PRECISION DRIVE SYSTEMS

Precision Drive Systems LLC
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HIGH SPEED SPINDLES, TOOLING, & ACCESSORIES FOR MACHINES & ROBOTS

ELECTRIC SPINDLE CARE AND MAINTENANCE

Warm Up
Applying load to a cold spindle will cause premature failure of bearings. Run the spindle at 9,000 rpm for 10 minutes or until the spindle bearing supports reach about 98 degrees F (body temperature). (compressed air cooling should be off during this time) This allows bearings, supports and shaft to reach their designed dimensions. We recommend that warm-up is part of the machine control software.

Cutting
Keep down-feed rates less than 20 in/min for the first 1 mm of cut depth. Ramp to full depth at an angle less than 20 degrees. This minimizes axial force. Above all, avoid "crashes" into the table, fixtures or work.

Tooling – To maintain quality Tools
Keep tools **sharp** to reduce cutting force, heat and to maintain cut quality. Monitor increase in electric current to the spindle to detect loss of tool sharpness. Heat from tools overheats bearings, evaporates essential grease components and lessens bearing life. Maximum outside temperature of bearing supports is **150 degrees F.** Excess heat or dirt will cause tool holders to jam in automatic tool change spindles.
Use only **balanced** tools and tool holders. Rebalance all tools after each sharpening. Vibration from unbalanced tools rapidly destroys bearings. The balance standard for tooling is 1.0 g (ANSI 1940/1).
Replace worn, scratched or deformed tool holders and collets to prevent slip (heat), imbalance and run-out. **SNAP collets into eccentric ring of collet nut – Should be Flush.** Collet life is usually less than 700 hours with normal use. Ensure collets are tightened to the right torque. (ER25 mini-nut 3hp = 29 ft lbs., ER25 E-type nut 5hp = 95 ft.lbs.

Cleaning
Keep spindle body, fans and airways clean for proper cooling. Tool tapers, shafts and collets must be scrupulously clean. Minor contamination of collets causes poor quality cuts from tool misalignment, imbalance and slip. Tool slip can lead operators to over-tighten collets and damage to threads.

Cool Down
Allow cooling system (fan, compressed air or liquid) and bearing pressurization (if fitted) to run for 10 minutes after stopping work. This minimizes condensation and contaminants being drawn back into bearings.

Help
Please call Precision Drive Systems (704) 922-5261 if you have suggestions or need assistance. We will be glad to help and learn from your experience.

APPLICATION

- Engraving or cutting plastic, plywood, or fiberboard up to 0.25” thick, below 500 in/minute feed rate, use spindles around 1.5 to 5 HP up to 40,000 rpm. Their small size and weight also make them highly maneuverable to suit small routers and robots with 5-axis or 3-D carving or trimming capabilities.
- Cutting wood, plastic, or aluminum using straight tools below 0.75” diameter at feed rates around 300 to 600 in/minute use spindles between 5 and 10 HP, 12,000 to 24,000 rpm.
- Heavy-duty demands including large profile tools over 1.0” diameter at high feed rates of 500 to 3,000 inches per minute in high-density materials eg phenolic, hardwood, aluminum, use higher power spindles, 10 to 20 HP from 9,000 to 18,000 rpm.

CUTTING APPLICATION RANGE by MATERIALS

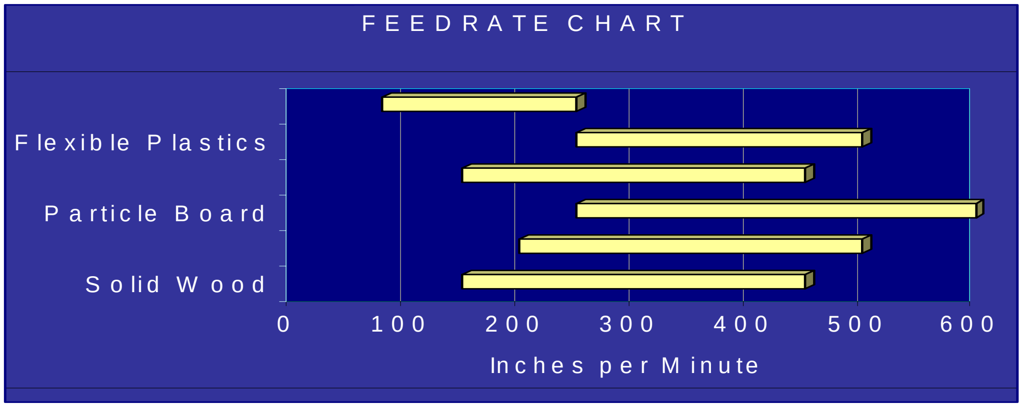
MATERIALS	STOCK	RV	RS	RC	RA
Titanium & Thermal Resistant Alloys	Foil	Not Suitable	Not Suitable	Not Suitable	Not Suitable
Nickle Alloyed Steel	Sheets	Not Suitable	Not Suitable	Not Suitable	Caution
Stainless Steel (300 Series)	Sheets	Not Suitable	Not Suitable	Not Suitable	Caution
Stainless Steel (400 Series)	Sheets	Not Suitable	Not Suitable	Not Suitable	Caution
Carbon Alloyed Steel	Sheets	Not Suitable	Not Suitable	Not Suitable	Caution
Mild Steel	Sheets	Not Suitable	Not Suitable	Caution	Caution
Stone, Marble, & Granite	Block & Slabs	Not Suitable	Not Suitable	Caution	Normal Application Range
Aluminum & Light Alloys	All	Not Suitable	Caution	Normal Application Range	Normal Application Range
Phenolics & Fiberglass	Sheets & Molded	Not Suitable	Caution	Normal Application Range	Normal Application Range
Polycarbonate Rigid Plastic	Sheets	Caution	Caution	Normal Application Range	Normal Application Range
Sold Hardwoods, Oaks, Maple, Ash	All	Caution	Normal Application Range	Normal Application Range	Normal Application Range
Plywood & OSB	Sheets	Normal Application Range	Normal Application Range	Normal Application Range	Normal Application Range
Solid Soft Woods, Pine, Fir, Birch	All	Normal Application Range	Normal Application Range	Normal Application Range	Normal Application Range
Flexible Plastic & PVC	Sheets & Pipes	Normal Application Range	Normal Application Range	Normal Application Range	Normal Application Range
MDF (Medium Density Fiberboard)	Sheets	Normal Application Range	Normal Application Range	Normal Application Range	Normal Application Range
Particle Board	Sheets	Normal Application Range	Normal Application Range	Normal Application Range	Normal Application Range
Rigid Foam (Vitrified Plastic)	Blocks & Molded	Normal Application Range	Normal Application Range	Normal Application Range	Normal Application Range

Trimming, Polishing, and Deburning is suitable for all series RA, RC, and some larger RS models

SPEED

Incorrect spindle speed is a common error in CNC machining. Generally, each material and cut has an ideal tool profile and cutting speed. Larger diameter tools require slower speeds. Spindle speed and feed rate for a given cut must be balanced for best work quality, tool life and spindle life. Speed is controlled by a FREQUENCY INVERTER connected to the electric spindle. All spindles are 3 phase 60 cycle with infinitely variable speed from 0 to max. rpm by correctly programming your frequency inverter drive for each spindle.

FEED RATE



Feed rate must be balanced with spindle speed. Changing one influences the other. Too slow feed rates decrease tool life due to overheating and may leave burn marks on the work. Heat builds in the tool when not enough material is removed to cool the cut interface. Often, determining the best feed rate can only come from trial and error. General feed rate chart for different materials is shown as a starting point. Your cutting tool suppliers can advise cutting data for various materials.

MATERIAL	CHIP LOAD	INCHES
	Minimum	Average
Solid Wood – dense	0.006	0.015
Solid Wood – soft	0.008	0.020
Particle Board	0.010	0.025
MDF	0.008	0.015
Rigid Plastic	0.010	0.020
Flexible Plastic	0.015	0.025
Aluminum	0.002	0.009

FORMULA: $\frac{(\text{Feed Speed }^{IN}/_{MIN} \div \text{RPM})}{\text{Number of Cutting Edges}} = \text{Chip Load}$

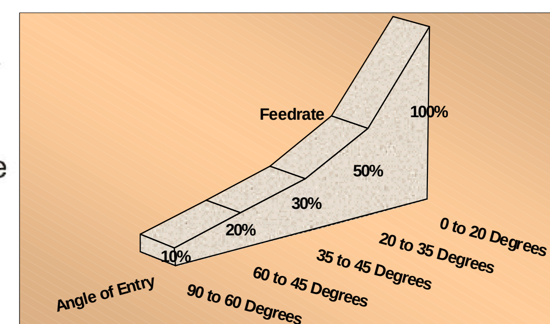
EXAMPLE: $\frac{(360\ ^{IN}/_{MIN} \div 18{,}000\ \text{RPM})}{2\ \text{Cutting Edges}} = 0.010\ _{IN.}\ \text{Chip Load}$

– or –

$= 0.010\ _{IN.}\ \text{Feed/Tooth}$

CUTTING ENTRY ANGLE

Keep down-feed rates <20% for the first 1 mm of depth. Ramp down to full cut depth at an angle less than about 20 degrees. This minimizes axial force. Above all, avoid “crashes” of the spindle into the table, fixtures or work. Your spindle bearings are rated for high radial (side-cutting) loads and low axial (end cutting) loads. We offer other spindles for heavy boring duty for drilling many holes larger than 5/8" diam.



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Be Kind To Your Collets

Collet toolholders are too important to the machining process to use them incorrectly. Follow this simple advice.

The way a collet was designed to be used usually differs from the way that collets are used in practice. This is unfortunate given the critical role that collets play. A collet is the wedge between the toolholder and the cutting tool. This wedge, not the toolholder itself, is what does the actual tool holding. By gripping and positioning the tool, the collet determines both clamping force and runout, and therefore it can also determine the very ability of the process to produce a good part. Improving how well collets are used and cared for is an easy way for the shop to make better use of its tools. This article offers some simple advice.

Perhaps the simplest advice of all relates to the detail that is most often overlooked: cleaning. Collets are coated in a thick, rust-prohibitive oil before they are packed and shipped. This heavy coating may be great at preserving the collet, but it's horrible to leave on during use. The oil reduces gripping force and may also affect runout.

To remove the protective coating, spray collets with denatured alcohol. Usually, the collet can then just be dried with a towel.

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If the collet has been in use for a while, it may have picked up deposits on its tapered areas. The deposits can be the result of dirt in the toolholder, workpiece material getting into the collet cavity, dirty coolant or even the burning of any oil that was left on the collet's surface. When trying to remove one of these deposits, avoid implements that will remove or deform the collet's metal. A simple, lightweight brass brush is probably the best cleaning tool to use. This can be used with or without a cleaning agent. If the deposit can't be removed this way, then it's time to replace the collet. Foreign matter on the collet that is big enough to see will affect how well the collet performs.

Assembling the toolholder incorrectly can leave a gouge around the nose of the collet. The collet can't be fixed once it has been damaged in this way.

Clean the inside of the collet as well. Denatured alcohol also works here. After cleaning, visually inspect the ID for any debris or signs of damage.

Finally, clean the slots. The slots provide the collet with its ability to collapse and hold the tool, so anything inside a slot that gets in the way of this collapse will reduce the clamping force and increase runout. Thoroughly clear the slots of debris using a thin metal or plastic blade.

Signs Of Misuse Or Damage

After cleaning the collets, check them for signs of misuse. This inspection takes only a moment and can usually be done during the toolholder assembly process. Here are the signs to look for:

1. Is there a gouge around the nose of the collet? This means the collet and nut have been assembled incorrectly. The collet can't be fixed once it has been damaged this way.
2. Is there a deep line around the collet gage line? This indicates the tools have not been inserted to the minimum depth required for clamping.
3. Has the collet lost roundness? Either in the hole or around the outside form?
4. Are there burrs on the collet?

If the answer to any of these questions is yes, then replace the collet.

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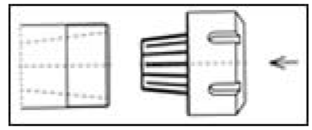
What Can Cause Poor Runout?

After cleaning and visual inspection, proper assembly of the toolholder is the next important step. There are various ways that even a good collet can contribute to poor runout because of some aspect of the toolholder assembly.



To assemble a collet toolholder correctly, put the collet in the nut before the nut is screwed onto the holder. The photo at the beginning of this article also shows correct assembly.

1. *Improper collet-to-nut assembly.* In an incorrect assembly, the collet is placed in the holder first, then the nut is clamped on. In a correct assembly (pictured in the photo at the beginning of this article), the collet goes into the nut first, then the tool is inserted and then the nut is screwed onto the holder. The incorrect assembly can cause runout as high as 0.001 inch.
2. *Not inserting the tool deep enough into the collet.* For every collet there is a rated minimum tool depth. If the tool is clamped in place at a more shallow depth than this, runout will occur as the collet deforms incorrectly.
3. *Over-tightening the nut.* Turning the nut too tightly will also deform the collet in a way that leads to excessive runout.
4. *A bad pull stud.* The pull stud, or retention knob, is screwed in at the end of the toolholder's taper. In a case where this stud or knob was worn, the author has seen a runout of 0.001 inch. Replacing the stud (and making no other change than this) brought runout down to 0.0001 inch.

How To Get Better Runout And Higher Clamping Force At The Same Time

So much for the possible causes of poor runout. What can the user do to actually improve the collet toolholder's performance? Here are some tips:

1. First, clean the assembly—not just the collet, but also the nut and holder.

2. Put a light coat of oil on the outside of the collet. There should be enough oil to coat the collet, but any excess is too much. The purpose is just to reduce any friction between the collet and the toolholder when the collet is pushed into the cavity. A collet that slides more easily lets the nut apply more of its torque toward pushing collet into the holder and closer to the centerline. The result is better runout and higher clamping force.

3. Make sure at least 2/3 of the collet's gripping surface is used. If the tool is not inserted to the collet's minimum depth, then an improper deformation of the collet will lead to runout. Failing to use the correct depth will also fail to capture the amount of shank required for the collet to achieve its intended gripping force.

4. Make sure the tool isn't pushing against a metal backup screw. Some holders provide this screw as an adjustment aid to set the tool length. This screw can get in the way of holding the tool as securely as possible. The problem arises when the collet is free to move slightly during toolholder assembly, but the tool is constrained against this screw. The resulting friction between the moving collet and the stationary tool can reduce the clamping force. Our studies have shown that it can reduce the force by up to 50 percent.

5. Using a tool with a Weldon flat can also bring about a lower clamping force. While a tool with a Weldon flat can indeed be used in a collet, the tool will see less clamping force by up to 30 percent—or just about the same area that the flat takes up along the clamping length.

6. When tightening the nut, torque down on it only to the value specified for this nut. Use a quality torque wrench to observe this limit. Exceeding the torque does not provide more clamping force; it just leads to runout. In fact, the more force is applied, the more the top of the collet wants to twist with the nut. Too much force can actually twist the collet's top, deforming the collet, which will increase runout and reduce clamping force.

7. Avoid this collet-twisting phenomenon by using a nut that reduces the friction between the nut and collet. Different varieties of nuts achieve this low friction using an impregnated coating, a ball bearing or a friction bearing.

Collet toolholders are ineffectively used in many shops. By following all of the advice above, a shop can realize greater holding strength and better precision from its collet toolholders than what many shops are able to achieve.

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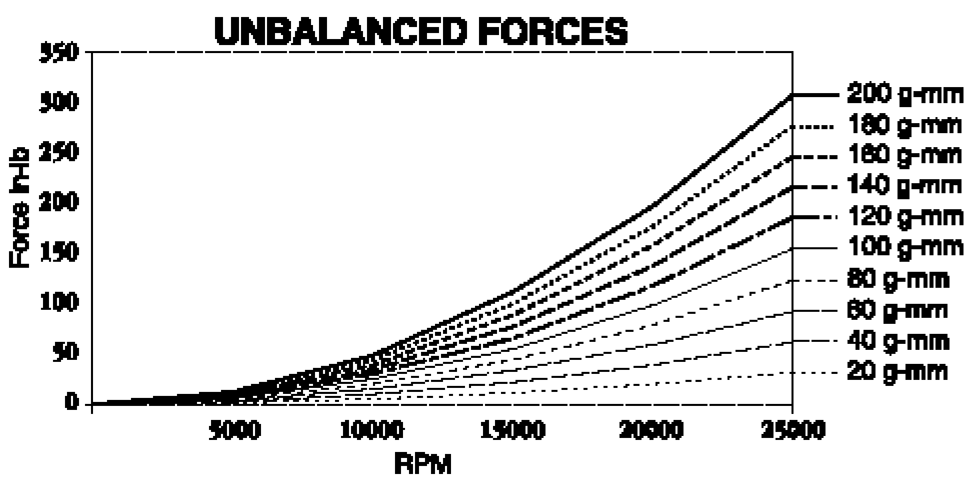
Balanced Tooling Overview

Rotating tool-holders with excess mass on one side can create havoc at speeds of 8000 rpm or higher. Unbalanced centrifugal forces and the vibrations they produce increase with the square of the rotational velocity. **In a tool assembly the force produced by an unbalance at 10,000 rpm is 100 times greater than that produced at 1000 rpm. If equal opposing forces don't offset these rotational forces, performance degrades.** (Taken from Manufacturing engineering online)

With the **advent of higher spindle speeds,** it is necessary to thoroughly understand the need for balanced tooling. When running at low spindle speeds, a slight imbalance of the tooling will not affect your machine tool's spindle. However, **as the rpm increases, this "slight" imbalance becomes "considerable".** As the imbalance increases, the amount of force (centrifugal) generated increases. When this **force becomes high enough, the machine tool's spindle can be damaged.** This imbalance can also cause deflection of the tool and inaccuracies in the machining process. Take a look at the "Unbalanced Forces" chart shown below.

The out-of-balance is measured in g-mm (gram-millimeters) and the resulting force as the rpm increases is measured in in-lb (inch-pounds). There are **many factors** which contribute to an imbalance in the tooling. The first is the balance of the holder itself and its assembled components (holder, retention knob, cap). But there are other factors. These factors include: the condition of the **spindle taper - proper angle,** damage (nicks, fretting, etc.); the condition of the holder's taper (nicks, fretting, etc.) after the holder has been used; the **condition of the tooling -** adjustable boring holders, drill chucks, drills, end mills, boring bars. The **assembly tolerance of the components of the tool holder are a factor of imbalance** when the holder assembly was not balanced by the manufacturer. All of these factors must be at their optimum when doing high speed machining. **Like a chain, a balanced system is only as good as its weakest link**. As the chart shows, balance is critical at the higher rpm's. (Taken from Tooling & Production online)



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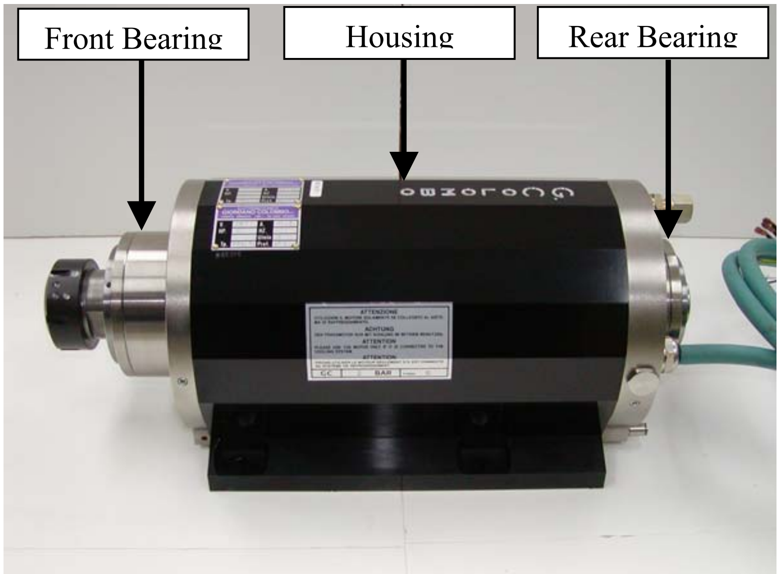
Spindle Operating Temperatures



Spindle Model	Temperature Reading Locations		
	Front Bearing	**Housing**	**Rear Bearing**
RV and RS	Δt 25°C (45°F)	Δt 15°C (59°F)	Δt 25°C (45°F)
RC	Δt 18°C (32°F)	Δt 10°C (50°F)	Δt 18°C (32°F)
RA	Δt 15°C (27°F)	Δt 5°C (9°F)	Δt 15°C (27°F)
Tolerance: +/- 2°C (3.6°F)			

Note: The temperatures shown are the delta above ambient.

A reference for the ambient temperature is standard room temperature or 25°C (77°F).

Recommended spindle chiller settings for RA liquid cooled spindles:

Lower temperature setting at the chiller (output temp): 25°C (77°F)
Upper temperature limit for chiller (input temp): 30°C (86°F)
Tolerance: +/- 2°C (3.6°F)

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Common Spindle Failures

(1) High Radial Load ---- The failure that occurs when the machine feed rate is too fast for the material being cut or when high feeds are pushing a tool with chipped or very dull cutting edges. This is determined by the failure of the first of the front bearing pair.

(2) High Axial Load--- The failure that occurs when the spindle suffers a high axial impact, such as plunging into the material rather than ramping in, or crashing into the work table. This failure is determined by the failure of the second of the front bearing pair.

(3) Unbalanced Tooling --- Failures occur when the tooling used is not properly balanced or exceeds the recommended advised tool dimensions or weight limitations. This failure symptom is observed in the damage to the rear bearing pair.

(4) Actuation While Running --- The failure that occurs when the piston of the pneumatic actuator contacts the drawbar while the spindle is still rotating. This can be caused by operator or programming errors. The failure or adjustment of the proximity sensors to read the position of the drawbar or the sensor or relay that senses shaft motion can also cause it. Another possible cause is contamination of the pneumatic actuator or the exhaust muffler of the actuator. This failure is determined by the witness marks on the end faces of the actuator piston rod and the drawbar nut.

(5) Shorted Winding --- This failure normally occurs when the spindle is not receiving the proper input power. In most cases, it is a result of the parameters of the frequency inverter not corresponding properly to the electrical characteristics of the spindle. This is normally determined by conferring with the customer.

(6) Tool Sticking in Taper --- This is normally due to the transfer of heat caused by an oversized tool. It can also be caused by an improper ejection stroke of the drawbar due to contamination in the actuator or broken springs in the drawbar assembly. This is normally determined by the examination of the drawbar.

(7) Tool slipping in taper --- This is normally due to the transfer of heat from long heavy cuts, resulting in a thermally expanded or contracted tool taper. It can also be caused by an improper ejection stroke of the drawbar due to contamination within the pneumatic actuator or broken springs in the drawbar assembly. This is normally determined by the examination of the drawbar.

(8) Other --- Spindle fails due to unusual circumstances such as shipping damage, electric fan failure, electronic box malfunction, ect.

Crash ---- This is normally caused by operator or programming errors. This failure occurs when the spindle is driven into the worktable or surrounding components on robot applications. This is determined by the physical damage of the shaft taper and spindle body.

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Troubleshooting

Problem	Check
1. Unable to reach maximum rated rpm	Verify VFD parameter settings. Verify input line voltage
2. Spindle vibration or rough edge cut on work piece	Balance Tool holders. Balance cutter. Dull cutter. Tool length exceed maximum allowed.
3. Inadequate Bearing Life. Spindle noise or premature failure	Overheating. Excessive feed rates. Unbalanced tooling. Check warm-up procedure. Check feed rate. Check ramp in angle
4. Spindle Overheating	Verify condition and operation of spindle cooling system. (e.g. compressed air supply set properly, electric fan operating, shaft fan operating, chiller operating). Check incoming voltage. Check VFD for proper settings to match spindle.
5. Cutter stalls in cut	Reduce depth of cut. Dull cutters
6. Tool holder sticking in spindle taper	Verify the actuator is functioning. Verify adequate air pressure to the actuator. Check tool ejection (2.67-3.05mm ISO & 0.5 HSK). Check cleanliness of spindle taper and tool holders. Check for proper pull stud. Note: Always remove tool holders from spindle before shutting machine down.
7. Tool holders loose	Check taper (visual) for fretting. HSK requires regular cleaning to maintain proper clamping force. Check for worn tool holders. Check for worn taper. Check for proper pull stud.
8. Popping sound during tool change	Check for contamination in air line
9. (Automatic Tool Change)One of the most common failures is actuation while running.	Check all adjustments and signals of sensors. “ Use of sensors is required for valid guarantee.
10. Cutter dropping out	Check collet nut threads for damage or wear, possible over tightening of collet nuts.
11. Cutters break	Check cutter length. Possible feedrate too high. Removing too much material in one pass.