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MANUFACTURING™ TECHNOLOGY SERIES

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Unique Tooling Solutions for Maximizing Productivity

Matt Goss
Applications Engineer
Greenleaf Corporation

MANUFACTURING™ TECHNOLOGY SERIES

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Founded in 1945 by
Walter Greenleaf, Sr.

Family owned and operated

Facilities in PA and NC

450 + Employees

Sales in over 60 countries

ISO 9001 Since 1994

Saegertown, PA
Location

Greenleaf Europe and Greenleaf China

Greenleaf Corporation designs and manufactures standard and special Ceramic and Carbide Inserts and the supporting Steel Tooling.

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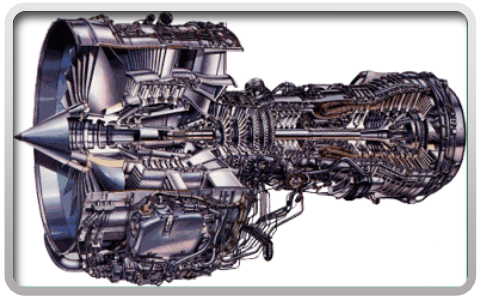
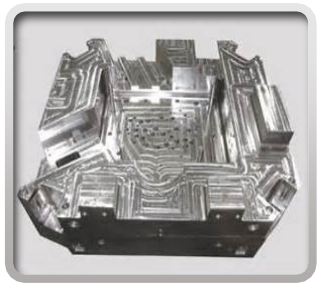
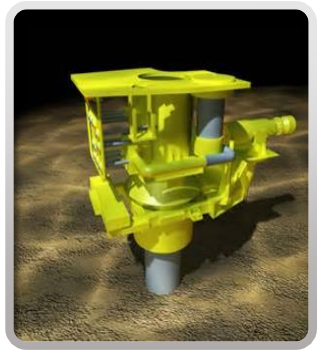
Where You Find Greenleaf



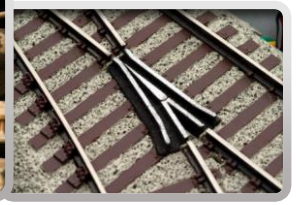
Aerospace



Die & Mold

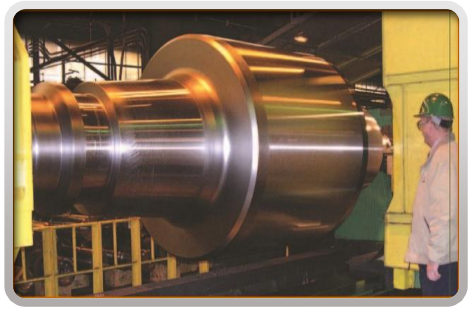


Oil & Gas, Energy



Railroad

Bar Peeling &
Tube Scarfing



Roll Turning &
Heavy Machining

Crank/Cam

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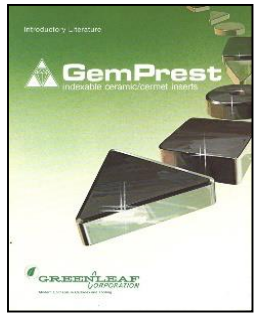
A History of Continuous Innovation

Greenleaf®

1945

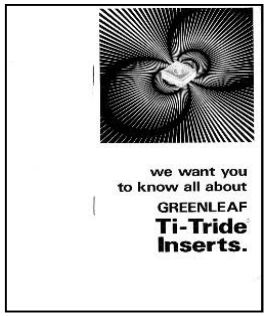


1973

2006

2016

1971



1985

2011

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Today's Agenda

1. What are whisker-reinforced and phase-toughened ceramics?
2. Properties of whisker-reinforced and phase-toughened ceramics
3. Common HRSA materials suitable for machining with ceramics
4. Applications most suitable for machining with ceramics
5. Programming tips for machining with Ceramics
6. Tool maintenance and handling
7. Tool wear and how to evaluate tool life

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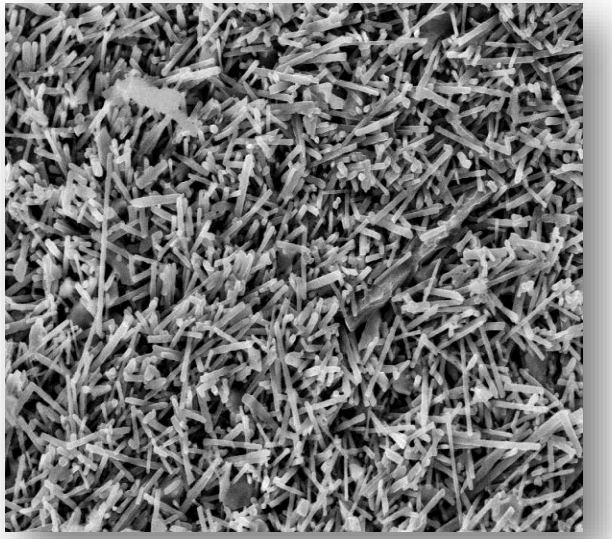
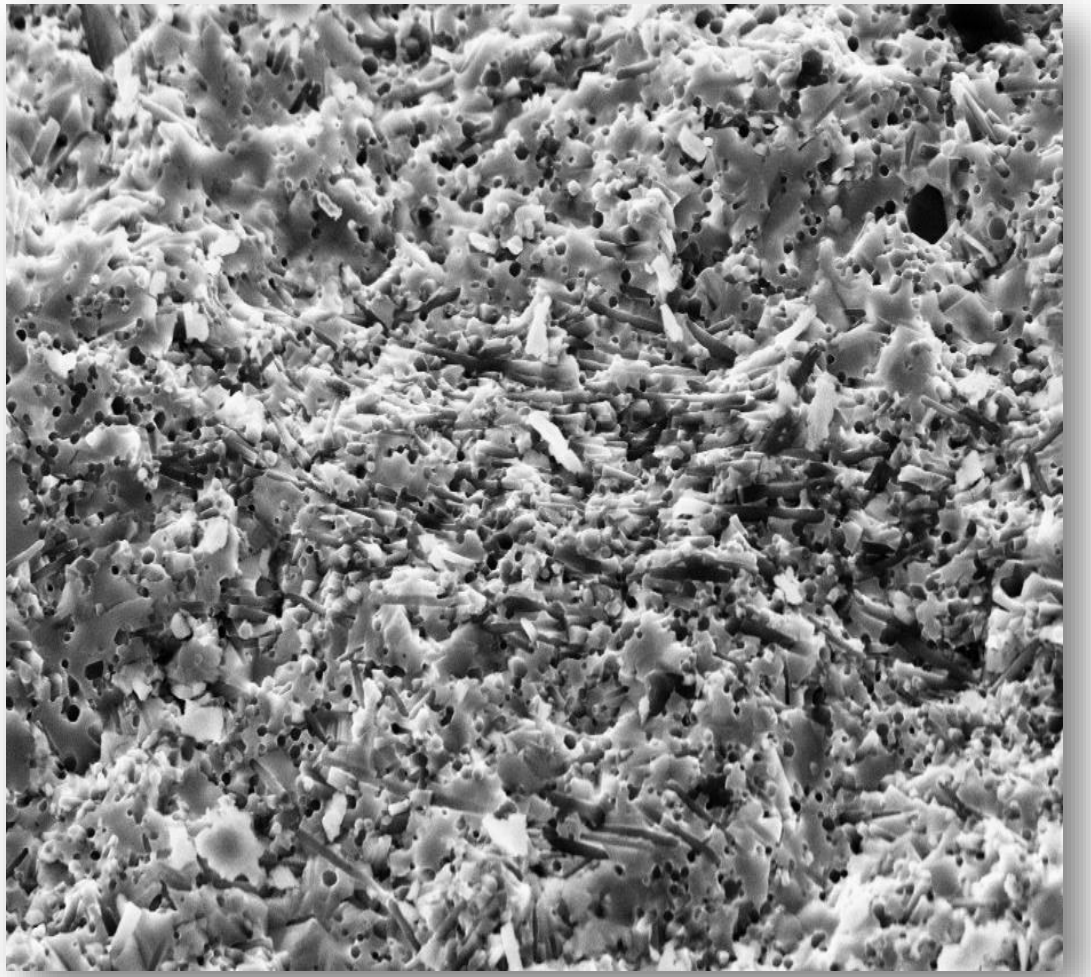
Whisker-Reinforced Ceramics

SiC Whiskers



+

Aluminum Oxide (Al_2O_3)



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Whisker-Reinforced Ceramics

Greenleaf WG-300: T
Significant Advance in C
Materials Since Coated

Greenleaf Ceramic/Ceramic Composites

What are they? Proven ceramic cutting tool materials reinforced with a lattice of small single crystal silicon carbide "whiskers". The combination produces materials with the abrasion resistance of ceramics but with the strength and thermal shock resistance of cemented carbides. **WG-300,** the first grade in this new family of cutting tool materials, has over twice the fracture toughness of traditional ceramics, and is ready for immediate delivery from stock in a variety of insert styles.

FRACTURED SURFACE 4000 X

WG-300, readily identified by its green color, and other Greenleaf composites, can be used in ways you never thought possible:

- with ground-in chipforms
- on interrupted cuts
- at speeds from as low 50 sfpm to as high as 5000 sfpm
- on older less rigid machines
- even with positive rakes!

GREENL
VOR
GREENLEAF DRIVE, SAEGERTOWN, PA 164

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MACHINING HARDENED BEARI
FOR THE WIND TURBINE MARKET

Objective: Semi-finish and f
faces and grease groove with V

Problem: Customer was un
plete a part within tolerance v
rent tooling due to tool instab

Solution: Greenleaf is holding
getting approximately a 10 -12
Tool life is excellent at 22 plus n

CRDPN-203V
RCGN-3V
RCGN-4V
CRDPN-204VS

Hard Turn Finis
42 CRM04 Q
57-60 H/Rc
RCGN-3V WG-600

DIA: 90" (2340
SFM: 700 (214m/
IPT: .006" (.16mm
LOC/TIME: 22 mi
DOC: .007" (.18

Greenleaf®

Greenleaf Corporation
Saegertown, PA 16433
800-458-1850
www.greenleafcorporation.com
www.greenleafglobalsupport.com

METAL REMOVAL RATES
UP TO 10X GREATER THAN
CARBIDE AND
3X GREATER THAN SIALON

WG-700™

WG-700™ is the latest coated whisker-reinforced ceramic material from Greenleaf Corporation. ***WG-700™*** offers extended tool life at high cutting speeds. Its superior toughness combined with a nano layered "platinum" coating allows ***WG-700™*** to excel in the machining of difficult-to-cut materials, such as nickel- and cobalt-based super alloys.

Higher feed rates, more speed & longer tool life!

INSERT	Current Ceramic RNGN-45	WG-700™ RNGN-45 T1
SPEED	900 SFM (275 M/min)	1200 SFM (366 mm/min)
FEED	.008"/Rev (0,20 mm/Rev)	.012" (0,30 mm/Rev)
DOC	.070" (1,78 mm)	.070" (1,78 mm)
METAL REMOVAL RATE	4.2 in³/min (69 cm³/min)	8.4 in³/min (137.6 cm³/min)
	-Heavy notching & top chipping -Unable to complete cut	-Minimal notching -Twice the metal removal rate

With ***WG-700™***, customers can expect superior wear resistance and toughness at high speeds and feeds, maximizing their production capabilities in these ultra-competitive times.

Greenleaf's products are engineered to provide optimal performance against a wide range of materials under the most rigorous metal cutting conditions. In addition to specially engineered tool-holding systems and a comprehensive line of carbide inserts, Greenleaf offers high-quality ceramic and ceramic composite materials, which can be custom designed for specific machining applications.

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eurooffice@greenleafcorporation.com

Greenleaf (Hunan) High-Tech Materials Co., Ltd.
Changsha, Hunan 410100, China
+86-731-84658507
info@greenleafcorporation.com.cn

MADE IN THE USA
Greenleaf Corporation is ISO 9001 Certified.
U.S. Patent No. 6,447,896 B1

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Phase-Toughened Ceramics

Greenleaf Tooling Solutions

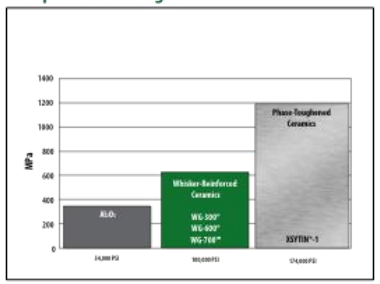
What Are Phase-Toughened Ceramics?

Phase-toughened ceramics are ceramic-composite cutting tools offering almost twice the strength of other commercial ceramic-composite cutting tools. Greenleaf offers XSYTIN®-1 — the first of its kind.

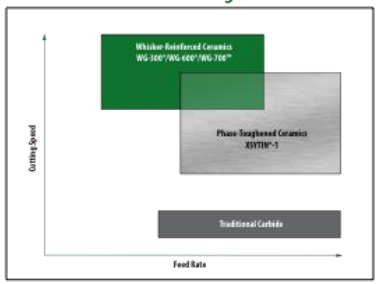
XSYTIN®-1

- XSYTIN®-1 is engineered to provide ultra-high strength and wear resistance for demanding, high-force cuts.
- Applied at extreme feed rates, XSYTIN®-1 has the ability to greatly enhance productivity while providing predictable performance.
- With a wide operating range, XSYTIN®-1 elevates productivity in more materials than any other ceramic cutting tool on the market today.

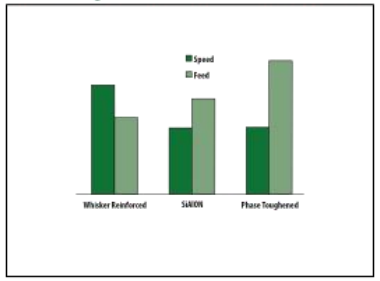
Comparable Strength



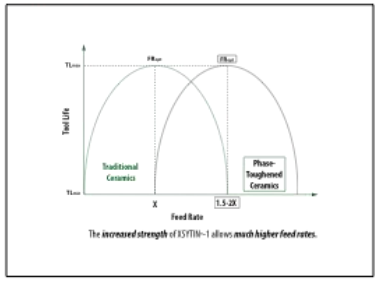
Ceramic vs. Carbide Turning



Phase-Toughened vs. Traditional Ceramics



Tool Life vs. Feed Rate



The *increased strength* of XSYTIN®-1 allows *much higher feed rates.*

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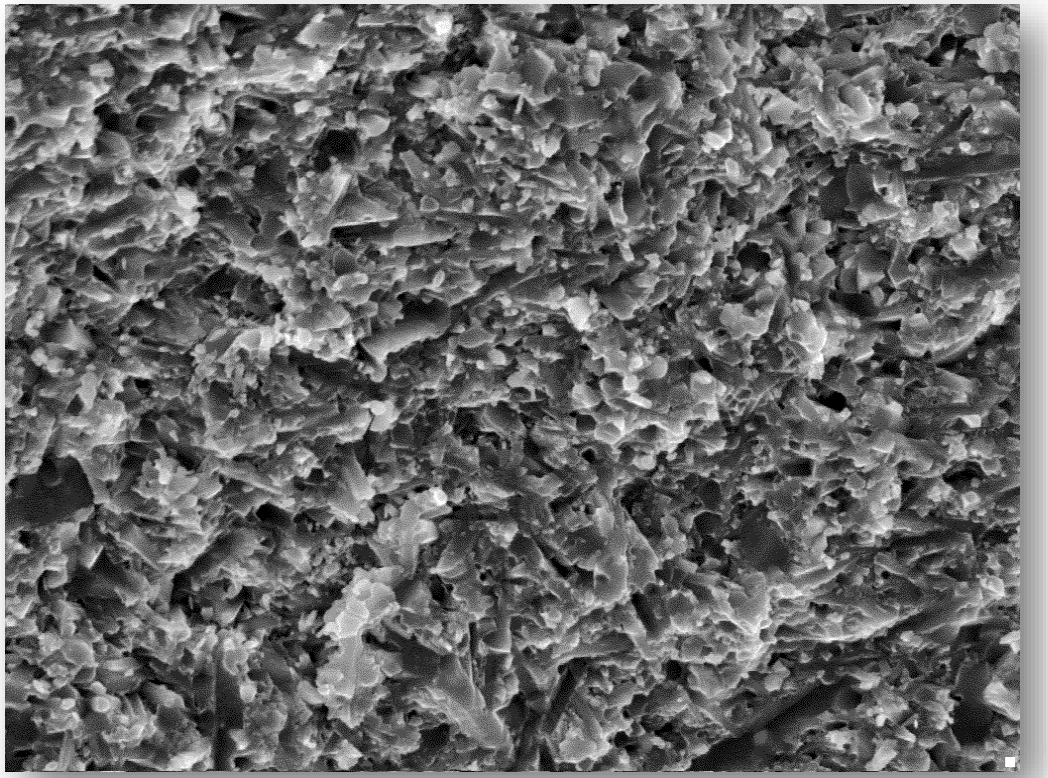
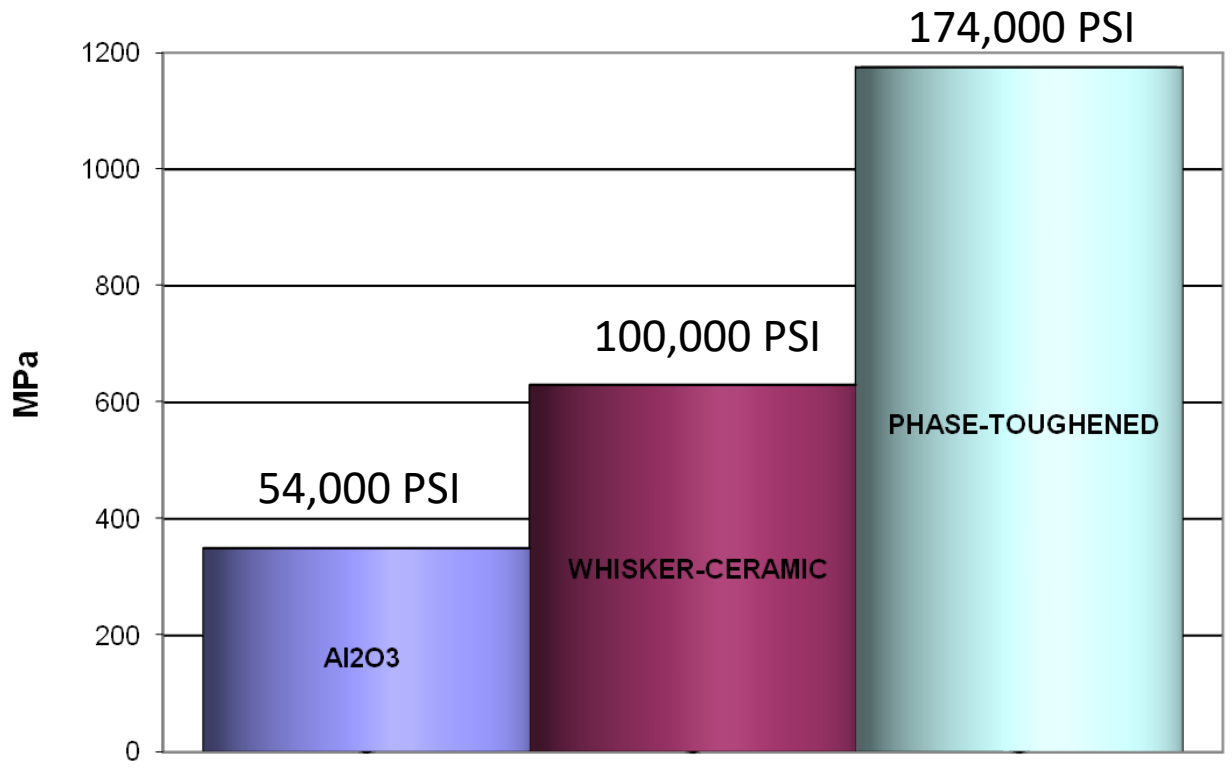
Phase-Toughened Ceramics

Unique ceramic blend



In-place grain growth

Comparable Strength



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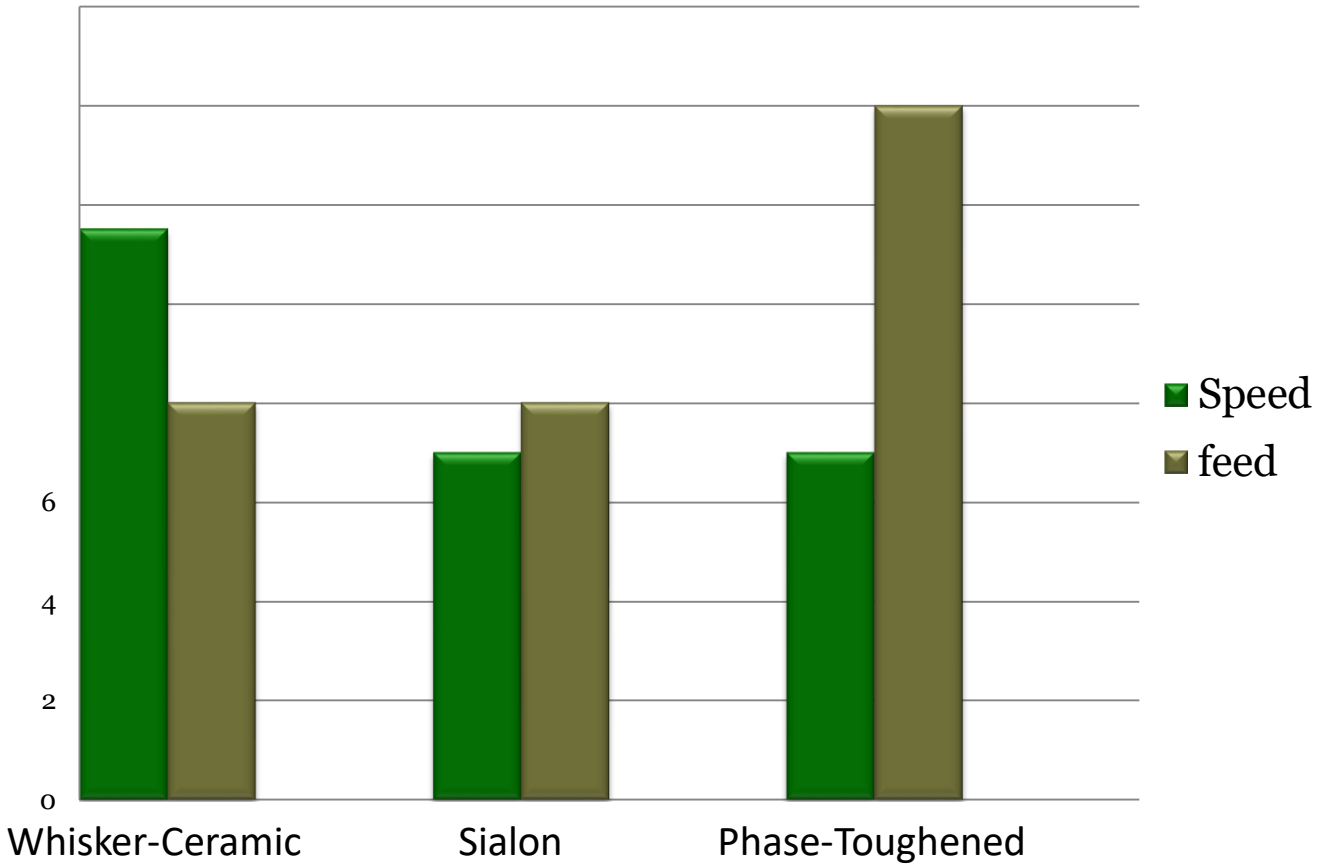
Phase-Toughened vs. Traditional Ceramics



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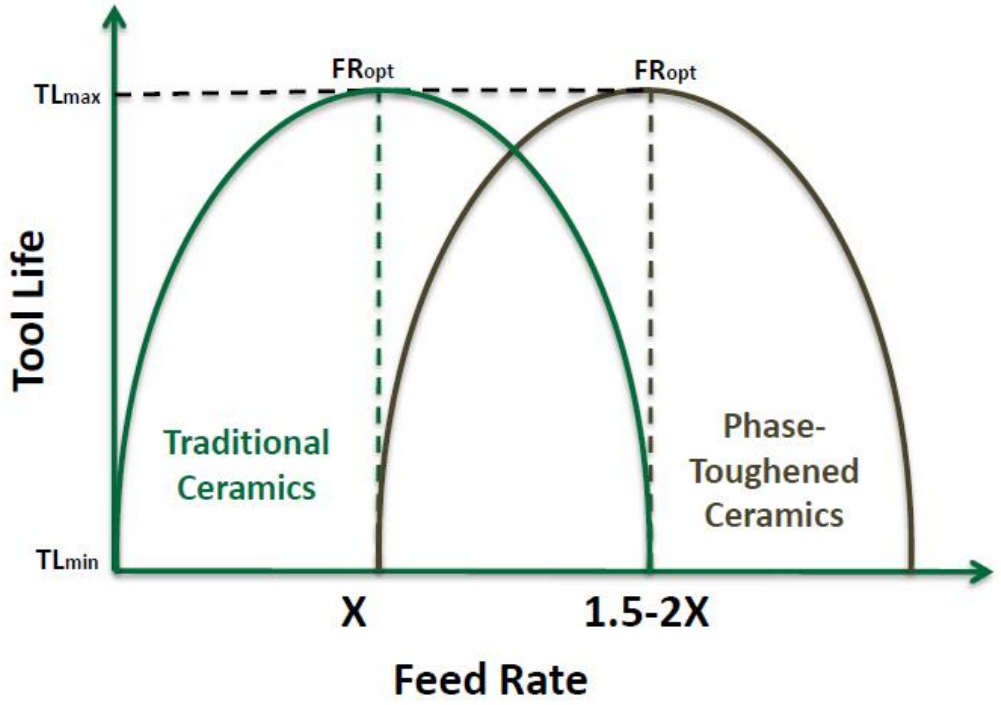
Tool Life vs. Feed Rate



*The **increased strength** of XSYTIN®-1 allows **much higher feed rates**.*

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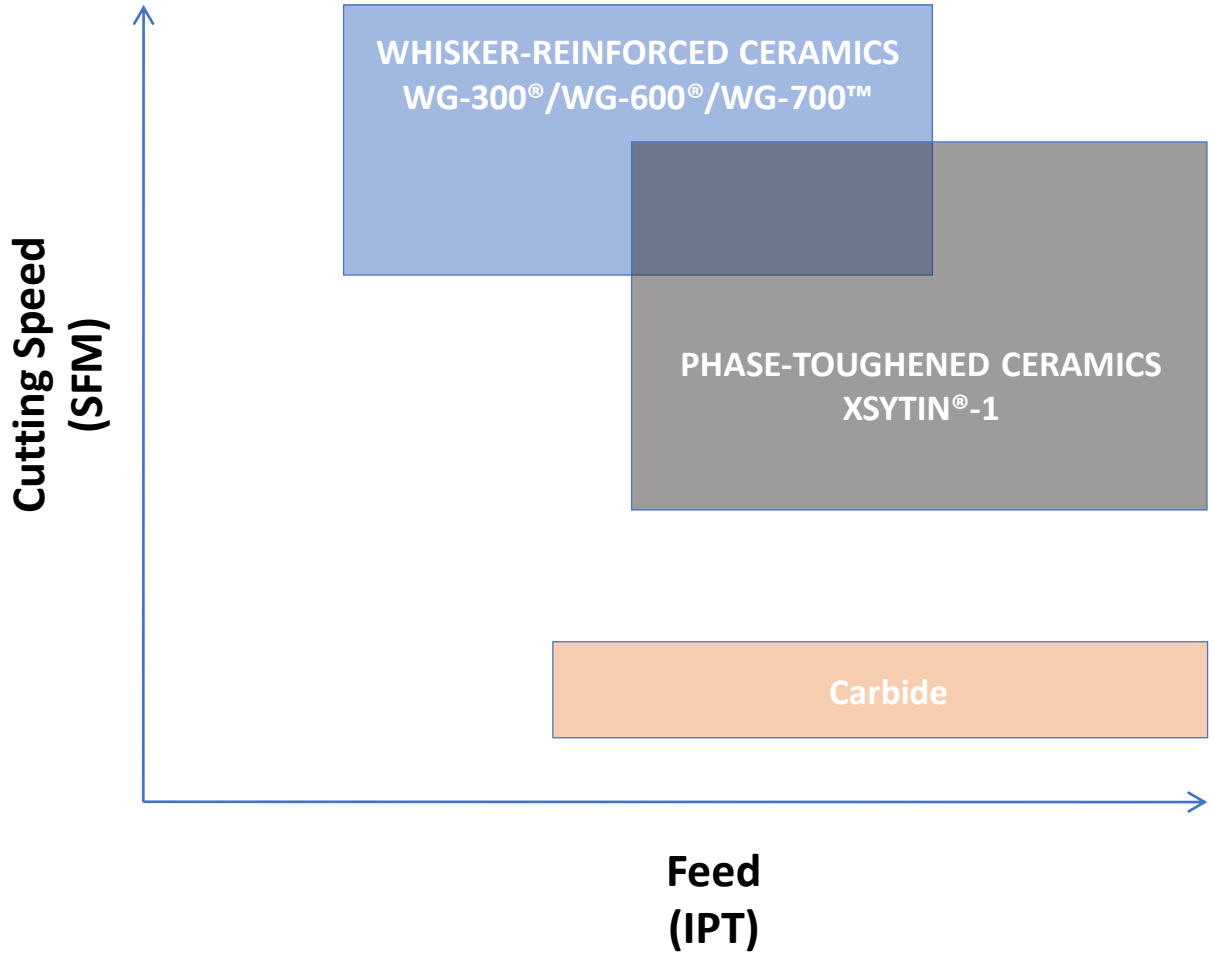
How Ceramics Work

Ceramic vs. Carbide Turning



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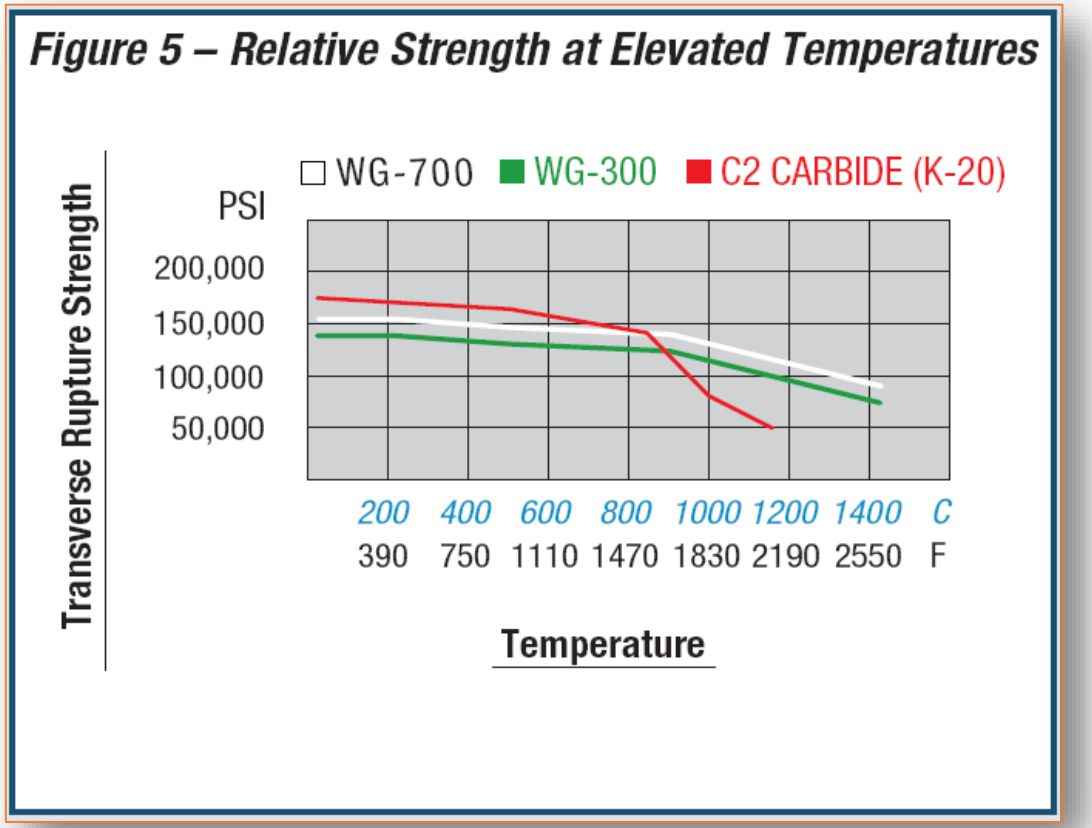
Heat Dissipation in Ceramic Machining



Whisker ceramics retain strength and hardness well beyond 1000°C

Carbide will turn to taffy at that temperature!

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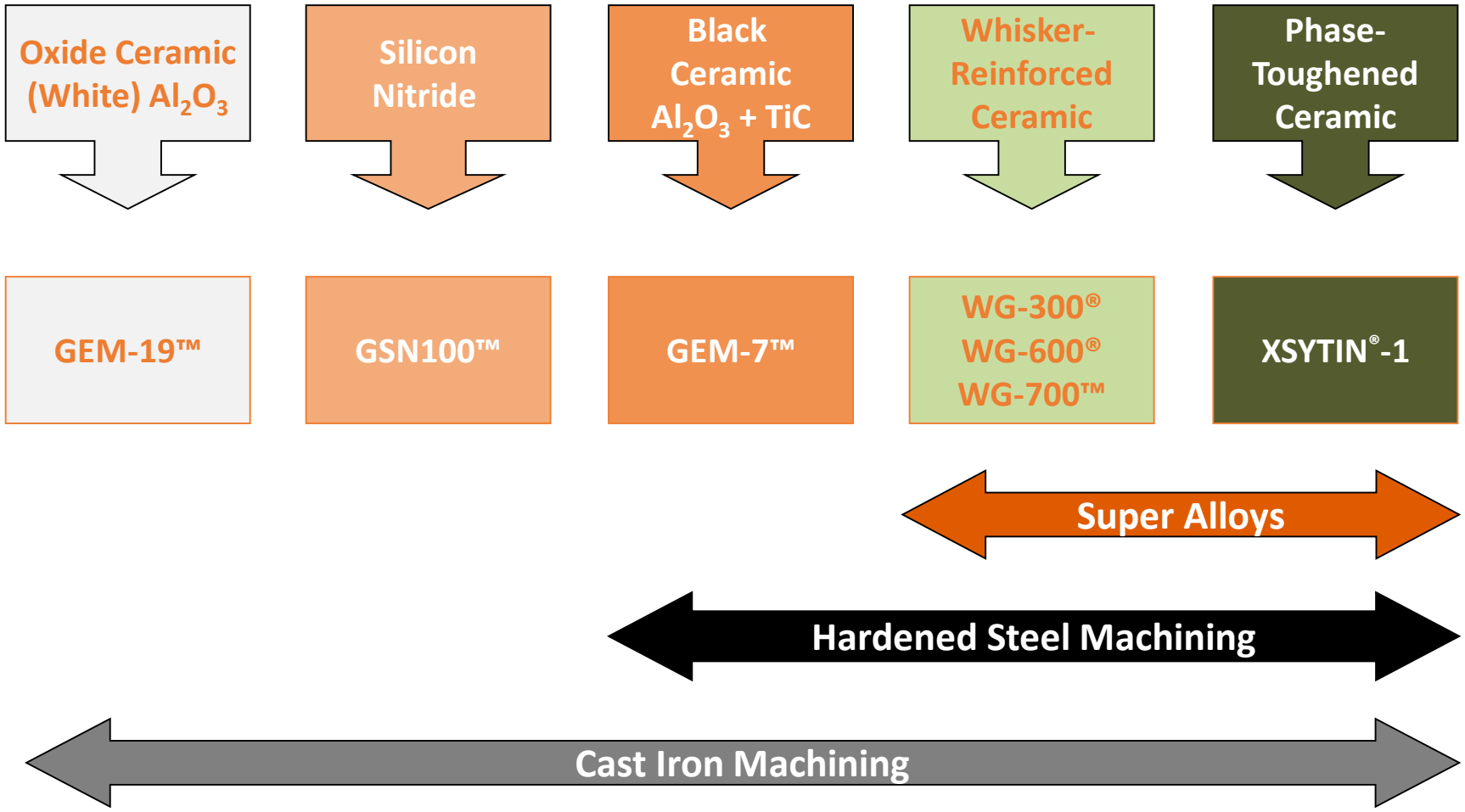
Greenleaf Ceramic Grade Profile



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HRSA Materials

Nickel Alloys

Inconel

Waspaloy

Hastelloy

Cobalt-Based Alloys

Stellites

Haynes Alloys

Weld Overlays

Powdered Metals

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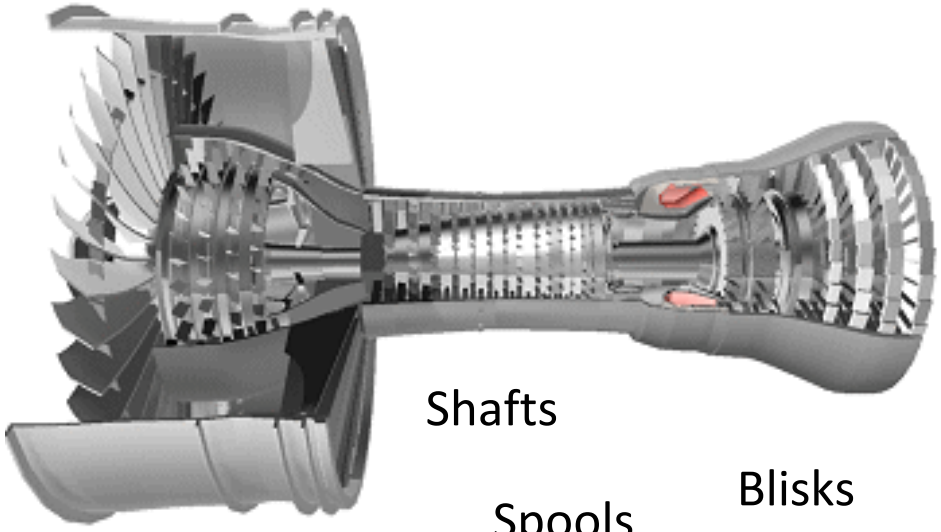
HRSA Applications

Turbine Engine



Shafts

Blisks

Spools

Discs

Cases

Oil & Gas

BOP

Adapters

Flanges

Valves

High-Temperature Resistance

Wear & Corrosion Resistance

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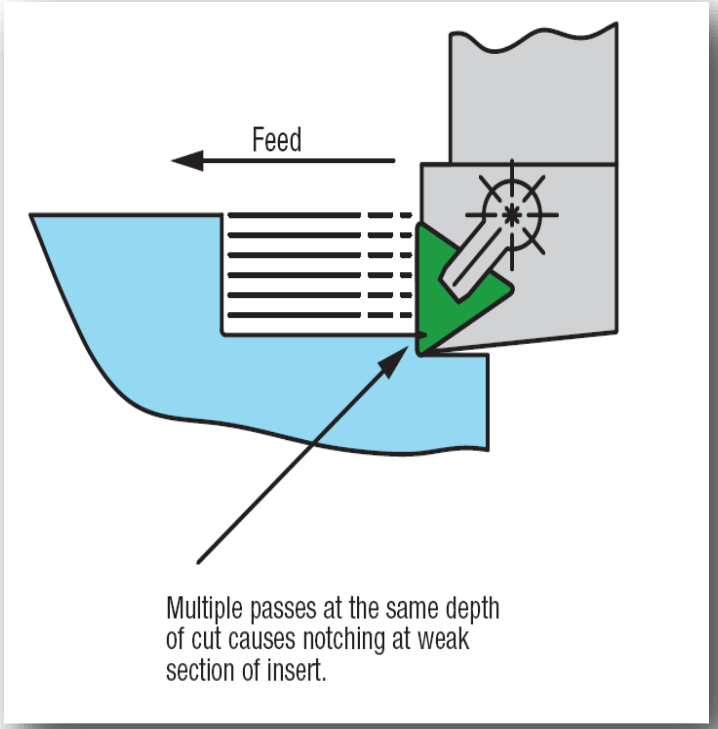
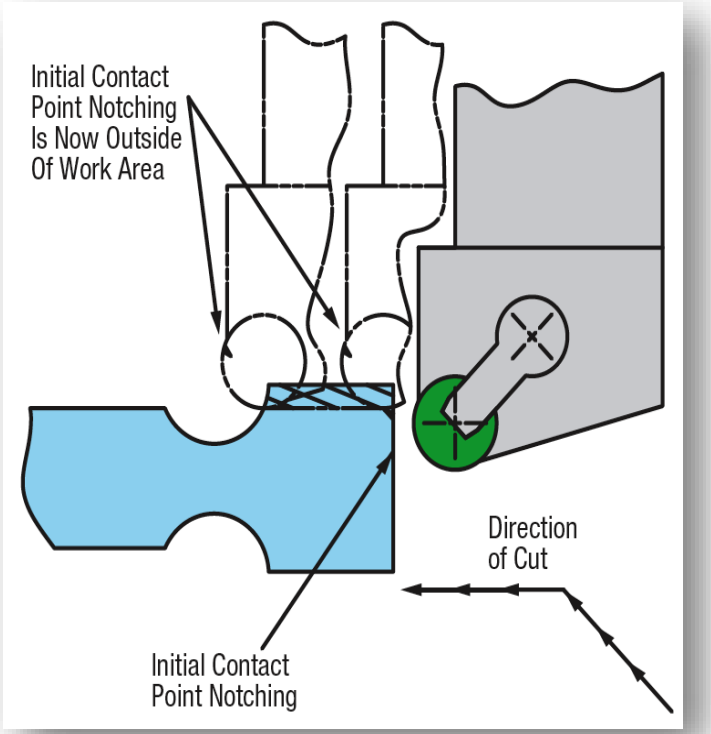
Programming Techniques

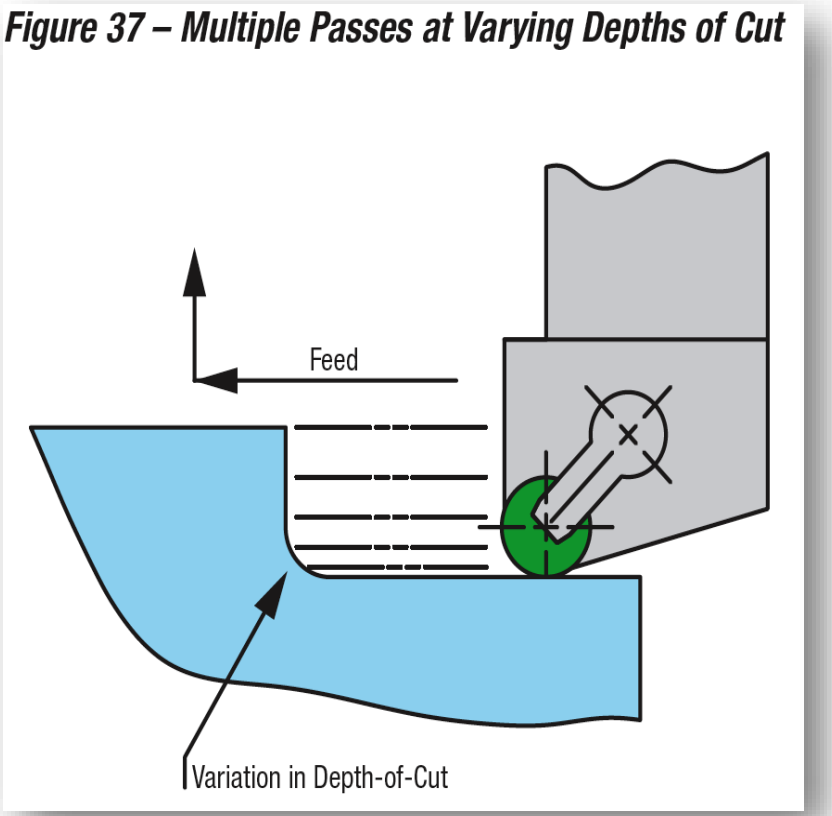


DOC Notching



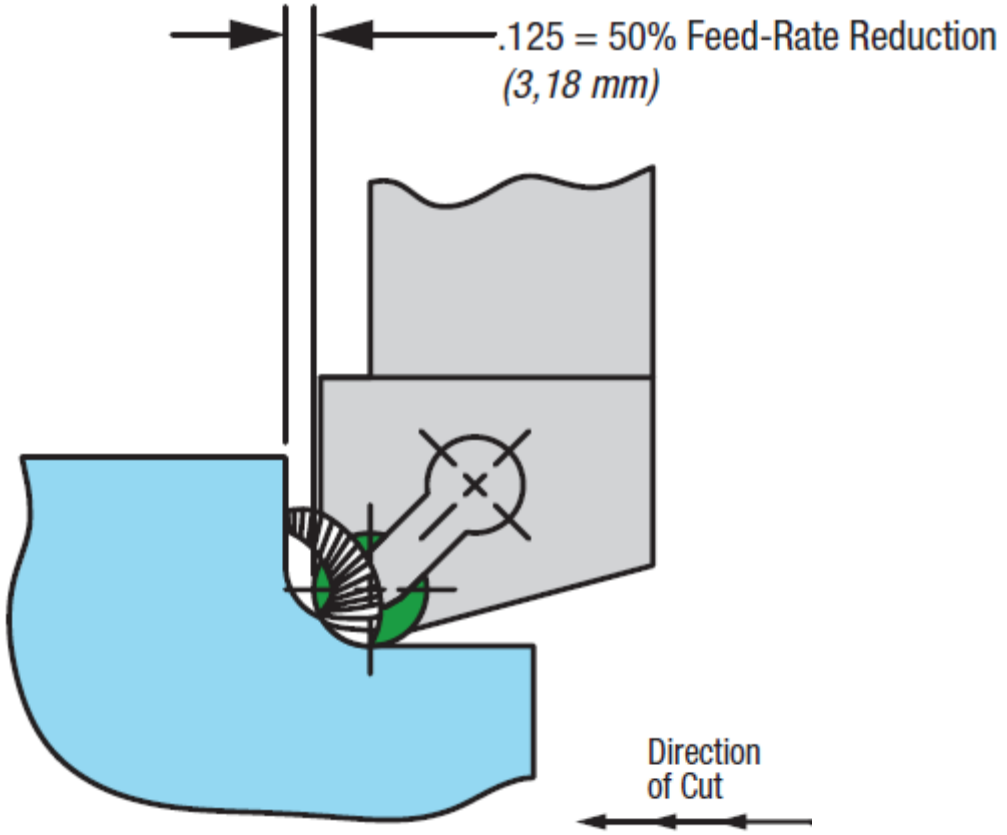
Pre-Chamfering

Programming Techniques



Varying the Depth of Cut

Programming Techniques



Turning to a Shoulder

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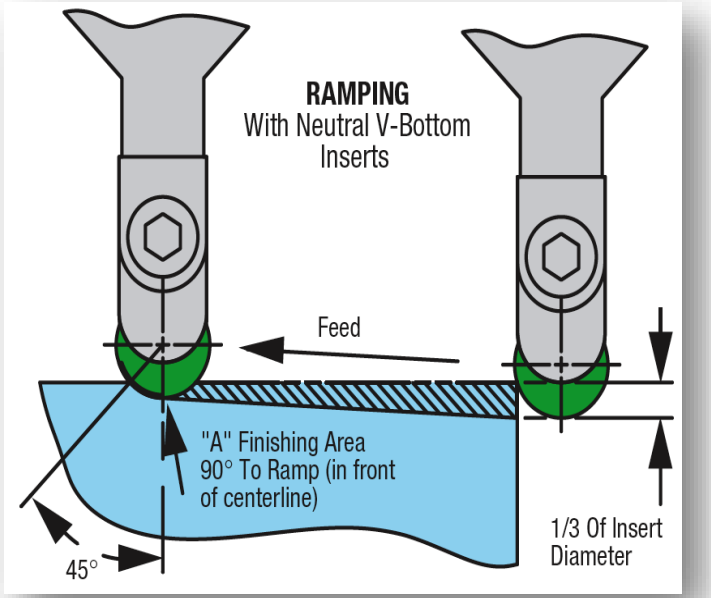
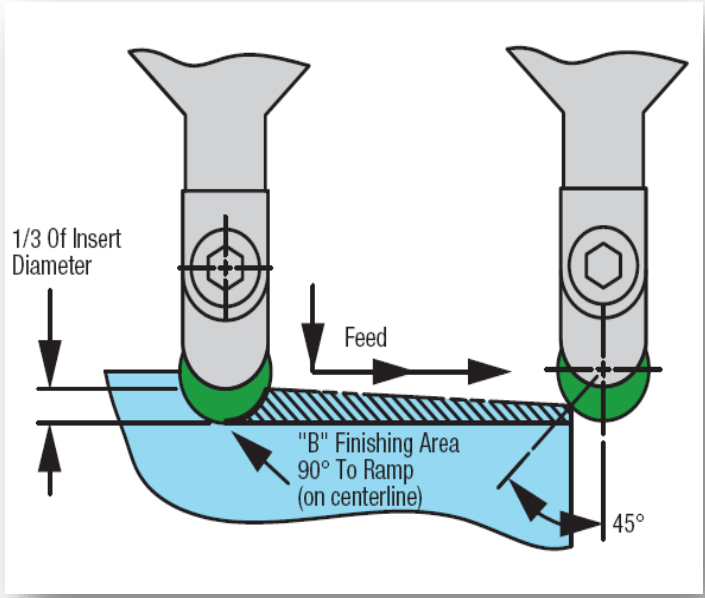
Programming Techniques





DIAMETER		"A"		"B"		"C"
inches	*mm*	inches	*mm*	inches	*mm*	minutes
.250	*6,3*	.080	*2,0*	.040	*1,0*	3
.375	*9,5*	.120	*3,0*	.060	*1,5*	4
.500	*12,7*	.160	*4,0*	.080	*2,0*	5

Ramping

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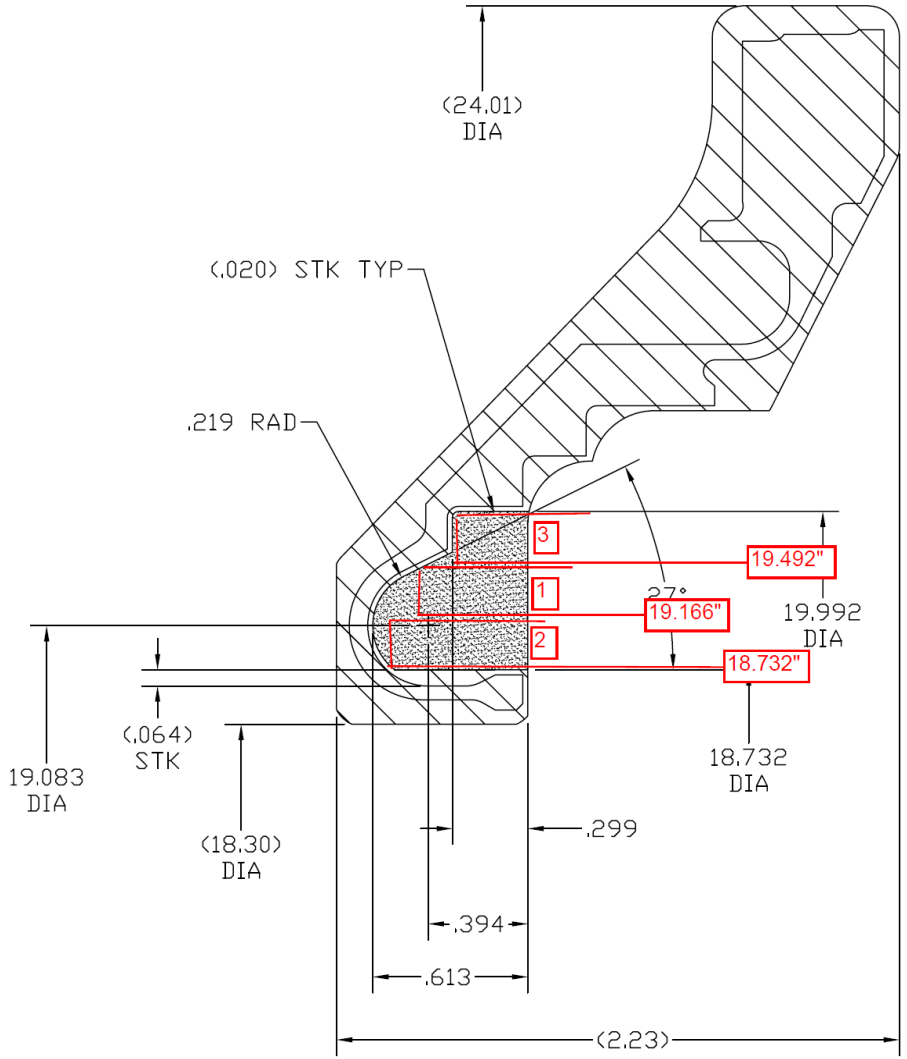
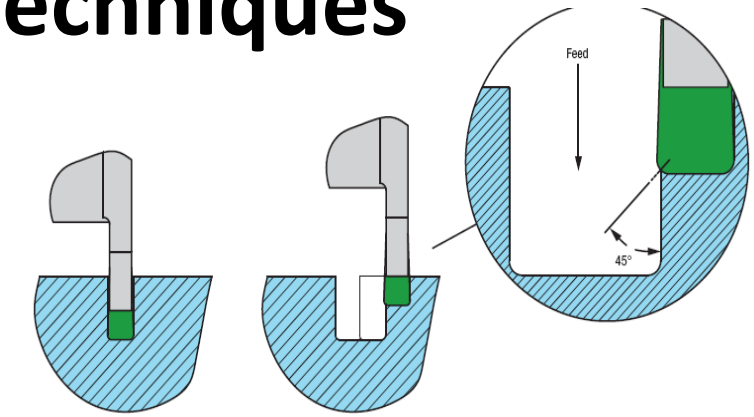
Programming Techniques





Greenleaf Solution

Layout optimal tool path and step over for WG-6250-3

- 900 SFM (274 m/min)
- 0.0025 IPR (0,06 mm/rev)
- 1 insert per part
- 3-minute cycle time

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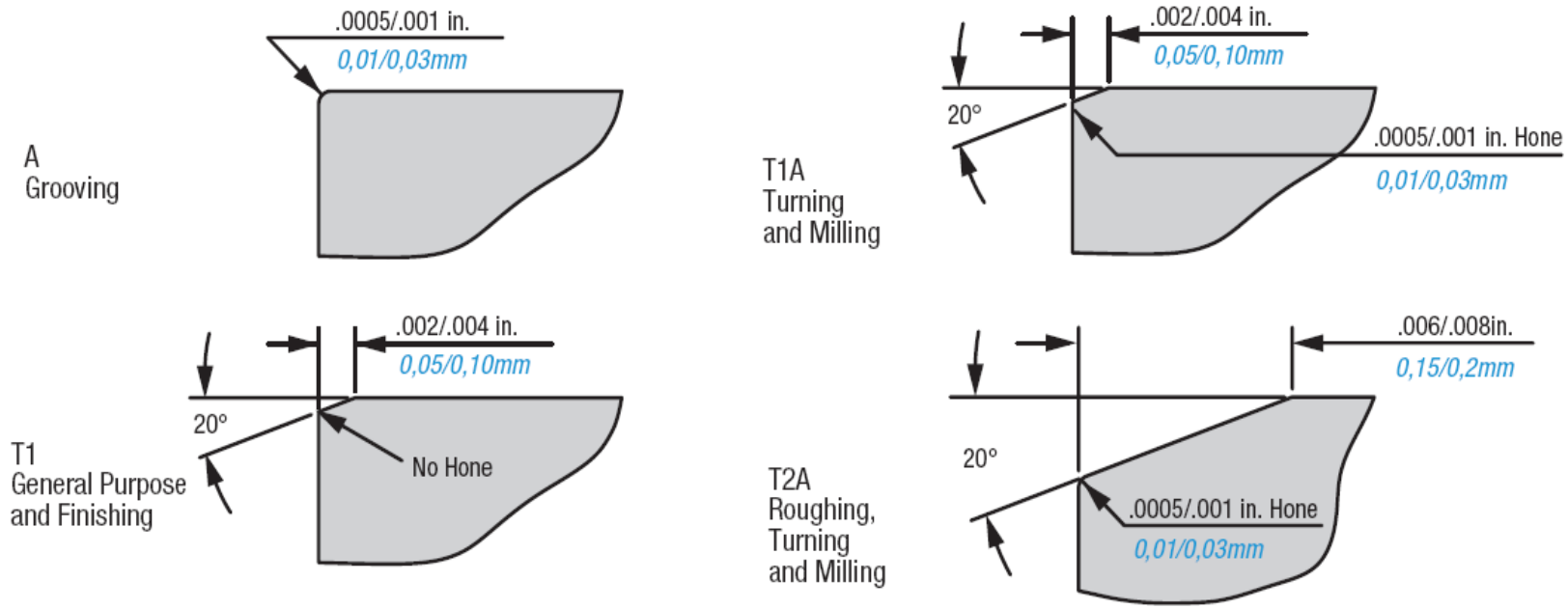
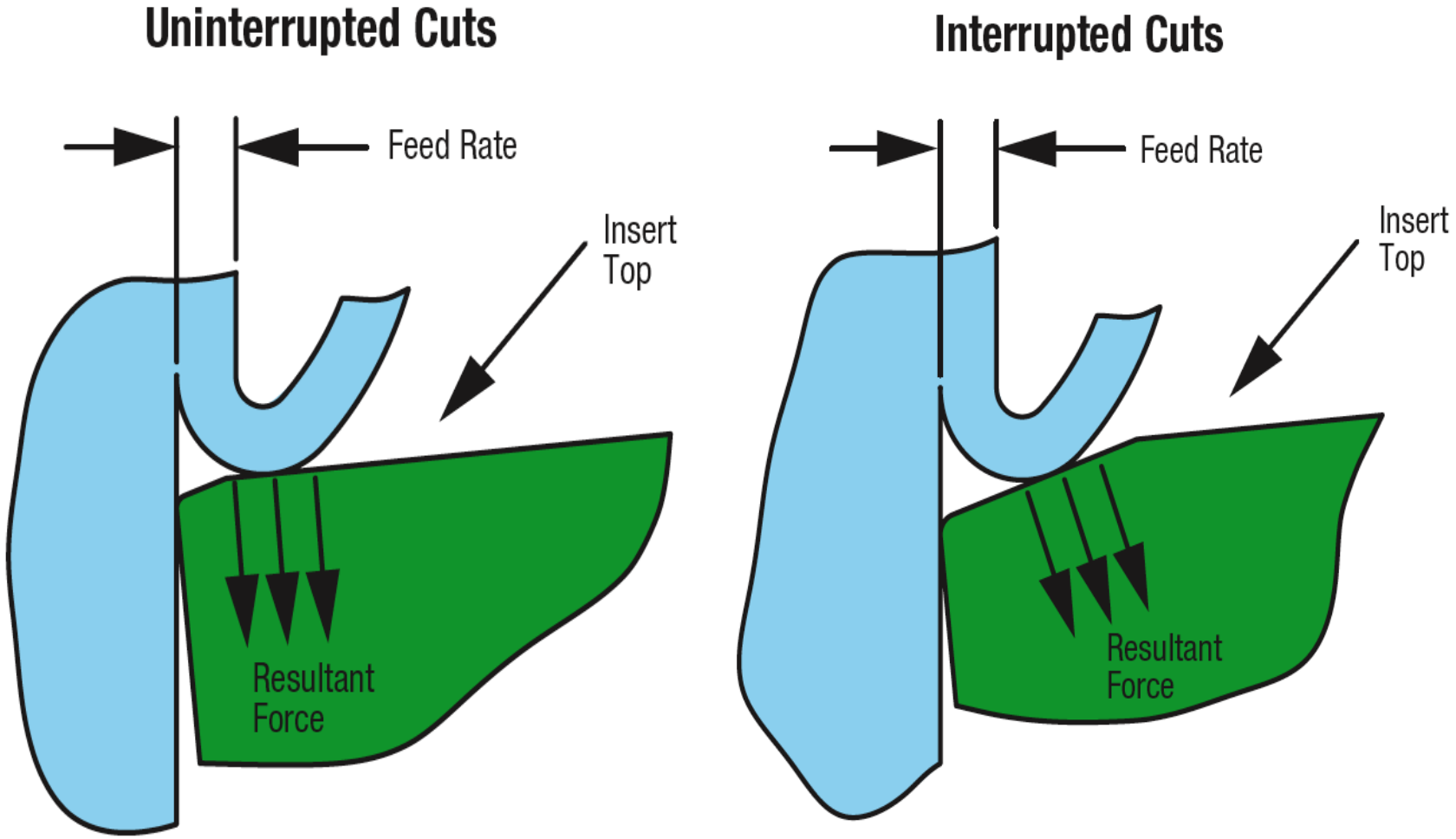
Standard Edge Preps

Figure 24 – Standard Edge Preparations



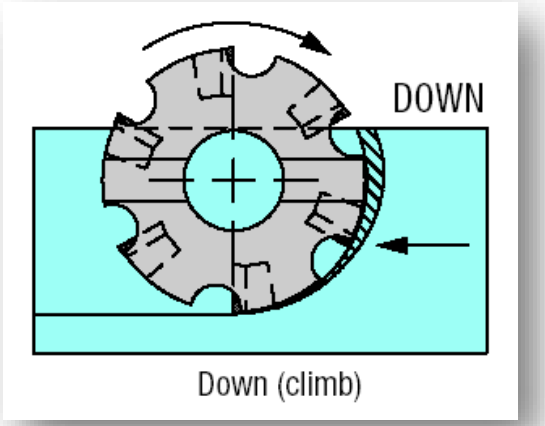
Edge Prep for Interrupted Cutting



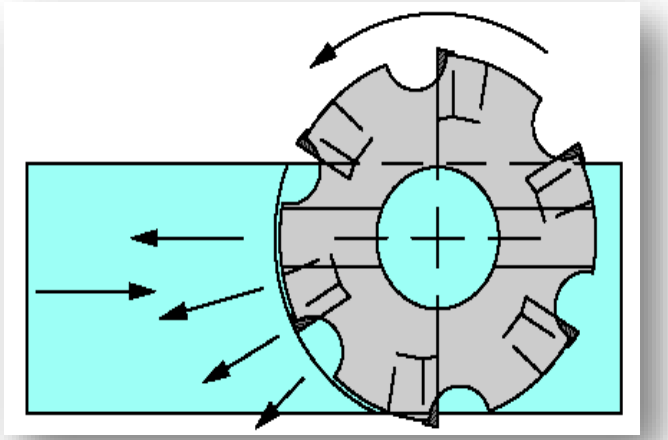
Programming Techniques

Keep cutter engaged in cut

Climb (Down) Milling



Cutter Positioning



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Tool Maintenance

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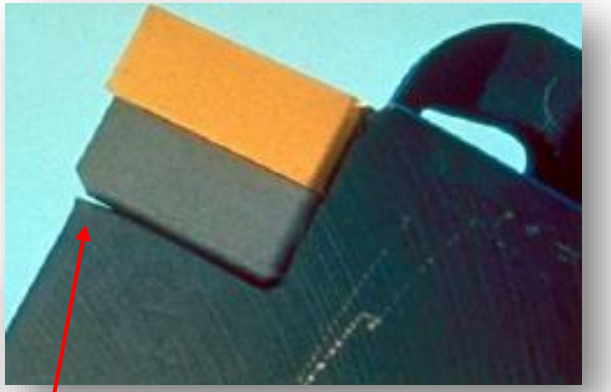
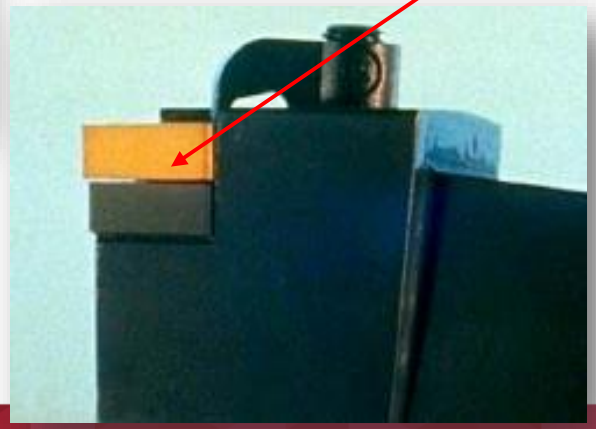
Tool Maintenance

Inspect the insert pocket, seating and clamping

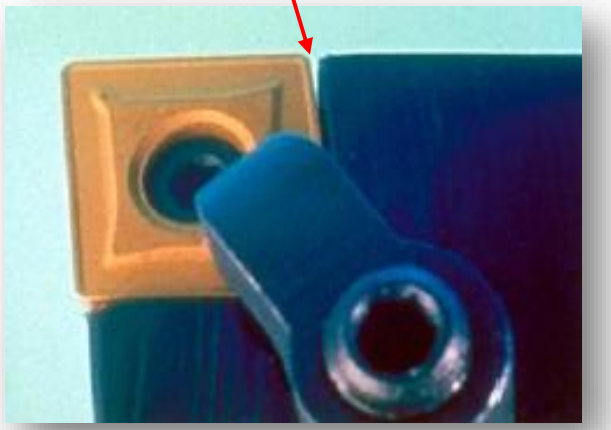
Damaged shim seat



Poor seating



Bell-mouthed insert pocket



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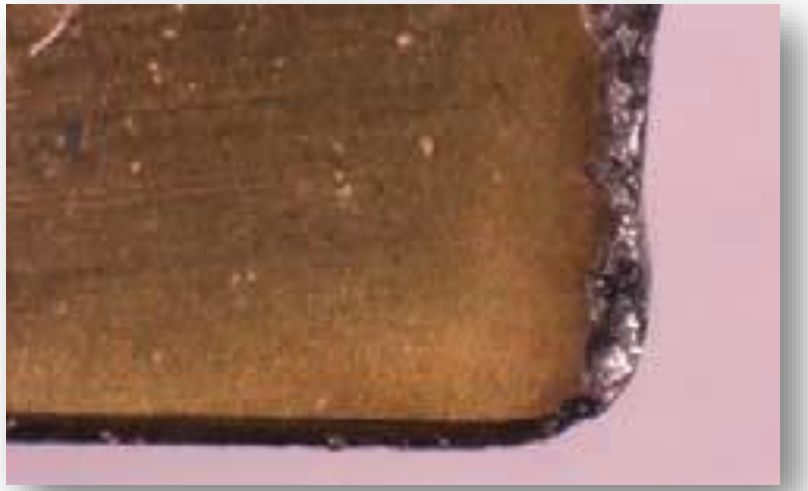
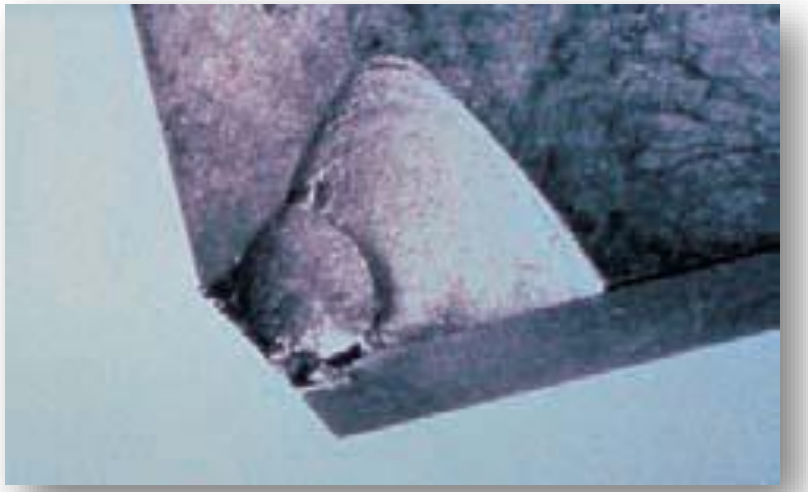
Ceramic Tool Wear

Undesirable Tool Wear

Chipping



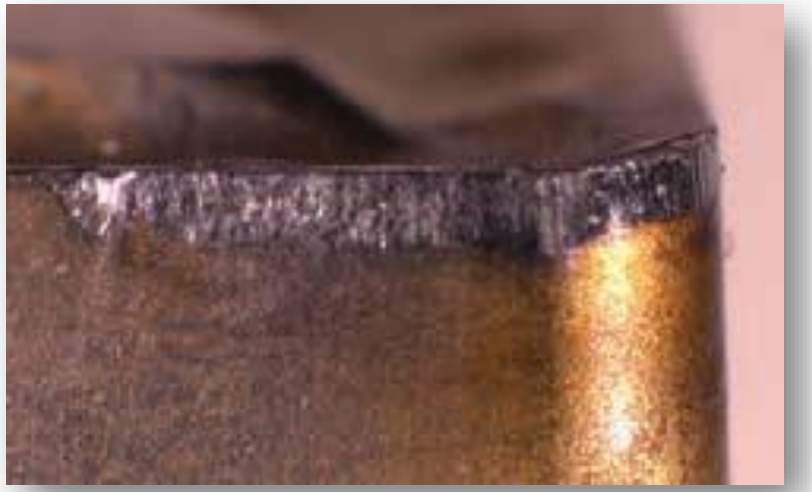
Fracture



Ceramic Tool Wear

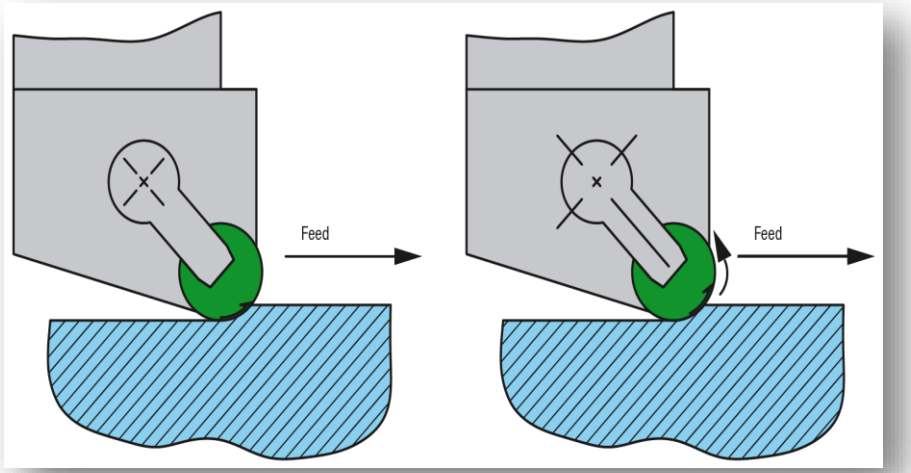
Typical Tool Wear

Flank Wear

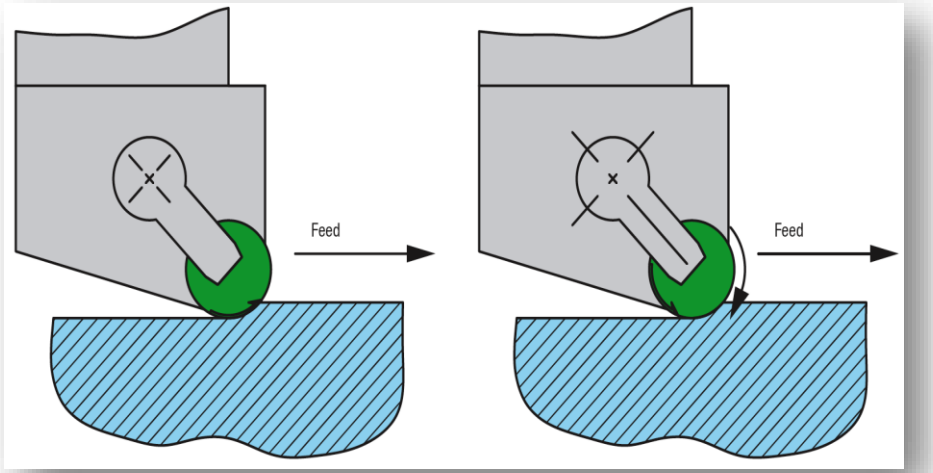


Notching

Proper Indexing Techniques



Heavy notch,
light flank wear



Heavy notch,
heavy flank wear

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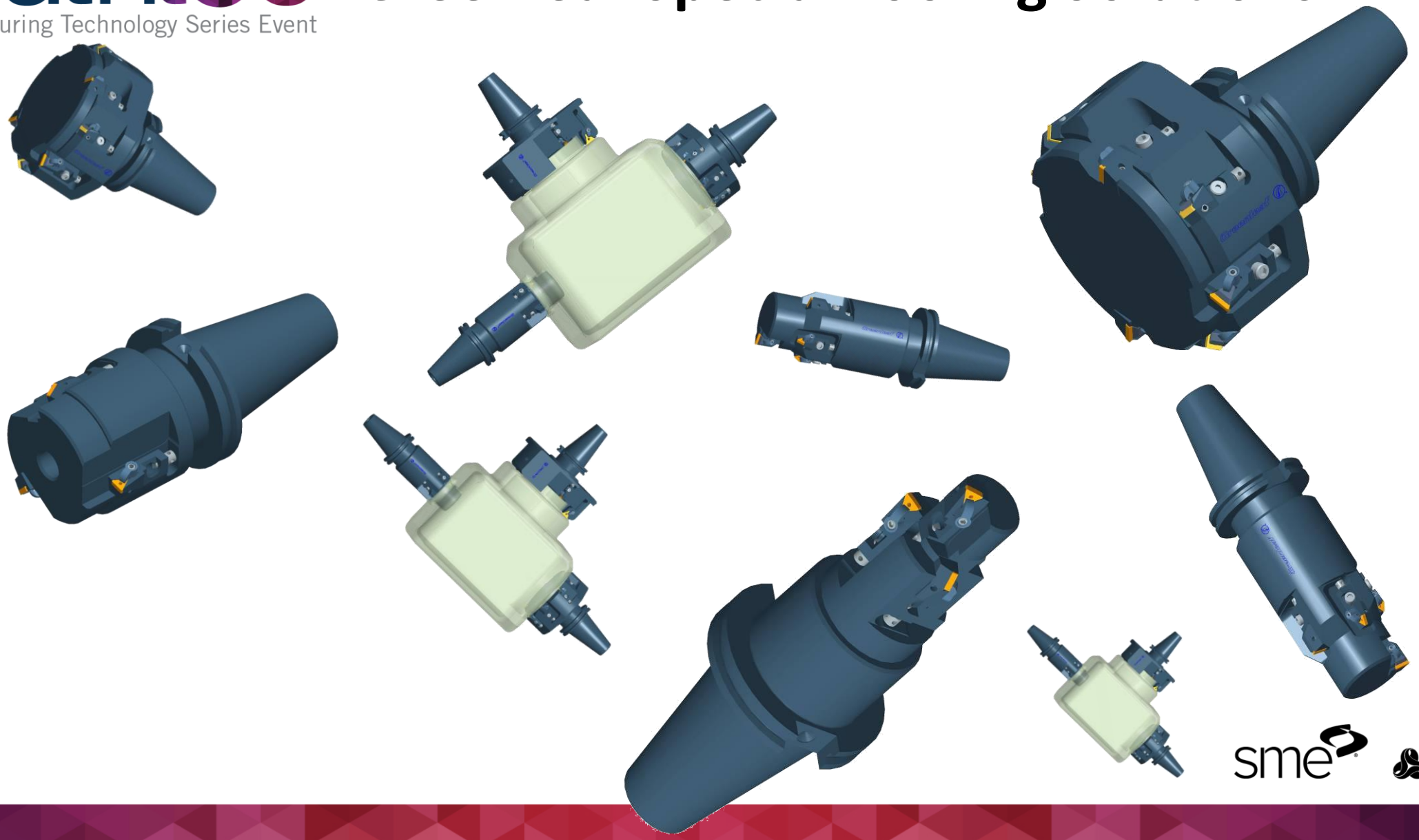
Greenleaf Special Tooling Solutions



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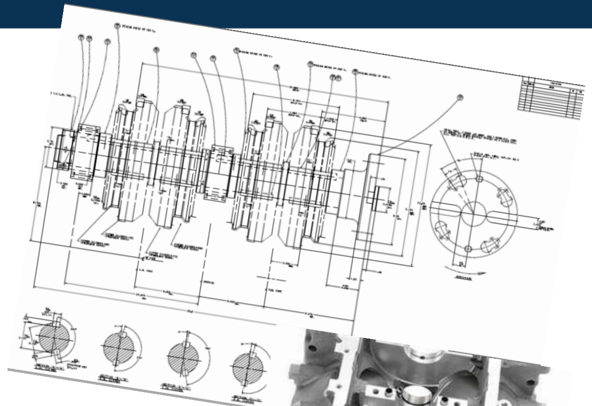
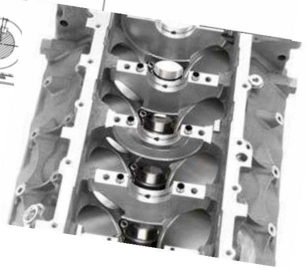
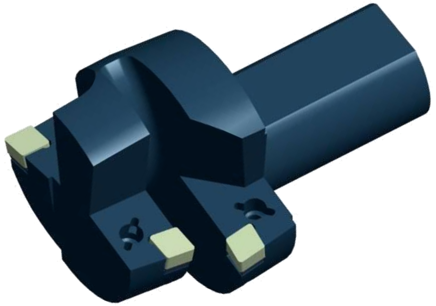
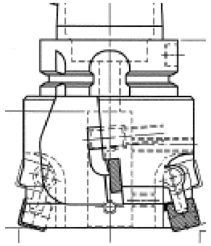
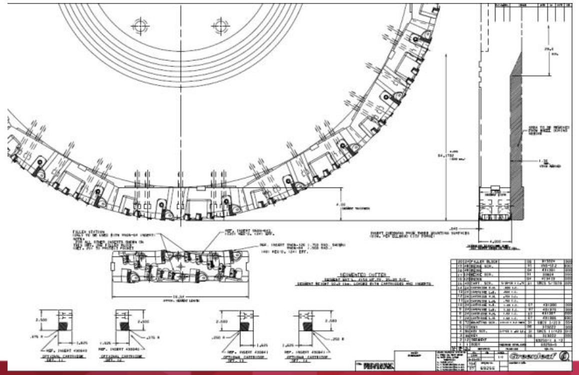
Automotive

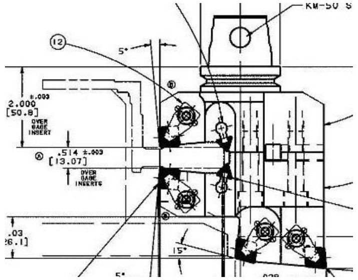












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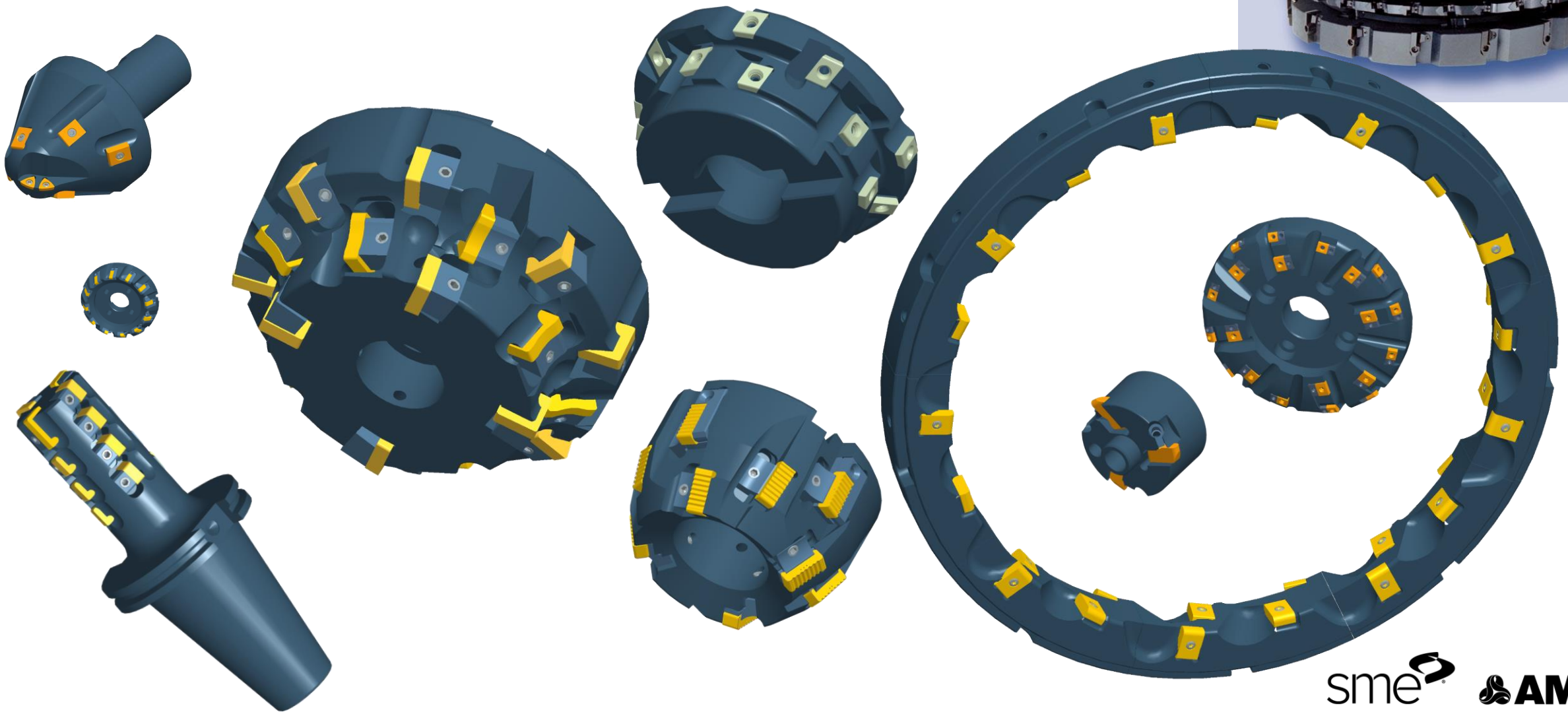
Special Milling Cutters



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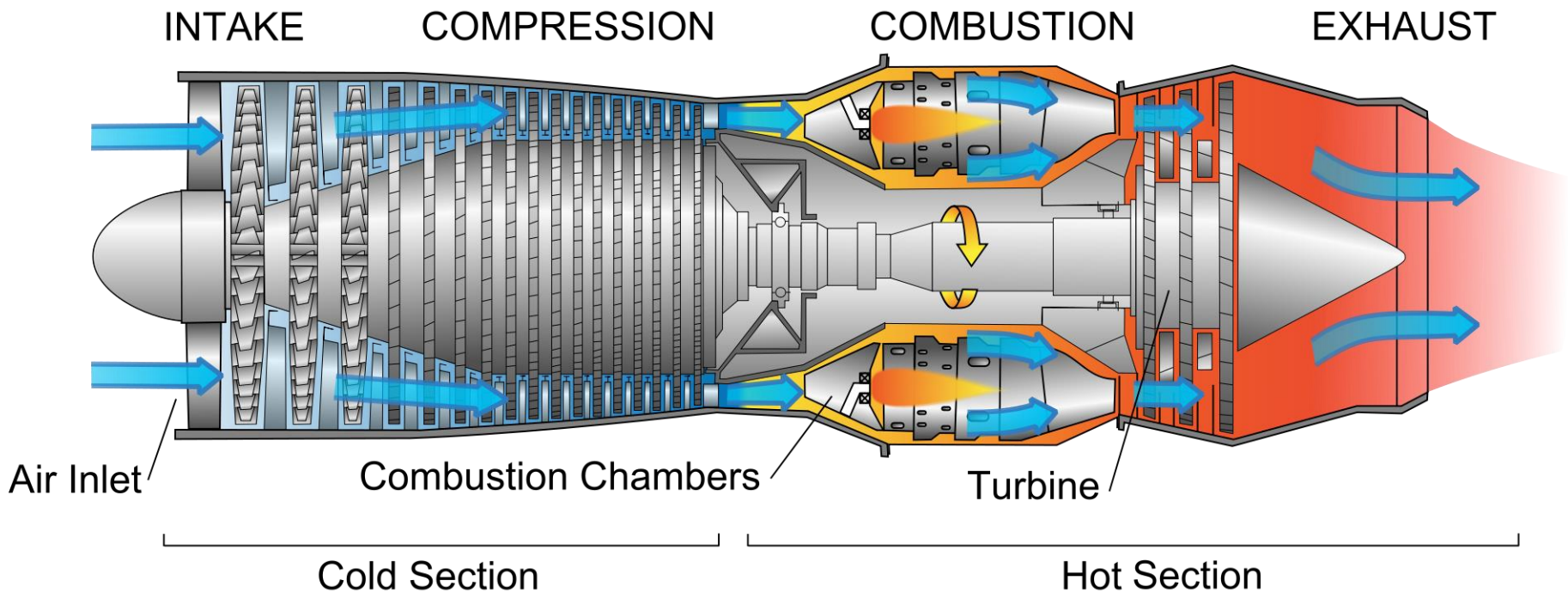
Aerospace Engines: Greenleaf's Comfort Zone



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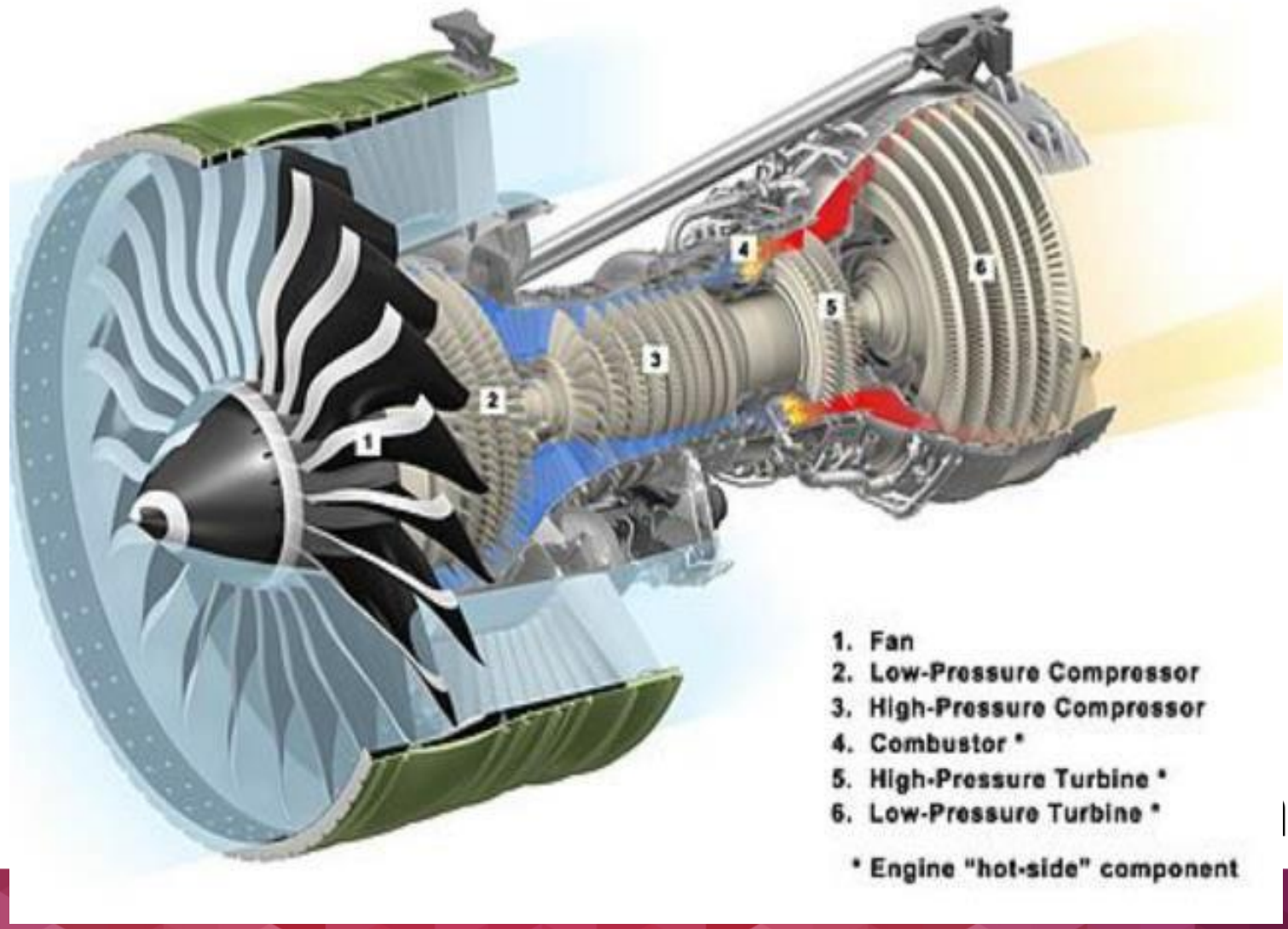
Aerospace Engines: Greenleaf's Comfort Zone



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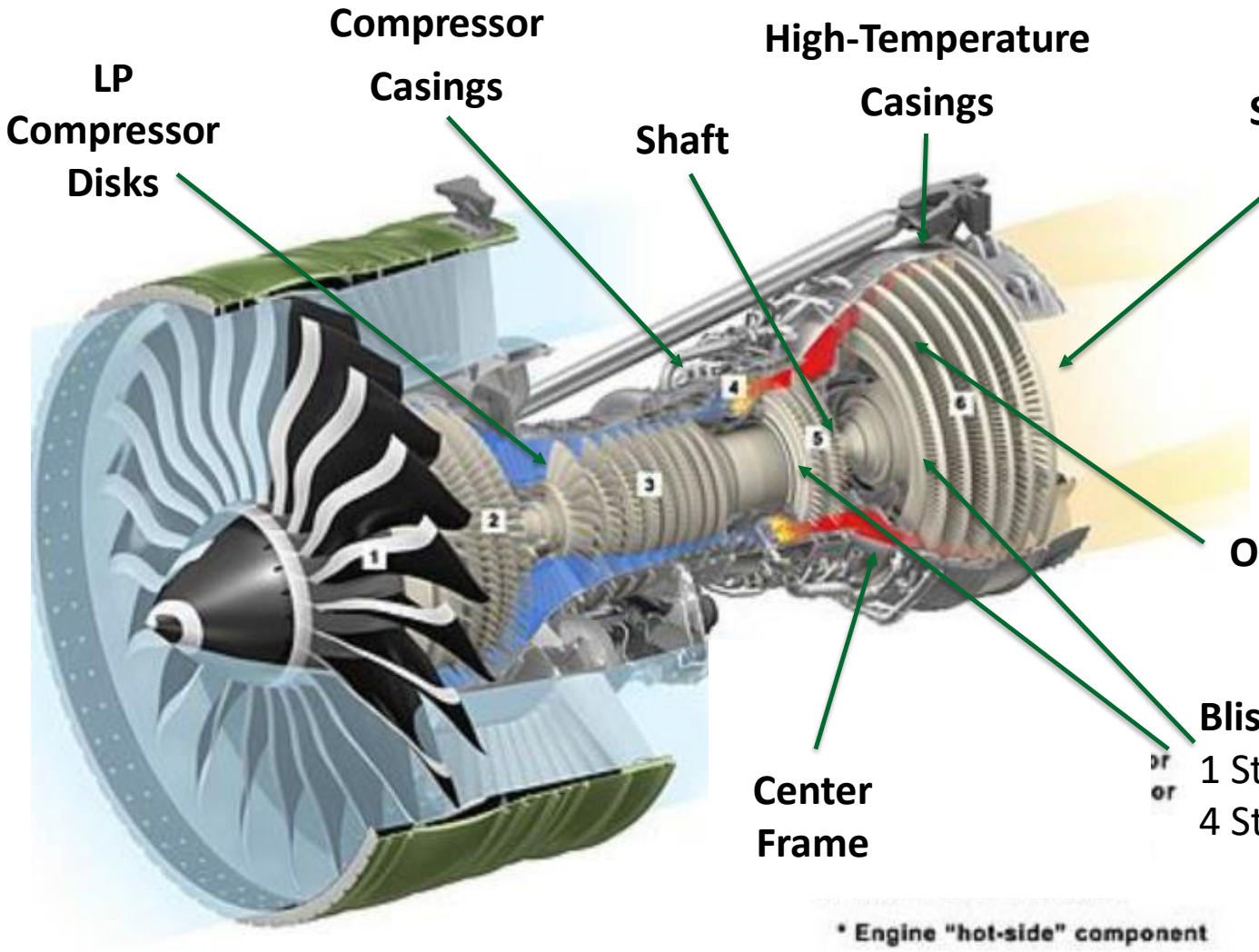
Aerospace Engines: Greenleaf's Comfort Zone



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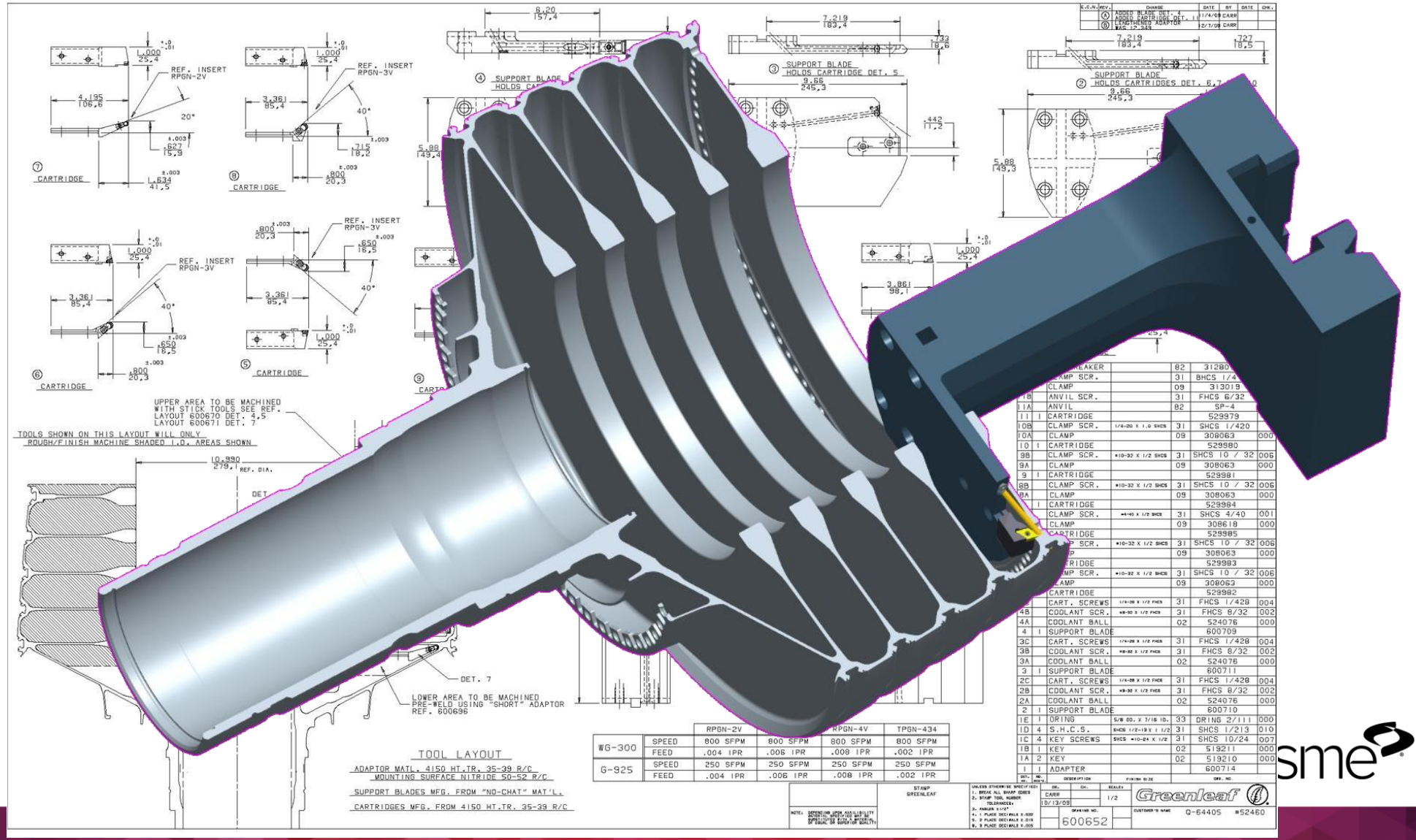
Tool Layouts

Tungsten Heavy-Metal Tooling



		RPGN-2V		RPGN-4V	TPGN-434
WG-300	SPEED	800 SFPM	800 SFPM	800 SFPM	800 SFPM
	FEED	.004 IPR	.006 IPR	.008 IPR	.002 IPR
G-925	SPEED	250 SFPM	250 SFPM	250 SFPM	250 SFPM
	FEED	.004 IPR	.006 IPR	.008 IPR	.002 IPR

		CLAMP		09	313019
1B	1	ANVIL SCR.		31	FHCS 6/32
1A	1	ANVIL		82	SP-4
11	1	CARTRIDGE			529979
10B	1	CLAMP SCR.	1/4-20 X 1.0 SHCS	31	SHCS 1/420
10A	1	CLAMP		09	308063 000
10	1	CARTRIDGE			529980
9B	1	CLAMP SCR.	#10-32 X 1/2 SHCS	31	SHCS 10 / 32 006
9A	1	CLAMP		09	308063 000
9	1	CARTRIDGE			529981
8B	1	CLAMP SCR.	#10-32 X 1/2 SHCS	31	SHCS 10 / 32 006
8A	1	CLAMP		09	308063 000
	1	CARTRIDGE			529984
		CLAMP SCR.	#4-40 X 1/2 SHCS	31	SHCS 4/40 001
		CLAMP		09	308618 000
		CARTRIDGE			529985
		SCR.	#10-32 X 1/2 SHCS	31	SHCS 10 / 32 006
				09	308063 000
		RIDGE			529983
		MP SCR.	#10-32 X 1/2 SHCS	31	SHCS 10 / 32 006
		LAMP		09	308063 000
		CARTRIDGE			529982
		CART. SCREWS	1/4-28 X 1/2 FHCS	31	FHCS 1/428 004
4B		COOLANT SCR.	#8-32 X 1/2 FHCS	31	FHCS 8/32 002
4A		COOLANT BALL		02	524076 000
4	1	SUPPORT BLADE			600709
3C		CART. SCREWS	1/4-28 X 1/2 FHCS	31	FHCS 1/428 004
3B		COOLANT SCR.	#8-32 X 1/2 FHCS	31	FHCS 8/32 002
3A		COOLANT BALL		02	524076 000
3	1	SUPPORT BLADE			600711
2C		CART. SCREWS	1/4-28 X 1/2 FHCS	31	FHCS 1/428 004
2B		COOLANT SCR.	#8-32 X 1/2 FHCS	31	FHCS 8/32 002
2A		COOLANT BALL		02	524076 000
2	1	SUPPORT BLADE			600710
1E	1	ORING	S/B ID. X 7/16 ID.	33	ORING 2/111 000
1D	4	S.H.C.S.	SHCS 1/2-13 X 1 1/2	31	SHCS 1/213 010
1C	4	KEY SCREWS	SHCS #10-24 X 1/2	31	SHCS 10/24 007
1B	1	KEY		02	519211 000
1A	2	KEY		02	519210 000
1	1	ADAPTER			600714

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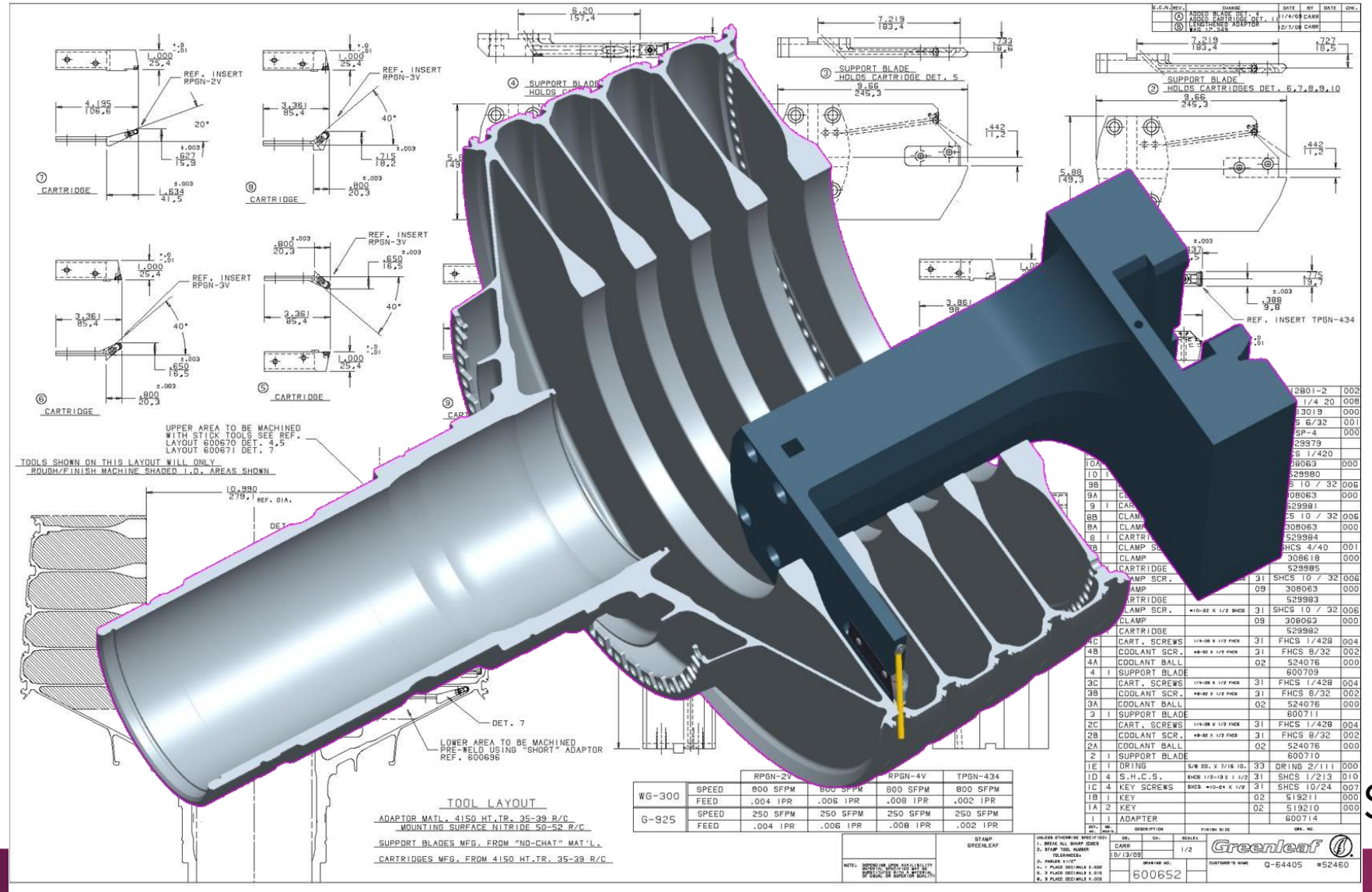
Tool Layouts

Tungsten Heavy-Metal Tooling



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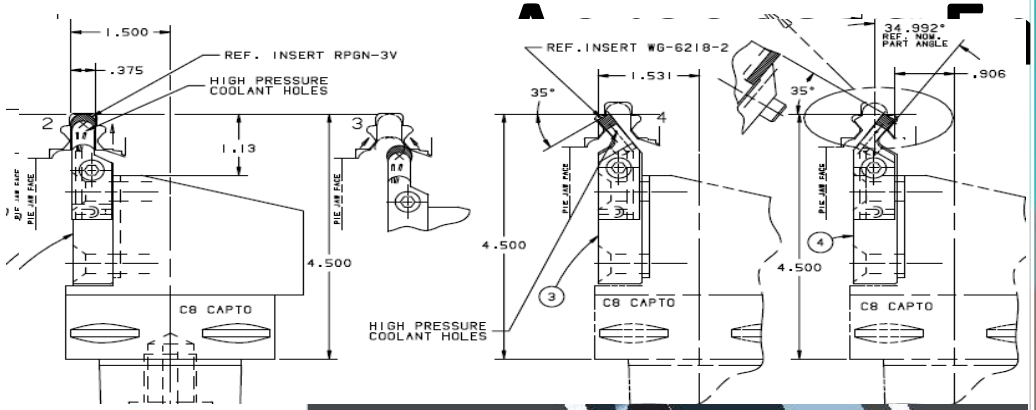
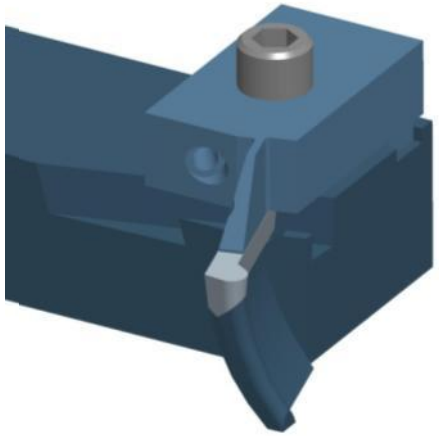
High- and Mid-Pressure Coolant





NEW custom design
using high pressure
are being developed

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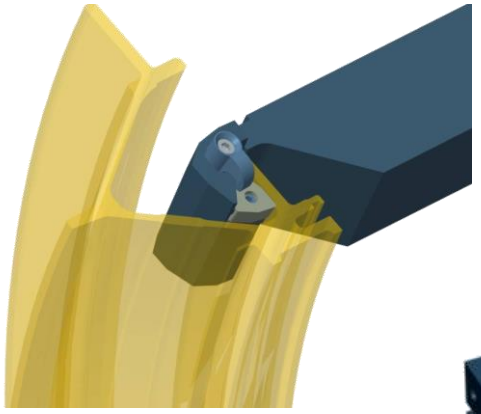
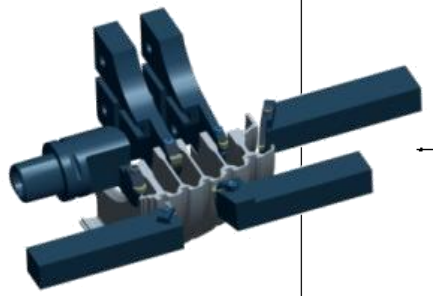
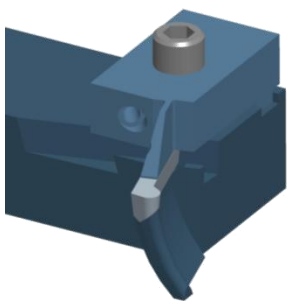
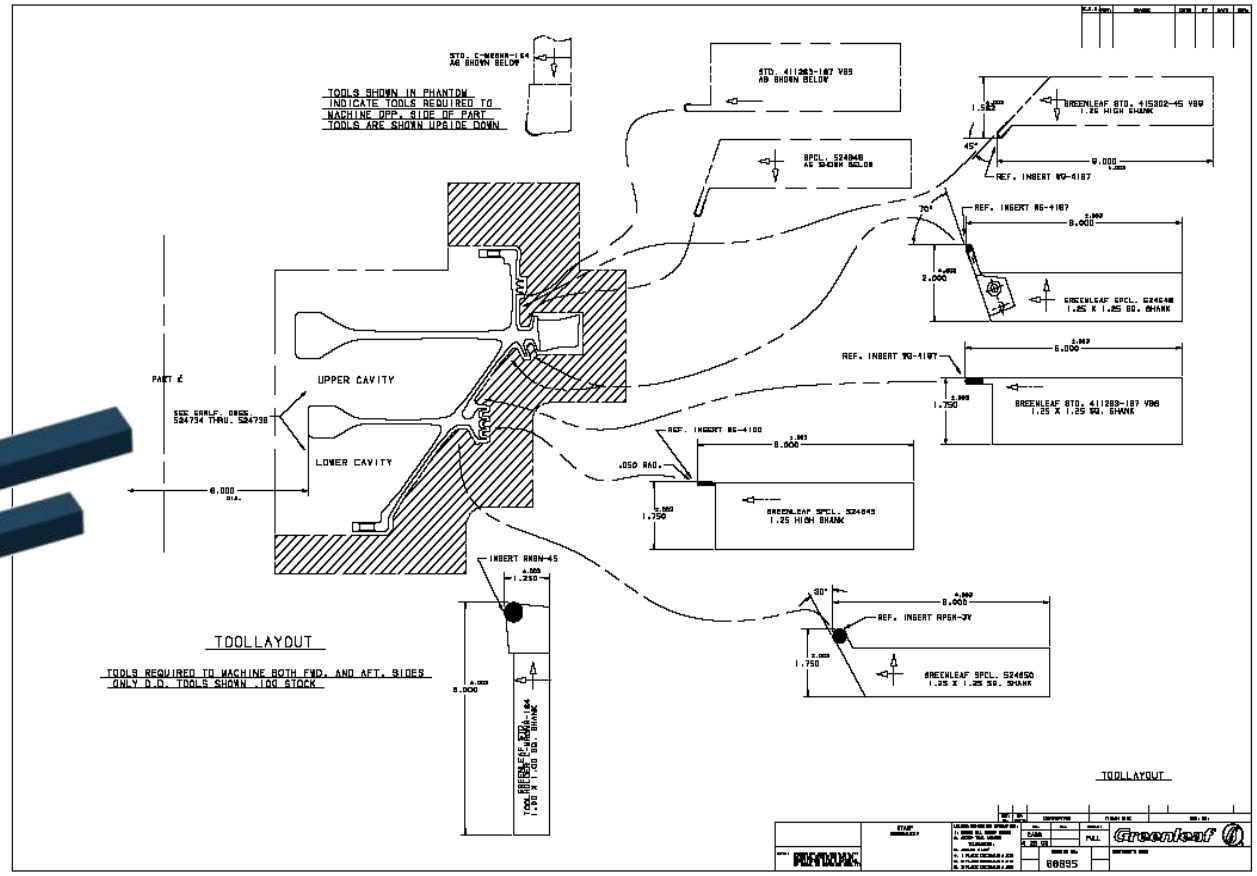
Aerospace Engineering









While Greenleaf has a full line of standard cutting tools, we have also custom designed and manufactured thousands of special inserts and tools for aerospace and power generation parts.

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Priority Components:
Low Pressure Compressor Section

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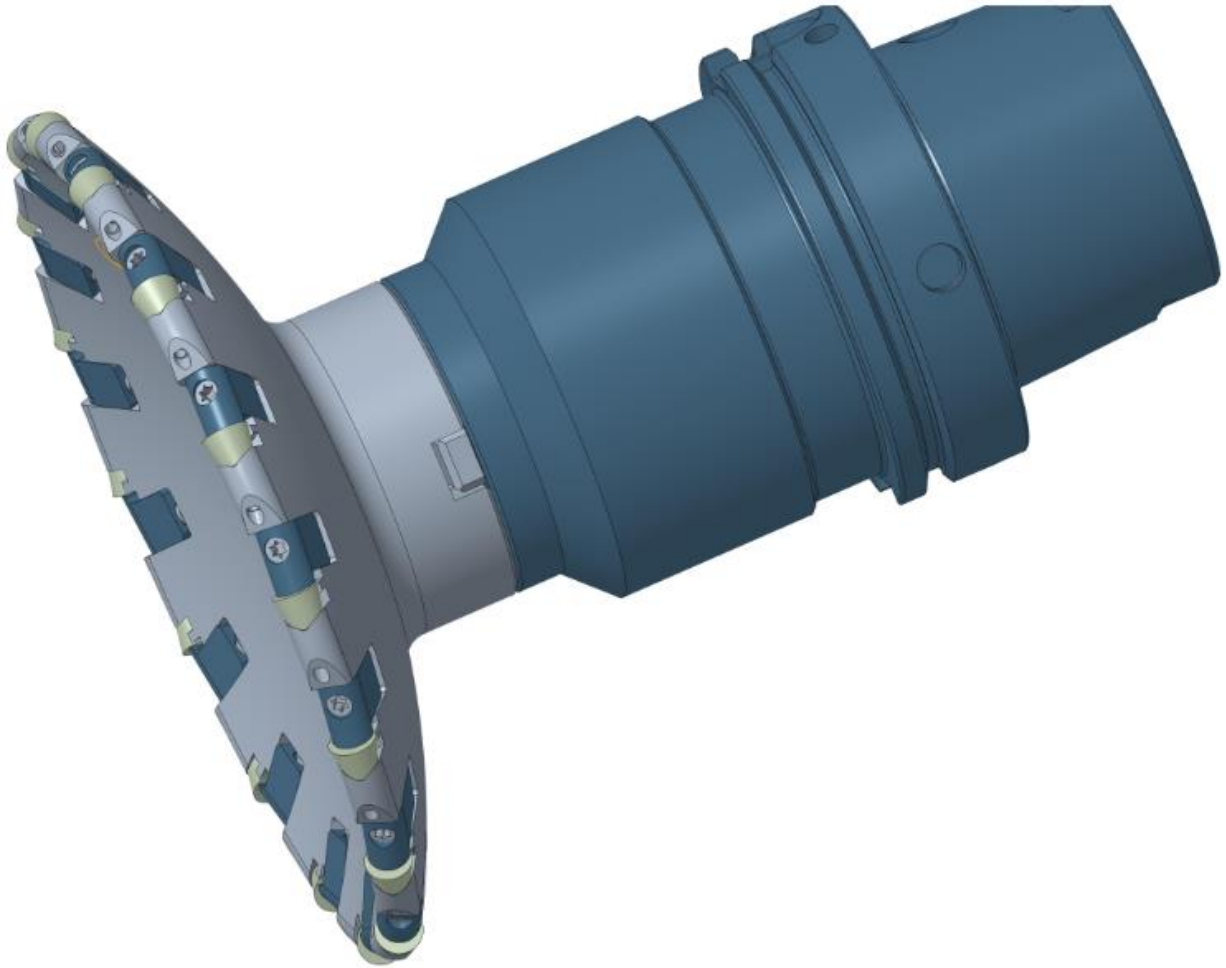
Rough Milling Blisk Slots



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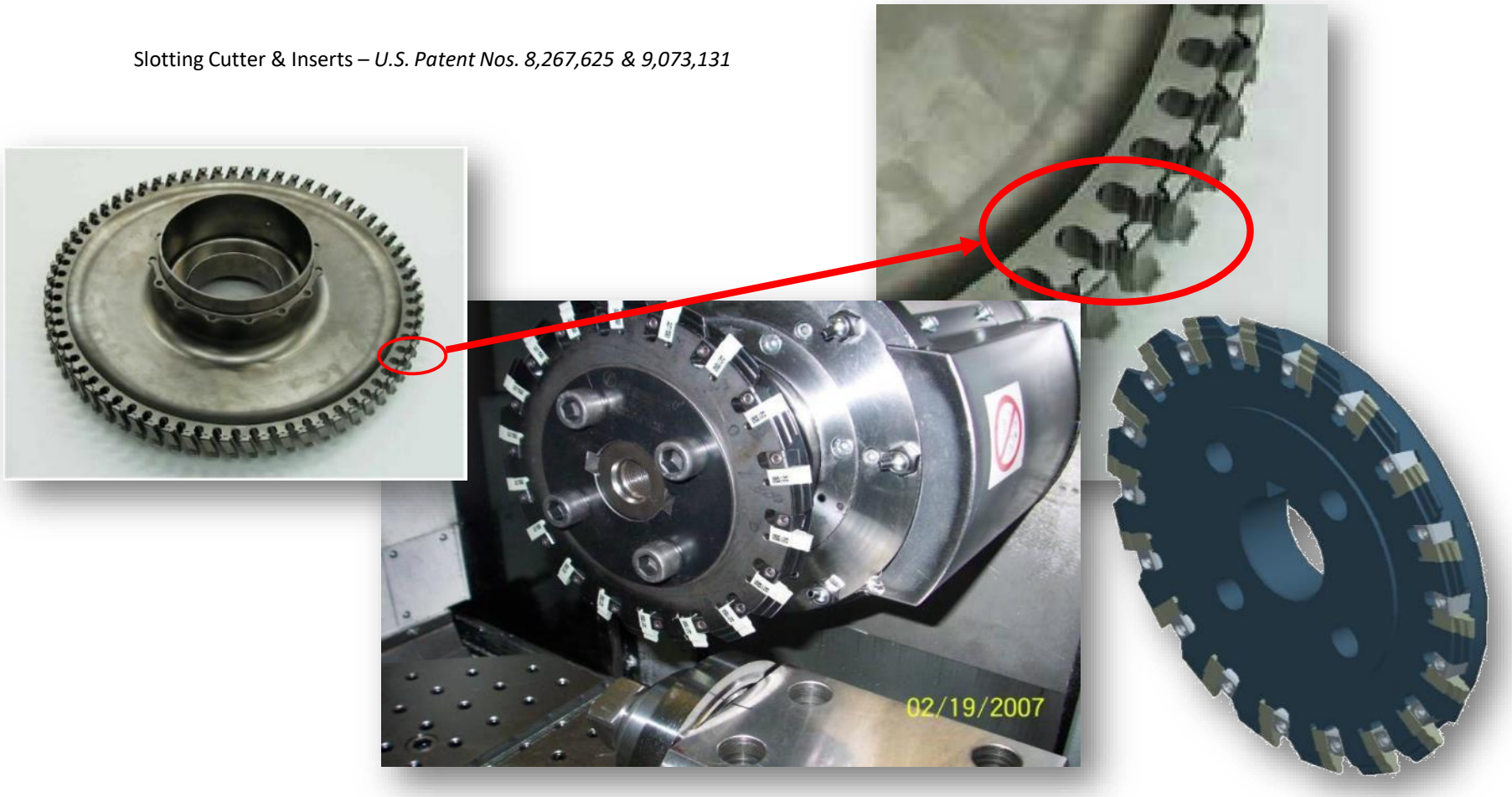
Rough Milling Turbine Disk Slots

Slotting Cutter & Inserts – *U.S. Patent Nos. 8,267,625 & 9,073,131*



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Rough Milling Turbine Disk Slots

Material:
Rene 95, 48-50 HRc

Speed: 2874 SFM (876 m/min)
Feed: 53 IPM (1346 mm)
Chip Load: 0.0024 (0,06mm)

Part thickness: 1.13” (28,7mm)
Time to feed: 1.3 seconds

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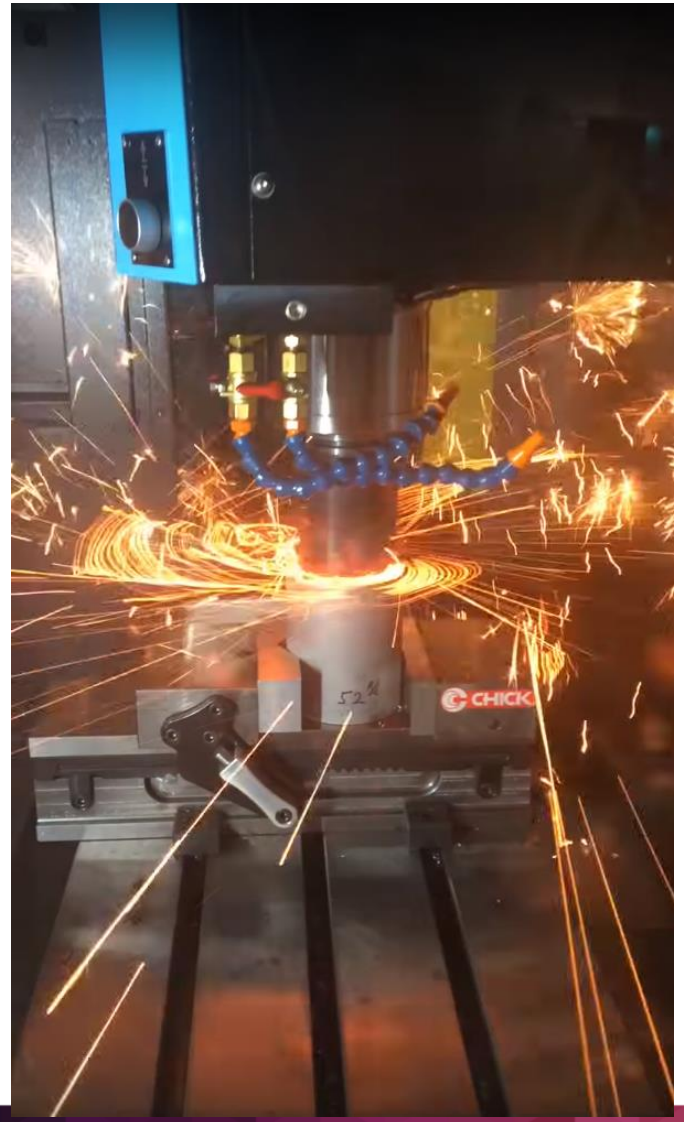
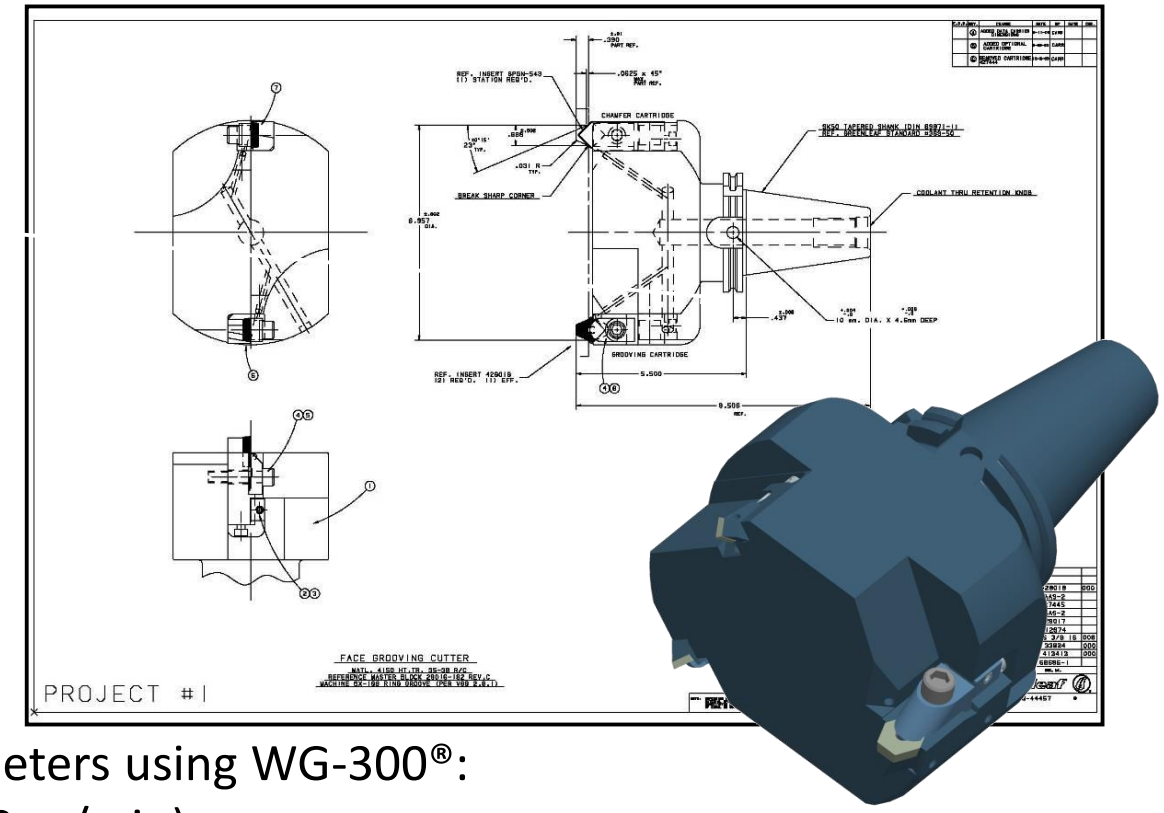
Overview of the Ring Max™ System



One chamfer insert

One grooving insert

BX-169 Groove
6.957” (171.71mm)
cutting diameter



New machining parameters using WG-300®:
Speed: 1,600 SFM (488 m/min)
Feed: 0.0012 IPR (0,03 mm/rev)

28 second cut time!

Concept sold to many companies around the world.

Finishes groove in 1 plunge with 1 edge!

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Technical Ceramics

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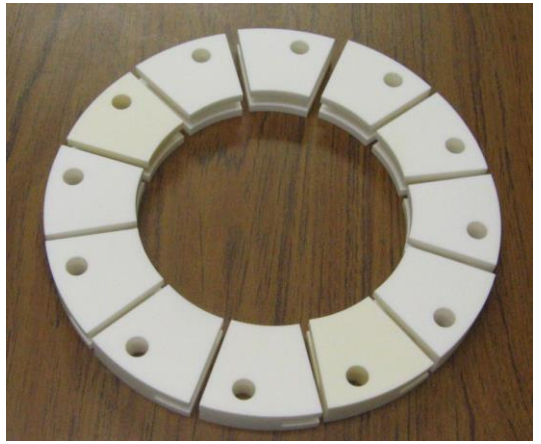
Technical Ceramics

- Cutting tools
- Metal forming
- Extrusion dies
- Can tooling
- Valves and seals
- Pumps
- Bearings
- Fluid flow control

- Electronics
- Microwave absorbers
- Semiconductor components
- Wear components
- Medical components
- Implants
- Battery dies
- Weld rolls



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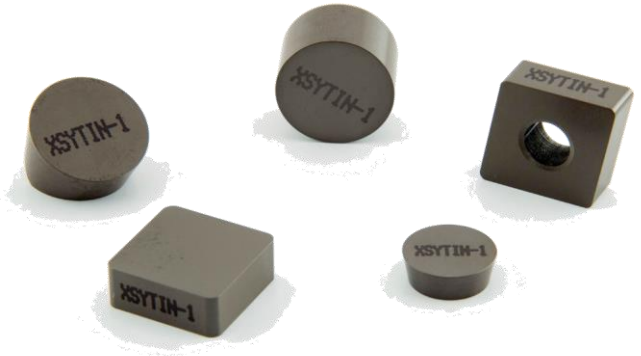
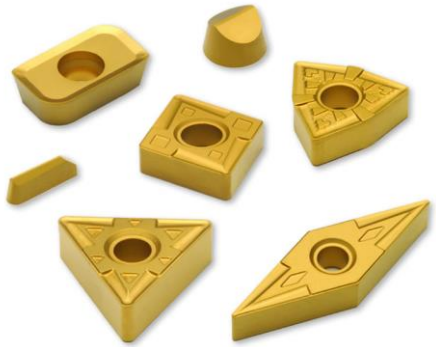


Greenleaf®
Tooling Solutions



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