Composite Machining

For decades, the aircraft industry has utilized composite materials in multiple applications, including flight surfaces and some internal cabin parts. Unfortunately, these materials are unique to each design in their fiber layering techniques, resins, and curing processes, which creates great challenges to consistency in manufacturing and assembly.

Composite materials are bonded together to form complex structural sub-assemblies that must be either assembled together or attached to other structural components, such as aluminum or titanium. This presents a unique set of challenges that requires radical new technologies.

One of the newest materials using carbon fiber and resins is called CFRP (Carbon-Fiber Reinforced Polymer). Due to attractive properties, such as weight-to-strength ratio, durability, and extreme corrosion resistance, CFRP is used mostly in primary structure applications like aircraft hull and wings.

Kennametal has years of experience working with material suppliers, machine tool providers, aircraft OEMs, and parts manufacturers. We have invested substantially to better understand how to machine CFRP/CFRP and CFRP/metals combinations. Our research has led us to become a leader in this field and has resulted in many exciting innovations, like our diamond-coated drills and orbital holemaking solutions.

We would like to share some of this knowledge and are pleased to present the following guide to machining composite materials — from understanding their properties to selecting the best technologies.





Characteristics of Composite Materials

Composite materials are generally composed of soft, tough matrix with strong, stiff reinforcements. Fiber-reinforced polymers are the broad class of composites usually targeted.

Fiber Reinforcements

- Carbon fiber/Graphite fiber (high strength or high modulus)
- Glass fibers
- Ceramic fibers
- Polymer fibers (Kevlar, Polyethylene)
- Tungsten fibers

Polymer Matrix

- Epoxy
- Phenolic
- Polyimide
- Polyetheretherketone (PEEK)

- CFRP/carbon-fiber reinforced polymers (particularly epoxy) have gained tremendous importance due to their high strength-to-weight ratio.

Properties Compared to Common Engineering Materials

Material	Tensile Strength (MPa)	Density (g/cm³)
Carbon-fiber epoxy	1,500–3,000	1,5–2,0
Aluminum	600	2,7
Steel	600–1,500	8,0

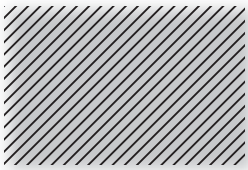
- High strength-to-weight ratio leads to widespread acceptance in structural aerospace components.
- Corrosion resistance and radiolucent properties have made CFRP/carbon-fiber attractive in the medical industry.

Overview • Effect of Attributes on Mechanical and Machining Properties

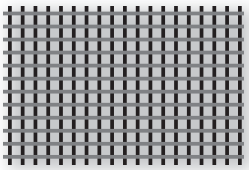
Attribute	Properties	Comments on Machining
Fiber	High strength, high modulus	Abrasiveness of fiber increases with strength
Fiber length	—	Small pieces of fiber delaminate easier and present machining difficulties
Fiber diameter	Increasing diameter decreases tensile strength	While tensile strength reduces with diameter, cutting forces are expected to increase
Matrix	Toughness	—
% Volume of fibers	Improves mechanical properties	Adversely affects machinability
Fiber layout: Unidirectional or fabric weave	Affects the degree of anisotropy of properties	Delamination is usually severe in unidirectional tapes

Types of Fiber Layout

Fiber can be laid in the matrix in several different configurations. Two common examples are:



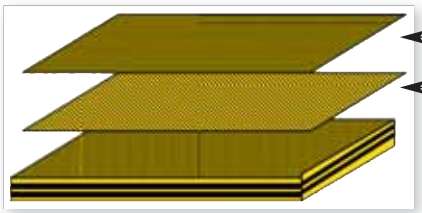
Unidirectional tape



Fabric weave

Methods of Fabrication

- Most common method: Fiber-resin “prepregs” (tape), with one laid over top of another (each tape laid in one or several directions) and one bag/vacuum molded to form a laminate.
- Other methods include bulk resin impregnation, compression molding, filament winding, pultrusion, etc.

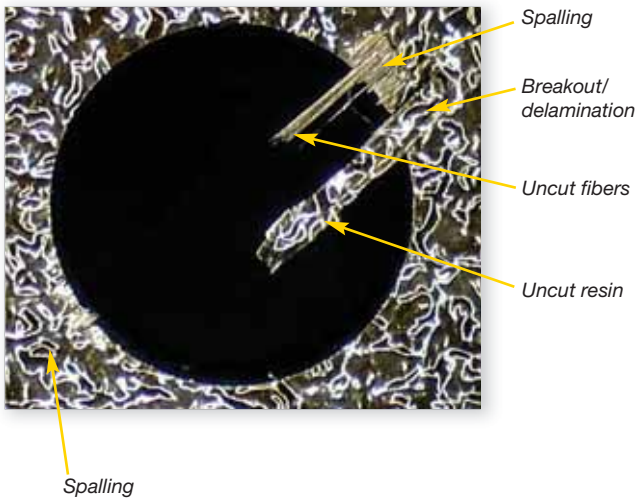


Tape-layered composite with each tape having unidirectional fibers in different directions.

Machining Challenges

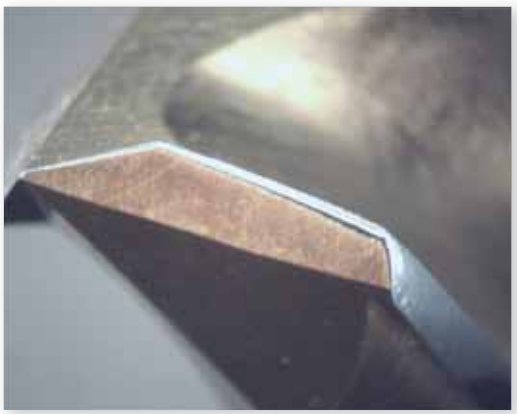
Surface Quality

— Delamination (separation of layers)
— Fiber pullout
— Uncut fibers
— Breakout

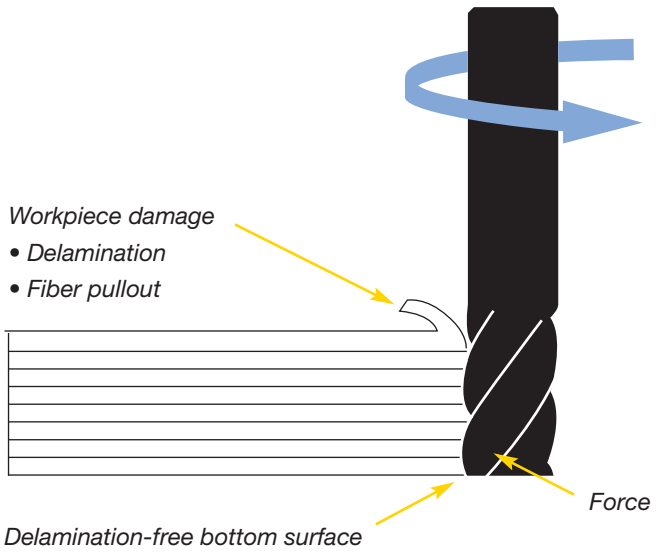


Rapid Tool Wear

Very rapid flank wear due to the abrasive nature of composites.



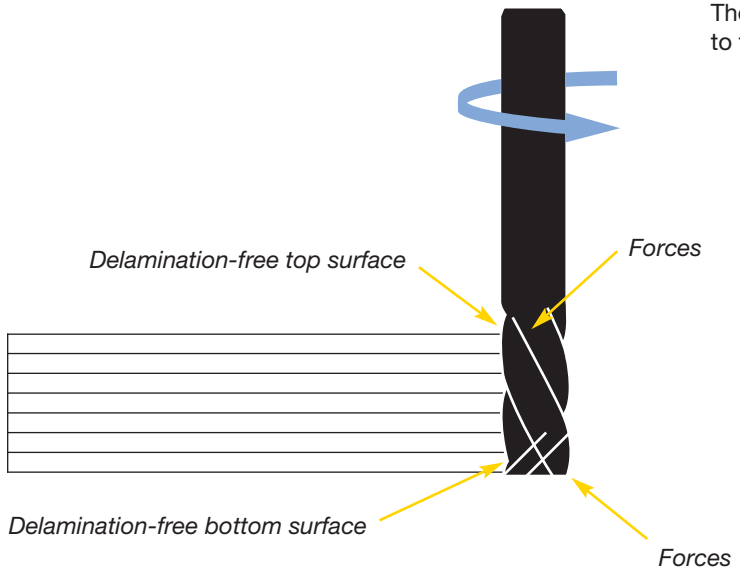
Standard End Milling



Tool Design for Composite Routing

The standard style end mills generate cutting forces in only one direction. With a positive helix cutter, this will have the tendency to lift the workpiece while causing damage to the top edge.

Compression End Milling



The compression-style router generates cutting forces into the top and bottom surfaces of the workpiece. These forces stabilize the cut while eliminating damage to the workpiece edges.



End or Face Milling Mill 1–10™

The Kennametal Mill 1-10 Indexable Milling Series — Face Milling, up to 100% Engagement with PCD Inserts

Ideal for applications utilizing Carbon-Fiber Reinforced Polymer (CFRP).

- Aggressive ramping rates, high RPM capabilities, and a superior surface finish — time after time.
- Varying axial depth of cut, meeting the challenges of a wide range of applications.
- No material breakout or burr formation upon entry or exit of the workpiece.



Choose the Mill 1-10 to mill 90° walls.

Visit **www.kennametal.com** or contact your local Authorized Kennametal Distributor.

www.kennametal.com

KENNAMETAL®

Composite Milling Solutions

Kennametal has the right milling solutions designed for machining difficult CFRP (Carbon-Fiber Reinforced Plastic) and non-ferrous components. Our diamond-coated (Grade KCN05™) products provide excellent tool life while producing smooth finishes with improved edge quality. Our unique geometries are free cutting, reducing heat generation and providing high quality machined surfaces.



Compression-Style Router • Helix 25°

Cutters are designed for high feed rates and producing excellent quality edges on both sides of the material. This up-cut down-cut geometry generates the forces into the workpiece, providing stable cutting conditions.



Burr-Style Routers • Helix 15°

Cutters were originally designed for trimming fiberglass, but also are found to work in CFRP. Excellent temperature control while producing good surface quality.



Down-Cut-Style Router • Helix 25°

Cutters are designed for surface work having great ramping capabilities for producing pockets. Geometry designed to produce down forces to eliminate surface delamination.



Ball-End-Style Routers • Helix 30°

Cutters are designed for slotting and profiling while providing excellent tool life.

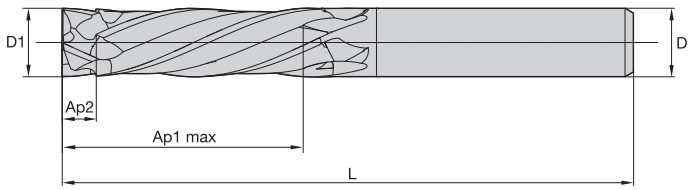
Features

- Kennametal standard
- Through hole capability
- Plain shank
- Through coolant
- Helix angle 25°

Application

- Slotting and side milling
- Ramping capabilities
- Aerospace composites and fiberglass





Compression-Style • KCN05 • Inch

order number	catalog number	D1	D	L	Ap1 max	Ap2	Z
4137446	CCNC0250J3AH	.250	.250	2.500	0.750	.125	3
4137447	CCNC0250J3BH	.250	.250	4.000	1.500	.125	3
4137448	CCNC0375A4AH*	.375	.375	3.250	0.750	.125	4
4137449	CCNC0375A4BH*	.375	.375	4.000	1.500	.125	4
4137279	CCNC0500A4AH*	.500	.500	3.250	0.750	.125	4
4137280	CCNC0500A4BH*	.500	.500	4.000	1.500	.125	4

Compression-Style • KCN05 • Metric

order number	catalog number	D1	D	L	Ap1 max	Ap2	Z
4137452	CCNC0600A3AH	6,00	6,00	63	18	3,2	3
4137453	CCNC0600A3BH	6,00	6,00	100	36	3,2	3
4137281	CCNC1000A4AH*	10,00	10,00	83	18	3,2	4
4137282	CCNC1000A4BH*	10,00	10,00	100	36	3,2	4
4137443	CCNC1200A4AH*	12,00	12,00	83	18	3,2	4
4137444	CCNC1200A4BH*	12,00	12,00	100	36	3,2	4

***** *Through coolant available on 4-flute styles only.*

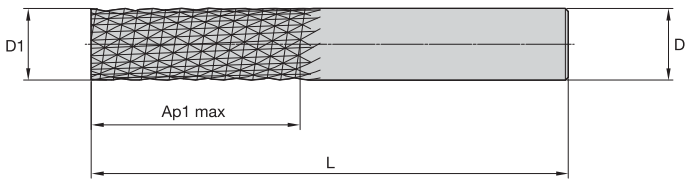
Features

- Kennametal standard
- Plain shank
- Helix angle 15°

Application

- Slotting and side milling
- Ramping capabilities
- Aerospace composites and fiberglass





Burr-Style • KCN05 • Inch

order number	catalog number	D1	D	L	Ap1 max
4137459	CBDB0250JXAS	.250	.250	2.500	.750
4137460	CBDB0250JXBS	.250	.250	4.000	1.500
4137461	CBDB0375JXAS	.375	.375	3.250	.750
4137462	CBDB0375JXBS	.375	.375	4.000	1.500
4137473	CBDB0500JXAS	.500	.500	3.250	.750
4137474	CBDB0500JXBS	.500	.500	4.000	1.500

Burr-Style • K600 • Inch

order number	catalog number	D1	D	L	Ap1 max
4137493	CBDB0250JXAS	.250	.250	2.500	.750
4137481	CBDB0250JXBS	.250	.250	4.000	1.500
4137482	CBDB0375JXAS	.375	.375	3.250	.750
4137483	CBDB0375JXBS	.375	.375	4.000	1.500
4137484	CBDB0500JXAS	.500	.500	3.250	.750
4137485	CBDB0500JXBS	.500	.500	4.000	1.500

Burr-Style • KCN05 • Metric

order number	catalog number	D1	D	L	Ap1 max
4137475	CBDB0600AXAS	6,00	6,00	63	18
4137476	CBDB0600AXBS	6,00	6,00	100	36
4137477	CBDB1000AXAS	10,00	10,00	83	18
4137478	CBDB1000AXBS	10,00	10,00	100	36
4137479	CBDB1200AXAS	12,00	12,00	83	18
4137480	CBDB1200AXBS	12,00	12,00	100	36

Burr-Style • K600 • Metric

order number	catalog number	D1	D	L	Ap1 max
4137486	CBDB0600AXAS	6,00	6,00	63	18
4137487	CBDB0600AXBS	6,00	6,00	100	36
4137488	CBDB1000AXAS	10,00	10,00	83	18
4137489	CBDB1000AXBS	10,00	10,00	100	36
4137490	CBDB1200AXAS	12,00	12,00	83	18
4137491	CBDB1200AXBS	12,00	12,00	100	36

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Additional Burr-styles point styles available upon request:

Non-End Cutting



Drill Point Cutting



End Mill End Cutting



Down-Cut-Style Routers • KCN05

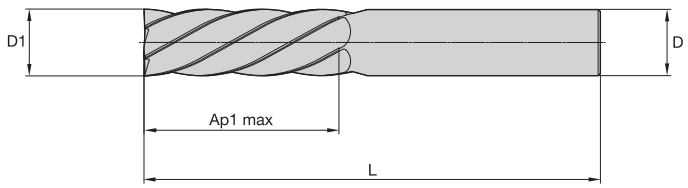
Features

- Kennametal standard
- Plain shank
- Helix angle 25°

Application

- Slotting and side milling
- Ramping capabilities
- Aerospace composites and fiberglass





Down-Cut-Style • KCN05 • Inch

order number	catalog number	D1	D	L	Ap1 max	Z
4137719	CDDC0250J6AH	.250	.250	2.500	.750	6
4137720	CDDC0250J6BH	.250	.250	4.000	1.500	6
4137721	CDDC0375J6AH	.375	.375	3.250	.750	6
4137722	CDDC0375J6BH	.375	.375	4.000	1.500	6
4137733	CDDC0500J6AH	.500	.500	3.250	.750	6
4137734	CDDC0500J6BH	.500	.500	4.000	1.500	6

Down-Cut-Style • KCN05 • Metric

order number	catalog number	D1	D	L	Ap1 max	Z
4137735	CCNC0600A3AH	6,00	6,00	63	18	6
4137736	CDDC0600A6BH	6,00	6,00	100	36	6
4137737	CDDC0375J6AH	10,00	10,00	83	18	6
4137738	CDDC0375J6BH	10,00	10,00	100	36	6
4137739	CDDC0500J6AH	12,00	12,00	83	18	6
4137740	CDDC0500J6BH	12,00	12,00	100	36	6

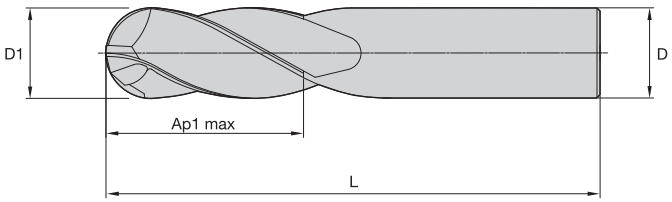
Features

- Kennametal standard
- Plain shank
- Helix angle 30°

Application

- Slotting and side milling
- Aerospace composites and fiberglass





Ball-End-Style • KCN05 • Inch

order number	catalog number	D1	D	L	Ap1 max	Z
4152648	CRBD0375J4AR	.375	.375	3.250	.750	4
4152649	CRBD0500J4AR	.500	.500	3.250	.750	4

Ball-End-Style • KCN05 • Metric

order number	catalog number	D1	D	L	Ap1 max	Z
4152650	CRBD1000A4AR	10,00	10,00	83	18	4
4152651	CRBD1200A4AR	12,00	12,00	83	18	4