. More prone to retained austenite than H13 if not properly processed — use an accredited stainless tool steel heat treater.
Applications	Medical device inserts; PVC/fluoropolymer tooling; food-contact components; heel blocks (high-humidity); glass-filled corrosive resin core inserts.

NAK80

Pre-Hardened Mirror Steel

JIS NAK80 · Daido Steel · HRC: 37–43

NAK80 is a Japanese precipitation-hardened tool steel specifically designed for high-polish and optical surface applications. Its unique Ni-Al-Cu metallurgy produces a fine, uniform grain structure with outstanding polishability. No post-machining heat treatment required — the grade of choice when lead time is a priority and heat treatment distortion cannot be tolerated. Excellent weldability allows repair without full re-heat treatment.

HARDNESS (PRE-HARDENED)	37–43 HRC
POLISHABILITY	Outstanding / A1
WELDABILITY	Excellent
MACHINABILITY	Very Good
WEAR RESISTANCE	Moderate
CORROSION RESISTANCE	Limited

Composition	0.15% C, 3.0% Ni, 1.5% Cu, 1.0% Al, 0.3% Mo. Precipitation hardened — properties develop during aging, not quench-hardening.
Best for	High-gloss and optical cavity inserts; display bezels; lens housings; transparent covers; Class A automotive interior trim; short to medium volume (<500k shots).
Avoid for	Abrasive resins (glass/mineral-filled). High-cycle wear applications. Corrosive resin environments. Applications requiring >44 HRC.
Heat treat	No post-machining heat treatment required — supplied and used in the pre-hardened condition. Polishing to A1 mirror (VDI 0–2) available as a value-added service.
Applications	Optical lens cavities; high-gloss display bezel inserts; transparent cover cavities; consumer electronics cosmetic components; Class A automotive interior surfaces.

STAVAX ESR

Premium Stainless Tool Steel

Uddeholm STAVAX ESR · DIN 1.2083 ESR · HRC: 50–54

STAVAX ESR is the premium stainless tool steel for the most demanding optical and medical applications. Electroslag remelting produces a uniformity and cleanliness that enables true mirror-grade polishing (VDI 0, Ra <0.01 µm) while providing outstanding corrosion resistance. Commands a significant price premium over 420SS — justified wherever optical clarity, regulatory compliance, or long-term corrosion resistance are non-negotiable.

HARDNESS (HT)	50–54 HRC
CORROSION RESISTANCE	Outstanding
MIRROR POLISHABILITY	Outstanding / VDI 0
WEAR RESISTANCE	Very Good
TOUGHNESS	Moderate
MACHINABILITY	Moderate

Composition	0.38% C, 13.6% Cr, 0.3% Mo, 0.2% V. ESR process produces exceptional microstructural uniformity.
Best for	Transparent optical parts (lenses, light guides); medical-grade implantable and sterile-contact components; humid/chemical environments; FDA/ISO 13485 regulated products.
Avoid for	High-impact or shock-loading applications (use H13 or S7). Standard industrial parts where corrosion resistance is not needed — cost premium not justified.
Heat treat	Harden 1020–1060°C, forced air or vacuum quench, double temper at 200–250°C for HRC 50–54. Vacuum heat treatment strongly recommended to preserve surface quality.
Applications	Optical lens and light guide inserts; medical device cavity inserts; transparent cover inserts; dental tool components; Class A optical automotive components.

RMI SOURCING NOTE

STAVAX ESR sourced from Uddeholm exclusively. Named Uddeholm mill certificate supplied as standard. Lead time 5–7 days for standard sizes. Vacuum HT at Uddeholm-accredited facility.

S7

Shock-Resistant Tool Steel

AISI S7 · Air/Oil Hardening · HRC: 54–58

S7 is the shock-resistant grade for applications involving impact, cyclic loading, or unsupported thin sections. High hardness (54–58 HRC) with exceptional impact toughness — surpassing H13 in shock scenarios. The right choice when slender core pins or side-actions experience significant side-loading and chipping/cracking of harder steels has been a problem. Air-hardening provides excellent dimensional stability during HT.

HARDNESS (HT)	54–58 HRC
IMPACT TOUGHNESS	Outstanding
DIMENSIONAL STABILITY (HT)	Very Good
WEAR RESISTANCE	Very Good
POLISHABILITY	Good
MACHINABILITY (PRE-HT)	Moderate

Composition	0.50% C, 3.25% Cr, 1.40% Mo. Air or oil quench; excellent dimensional stability during heat treatment.
Best for	Thin-wall and unsupported core inserts; side-actions with high side-load; high-cycle medical tooling (20M+ cycles); electronics connector inserts; applications where H13 has shown chipping.
Avoid for	Large sections >150mm (through-hardening issues). Mirror finish requirements. Highly corrosive resin environments.
Heat treat	Air harden from 927–1010°C; temper to target hardness. Air-quench produces minimal distortion — ideal for complex geometry or close-tolerance inserts.
Applications	Thin-wall core inserts; side-actions (heavy side-load); core pins (high L/D ratio); stripper bolts and knockout pins; high-cycle medical tooling.

D2 / 1.2379

High-Chrome Cold Work Steel

AISI D2 · DIN 1.2379 · HRC: 58–62

D2 is the extreme wear-resistance grade — right when abrasion by highly filled resins is the primary failure mode. Its dense carbide network provides wear resistance far beyond H13 or P20. The tradeoff is brittleness: D2 will crack under impact loading or significant side-load. **Specify D2 when wear is killing your tools, not as a default upgrade.**

HARDNESS (HT)	58–62 HRC
ABRASION RESISTANCE	Outstanding
WEAR RESISTANCE	Outstanding
TOUGHNESS	Low — brittle
POLISHABILITY	Limited
MACHINABILITY	Difficult

Composition	1.55% C, 11.5% Cr, 0.8% Mo, 0.9% V. High carbide volume — primary source of wear resistance. Despite high Cr, corrosion resistance is limited as Cr is locked in carbides.
Best for	Core inserts for 50%+ glass-filled resins; runner and gate components under severe abrasive wear; wear plates and guide components under abrasive sliding contact.
Avoid for	ANY application with side-loading, impact, or cyclic lateral forces. Thin sections or unsupported inserts. Where polishability is required. Corrosive environments.
Heat treat	Oil quench or air cool from 1010–1040°C. Multiple tempers required. Sub-zero treatment (−80°C) after quench strongly recommended for dimensional stability.
Applications	Core inserts for heavily filled abrasive resins; runner and gate inserts (wear-critical); wear plates; stripping edges; abrasive compound tooling.

718 / 718HH

Pre-Hardened Nickel-Bearing Steel

DIN 1.2738 · Also: P20+Ni · HRC: 33–40 (HH: 38–42)

718 (1.2738) is the nickel-bearing variant of P20, designed for more consistent through-hardening in thick cross-sections. The ~1% Ni addition extends hardenability significantly — making it the preferred pre-hardened grade for multi-cavity tools where uniform hardness across all inserts is critical. 718HH (Higher Hardness) at 38–42 HRC eliminates heat treatment variability as a risk factor entirely.

HARDNESS (PRE-HARDENED)	33–40 HRC (718HH: 38–42)
THROUGH-HARDENABILITY	Excellent in thick sections
MACHINABILITY	Very Good
POLISHABILITY	Good / A-series
WELDABILITY	Good
WEAR RESISTANCE	Moderate

Composition	0.38% C, 2.0% Cr, 0.2% Mo, 1.0% Ni. Ni addition extends hardenability to 400mm+ cross-sections consistently.
Best for	Multi-cavity insert sets requiring uniform hardness (8, 16, 32+ cavity); large cross-section blocks >80mm; high-volume programs where P20 hardness variation has caused cavity-to-cavity inconsistency.
Avoid for	Applications requiring >45 HRC. Corrosive resin environments. Optical surface requirements.
Heat treat	Supplied pre-hardened — no post-machining HT required. Can be nitrided for surface hardening without distortion. 718HH achieves 38–42 HRC from the mill.
Applications	Multi-cavity insert sets (8+ cavity, uniformity-critical); large cavity blocks; automotive interior trim; high-volume consumer goods tooling.

RMI SOURCING NOTE

718/1.2738 available in standard block and round stock. Hardness certification per piece supplied on multi-cavity orders. ±1 HRC banding across the set available on request.

1.2316

Stainless Hot Work Tool Steel

DIN 1.2316 · Similar: AISI 422 · HRC: 46–52

1.2316 is the corrosion-resistant alternative to H13 — combining the thermal fatigue resistance of H13 with the corrosion resistance of 420SS. Correct specification for molds processing PVC, fluoropolymers, halogenated flame retardants, and hygroscopic resins in humid climates. Often more cost-effective than STAVAX where both wear resistance and corrosion resistance are required but mirror finish is not.

HARDNESS (HT)	46–52 HRC
CORROSION RESISTANCE	Excellent
WEAR RESISTANCE	Good
THERMAL FATIGUE RESIST.	Good
POLISHABILITY	Good / B-series
MACHINABILITY	Moderate

Composition	0.36% C, 16.0% Cr, 1.1% Mo, 0.5% Mn. Higher Cr than H13 for genuine corrosion resistance at tool steel hardness.
Best for	PVC tooling; fluoropolymer programs; halogenated FR resin tooling; humid operating environments; medical components requiring both hardness and corrosion resistance without STAVAX cost.
Avoid for	Mirror-grade optical applications (STAVAX is superior). Applications where highest impact toughness is needed (H13 or S7 preferred).
Heat treat	Vacuum harden at 1020–1070°C, gas quench, double temper at 200°C. Vacuum or controlled atmosphere mandatory to prevent surface oxidation.
Applications	PVC and fluoropolymer tooling; halogenated FR resin tooling; medical components requiring corrosion + hardness; humid environment molds; chemical-resistant core and cavity inserts.

RMI SOURCING NOTE

1.2316 sourced from Böhler or Uddeholm equivalent. Allow 5–7 days material procurement. Vacuum heat treatment mandatory; accredited facility arranged as standard.

Chapter 2

Application & Insert Type Matrix

Quick reference for matching insert type and application to primary and alternative steel grades. Primary grade is the best-practice first choice. Alternative is a cost or availability option with trade-offs. Always verify with the grade section before substituting.

Insert / Component	Primary Grade	Alternative	Key Requirement	Volume
Core inserts — general purpose	**P20**	718	Machinability; moderate hardness; no post-HT	<500k shots
Core inserts — high volume	**718HH**	H13	Uniform through-hardness in thick sections	500k–2M shots
Core inserts — abrasive resins (GF, MF, CF)	**H13**	D2 (extreme)	Wear and abrasion resistance; maintains dimensions	Any volume
Cavity inserts — standard	**P20 / 718**	H13	Polishability, machinability, cost	<500k shots
Cavity inserts — Automotive Tier 1	**H13 Assab 8407**	—	Named mill cert, FAI package, thermal fatigue resistance	High volume
Optical / mirror cavities	**STAVAX ESR**	NAK80	Mirror polish VDI 0–2; ESR cleanliness; corrosion resistance	Any volume
High-gloss cosmetic cavities	**NAK80**	STAVAX	Mirror polish; no post-HT; excellent weld repair	<500k shots
Sliders and side-actions	**H13**	S7	Fatigue resistance; toughness under cyclic lateral loading	Any volume
Lifters	**H13**	P20	Wear resistance; toughness; dimensional stability	Any volume
Heels and heel blocks	**420SS**	P20	Sliding contact resistance; corrosion in humidity	Any volume
Core pins — standard	**H13**	S7	Hardness; wear resistance; deflection resistance	Any volume
Core pins — fragile / high L/D	**S7**	H13	Impact toughness; dimensional stability; no chipping	High cycle
Medical device inserts	**STAVAX ESR**	420SS / 1.2316	Corrosion resistance; regulatory compliance; polish	Any volume
PVC / fluoropolymer tooling	**1.2316**	420SS	Corrosion resistance to halogen/acid off-gassing	Any volume
Multi-cavity insert sets	**718HH**	H13	Batch-consistent hardness ±1 HRC across all cavities	High volume
Gate inserts — abrasive resins	**D2**	H13	Extreme wear resistance at gate contact points	High volume
Stripper plates and rings	**P20**	718	Toughness; machinability; no heat treat distortion	Any volume

Volume Guide reflects economic and performance optima, not hard limits. High-volume programs always justify H13 or 718HH in wear-critical positions regardless of absolute shot count.

Chapter 3

Surface Treatment & Coating Reference

Surface treatments extend insert life, improve release characteristics, and protect against corrosion and wear. The right treatment amplifies the properties of the base steel; the wrong treatment wastes cost. Each treatment has substrate requirements — not every treatment suits every grade.

Gas / Plasma Nitriding

Purpose	Case hardening to 70+ HRC surface layer (compound layer 5–20 µm). Excellent wear and corrosion resistance with negligible dimensional change (<0.01 mm). Most cost-effective treatment for extending insert life in abrasive applications.
Surface hardness	900–1,200 HV (~70 HRC equivalent). Case depth controlled by process duration.
Process	Ammonia atmosphere (gas) or nitrogen plasma at 480–530°C, 4–72 hours depending on case depth required. No quench — slow cool in atmosphere.
Best substrate grades	H13, P20, 718, S7, 1.2316
Avoid with	420SS and STAVAX — stainless passivation layer inhibits nitrogen diffusion without special pre-treatment (salt bath activation possible).
Applications	Sliders, core inserts, side-actions, runner components subject to abrasion. Most commonly applied treatment on H13 slider sets.
Note	Can be applied to finish-machined inserts without distortion risk. Brittle compound layer on surface can be removed by polishing if needed for cosmetic applications.

PVD Coating — TiN / TiAlN / CrN

Purpose	Physical vapour deposition produces extreme surface hardness (2,000–3,300 HV) with very low friction (0.2–0.4). TiAlN provides enhanced hot hardness for elevated-temperature gate applications.
Surface hardness	TiN: 2,000 HV · TiAlN: 3,000 HV · CrN: 1,800 HV. Coating thickness 2–5 µm.
Process	Vacuum chamber deposition at 150–500°C substrate temperature. Applied to finish-hardened inserts. Substrate must be polished to Ra <0.2 µm before deposition.
Best substrate grades	H13, 420SS, STAVAX, D2
Avoid with	Soft pre-hardened grades (P20, 718 standard) — coating only effective on hard substrate >44 HRC.
Applications	Core inserts and sliders for abrasive resins; gate and runner inserts; high-cycle tooling where surface degradation is the limiting factor.
Note	Colour guide: TiN = gold, TiAlN = purple-grey, CrN = silver. Coating adhesion critically depends on substrate surface preparation — fully clean and deoxidise before deposition.

DLC — Diamond-Like Carbon

Purpose	Highest available hardness coating (4,000–8,000 HV), ultra-low friction (0.05–0.15), excellent chemical resistance, near-zero reactivity with most resins. Preferred for optical inserts where resin adhesion ("sticking") causes surface damage.
Surface hardness	4,000–8,000 HV depending on DLC type. Friction coefficient 0.05–0.15 (dry). Thickness 0.5–3 µm.
Process	PECVD or PVD at low temperature (<200°C). Can be applied to pre-hardened grades due to low deposition temperature.
Best substrate grades	NAK80, STAVAX, H13 (polished substrate)
Avoid with	Rough or EDM-finish surfaces — DLC spalls on rough substrates. Not suitable for textured surfaces.
Applications	Optical cavity inserts (prevent resin adhesion on mirror surfaces); medical components requiring chemical inertness; high-cycle cosmetic components.
Note	Significant cost increase — justify with demonstrated resin adhesion problem. Substrate finish must be maintained to near-final quality before coating.

Hard Chrome Plating

Purpose	Electrolytic chrome deposition: excellent corrosion and wear resistance, improved release properties, and dimensional build-up capability for worn inserts. Lower cost than PVD but lower hardness and less uniform.
Surface hardness	800–1,000 HV. Thickness variable 5–250 µm (repair use). Low substrate temperature (<70°C) — no softening risk.
Process	Electrolytic process in chrome bath. Check regulatory status of hexavalent chrome in your jurisdiction before specifying.
Best substrate grades	P20, 718, 420SS, H13
Avoid with	Optical surfaces — chrome introduces micro-roughness unless re-polished post-plating.
Applications	Core inserts requiring corrosion protection in storage/transit; worn insert dimensional repair; sliding components requiring improved release.

TiCN — Titanium Carbonitride

Purpose	Intermediate between TiN and DLC. Higher hardness than TiN (3,000 HV), lower friction, rose-gold appearance. A practical upgrade from TiN for abrasive resin programs.
Surface hardness	3,000 HV. Friction coefficient 0.2–0.3. Thickness 2–4 µm. PVD process at 180–500°C.
Process	PVD at 180–500°C, applied post-hardening and finish machining.
Best substrate grades	H13, 420SS, D2
Avoid with	Soft substrates; textured surfaces.
Applications	Core inserts for 30–50% glass-filled resins; wear-critical gate components; multi-cavity inserts in high-cycle industrial programs.

Chapter 4

Multi-Cavity Tooling: Steel Selection Principles

Multi-cavity tooling introduces material selection requirements that do not apply to single-cavity tools. Every insert in the set must perform identically — dimensional consistency, surface finish, wear rate, and thermal response must all match across cavities. A single insert that wears faster or holds differently to temperature will produce out-of-spec parts from that cavity while all others remain acceptable.

01 Batch Matching Is Non-Negotiable

All inserts in a multi-cavity set must come from the same steel batch (same mill heat number) and be processed through the same heat treatment cycle, in the same furnace load. Even two pieces of nominally identical H13 from different batches can show 2–3 HRC hardness variation after identical heat treatment due to minor compositional differences within the grade specification.

In a 16-cavity tool, 3 HRC variation across cavities means differential wear of approximately 15–20% per million cycles — a cavity imbalance problem that manifests as dimensional drift and weight variation in the finished part. Purchase all blanks in one order, from one batch, before machining commences. Batch documentation (heat number per insert) is standard on every RMI multi-cavity order.

02 Specify a Hardness Band, Not Just a Grade

A steel grade specification (e.g., "H13, 48–52 HRC") allows 4 HRC variation. For multi-cavity tooling, specify a tighter band: "H13, 50 ±1 HRC across the set" — all inserts must land within a 2 HRC window. This requires the heat treater to process all inserts simultaneously and verify each one individually. Achievable and not significantly more expensive.

718HH (pre-hardened, 38–42 HRC) is often preferred over heat-treated H13 for high-volume multi-cavity tools precisely because pre-hardened stock from a single batch can be certified to ±1 HRC at the mill — eliminating heat treatment variability as a risk factor entirely.

03 Never Mix Steel Grades in the Same Cavity Set

Do not mix P20 and H13 in the same multi-cavity insert set, even if the drawings permit either. These grades have different thermal expansion coefficients (H13: ~11.9 μm/m·°C; P20: ~12.2 μm/m·°C). In a tool cycling from 30°C to 80°C, a 100mm insert shows approximately 0.03mm differential expansion — enough to cause flash in precision applications or shorts in thin-wall parts.

Exception: Wear-resistant inserts in different functional roles (e.g., D2 gate inserts in an otherwise H13 cavity set) are acceptable — a D2 gate insert does not form part of the matched cavity geometry.

04 Machine the Spares at the Same Time

Record the heat number and batch certificate for every insert set. When spares are needed — and they will be needed — matching the batch is only possible if the documentation was kept. Machine spare inserts from the same batch at the initial production run.

Storage requirement: dry controlled environment, light corrosion inhibitor, individually labelled with heat number, hardness reading, and the mold/cavity reference. Cost of spares at initial machining is a fraction of re-tooling cost.

05 Verify Cavity-to-Cavity Consistency Before Release

Before releasing a multi-cavity set to the mold builder, verify cavity-to-cavity dimensional consistency with a CMM measurement across the complete set — not a sample check. A ±0.01mm tolerance on a cavity feature means the full set can have 0.02mm spread, which is significant in precision optical or medical tooling.

A matched cavity record documenting the dimensional comparison is the only way to confirm the set is consistent before it enters the mold. This flags problems before tool assembly — not after first shots.

Chapter 5

Common Failure Modes & Prevention

The following failure modes are drawn from observed insert failures across automotive, medical, and industrial programs. Each entry cross-references the steel grade and treatment decisions that prevent the failure.

Failure Mode	Symptoms	Root Cause	Prevention — Steel & Treatment
Abrasive Wear	Dimensional growth at cavity walls; increasing flash; weight gain on parts. Accelerates above 50–100k cycles with wrong grade.	Steel too soft for resin abrasivity. P20 or 718 in glass-filled or mineral-filled applications.	Upgrade to H13 (44+ HRC). Add PVD (TiAlN) or nitriding for extreme fill percentages. D2 for 50%+ GF resins at gate.
Thermal Cracking (Heat Checking)	Fine crack network at gate and runner areas. Visible after 200–500k cycles. Cracks propagate and chips release into cavity.	Inadequate thermal fatigue resistance. P20 or 718 at high injection temperatures.	H13 ESR grade mandatory. Ensure hardness ≥46 HRC — lower HRC accelerates heat checking. Vacuum nitriding can extend gate life.
Chipping / Brittle Fracture	Chunks of steel missing from slider faces or core tips. Sudden onset, often after a side-loading event.	Steel too brittle for shock loads. D2 in side-action application. H13 above 52 HRC or incorrect temper.	S7 for shock-prone geometry. Verify H13 ≤52 HRC. Confirm double temper was performed — single temper leaves retained austenite that embrittles.
Corrosion Pitting	Pitting, rust staining, roughening cavity surface developing over months. Storage rust accelerates degradation.	Standard tool steel in corrosive resin environment (PVC, FR, humid climate), or inadequate storage protection.	Specify 420SS, 1.2316, or STAVAX. Apply CrN PVD as interim. Correct storage: dehumidified environment, corrosion inhibitor oil.
Cavity-to-Cavity Weight Variation	Parts from different cavities show systematic weight difference. Pattern consistent by cavity number.	Multi-cavity set machined from different batches or heat treated in separate cycles — producing hardness variation and differential wear.	Batch-match all inserts (same heat number). Specify ±1 HRC band across the set. CMM cavity-to-cavity consistency record at first article.
Surface Polish Loss	Mirror or high-gloss surface degrades progressively. Parts show increasing surface defects after 100–300k cycles.	P20 or H13 specified for optical/cosmetic application. Non-ESR microstructure breaks down at surface under high-cycle polishing.	NAK80 for pre-hardened mirror applications. STAVAX ESR for best-in-class optical quality. DLC coating for anti-adhesion on polished surfaces.
Dimensional Drift	Part dimensions shift over production run. Flash appears progressively at parting line. Drift not attributable to wear alone.	Retained austenite not fully converted during heat treatment. Inserts transform in service at elevated injection temperature.	Sub-zero treatment (−80°C) after quench for H13, D2, STAVAX. Verify HRC after HT. Confirm double temper protocol followed.
Insert Cracking (Thin Sections)	Core pins or thin-wall inserts fracturing, often after impact or high-cycle runs. L/D ratio typically >5:1.	H13 too brittle in thin L/D geometry at upper hardness range. Cyclic side-load on unsupported section creates fatigue crack.	S7 for thin sections under lateral load. Reduce H13 target to 46–48 HRC for better toughness. Add support structure where geometry allows.
Weld Repair Failure	Weld repairs cracking or delaminating in production. Repaired area breaking out at repair boundary after 20–100k cycles.	Using weld-unfriendly grade (D2) or incorrect pre/post-heat protocol. Hydrogen cracking from insufficient preheat.	NAK80 for repair-friendly tools (excellent weldability). H13/P20 weldable with correct preheat (200°C min). D2 — avoid weld repair; replace the insert.

Chapter 6

18-Point Material Selection Checklist

Use this checklist at the start of every new tooling project — before steel is ordered. Any "Yes" or "Unknown" answer in a risk category should trigger grade upgrade consideration. Print and complete for every program file.

SECTION A — Resin and Process Requirements

[ ] 1 **Is the resin filled with glass, mineral, carbon, or other abrasive additives?**
Yes → H13 minimum for all core/cavity inserts. >40% fill → H13 + PVD or D2 for gate and high-wear areas.

[ ] 2 **Is the resin corrosive on degradation — PVC, fluoropolymers, halogenated FR grades?**
Yes → 420SS, 1.2316, or STAVAX mandatory. Avoid H13 and P20 in contact surfaces.

[ ] 3 **Is the melt temperature above 300°C?**
Yes → H13 ESR grade for gate inserts and hot-runner components. Thermal fatigue resistance critical.

[ ] 4 **Is the injection pressure above 1,500 bar?**
Yes → Minimum H13 at 48+ HRC for cavity and core inserts.

[ ] 5 **Does the part require a mirror-grade or optical surface finish (Ra < 0.05 µm / VDI 0–2)?**
Yes → NAK80 (pre-hardened) or STAVAX ESR (heat-treated). Not H13 or P20.

SECTION B — Application and Geometry

[ ] 6 **Are there sliders, side-actions, or lifters in the tool?**
Yes → H13 minimum. Side-load-critical or thin sections → evaluate S7. Thermal fatigue at gate → H13 ESR.

[ ] 7 **Are there core pins or unsupported inserts with L/D ratio above 5:1?**
Yes → Evaluate S7 for shock and fatigue resistance. Check H13 hardness is ≤48 HRC.

[ ] 8 **Are heels or heel blocks included?**
Yes → 420SS standard. High load + corrosive environment → STAVAX. Do not use P20 for high-cycle humid programs.

[ ] 9 **Is there a direct gate or hot-runner gate experiencing sustained high temperature?**
Yes → H13 thermal fatigue resistance mandatory. Add nitriding or TiAlN PVD for additional gate life.

[ ] 10 **Is the tool multi-cavity (4 or more cavities)?**
Yes → Apply full batch-matching protocol. Specify ±1 HRC band. CMM cavity-to-cavity record. Machine spares from same batch.

SECTION C — Volume and Life Requirements

[ ] 11 **Is the production volume above 1 million shots?**
Yes → H13 minimum for all wear-critical inserts. Evaluate PVD coating for sliders and gate components.

[ ] 12 **Is the production volume above 5 million shots?**
Yes → H13 ESR (Assab 8407) mandatory. PVD coating standard for high-wear areas. Review complete cavity grade specification.

[ ] 13 **Is the tool producing medical, implantable, or FDA/CE-regulated device components?**
Yes → STAVAX ESR or 420SS mandatory. Named Uddeholm/Böhler mill cert + material traceability required.

[ ] 14 **Is the tool operating in a humid, coastal, or chemically aggressive atmosphere?**
Yes → Corrosion-resistant grade for all exposed inserts. Storage protocol: dehumidified packaging, corrosion inhibitor, desiccant.

SECTION D — Documentation and Traceability

[ ] 15 **Does the customer require a First Article Inspection (FAI) package?**
Yes → Confirm in scope: mill certificate, full CMM report, hardness cert (per insert), heat treatment cert, DFM review record.

[ ] 16 **Does the customer or OEM specify a named mill — Assab, Uddeholm, Finkl, or Böhler?**
Yes → Confirm mill source before ordering. Named certificate required — distributor cert is not acceptable for Tier 1 automotive.

[ ] 17 **Is this an automotive Tier 1 program (IATF 16949 / OEM-directed)?**
Yes → H13 Assab 8407 or Orvar Supreme. Full Tier 1 documentation: CMM, FAI, named mill cert, DFM record, heat treatment cert.

[ ] 18 **Are spare inserts required?**
Yes → Machine spares from same batch simultaneously. Document heat number, hardness, and mold/cavity reference on each spare. Store dry, labelled, coated with corrosion inhibitor.

READY TO SPECIFY YOUR INSERTS?

Send your drawings to rfq@rapidmachinedinserts.com for a quote within 48 hours. Every quote includes a written DFM review, pricing, production lead time, and documentation package confirmation. Automotive FAI packages and Tier 1 documentation are our standard workflow.

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Get a quote in 48 hours.

Send your drawings to rfq@rapidmachinedinserts.com. Every quote includes pricing, production lead time, written DFM review, and full documentation package confirmation.

STEEL GRADES WE STOCK

P20 · 718 / 718HH · H13 (Assab 8407)
420SS · STAVAX ESR · NAK80
S7 · D2 / 1.2379 · 1.2316

LEAD TIMES

28–35 days: complex automotive inserts
14–21 days: standard commercial
Air freight to USA / EU / AU / JP

DOCUMENTATION

Named mill certs (Assab, Uddeholm, Finkl, Böhler)
CMM dimensional reports · FAI packages
Heat treatment certs · DFM review on every order

PROGRAMS SERVED

Automotive Tier 1 (IATF 16949)
Medical device (ISO 13485)
Consumer electronics · Industrial mfg