DuPont™ Vespel® CR Shapes

Machining Guide for Carbon-reinforced Fluoropolymers

Technical Information – July, 2015

DuPont™ Vespel® CR shapes, (plaques, rods, and tubes) are a family of proprietary products which offer superior chemical and creep resistance, particularly at elevated temperatures. Vespel® CR shapes are carbon-reinforced fluoropolymers and have machining characteristics similar to other fluoropolymers. CR Shapes can be machined with standard metalworking equipment to produce tolerances once considered too close for polymer-based materials. This is possible due to the material's inherent mechanical strength, stiffness and dimensional stability at machining temperatures. In most cases, the techniques used in machining metals are directly applicable.

This document is applicable only to Vespel® CR products made from carbon-reinforced fluoropolymers. The speeds and feeds recommended for specific machining operations are given as a starting point based upon our previous experience.

Suggested Tooling

The carbon-fiber reinforcement in Vespel® CR increases tool wear. Therefore, carbide tipped tools, and in cases of long machining runs, poly crystalline diamond (PCD)-tipped tools, are recommended for machining of production quantities. Also, light grinding is an acceptable method of machining contours and/or finished part dimensions.

As in machining all fluoropolymer materials, part temperatures should be maintained below 300 °C (572 °F) to avoid thermal decomposition. This can be accomplished by using the following standard polymer machining guidelines:

- Use coolant while machining or cutting, preferably a water soluble coolant oil.
- If no coolant is used, provide adequate ventilation.
- Machining conditions are accurate when no smoke is generated during machining.
- Allow the product temperature to cool to suitable temperature before handling.

Processing Safety

WARNING! VAPORS CAN BE LIBERATED IF MATERIAL IS OVERHEATED, WHICH MAY BE HAZARDOUS IF INHALED.

Before machining Vespel® CR, read the Material Safety Data Sheet that is shipped with the first product order. Vapors or fumes liberated from overheating, or from smoking tobacco products contaminated with machining dust, may cause flu-like symptoms (chills, fever, sore throat), commonly known as polymer fume fever, that may not occur until several hours after exposure and that typically pass within 36 to 48 hours. Vapors and fumes liberated during machining should be exhausted completely from the work area; avoid contamination of tobacco with machining dust.

Sawing and Drilling

Vespel® CR shapes are easily cut and drilled. Sawing and drilling guidelines typically used for materials like aluminum can be used for machining Vespel® CR. When machining large part quantities, special consideration should be given to tool selection for maximized tool life and cut quality.
For cutting large quantities of material with a band saw, a 6 TPI carbide tipped blade, with a standard saw set @5200 FPM is recommended.

For drilling large quantities of material, a cobalt or carbide tipped drill is recommended to minimize tool wear.

Holding Vespel® CR Shapes
The main precaution in holding Vespel® CR shapes for machining is to prevent any deflection caused by the holding fixture, collet or chuck. Unlike metal, polymer matrix composites will deform if held too tightly.

Vespel® CR-6100 rods and tubes have been marked at one end of the shape with either the words

"chuck end" or with an **"*"** (asterisk symbol). The purpose for the stamp at the end of the shape is intended to identify the chuck end for use in lathe chuck jaws for machining. This also warns users that the chuck end may not meet material consistency and properties described in the DuPont data sheet. DuPont does not recommend use of the 0.5 inches from this marked end due to the potential for less planar fiber orientation. Any use of such material, or alteration to maximize the consumption of the length of the tube or rod via the addition of the chuck end extension (e.g. bonding particle board to the end of the shape) is at the sole discretion of the altering party and DuPont hereby accepts no such liability.

Reliable Holding Methods

- O.D. or I.D. collet: This is the most reliable holding device with sufficient pressure to ensure a good hold.
- Chuck: Pie-Jaws that contact approximately 90% of the O.D. surface are recommended for uniform distribution of holding forces when machining thin walled, tight tolerance parts.

Turning
Vespel® CR can be machined by using standard lathe, chucker or screw techniques. To produce good machining finishes on turned Vespel® CR pieces, follow these recommendations:

- Use carbide tipped tools for work requiring close tolerances.
- Tools with a 5° to 15° rake angle at the front face and a positive (0° to 5°) back rake angle will help remove machining waste.
- Use coolant to minimize thermal effects and maintain dimensional stability.
- Feeds and speeds used for turning aluminum can be used as a guideline for Vespel® CR.

Milling
In general, milling conditions for Vespel® CR are similar to those used for metals. One should exercise the same precautions previously mentioned regarding heat build-up and care in holding.

Recommended Practices

- Avoid over-tightening in fixture to avoid material deflection.
- Use 3 or 4 flute carbide tipped end-mills or fly cutters whenever possible, as they work especially well.
- Cross and down feeds listed below have been demonstrated to produce good results:

Description	Cross Feed (mm / rev)	Down Feed (mm/rev)
Rough Machining	0.102-0.152	0.051-0.102
Finish Machining	0.076-0.127	0.051-0.102

Grinding
Close tolerance and contour machining can be achieved by grinding. A diamond dresser similar to those used in steel finishing provides good results. Best results are obtained by removing small amounts of material using light grinding passes. Again, we recommend using adequate coolant to avoid dimensional instability and thermal decomposition.

Typical operating conditions when using a 12.7 mm wide, 177.8 mm wheel are:	
Table surface velocity	24 m/min
Cross feed	0.508 mm/pass
Down feed	0.013-0.025 mm/pass
Wheel surface speed	914 – 1219 m/min

Measuring / Inspecting Parts
Although the same tools used to measure metal parts can be used to measure Vespel® CR parts, techniques differ because the possibility of deflection is greater with polymer matrix parts under the stress applied during measurement.

- **Micrometer** - When measuring the O.D. of rings (especially thin walled), do not use the micrometer in the usual fashion (twisting the barrel until it feels snug or until the ratchet slips) as this may actually deform the parts, causing an incorrect reading of the tolerance. Pass the parts through the gap, using the micrometer as a "no go" gauge. Use the same procedure for the upper tolerance limit, using the micrometer as a "go" gauge. The part should pass through without any pressure applied. To minimize distortion of thin walled cross-sections, a correctly-sized I.D. plug may be inserted into parts.
- **Plug Gauge** - When measuring hole sizes with a plug gauge, avoid forcing the plug into the hole, as it is entirely possible to force a plug gauge into a hole as much as 0.1016 mm under the plug gauge size, depending on the part design. Generally, plug gauges are better than hole micrometers because of the deformation the micrometers may cause. Air gauges work well for measuring internal diameters.
- **Surface Finish** - Inspect surface finishes using a visual reference. Measurements obtained using a surface profilometer can be erratic due to differences in hardness between polymer matrix and fiber reinforcement.

Machining Tolerance Guidelines
The following table has been assembled as a quick reference guide outlining some typical machining tolerances achievable using Vespel® CR. The data is not meant to represent product limitations.

Feature	Standard	Best (Small)	Best (Large)
ID (Ave.)	± 0.127	± 0.013	± 0.025
OD (Ave.)	± 0.127	± 0.013	± 0.025
Length	± 0.127	± 0.025	± 0.025
Counterbore Diameter	± 0.127	± 0.025	± 0.025
Filet Radius	± 0.254	± 0.127	± 0.127
Chamfer Depth	± 0.127	± 0.051	± 0.051
Counterbore Depth	± 0.127	± 0.051	± 0.051
Countersink Diameter	± 0.254	± 0.064	± 0.064
Concentricity	0.127	0.025	0.051
Roundness	0.254	0.025	0.076
Run-out (Face)	0.127	0.051	0.076
Squareness	0.127	0.051	0.076
Flatness	0.127	0.025	0.076
Angularity	± 5°	± 2°	± 2°
Surf. Finish (Machined)	125 Rq/Ra	63 Rq/Ra	63 Rq/Ra
Surf. Finish (Stamped)	250 Rq/Ra	250 Rq/Ra	250 Rq/Ra
Surf. Finish (Lapped)	32 Rq/Ra	32 Rq/Ra	32 Rq/Ra

Notes: (1) All tolerances are given in mm unless otherwise noted. (2) Small implies O.D. < 101.6 mm, Length < 25.4 mm, and/or wall thick. < 2.54 mm. (3) Surface finishes based upon comparison with visual equivalents.

For Distributors only
Distributors may cut rods, tubes, and plaques to varying lengths, and may cut or slice square plaques into varying thicknesses, lengths, and/or widths. However, under no circumstances shall the distributor alter the diameter of rods or tubes, nor create smaller diameter rods from rods, tubes, or square plaques without the prior written permission from DuPont. In the event a distributor elects to cut or slice product the distributor shall apply Authentic DuPont labels to the resulting non-labeled portion of the product. Please refer to the Distributor Agreement.

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