Machining carbon fibre materials
Sandvik Coromant - Precorp co-branded solutions for the machining of composites are aimed at giving a wide variation of competitive products and high technical service to our customers.

Sandvik Coromant - Precorp product solutions include carbide and PCD vein technology drills, countersink tools, milling cutters and reamers found in this userguide.
Composites

with a focus on carbon reinforced plastic (CFRP)

- Carbon fibre is being utilized at a greater scale which is increasing the demands on automated production to improve productivity.

- Carbon fiber can be made to become
  - stronger than steel
  - lighter than aluminium and as stiff as titanium

- Carbon fibre is commonly used to reduce the weight of the structural components on aircraft and thereby improving fuel economy, reducing emissions and increasing carrying load.

- As the material develops it gets more difficult to machine:
  - Increasing demand on cutting tool function and tool performance
  - High demands on hole and edge quality
Business environment - carbon fibre

- Composites and especially carbon fibre are being utilized at a greater extent due to its beneficial properties.

- Driving forces taking advantage of composite material properties are cost, environmental and technology benefits. Various industries are now using composites at a greater extent, especially in the aerospace industry.
Composites in modern aircrafts

- Benefits from composite materials are especially important where weight control is critical: Aerospace industry (main focus)
  - New aeroplane models: >50% in weight from composites!

- Materials depending on application.

- Structural application
  - High-Medium Temperature Epoxy

- Interiors
  - Phenolics, HS carbon fibres, Glass fibres, Aramid (Kevlar)

- Non-structural applications:
  - Low resistance resins: polyesters, vinyl/esters

Materials used in 787 body

- Fiberglass
- Aluminum
- Carbon laminate composite
- Carbon sandwich composite

Total materials used
By weight

- Composites 50%
- Other 5%
- Steel 10%
- Titanium 15%
- Aluminum 20%
- By comparison, the 777 uses 12 percent composites and 50 percent aluminum.
MATERIAL AND COMPONENTS INFO
What is composite material?

Definition: engineered materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct on a macroscopic level within the finished structure

- Polymer Matrix Composites (PMC’s) - The most common. Also known as FRP - Fibre Reinforced Polymers - these materials use a polymer-based resin as the matrix, and a variety of fibres such as glass, carbon and aramid as the reinforcement.

- Metal Matrix Composites (MMC’s) - Increasingly found in the automotive industry, the matrix is a metal such as aluminium, the reinforcement fibres such as silicon carbide.

- Ceramic Matrix Composites (CMC’s) - Used in very high temperature environments, these materials use a ceramic as the matrix and reinforce it with short fibres, or whiskers such as silicon carbide and boron nitride.
Fibre properties

- Carbon fibres are characterised by:
  - High strength ➔ difficult to cut
  - High elastic modulus ➔ abrasive

- Can be in unidirectional tapes (UD) or woven fabrics
## Composition: matrices (resins)

- **Epoxy**  
  The high-quality standard  
- **Phenolic**  
  Fire resistant  
- **BMI, cyanate**  
  High temperature  
- **Polyester, Vinylester**  
  Low cost  
- **Thermoplastic (PEEK, PEKK)**  
  High impact resistance
Fiber Orientation and Structure

- **Unidirectional reinforcement (UD), in which maximum strength and stiffness are obtained in the direction of the fiber**
  Properties:
  - highest strength in direction of fiber orientation
  - bad handling features
  - critical machining due to high delamination risk

- **Planar reinforcement, two-dimensional woven fabric**
  Properties:
  - uniform strength in all directions
  - better handling features
  - lower delamination risk
Machining composites

- FRPs are not homogeneous, therefore several aspects affect their machinability:

  - **Continuous Fiber**
    Continuous fiber can be combined with virtually all resins. They are used for weaving, braiding, filament winding applications, uni-directional prepreg tapes and prepreg tow for fiber placement.

  - **Chopped Fiber**
    Chopped fibers are used in compression and injection molding compounds to produce machine parts. The finished products have excellent corrosion, creep and fatigue resistance plus high strength and stiffness characteristics.
Common production methods

- **Prepregs**
  - Fibres and resin come together as a “tacky” fabric
  - Are stacked up by hand

- **Injection**
  - The dry fibres structure is injected with liquid resin
  - Beneficial on large components

- **Automatic placement:**
  - Preimpregnated fibre tapes are placed by a CNC machine
  - Used on large structures
Additional features

- **Glass cloth** -
  UV protection, paint preparation

- **Gelcoat** -
  For surface finish, corrosion protection

- **Lightning strike protection (LSP)** -
  Al or Cu mesh or foil

- **Paint** -
  For aesthetics, corrosion protection, improved aerodynamics

- **Erosion-resistant** -
  neoprene, metal sheets

- **Hybrid cloth** -
  glass, Kevlar: white fibres
How to identify a material

- Visual inspection:
  - can help to identify some features of the material

- Geometry
  - Thickness
  - Application

- Surface
  - Finish
  - Coating

- Resin
  - Colour
  - Appearance

- Fibres
  - Colour
  - Fabric
How to identify a material

- **Geometry can suggest the application**
  - Thick component: primary structure
  - Thin component: interiors (some secondary structure, skin)

  From the application, composition can be predicted

- **Structural application**
  - High-Medium Temperature Epoxy, HS and IM fibres

- **Interiors**
  - Phenolics, HS carbon fibres, Glass fibres, Aramid (Kevlar)

- **Non-structural applications**
  - Low resistance resins: polyesters, vinylesters
Surface features

The variation of surface layers and its properties will effect hole exit and edge quality. Therefore, the geometrical shape of the cutting tool is very important.

- **Glass cloth**
  - a layer of white glassfibre
  - glassfibre layers can possibly generate break out problems such as splintering, although it can help limit the delamination when applied to carbon fibre exit face.

- **Gelcoat**
  - a plastic layer

- **Lightning strike protection (LSP)**
  - Al or Cu mesh or foil
  - lightning strike protection can potentially rip & tear on exit. Rather than being cleaned cut it may leave some uncut copper mesh fibres on the edge of the hole.

- **Paint**

- **Erosion-resistant**
  - neoprene, metal sheets

- **Hybrid cloth (glass, Kevlar)**
  - white fibres embedded in the fabric of the external layer
  - as the layers have specific demands, its very important to choose the correct drill point geometry to improve hole quality.

SANDVIK COROMANT USER'S GUIDE - COMPOSITE SOLUTIONS 17
Resin identification

Typically, most common composite materials, including fiberglass, carbon fiber, and kevlar, include at least two parts, the substrate and the resin. Epoxy resin is almost totally transparent when cured. In the aerospace industry, epoxy is used as a structural matrix material or as a structural glue.

- **Epoxy resins**
  - amber-brownish

- **Thermoplastics**
  - in some cases blue

- **Shiny**
  - Thermosetting (Epoxy)

- **Dull**
  - Thermoplastic, BMI

- Note: that carbon fibre composites can be layered with various type of fibres and glass layers, which can change the appearance.
Fibres identification

Carbon fiber is a material consisting of extremely thin fibres about 0.005–0.010 mm in diameter. The carbon atoms inside the fibres are bonded together in microscopic crystals. There are also other fibres such as glass fibre and aramid fibres.

- **Geometry**
- **Surface**
- **Resin**
- **Fibres**

**Colour**
- Carbon fibres - black
- Glass fibres - white
- Aramid fibres - yellow

**Fabric**
- Unidirectional
- Woven
Stacks

- FRPs are often used in stacks with aluminium or titanium
  - primary structural components
  - floor panels, for fastening

- Typical compositions

CFRP = Carbon fibre reinforced plastic
Ti = Titanium
AL = Aluminium
Health & Safety

- When machining, dust extraction is strongly required
  - For the operator safety
  - For the machine maintenance: carbon dust is electrically conductive: may affect electrical parts and increase wear on spindle
HOLE AND SURFACE QUALITY
Quality issues in CFRP

- Quality is not easily assessed:
  - there is no chip to look at
  - roughness measurement is not significant
  - damage can be not visible (delamination)

- The main indicator is the hole quality
  (and tool conditions)

- Delamination
  - Separation of the bottom layer(s) due to the “thrust” of the drill

- Splintering
  - Residual fibres in the interior of the hole, due to poor cutting action
Hole requirements

CFRP materials

- In composite materials, there can be loss of hole quality long before tool failure
- Therefore, the hole quality determines when the tool needs to be changed or indexed.

- **Typical hole quality demands**
  Typical requirements in the aerospace field:
  - roughness $Ra < 4.8 \, \mu m$
  - delamination $<1 \, mm$ over the diameter
  - no splintering
  - $c_p$ on hole size $>1.6$
Hole requirements

Stacked materials

- **Common demands**
  - Cpk>1,33
  - Ra<3,2 in carbon fibre
  - Ra<1,6 for Aluminium and titanium
  - Hole tolerance: +/- 20 µm to +/- 40 µm
  - No delamination or chipping in the hole exit
  - No chip erosion on the carbon fibre from the metallic stacked material

- **Criteria**
  - Chips evacuation
  - Lubrification through the center

- **Dimension control**
  - Holes are commonly pre-drilled
  - Finish hole size produced with one shot solution if possible
  - Reamer to be used when high demands on finish and size control

Holes are usually measured as diagram shows above every 90 degree
Increasing productivity

• Increased feed and speed will improve productivity, but another more critical factor is hole quality.

• Poor hole quality means the material must be repaired
  - Expensive and time consuming!

• An improvement in hole quality and reduced secondary operations will generate a large gain in productivity!
  - Shorter lead times in the total holemaking operation
  - Eliminated secondary operations possible and will reduce number of machines
  - Expensive components demand secure production process
MACHINING STRATEGIES AND MACHINES
Machining mechanism

• Composites: brittle fracture
  - The fibres are shattered and cut
    - The force needed is much lower
    - The tool toughness can be lower
    - Coolant or lubricant are often not necessary

• On the other hand, fibre hardness is extremely high
  - Highly abrasive

• Resins are weak
  - Interlayer fracture → delamination
  - Elastic mismatch → irregular surface
  - Easy pull-out of fibres → enhanced splintering
Machining strategies

• **CFRP**
  - Quality must be checked both at hole entry and exit: different cutting conditions may be needed.
  - Quality at exit is usually more difficult to achieve due to cutting forces.

• **Stacked materials**
  - Cutting speed on a stacked metallic material, such as titanium, usually needs to be lower than the CFRP.
  - The best cutting condition, for the metallic material, may be too slow for good productivity on the composite material. Therefore variable cutting data can be favourable.

Application example =
Entry layer : CFRP
Mid layer : Al or Ti
Exit layer : CFRP
Peck cycle metallic structure

Begin Cycle

Begin cycle at fast approach level (FAL). Typically 2.5mm above material.

Drill CFRP until the drill point is 0.5mm (0.020") above metallic material.

Beginning peck cycle, 1mm (0.040") for titanium or 3mm (0.115") for aluminium.

Drill retracts fully to FAL between pecks.

Reduction of feed rate on exit reduces risk for delamination and splintering.
Machining strategies

- Top and bottom surface are often different, hole quality can therefore depend on where the drill enters or exits.

- A coating or surface layer on the carbon fibre can change the output completely.
  For example:
  - Lightning Strike Protection (LSP): a fine or coarse copper mesh, allows for higher feed rate
  - Glass-cloth coating: increases the risk of delamination
  - Both materials can be more easily machined by choosing the correct geometry.

Hole quality issue

- Splintering/fraying
- Delamination

Solution

- CoroDrill 854: Point geometry designed to prevent splintering and fraying.
- CoroDrill 856: Designed to reduce delamination problems.
Machine types

CNC and PKM (Parallel Kinematic Machines)

• Facts
  - CNC controlled
  - Stable environment
  - Short tool overhang
  - High and stable RPM (20,000+)
  - Milling, drilling and reaming applications
  - CFRP and stacked materials

• Requirements
  - Cylindrical tools possible in collet or hydraulic chucks
  - Carbide and PCD tooling utilized depending on work piece material

• Common applications:
  - Surface milling
  - Edging
  - Holemaking: drilling and reaming
Machine types

Robots

• **Facts**
  - CNC controlled
  - Flexible solution
  - Short tool overhang
  - Holemaking primary focus
  - CFRP or stacked drilling
  - Machines with end-defector for tool localisation

• **Requirements**
  - Drilling focus
  - Cylindrical tools possible
  - Carbide and PCD tooling

• **Common applications:**
  - Holemaking: drilling, countersinking and reaming
  - Rivetting
Machine types

Power feed machines

• **Facts**
  - Electrical or pneumatic versions
  - Holemaking applications
  - Machinel adapted tooling
  - Low rpm (100-2000)
  - Limited flexibility in cutting data
  - CFRP or stacked drilling

• **Requirements**
  - Drills with threaded back end
  - Cylindrical tools possible in tool adapters
  - Carbide or dedicated PCD tooling

• **Common applications:**
  - Holemaking: drilling, reaming and countersinking.
Machine types

Power feed and hand tools

• Facts
  - Electrical or pneumatic versions
  - Holemaking
  - Machine adapted tooling
  - Low rpm (100-2000)
  - Limited flexibility in cutting data
  - CFRP or stacked drilling

• Requirements
  - Drills with threaded back end
  - Cylindrical tools
  - Carbide or dedicated PCD tooling
APPLICATIONS
Typical component features

- Holemaking
- Edging
- Trimming
- Faces
Application example

Holemaking in CFRP

- **Facts and demands:**
  - Fibre rich carbon fibre - Unidirectional
  - Minimal splintering of fibres
  - Good surface finish and dimensions
  - CNC machining centre

- **Solutions**
  - CoroDrill 854 drill point, diameter 6.35mm
  - N20C diamond coating

- **Cutting data**
  - VC: 150m/min
  - fn: 0.06mm/rev

- **Benefits:**
  - Excellent hole quality with no splintering
  - 800 hole tool life
  - Good hole production economy
Application example

Holemaking in CFRP

- **Facts and demands:**
  - Resin rich material
  - Electrical or pneumatic versions
  - Minimal delamination of fibres
  - Good surface finish and dimensions
  - CNC machining centre

- **Solutions**
  - CoroDrill 856 drill point, diameter 6.35mm
  - N20C diamond coating

- **Cutting data**
  - VC: 130m/min
  - fn: 0.05mm/rev

- **Benefits:**
  - Excellent hole quality, minimal delamination
  - 800 hole tool life
  - Good hole production economy
Application example

Holemaking in CFRP/AL stack

• Facts and demands:
  - Carbon fibre and aluminium stack
  - Minimal splintering of fibres
  - Reduced burr on exit
  - Good surface finish and dimensions
  - Pneumatic power feed machine

• Solutions
  - CoroDrill 854 drill point, diameter 9.525 mm
  - N20C diamond coating

• Cutting data
  
<table>
<thead>
<tr>
<th>Powerfeed</th>
<th>CNC machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>VC: 60 m/min</td>
<td>120 m/min</td>
</tr>
<tr>
<td>Fn: 0.03 mm/rev</td>
<td>0.04 mm/rev</td>
</tr>
</tbody>
</table>

• Benefits:
  - Excellent hole quality: surface and dimension
  - Tool life: 200 holes
Application example

Holemaking in CFRP/Ti stack

• Facts and demands:
  - Carbon fibre and titanium stack
  - Reduced burr on exit
  - Good surface finish and dimensions
  - Pneumatic power feed machine

• Solutions
  - Sandvik Coromant - Precorp drill solution
  - 86PT point geometry diameter 9.525mm
  - CD10 diamond tipped drill

• Cutting data
  - VC: 12m/min
  - fn: 0.05mm/rev

• Benefits:
  - Excellent hole quality with stable dimension
  - Stable manufacturing with 90 hole tool life
Application example

Holemaking: hand drilling in CFRP

• Facts and demands:
  - Carbon fibre
  - Reduced burr on exit
  - Good surface finish and dimensions
  - Hand held pneumatic machine design

• Solutions
  - PHT hand held drill
  - Right hand cut drill point
  - Left hand helix for drill stabilization

• Cutting data
  - VC: 60m/min
  - fn: 0.05mm/rev

• Benefits:
  - Good hole quality
  - Reduced drill grab eliminating splintering and delamination
Application example

Holemaking: hand drilling in CFRP/AL and CFRP/Ti stack

- **Facts and demands:**
  - Carbon fibre and metal stacks
  - Reduced burr on exit
  - Good surface finish and dimensions
  - Hand held pneumatic machine design

- **Solutions**
  - CMD: drilling of CFRP and metallic stacks
  - CMDP: drilling of pre drilled CFRP and metallic stacks

- **Cutting data**
  - **CFRP/Aluminum**
    - VC: 118m/min
    - fn: 0.05mm/rev
  - **CFRP/Titanium**
    - VC: 20m/min
    - fn: 0.05mm/rev

- **Benefits:**
  - Maintaining hole tolerance
  - Good surface finish and minimal exit burr
Application example

Edging of carbon fibre

- **Facts and demands:**
  - Primary structure carbon fibre
  - High material removal rates
  - Minimal splintering of fibres
  - Good surface finish and dimensions

- **Solutions**
  - CoroMill 390
  - Cutter: R390-032A32-11H
  - Diamond coated inserts (engineered solution)

- **Cutting data**
  - VC: 200m/min
  - Fz: 0.15mm/tooth
Application example

Sturtz milling: profiling of carbon fibre

- **Facts and demands:**
  - Tilting of tool 2-10 degrees
  - High rpm and feed rate
  - Primary structure carbon fibre
  - Hand held pneumatic machine design
  - 2D and 3D feature solutions
  - Good surface finish and dimensions

- **Solutions**
  - CoroMill 390
  - Cutter: R390-032A32-11H
  - CD10 PCD inserts (3mm modified radii)

- **Cutting data**
  - Vf: 1800 mm/min
  - 2mm depth of cut.
  - 5 degree sturtz angle.
  - fz: 0.2mm/tooth

- **Suitable process for large areas of shallow curvature, i.e. many aircraft wing and fuselage components.**
Ball end scanning Vs Sturtz

• 32mm diameter tools used with the same cutting data.

<table>
<thead>
<tr>
<th>Tool</th>
<th>32mm Ball</th>
<th>32mm Sturtz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Speed (M/min)</td>
<td>2011</td>
<td>2011</td>
</tr>
<tr>
<td>RPM</td>
<td>20000</td>
<td>20000</td>
</tr>
<tr>
<td>Feed/ Tooth (mm/min)</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>Table feed (mm/min)</td>
<td>12000</td>
<td>12000</td>
</tr>
<tr>
<td>No of flutes</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Step over (mm)</td>
<td>3.52</td>
<td>11</td>
</tr>
<tr>
<td>Passe / Sq Metre</td>
<td>284</td>
<td>91</td>
</tr>
<tr>
<td>Time for 1 Sq Metre</td>
<td>23.7</td>
<td>7.6</td>
</tr>
</tbody>
</table>

over 3 times faster generating the surface.

• Typical to use smaller ball end tools resulting in even greater productivity when switching to Sturtz techniques.
Application example

Surface machining of carbon fibre

• Facts and demands:
  - Primary structure carbon fibre
  - Minimal splintering of fibres and delamination
  - Good surface finish and dimensions

• Solutions
  - CoroMill Century with PCD inserts
  - Cutter: R590-04C3-11M
  - Inserts: R590-1105H-PS2-NL CD10

• Cutting data
  - Cutting speed: 300m/min
  - Fz: Roughing: 0.16 / Finishing: 0.1mm/tooth
  - Ap: Roughing: 2.5mm / Finishing: 0.5mm
Application example

Edging of carbon fibre

• Facts and demands:
  - Carbon fibre skin
  - Minimal splintering
  - Good surface: Ra value of 1.25 μm

• Solutions
  - CoroMill Plura engineered solutions
  - 1: Diamond coated carbide cutter
  - 2: PCD brazed cutter
  - Cutter diameter 10mm with 2 cutting edges

• Cutting data
  - Speed: 10.000 rpm, table feed: 3200mm/min
  - Fz: Roughing: 0.03 – 0.08mm/tooth
  - Fz: Finishing: 0.02 – 0.04mm/tooth
PRODUCT OFFER
## Product solutions

<table>
<thead>
<tr>
<th>Machine type</th>
<th>Operation</th>
<th>Material</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand drill</td>
<td>Drilling</td>
<td>CFRP</td>
<td>PHT</td>
</tr>
<tr>
<td>Hand drill</td>
<td>Drilling</td>
<td>CFRP/AL/Ti</td>
<td>CMD-P</td>
</tr>
<tr>
<td>Hand drill</td>
<td>Chamfer</td>
<td>CFRP</td>
<td>Countersink</td>
</tr>
<tr>
<td>Power feed</td>
<td>Drilling</td>
<td>CFRP</td>
<td>CD 854, 856, 85</td>
</tr>
<tr>
<td>Power feed</td>
<td>Drilling</td>
<td>CFRP/AL/Ti</td>
<td>86PT</td>
</tr>
<tr>
<td>CNC machine</td>
<td>Drilling</td>
<td>CFRP</td>
<td>CD 854, 855, 856, 85</td>
</tr>
<tr>
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<td>Drilling</td>
<td>CFRP/AL/Ti</td>
<td>86</td>
</tr>
<tr>
<td>CNC machine</td>
<td>Edging</td>
<td>CFRP</td>
<td>Plura PCD/N20C</td>
</tr>
<tr>
<td>CNC machine</td>
<td>Surface machining</td>
<td>CFRP</td>
<td>CM 590/390 PCD</td>
</tr>
</tbody>
</table>
Product solutions

• Standard products
  Holemaking
  - CoroDrill 854 and 856 composite geometries
  Milling
  - CoroMill Century and CoroMill 390

• TailorMade products
  Holemaking
  - CoroDrill 854, 855 and 856 (dimensions, grades)

• Engineered solutions
  Holemaking
  - PCD drills, reamers and countersink tools
  Milling
  - PCD milling cutters
  - Diamond coated milling cutters
## Product offer drilling

**CNC – automated machine**

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Tool Geometries</th>
<th>Tool Grades</th>
</tr>
</thead>
</table>
| **CFRP**      | - Fibre rich material  
                 - Allround geometry  
                 - Resin rich material | CoroDrill 854  
                          CoroDrill 855/85 geometry  
                          CoroDrill 856 | Carbide / PCD  
                          Carbide / PCD  
                          Carbide / PCD |
| **CFRP/Aluminium** | - Carbon fibre stack  
                           - Carbon fibre stack | CoroDrill 854  
                                    86A geometry | Carbide / PCD  
                                    PCD |
| **CFRP/Titanium** | - Carbon fibre stack | 86B geometry | PCD |

*Carbide tools available as uncoated or with N20C, diamond coating.*
## Product offer drilling

**Power feed machine**

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Drill Type</th>
<th>Tool Material</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CFRP</strong></td>
<td>CoroDrill 854</td>
<td>Carbide* / PCD</td>
</tr>
<tr>
<td>- Fibre rich material</td>
<td>CoroDrill 855/85 geometry</td>
<td>Carbide* / PCD</td>
</tr>
<tr>
<td>- Allround geometry</td>
<td>CoroDrill 856</td>
<td>Carbide* / PCD</td>
</tr>
<tr>
<td>- Resin rich material</td>
<td></td>
<td>Carbide* / PCD</td>
</tr>
</tbody>
</table>

| **CFRP/Aluminium/Titanium**       | CoroDrill 854    | Carbide* / PCD    |
| - Carbon fibre stack              | 86PT geometry    | Carbide* / PCD    |
| - Carbon fibre stack              |                  | PCD               |

*Carbide tools available as uncoated or with N20C, diamond coating.
# Product offer drilling

**Hand tool**

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<th>Material</th>
<th>Geometry</th>
<th>Tool Material</th>
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</thead>
<tbody>
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<td>PHT geometry</td>
<td>Carbide*</td>
</tr>
<tr>
<td>- Fibre rich material</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• CFRP/Aluminium/Titanium</td>
<td>CMD geometry</td>
<td>Carbide*</td>
</tr>
<tr>
<td>- Carbon fibre stack</td>
<td>CMDP geometry</td>
<td>Carbide*</td>
</tr>
<tr>
<td>- Carbon fibre stack</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• CFRP/Titanium</td>
<td>Counter sink</td>
<td>PCD</td>
</tr>
<tr>
<td>- Carbon fibre</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Carbide tools available as uncoated or with N20C, diamond coating.
# Product offer edging/slotting

**CNC – automated machine**

<table>
<thead>
<tr>
<th>CFRP</th>
<th>CoroMill Plura</th>
<th>CoroMill Plura - ball nose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon fibre</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon fibre</td>
<td></td>
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</tr>
<tr>
<td>Carbon fibre</td>
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</tbody>
</table>

*Carbide tools available as uncoated or with N20C, diamond coating.*

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*SANDVIK COROMANT USER’S GUIDE - COMPOSITE SOLUTIONS*
# Product Offer Edging/Slotting

CNC – automated machine

<table>
<thead>
<tr>
<th></th>
<th>Type</th>
<th>Machine 1</th>
<th>Machine 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CFRP</strong></td>
<td></td>
<td>CoroMill 590</td>
<td>PCD</td>
</tr>
<tr>
<td>- Carbon fibre</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>CFRP</strong></td>
<td></td>
<td>CoroMill 390</td>
<td>PCD</td>
</tr>
<tr>
<td>- Carbon fibre</td>
<td></td>
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</tbody>
</table>

*Carbide tools available as uncoated or with N20C, diamond coating.*
CoroDrill grades

Grade comparison

- **N20C, Solid Carbide with Diamond coating**
  - Low friction coefficient
  - Stable hole dimensions
  - Cost efficient
  - Not regrindable

- **N30C, Solid Carbide with Diamond like carbon coating**
  - Thin wear resistant coating
  - Limited life, lower tool cost.
  - Regrindable

- **CD10, veined PCD tip**
  - High hardness
  - Long and stable tool life
  - Cost efficient
  - Regrindable

N20C: Available on standard products and as TailorMade

N30C: Available as TailorMade option

CD10: Available as engineered solution
# Geometry selection guidelines

Material usage & curing temperature

CFRP

<table>
<thead>
<tr>
<th>Material</th>
<th>CD 854</th>
<th>CD 855 or 85/85C</th>
<th>CD 856</th>
<th>Cutting conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- (medium-high T epoxy)</td>
<td>0</td>
<td>0</td>
<td>X</td>
<td>MS LF</td>
</tr>
<tr>
<td>- Low temperature Epoxy</td>
<td>0</td>
<td>X</td>
<td>X</td>
<td>MS MF</td>
</tr>
<tr>
<td>- Non structural skin (Epoxy-Phenolic)</td>
<td>0</td>
<td>-</td>
<td>X</td>
<td>MS LF</td>
</tr>
<tr>
<td><strong>Thermoplastic</strong></td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>LS MF</td>
</tr>
<tr>
<td><strong>With glass skin</strong></td>
<td>-</td>
<td></td>
<td>X</td>
<td>MS LF</td>
</tr>
<tr>
<td><strong>With LSP</strong></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>MS HF</td>
</tr>
</tbody>
</table>

X = recommended  
0 = acceptable  
- = not recommended  
MS = medium speed  
LF = low feed  
MF = medium feed  
HF = high feed
Geometry selection guidelines

CFRP stacked material

<table>
<thead>
<tr>
<th>Material</th>
<th>CD 854</th>
<th>86PT* (for power feed and unstable CNC)</th>
<th>CD 856 (for stable CNC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium stack</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Titanium stack</td>
<td>-</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Ti/AL stack</td>
<td>-</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

X = recommended  
0 = acceptable  
- = not recommended
SOLUTION/PROBLEM SOLVING
Cutting data

- **Typically:**
  - speed 60-120 m/min
  - feed rate 0.02-0.15 mm/rev

- PCD allows for higher feed and sometimes speed

- With positive geometries high feed rate must be avoided (>0.1mm/rev)

- Low feed rate reduces delamination, especially at the hole exit

- High speed can melt/damage the resin (especially thermoplastics)

- Diamond coated and PCD drills have a higher thermal conductivity, which results in reduced effects on hole dimension variation.
# Machining strategies

<table>
<thead>
<tr>
<th>Problem</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delamination</td>
<td>• Reduce feed rate</td>
</tr>
<tr>
<td></td>
<td>• Consider a change in geometry</td>
</tr>
<tr>
<td>Splintering</td>
<td>• Consider a more positive geometry</td>
</tr>
<tr>
<td></td>
<td>• Increase speed</td>
</tr>
<tr>
<td></td>
<td>• Increase feed rate</td>
</tr>
<tr>
<td>Poor tool life</td>
<td>• Consider a different grade</td>
</tr>
<tr>
<td></td>
<td>• Consider a less positive geometry</td>
</tr>
<tr>
<td>Poor quality on a coated material</td>
<td>• Consider drilling from the opposite side</td>
</tr>
<tr>
<td>Disparity of quality on entry and exit</td>
<td>• Consider variable feed rate</td>
</tr>
</tbody>
</table>