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There are three basic issues that are always a concern when machining using cutting tools. Let's look at these issues and review the most common ways they are addressed.

1. Creation of heat from cutting
2. Removal of heat when cutting
3. Removal of chips

Heat Generation

As the cutting edge of the tool slides across the surface of the work, heat is generated. Lubrication in the form of oil or water can greatly reduce the friction and the subsequent heat. Certain coatings on cutting tools can also reduce friction, although don't assume that any particular coating will work for all cases. Some coatings are mainly for hardening the cutting edge and coatings work differently when cutting steel, aluminum, or other materials.

Heat is also generated by the flow or bending action of metal. Metal gets warm when it is bent and there is a good deal of bending or flow in the creation of a chip. This sort of heating is reduced when the material you cut is rigid. Cast iron is a good example. The chips left from cutting iron are not the curls you'd see from aluminum; they're basically dust generated as the brittle iron is broken up by the cutting tool. The result is far less heat generation when cutting iron than when cutting aluminum.

Removal of Heat and Chips

Dry Cutting

Dry cutting is generally the most limiting method. When cutting dry, the removal of heat is generally limited to heat transmission through the workpiece. Very little heat is carried away by the tool because the heat would have to flow through the spindle bearings. When cutting dry and running large volumetric rates there can be a very significant amount of heat carried away by the chips. In those situations the success of the cut depends on the high rate of metal removal. When the chips are large they will accept a good deal of heat with limited temperature rise. When chips are smaller, the cutting heat is nearly the same but the small mass of the chip results in high temperature. The chip can melt, bond to the tool, and the whole process cascades into a bad situation. The net result is that the process may fail if the operator starts taking lighter cuts, particularly on aluminum. It doesn't see intuitive, that more aggressive cutting keeps the tool cool, but this is often the case when dry cutting.

Pocketing or other operations that allow the chips to fall back into the cutting zone will end up with recutting of chips. This is a very bad situation and leads to rapid tool wear, overheating, and a poor surface finish. An occasional air blast by an operator can help avoid this. Be aware that a continuous air blast can consume a tremendous amount of air. Cutting with a continuous air blast will likely have your air compressor consuming significantly more electricity than your mill.

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Dry cutting can be preferred, sometimes even essential, when using certain types of cutting tools. These are mainly exotic ceramic inserts which suffer from thermal shock with the high frequency heating/cooling cycles experienced with each rotation of spindle. They can run hot and like to stay hot. Always follow the directions provided by your cutting tool manufacturer.

Flood Coolant

A water/oil mix is the most common solution for reducing heat and removing chips. By lubricating the cut, flood coolant is extremely effective in removing heat that is generated by the cutting tool. Flood coolant is also effective in removing chips.

Tormach machines are provided with a flood coolant pump suitable to most common applications. The coolant can be directed via a flexible hose. The flexible hose is part of a system of hoses, nozzles, valves, and fittings. If the geometry of your cut is complex you may find it useful to combine the standard hose with additional coolant plumbing, pouring coolant at various angles, heights, or flow rates.

In certain situations, such as cutting deep pockets or using complex cutting tools, the standard pump may prove insufficient flow. It is possible to substitute more powerful pump, such as Tormach Deluxe Coolant Pump (PN33216) or other fluid pump. A more powerful pump with greater flow and higher pressure can be more effective in clearing chips from deep pockets. A greater volume of flow, in combination with multiple nozzles to flow from all directions, will ensure that coolant envelops the cutter from all directions with no dead spots.

WARNING: Protect the controls. Neither the seal on the electrical cabinet door, nor the electrical controls on the cabinet operator panel are suitable for a direct spray of coolant. The operator must prevent direct spray on the electrical controls. If using a high pressure coolant stream it is possible for the flow to be redirected up and toward the controls by some pocket, corner, clamp, or other feature on the machine. This must be avoided.

WARNING: Access to Emergency Stop must not be inhibited. A more powerful flow of coolant will introduce the potential for a messy shop and encourages operators to shield the machining area. Whether shielding is done via ad-hoc coolant shields, a shower curtain type shield, or a full enclosure around the machining area, access to the Estop must not be restricted. Tormach offers a Remote Estop Kit (PN 30790) and information about Estop wiring (Service Bulletin 22) that will allow the use of additional coolant shielding without reducing accessibility to Estop.

WARNING: Pumps in excess of 1/6 horsepower or 125 watts will degrade the relay contact used to control the pump. This will lead to very short life span of a circuit board inside the machine. For pumps of 125 watts or larger we recommend the addition of the optional External Power Contactor (PN 33044). The External Power Contactor will control devices up to 2 horsepower.

Mist Coolant and Micro Fluid Systems

Misting systems can provide both lubrication and cooling. There is very little liquid needed when cooling is achieved by evaporation instead of through flood of liquid. This method may or may not remove chips, depending on the air flow you use. There are several types of delivery systems.

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Siphon feed mist coolant systems are basic simple devices. These are available a low cost, but are not recommended by Tormach. The incorporate what's known as the Bernoulli Effect, atmospheric pressure pushes down on the surface of the liquid, which pushes the liquid up a tube where it is mixed with the fast-moving air. The liquid is broken into many small particles (atomized) and sprays out into the room. This is the same the same as an old fashion perfume mister or simple paint spray gun.

Siphon systems work, but they use a great deal of air and create an unhealthy shop environment; as the coolant is delivered in a very fine mist, it tends to hang in the air. This method is really more of a fogger than a mister, and it will leave an oily film on everything in the shop (including you and your lungs) if you use it for extended periods of time.

Non-fogging misters are far more desirable. Tormach offers a system called Fog Buster (PN 32682) which uses a very small amount of air and does not atomize the coolant anywhere near as much as a simple siphon system, meaning that the mist particles are larger and do not tend to float in the air. This keeps the shop atmosphere breathable, reduces coolant consumption, and greatly reduces the compressed air usage. Non-fogging misters are not as effective as flood coolant for removing large amounts of metal chips, but there is enough air to keep the tool clean.

Other manufacturers provide micro-mist and micro-drop systems. Micro-mist systems act similar to the Fog Buster. Micro-drop systems are effective for delivering small and measured amounts of cutting fluids or oil. In the triad of heat generation, heat removal, and chip removal, a micro drop system really only works toward reducing heat generation. This may seem like less of a solution but with certain machining processes, like tapping, reducing heat generation is the biggest part of the problem. These are really specialty systems that work best for certain types of operations.

Protection from Coolant

Not everything you can put on your mill is suitable for use with coolant. Each of the mill accessories is slightly different in how they should be treated.

- **Companion Spindles**: An electric companion spindle is a die grinder, spindle motor, or router motor which is parallel mounted to the side of the primary spindle. These have open frame motors and are not suitable for use in the presence of liquids. We strongly recommend against using coolant with these types of devices.
- **Tormach Speeder**: A mechanical high speed spindle, the Speeder uses a labyrinth type seal at the nose of the spindle. The labyrinth will throw off coolant to keep it out of the bearings so it is essential that a flood of coolant is only present when the spindle is turning. Neither the upper bearings of the Speeder nor the interior idler bearings have any coolant seals. Be careful when using coolant in combination with this accessory. We suggest a restrained use of mist coolant as the preferred solution if dry cutting is not effective.
- **Duality Lathe**: The Duality Lathe contains a motor, motor driver, and speed control, none of which are sealed against coolants. We recommend a manually applied mist or an occasional brushed on coolant or lubricant.
- **Rotary Tables**: Tormach offers a variety of motorized rotary tables for integration with the mills. The tables are not sealed against immersion or a direct flow of coolant at the juncture between the rotating table and the body of the device. This is not normally a problem and should not prevent the restrained use of flood or mist coolant. The work will generally be held in a chuck or fixture and several inches from the area where coolant might enter the table. If you restrict coolant to the area where the cutting action is taking place then

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it's easy to keep the back portion of the rotary table dry.

Another factor to consider when using coolant with the rotary table is the nature of the coolant itself. Conventional coolants are mostly water, but also contain oil, anti-corrosion agents, and emulsifying agents to allow the water and oil to mix. Similar to the lower unit of an outboard motor, a small amount of water mixing with the oil in the gearbox is not a serious problem and will not result in corrosion. Your milling machine itself is mainly constructed of exposed iron and steel yet, if treated properly, it will not rust in the presence of coolant.

Do not store your rotary table for a long period of time if it has accumulated a volume of coolant. Eventually the oil/water emulsion will separate and you could have problems. If you suspect coolant inside, just drain out the table and refill with oil.

Mixed Systems and Operator Interaction

Automated application of coolant and other cutting fluids can take a great deal of time to optimize. This sort of work is important when developing a process for volume machining, but short runs or prototype work usually calls for a more casual approach with less planning and more operator involvement.

- Shielding against coolant splash often takes the form of strategically placed temporary shields, either on magnetic bases, clamps, or mounted on fixtures.
- Be observant and have an air gun handy if chips seem to be building up too much.
- Add an M1 stop in your G-code programs where you think you many need some interaction. This is a temporary stop to pause the machine, and will allow you to rearrange the coolant hose, add some tapping fluid, inspect the tool, clear some chips, or anything else that might need some attention.
- Keep a hand mister filled with coolant at the ready.
  SAFETY FIRST! Do not fall prey to the desire to help a cut along by reaching into the cutting zone to clear chips or redirect coolant flow. Cutting tools are expensive but replaceable. Your fingers are irreplaceable.

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