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Part fixturing for diamond machining

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Abstract

Successful production of diamond turned components can be extremely dependent on the fixturing used to support the workpiece during the machining operation. Typical fixturing methods include vacuum chucking, air chucking and mechanical clamping. Depending on the type of part to be machined, suggested fixturing methods can vary widely. For example, a part requiring a flycut surface is not subject to the centrifugal forces and balance requirements of a part that must be turned about an axis of rotation. Therefore, in many cases the fixturing required for flycutting may be much simpler than that required for turning. In all cases, there are general guidelines that should be followed to determine the best method of fixturing.

Introduction

To insure the best cutting results in flycutting and turning operations, it is important to closely evaluate some key areas of concern to fixturing. These areas are:

- 1) Upfront engineering
 - a) Workpiece design
 - b) Fixture selection or design
- 2) Workpiece distortion
 - a) Qualification of mounting surfaces
 - b) Mounting techniques
 - c) Centrifugal forces
- 3) Dynamic balance
- 4) Vibration and/or chatter

With the proper attention given to these concerns, we can significantly reduce part inaccuracies due to poor fixturing.

Upfront engineering

One of the easiest ways to insure a successful result, is to understand and allow for the required manufacturing operations at the design stage of the part. Although this is not always possible, it can optimize the cost and labor required to achieve a satisfactory result. For example, a part diameter to thickness ratio of 8:1 or better is desired for most diamond turning. It may also be desirable to incorporate an alignment reference surface into the design of an optical part. This can normally be manufactured during the same set-up used for machining of the optical surface and can eliminate the cost of a tedious alignment procedure during system assembly.

The quantity and type of part to be machined generally determine the type of chucking required. Wherever possible, it is preferable to use a vacuum chuck because of the even distribution of force over the holding area. They are normally made of aluminum so they can be machined in place to accuracies as good or better than the accuracies required on the final part. Depending on the thickness of the part, chucking forces can create enough distortion to cause the part to replicate the surface of the chuck. Due to low sheer strength in vacuum chucking, it is generally recommended for parts with surface mounting area of one square inch or more.

Shaft type parts with length to diameter ratios of 1:1 or more are normally held in precision air chucks. Once again, the aluminum jaws are machined in place to assure sufficient accuracy. Like the vacuum chucks, the clamping force can be adjusted to reduce internal stress on the part.

In some cases, part designs don't lend themselves to vacuum or air chucking. In this event it is normally possible to hold a part for machining by the same method used to hold the part during system assembly. For example, some parts have small pad feet with tapped holes for mounting purposes and these feet can be used to support the part for machining. In these cases, it may also be necessary to add vibration damping materials to the part

due to lack of rigidity during the machining process. Whenever this type of mounting technique is used, it is desirable to bolt the part to an adaptor plate which can then be held by a vacuum chuck.

Workpiece distortion

Distortion can be caused by any one (or a combination) of the following items.

- a) Inaccurate chucking surfaces or part mounting surfaces.
- b) Internal stress from excess clamping force.
- c) Poor mounting techniques.
- d) Centrifugal forces when the part must be rotated for machining (turning applications).

To insure accurate surfaces on the fixtures used for chucking, it has already been mentioned that aluminum chucks are mounted on the machine and then diamond machined in place. Sometimes it is desirable to make a fixture in hardened steel to resist scratching. In this case, the fixture is ground and lapped to the required accuracies then measured and adjusted during mounting to the machine. Again, depending on the thickness, the part mounting surface must also be as accurate as the fixture surface. Many times, it is possible to diamond machine this surface to obtain the accuracy required. If it can not be diamond machined, it must then be qualified by grinding and/or lapping. Final documentation of accuracy on the fixture and part mounting surfaces is normally obtained prior to machining of the optical surface.

Care must also be taken to assure cleanliness during mounting of the part to the fixture. A small particle of dirt between these surfaces can create distortion and may also limit proper sealing in a vacuum chuck application. To reduce internal stress on the material structure, clamping forces should be adjusted so they hold the part securely and are safely in excess of the cutting forces. Severe clamping force can mar the mounting surface and cause unwanted stress.

Centrifugal forces can also cause distortion on parts that must be rotated for machining and cannot be fully supported by the mounting surface. For example, a 9 inch diameter, thin wall, concave part that can only be mounted by pad feet at a 3 inch diameter bolt circle, will tend to "flatten out" when it reaches a rotating speed where centrifugal forces exceed the compliance of the wall structure. To correct this condition, it may be possible to reduce cutting speeds and feeds to a level where the part is more stable. If this doesn't work, special potting fixtures may be required to support the entire surface during machining.

Dynamic balance

All rotating parts and fixtures must be dynamically balanced to achieve the best workpiece accuracy. An out of balance condition can create vibration throughout the entire machine and cause poor accuracy as well as damage to the diamond tool. If off-axis parts are not evenly spaced or counterbalanced, they should be statically balanced prior to running the spindle. After static balancing, all new part and fixture combinations should be single plane dynamically balanced at the cutting rpm. This is normally done by changing adjusting screw weights around the periphery of the holding fixture. Wherever possible, fixtures are designed with tapped holes every 15° apart around the periphery to allow for dynamic "trim balancing". Vibration pickups of a portable balancing unit are attached radially on the spindle housing to detect the unbalance motion. The part fixture combination is then balanced to less than 10 microinches amplitude of vibration. Axial vibration can only be corrected by more accurate radial balancing. On some overhung spindle loads, this may be accomplished by dual plane balancing at the part fixture and the rear of the spindle.

Vibration and/or chatter

Apart from improper balancing, vibration and/or chatter can be caused by insufficient clamping force or lack of material stiffness on thin wall parts. Providing the problem is detected, insufficient clamping force can be immediately corrected by adjusting clamping pressure. A problem with material stiffness on unsupported thin wall parts can be much more difficult to correct.

The use of various vibration damping materials adhered to the back of the unsupported surface has proven quite successful. These can be applied by filling honeycomb structures with a liquid type material and allowing time to cure to a solid form, or by adhering a sheet type material to the back of the thin wall surface. Both types can be removed after machining and have significantly reduced vibration and chatter.

Conclusion

Part fixturing plays an important roll in the success of diamond machining and should be reviewed thoroughly prior to the start of a project. A few hours of thought at the beginning of a project can save countless hours of trying to determine a problem and correct for a part that doesn't meet the final accuracy requirements.