CNC Router Materials

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Abstract

Choosing materials to work with on a CNC router requires consideration of factors beyond just the desired final part. Different materials are affected in diverse ways by the router, varying by end used and machine settings. The router itself, especially the end used, is affected by the material. It is important to understand the material options available, and to be able to draw predictions from the behavior of known materials when deciding to work with a nonstandard material.

Objectives: The student will be able to

- Identify common materials used in CNC routers
- Anticipate where potential problems with these materials may occur
- Avoid problems by choosing suitable materials for the job and by applying knowledge to select the best router end and settings
- Make predictions about the behavior of different materials

MatEdU core competencies addressed

0D Demonstrate General Technical Competence
1C Demonstrate Laboratory Skills
6A Apply Basic Concepts of Mechanics
7A Illustrate the General Nature of Metals
7B Discuss the General Nature of Plastics
7C Describe the General Nature of Composite Materials
7E Describe the General Nature and Behavior of Ceramics and Glasses
9C Identify Types, Properties and Processing of Aluminum and its Alloys
12A Describe the Properties and Testing Processes for Wood
19A Demonstrate Processes to Promote Quality Management Practices

Key Words: Router, CNC, composite, metal, polymer, material properties, material removal rate

This work is part of a larger project funded by the Advanced Technological Education Program of the National Science Foundation, DUE 140061

Type of activity: Discussion, Presentation, Demo

Time required: One class period without demo

Grade Levels: Secondary and up

Equipment and Supplies needed:

Representative material samples if desired

Personal protective equipment when working with an unenclosed CNC Router must be used for protection from flying chips, airborne particulate, and the dangerous tool end:

- Safety glasses / Eye protection
- Face shield / Face protection
- Facemask or Respirator / Breathing protection
- Long hair securely tied back / Hair protection
- Earplugs or Earmuffs / Hearing protection
- Long sleeves and pant legs / Skin protection
- Closed-toe shoes with good traction / Foot and balance protection
- Never wear gloves or move hands near a running router
- Brush for removing sharp chips from surface / Hand protection

Instructor Background and Notes:

In this module, the word "end" will be used to refer to all router cutting surfaces. In the industry, different types of ends may be referred to as ends, bits, endmills, cutters, or drills (to name a few). Some of these names are more appropriate for certain ends, but for the sake of clarity, all will be referred to collectively as "ends" in this document.

It is important to remember from basic CNC routing that all router ends, from plunge drills to stylized edging bits, depend on the ability to pass the material they have removed out of the space they are operating in. In this way they can be considered to be simultaneously a cutting surface and a particulate pump.

Anything that prevents the removal of the particles also prevents the end from continuing to operate.

The primary cooling mechanism for the end is the removal of material, therefore material that stays in contact with the end for longer also decreases its cutting ability by softening the end with heat and thus increasing its wear rate.

The recommended speeds and removal rates provided by the manufacturers of the router ends for specific materials should always be used.

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Safety Concerns to Watch

There is a significant risk of fire caused by excessive friction with improper clearing of chips or dull cutting surfaces on a router end.

Risk of explosion occurs when high-surface-area particles (dust) produced by a router floating in the air are exposed to ignition sources like electrical motors or hot cutting ends. Ensure that all dust is vacuumed away while cutting and that the area is well-ventilated.

Inhaling dust from some materials can cause respiratory diseases, poisoning, and cancer. Consult and post the MSDS (Material Safety Data Sheet) for the materials you are cutting by consulting your OSHA representative or conducting a search for the MSDS online.

Cutting conductive materials like metals and carbon fiber creates both dust and coarse particles that are capable of settling inside of electronic equipment and causing electrical shorts, electrical fires, and battery explosions. Always use proper ventilation, clean up particles, and have a working fire extinguisher at hand.

Woods

There are many types of wood available to work with on a CNC router, and the variability of their properties should not be underestimated. They vary in hardness, toughness, stiffness, and density, among other properties. All wood, however, is a composite of the natural polymers cellulose and lignin, with some content of sap or resin.

It is important to remember that <u>properties will change with the moisture content of the wood.</u> In general, moisture makes wood softer, more flexible, denser, and more adhesive. Woods used with routers should always be <u>stored in a dry environment and cut when dry</u>.

Not surprisingly, woods across the spectrum of properties are fairly ideal for use in a CNC router. Wood has a low hardness compared to regular steel router ends, so there is little wear on the machine. Wood also has very low ductility, and so the removed wood will fracture into small chips which are easily thrown or vacuumed from the work area, allowing the end to stay relatively cool.

NOTE: Operators should expect to decrease the material removal rates used on denser or tougher woods accordingly.

Composite Laminates and Plywood

When cutting a material with any method, care should first be taken to consider the failure mechanism of the material. In the case of laminated composites (i.e.,

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carbon fiber layup, some fiberglasses, and plywood), the failure mechanism to be aware of is delamination of the layers. This can be tested at any edge of a material by attempting to pry the edge open, and observing the behavior of the crack made:

1. Crack always spreads to the surface by shortest path – Cross-layer failure
2. Crack spreads into the plane of the sheet – Failure by delamination

For the material that fails by delaminating, the edges are likely to shred and buckle vertically during routing. To prevent this result, use of a compression end is recommended.

A compression end combines a downward spiral cutting edge at the top with an upward cutting spiral edge at the bottom. This means that the material being cut has its top and bottom surfaces compressed towards the center during cutting, allowing the material's strength in compression to resist its weakness to crack opening in tension.

Keep in mind that compression ends push removed material out laterally, not upward or downward, so material can only be removed along an exposed edge.

Remember that the compression zone between the two cutting directions on the end must be centered in your material.

- The components of your composite should be considered both jointly and separately.
- If the matrix of the composite is a polymer resin, then apply the considerations appropriate to that type of plastic.
- If the composite contains abrasive fibers or particles, use an appropriately hardened router end and cooling to reduce wear.

Plastics

Foams

Polymer foams are available for CNC routing, and have the advantage of creating no noticeable wear on the end, while allowing complex shapes to be created for custom packaging, aesthetics, test geometry, or for low-risk practice. The defining characteristic of these materials is their low shear strength, allowing them to be cut quickly and easily.

When choosing these materials, if the tensile strength of the foam is even lower than the shear strength, then chunks could be torn away instead of cleanly cut chips. It is also possible for pieces of relatively tough and flexible foam to tear off and wrap around the router end.

For the rare foams with this risk, make sure to use sharp cutting ends at high RPM with aggressive channels, and not abrasive or shallow ends. Stiff foams, however, may be abraded instead of cut to prevent them from deforming.

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Soft Plastics

Soft plastics (like low-density polyethylene) are defined by a relative measure: They are polymers that produce "curls", or very long chips, when cut. This means that they are less hard and likely more ductile. Keep in mind that <u>a softer plastic is also likely to have a lower melting point,</u> and to lose dimensional tolerance by flexing on cuts when hot. Reduce this tendency with a cool ambient temperature, fans, and shallow cuts. A cutting end with fewer flutes or less aggressive channels may reduce the problems caused by jamming with long curls.

Hard Plastics

Hard plastics (like poly methyl-methacrylate) are defined by a relative measure: They produce short chips with broken ends when cut. This means that they are stiffer and may be cut with less aggressively channeled ends, since removing the smaller particles should be easier. <u>However, overheating can still easily be an issue</u>.

Hard plastics deform less in the bulk when overheated, but may melt or degrade right at the cutting surface, causing scorched plastic material to build up on the router end and prevent it from cutting. Reduce this tendency with a cool ambient temperature, fans, and shallow cuts.

Metals

In the vast majority of circumstances, the only metal which should be cut with a router is aluminum. Some high-Si alloys of Al are very hard, and should only be used in mills.

Aluminum will produce long curls when cut with regular ends, which often result in jamming if a large amount of clearance is not available. When aluminum must be cut with little tolerance, a special chipbreaker end should be used. This kind of end, with properties between those of abrasive ends and many-fluted cutting ends, has a "diamond" rhombohedral surface pattern which prevents a single cutting surface from staying in contact with a broad amount of material during an entire cutting revolution, thus breaking material removed into many discrete chips.

<u>Be aware</u> that the hardness and diffusion cooling of a metal is sensitive to the ambient temperature, and so the correct settings for your router may change if

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the temperature in your workspace is not controlled. When heat builds up the end wears out at an accelerated rate due to softening, and the surface of the metal becomes more ductile, which causes "smearing" deformation instead of clean, accurate cuts. Cut relatively slowly and use cooling fans.

In rare cases, metals other than aluminum may be routed.

- Some alloys of brass are soft enough to be routed with extreme care, choose very hard ends and CNC paths specifically designed for that purpose.
- Theoretically, very soft metals like pure copper, gold, or lead can also be routed.
- In the case of a dense, highly malleable material like the soft pure metals, choose aggressive cutting ends with few flutes.

Stone and Ceramic

Very stiff, hard materials with low toughness like sedimentary stone and common ceramic (granite, sandstone, tile) can be routed with hard abrasive ends.

These ends are often made of a metal with embedded diamond particles as the abrasive. For very low toughness tile, a shallow, densely-fluted or chipbreaker end made of HSS or carbide may be appropriate.

Generally, a CNC router is used for these materials when relief detailing or complex edge patterns are needed. Because of the high hardness and low thermal conductivity of stone and ceramic materials, a large amount of heat is created and very little is conducted away by the surface and removed particles. This means that heat buildup on the router end is a major problem. Direct water cooling is recommended.

Summary

This module identified common materials used in CNC routers and described appropriate materials for specific uses; while predicting the behaviors of different materials when inserted into those roles.

Acknowledgements

The author would like to thank the reviewer for his input on practicalities of CNC operation and on his focus on safety concerns.

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