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CNC Grinding of Valve Housing Piston Holes

F. A. Ashbaugh

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Allied-Signal Aerospace Company
Kansas City Division

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Prepared by F. A. Ashbaugh

Grinding has traditionally been used for machining operations requiring close dimensional tolerances and good surface finishes. With the development of new CNC grinders, tools, and machining techniques, it is now practical to machine critical features such as are found on valve housing piston holes.

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SUMMARY

The critical inside features of the piston holes on valve housings present a variety of manufacturing problems that account for numerous rejects, rework, scrapped parts, and deviations. Some of these problems involve surface finish, close tolerances, heavy burrs (especially at the cross holes), nicks, scratches, small inside radii, waviness, chatter, bellmouth, and workmanship.

Heavy burrs at the cross holes contribute to many of these defects. In removing the burrs at the cross holes, the inside surfaces are damaged (nicks and scratches), which requires additional rework and polishing. Polishing has been a necessary traveler operation to obtain the required surface finish and to remove any marks from deburring, rework, or gaging.

Grinding has traditionally been used for machining operations requiring close dimensional tolerances and better surface finishes than can be obtained from other metal removal techniques. Using a grinding process for the last metal removal operation, the close tolerances and surface finishes can be easily held while eliminating the adverse conditions from the current metal removal processes.

Pre-machined test parts were sent to a machine tool supplier to have the critical inside features of a typical piston bore finish machined using an internal CNC grinder equipped with high-frequency spindles. The piston bore and sealing angle were ground using a standard 120-grit silicon carbide wheel. The wafer step was machined using a solid carbide tool designed and built at Allied-Signal Inc., Kansas City Division (KCD).

Six consecutive parts were machined for evaluation. The repeatability on all six parts was within print requirements. The inside corner radii was less than 0.002 in. and the surface finish was 8.2 arithmetical average or better as defined by ANSI B46.1, Surface Texture.

Machining parts by this grinding process would eliminate bellmouth, chatter, waviness, and traveler polishing operations. It would produce a superior surface finish, small inside radii, and small easily removable burrs. It would also hold tolerances closer and significantly reduce scrap, rework, rejects, and deviations.

DISCUSSION

SCOPE AND PURPOSE

The purpose of this project was to evaluate the capability of producing the critical inside surfaces of valve housing piston holes using CNC inside diameter (ID) grinders. Grinding of these features is expected to reduce deburring time, polishing, rework, scrap, and deviations. Superior, uniform sealing angle surfaces and a more consistent process are also expected.

PRIOR WORK

Grinding has traditionally been the preferred machining method when close tolerances and good surface finishes are required. However, at KCD, piston holes have normally been produced using form reamers. This process does not produce consistent surface finishes. It has the potential to cause bellmouthing, and it always creates heavy burrs at the cross holes. ID grinding has never been employed in the valve manufacturing process at KCD.

ACTIVITY

For this evaluation, CNC ID grinders equipped with high-frequency spindles were selected. The benefits expected were good uniform surface finish, little or no burrs at the cross holes, close tolerances, and very small inside radii. The grinding process would also eliminate polishing operations, nicks, scratches, waviness, chatter, and bellmouthing, while reducing scrap, rework, deviations, and rejects for workmanship.

Grinding of piston holes has been contemplated at KCD for several years. Recent developments in CNC grinders, high-frequency spindles, and tooling now make grinding of small holes, forms, and shapes very practical.

Quotes were obtained from several qualified tool manufacturers to grind the critical inside surfaces of a typical piston hole. Several test parts were sent to the low bidder to be machined. Although this bidder was the lowest for machining the test parts, they are one of the top three machine tool builders that offer a machine that can meet KCD requirements.

The test parts were machined on a CNC high precision internal grinding machine using a 120,000-rpm high-frequency spindle. The test parts were scrapped production parts that were finished

to print requirements on the piston holes. These tests removed approximately 0.002 in. on all surfaces. This evaluation did not require that print dimensions be held. The primary concerns were repeatability of diameters, depths, and surface finish. In actual production, parts will be completely finished except approximately 0.002 in. of material will be left on all critical surfaces of the piston hole.

The CNC grinder will be the last metal removal operation. This operation will replace two current operations to finish size the piston bore, the sealing angle, and the wafer step. It will also eliminate the polishing operation now required on all valves. The piston bore and sealing angle surface were ground using a standard 120-grit silicon carbide wheel. The wafer step was machined using a special solid carbide tool designed and built at KCD (Figure 1). Experience at KCD has proven that a solid carbide tool running at very high speeds and taking very light cuts will show minimal wear after extended use. This tool is the key to holding a 0.002-in. maximum inside radius.

Figure 1. Solid Carbide Grinding Tool

After initial setup, six consecutive test parts were machined to evaluate the machine for capability and repeatability. These parts were machined without changing tools or tool settings. The following list shows the print requirements and the test results.

PRINT REQUIREMENTS

TEST RESULTS

1. A surface finish of 32, free of nicks, scratches, and lay lines.	An 8.2 arithmetical average (worst condition) with uniform surface texture.
2. Diameters within ± 0.0004 in.	0.0005-in. total indicator reading (TIR) total variation on all parts.
3. Depth to shoulders within ± 0.0004 in.	0.0004-in. TIR total variation on all parts.
4. Depths to angles (over balls) within ± 0.008 in.	Maximum variation of 0.0028 in. checking over three sets of balls; 0.230-, 0.238-, and 0.240-in. diameters.
5. Some bellmouthing allowable.	Bellmouthing eliminated.
6. No physically detectable raised metal on the sealing angle surface.	Burrs at the cross holes were virtually eliminated.
7. 0.002-in. maximum radius.	0.001-in. radius.

All of the features are within the print requirements. It is expected that with proper machine adjustments (feeds, speeds, and programming) and tooling that some of these features could be improved.

Most of the variation in the diameters of the piston holes (ref. requirement 2) was caused by taper. Adjusting the head stock to eliminate the taper would result in a total diameter variation of 0.0002 in.

ACCOMPLISHMENTS

As anticipated, the CNC internal grinder can produce the critical features of valve housing piston holes. The surface finish and texture is much better than required. This is a natural result of the grinding process. The inside corner radius of the wafer step is less than 0.002 in. This is a result of the KCD in-house design of a solid carbide cutting tool. By using a solid carbide tool to finish the wafer step, the inside corner radius was held to 0.001 in. Using a CNC internal grinder as the last metal removal operation to finish the critical features of valve piston holes will eliminate heavy burrs, waviness, chatter, and bellmouthing. Nicks and scratches will be eliminated as a result of improved machining processes. Only marks from inspection and other secondary operations will appear. Flowtime, scrap, rework, and SXR's will be reduced.

FUTURE WORK

Production is planned for a quantity of development parts that can be tested and evaluated by the customer.

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