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EXTRUDE HONE DEBURRING

Technological Spinoff Report

L. K. Gillespie and
L. H. Luebbert, Jr., Project Leaders

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EXTRUDE HONE DEBURRING

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Prepared by L. K. Gillespie and L. H. Luebbert, Jr., D/822

The success of miniature timers, switches, or actuators depends on burr-free sharp-edged parts. Traditional methods of making these nearly perfect edges on miniature parts are costly and often cannot produce the precision or repeatability specified on some of these piecepart designs. Extrude hone deburring can produce burr-free edges with a 0.002 inch (50.8 μm) maximum edge break. Preliminary test results show that the extrude hone deburring process can decrease deburring times by 50 percent or more on many parts.

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SUMMARY

Component parts of small mechanisms have typically required near-sharp edges to assure reliable component operation. A burr-free condition is also needed to minimize possible jamming of the mechanism if burrs should break loose during operation. In the past, reliable removal of machining burrs, combined with protection of the near-sharp edge requirements, has dictated that deburring be done only by hand which is time consuming and inherently operator variable.

Extrude hone deburring is one of 19 processes studied to produce more precise deburring. With the exception of vibratory deburring, no other process studied to date has the flexibility and control of extrude hone deburring. It is best used when burrs are relatively inaccessible and long hand deburring times are anticipated, or when repeatable features must be deburred, such as a part with 15 slots or holes. Deburring times have been reduced 50 percent or more.

The deburring machine, with appropriate tooling, forces abrasive laden media or putty through or along a part to remove burrs and create a radius. The precise control of burr removal and radius generation depends on the type of media, volume of media used, media viscosity, type of abrasive used (Al_2O_3 , SiC, BC), ratio of abrasive to media, grit size of the abrasive, and media pressure. This process is similar to electrochemical deburring in that the process capability is not directly affected by the precision of the machine tool. In most other machining processes, the machine tool's precision determines to a large extent the degree of precision achieved in the machining operation.

The extrude hone process was studied in three phases: first, a trial deburring of several parts in steel, aluminum, and brass; second, deburring 450 special plates with 2500 holes 0.025 inch (0.635 mm) diameter to determine the relationships of the process variables; and third, placing a contract with Extrude Hone Corporation to develop the tooling and a process to deburr three production parts. Because deburring times could be reduced by 50 percent or more with extrude hone deburring, a machine is in the process of being purchased.

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DISCUSSION

SCOPE AND PURPOSE

The processes and techniques to control deburring by the extrude hone process had to be defined, developed, and improved. Although the specimens used are miniature parts like those used in extremely small mechanisms, the results will apply to many other situations. The techniques investigated are those required to deburr and at the same time produce 0.002 inch (51 μ m) and 0.003 to 0.005 inch (76 to 127 μ m) corner breaks.

ACTIVITY

Extrude hone deburring is a process of forcing a rheopetic putty-like carrier filled with abrasive grit through or along a part to remove burrs and create radii. The rheopetic media under pressure stiffens when it encounters a restriction or changes direction (for example, at the intersection of holes). In most liquid or slurry applications, the burr receives little of the applied energy; the putty-like extrude hone carriers, however, allow a much larger percentage of the applied energy to be converted to work on the burr.

The success of the process is based on two principal factors: tool design and burr orientation. The tooling involved directs the media flow while holding and positioning the part. The burr has to be in the path of the flow and it must be short enough that it will not bend flush with the surface. Large burrs as well as short ones can be removed, but dimensional accuracy may be affected. Piecepart and tool geometry determine how much size is affected.

The entire extrude hone operation takes 2 to 3 minutes. Any internal or external feature can be deburred if the media can be forced over the burr laden edge. In operation (Figure 1) the extrude hone putty-like media is dropped into a cylinder below the work table. The workholding fixture (in this case, a containment pipe) is then placed above the cylinder. The part is placed in the fixture and a hydraulic cylinder clamps the fixture between the two workplates. Another hydraulic cylinder then forces the extrude hone media up through holes in the fixture (the lower workplate). The only open path for media flow at this point is through the holes in the workpiece and into a vacant upper cylinder. When a predetermined volume of media has been forced through the part, the upper cylinder forces the media to flow back through the part into the lower cylinder. Once the cycle is complete the upper clamp rises and the part is removed from the fixture, blown clean in a media collection box, and ultrasonically cleaned. Any media left

Figure 1. Extrude Hone Deburring Operation

in the fixture can be removed with another piece of hand held media. In most instances, the media can be removed by creating a suction with the lower media cylinder.

Process repeatability can be controlled by two methods: a preset timer that controls the amount of time pressure is applied in each direction, or a volume control system that measures the displacement of the hydraulic media cylinders. The volume control has higher repeatability, but one was not available during testing so a preset timer was used.

Besides varying the media volume, deburring effects can be varied by these actions:

- Changing the type of putty used,
- Changing the consistency of the putty,
- Changing the type of abrasive (SiC, Al_2O_3 , BC),
- Changing the ratio of abrasive to putty (two parts abrasive to one part putty is typical),
- Changing the grit size of this abrasive, and
- Varying the pressure on the media [1500 psi (10.3 MPa) normal pressure].

The extrude hone process was developed with the silicon rubber commonly marketed under the name "Silly Putty." Adding varying amounts of silicone oil decreases its viscosity; however, the oil remains after deburring and can contaminate some parts. No widely accepted method has been developed to remove it. If silicone oil contamination cannot be tolerated, kneaded rubber and a Type X media (a powder mixed with water) can be used. All initial production applications will be with Type X media; however, the experiments were performed using all three.

Phase 1 Testing

In the preliminary phase, each of the parts shown in Figure 2 were deburred by this process, except the screw machine part and the large spur gear. The screw machine part was not deburred because extrude hone was no better than conventional methods for this particular geometry. The large spur gear could easily be deburred by this process, but was not because of lack of time in this first phase.

The bases (Figures 3 and 4) were partially hand deburred for 5 to 10 minutes prior to extrude hone deburring to remove very long and thick burrs; the extrude hone process then required only 15 seconds to radius the edges. Parts not roughly deburred ahead of time still had some burr left after extrude honing. The resulting surface finish produced in the holes varied from 6 to 18 RMS.

Each of the flat plates was rubbed on 400 grit silicon carbide paper to throw the burr into the hole, extrude hone deburred for 5 to 20 seconds, blown

Figure 2. Miniature Configurations Studied

clean with air, and then rinsed in trichloroethane. The edge radius and enlargement of hole size was typically independent of the workpiece material (Figure 5). A considerable amount of data scatter was observed in this particular test.

Figure 3. Base

Figure 4. Reaming Burrs on 17-4 PH Stainless Steel Base

Figure 5. Results of Preliminary Tests on 0.060 Inch Thick (1.5 mm) 302 Stainless Steel, Alloy 6 Brass, and 6061 Aluminum, With a 0.028 Inch Diameter (0.7 mm) Hole Deburred With 320 SiC Using Silicone Rubber as a Carrier

The fine edge blanked pawls were placed between two Nylatron urethane cylinders without providing positive or repeatable positioning. As a result of cylinder hole/part hole eccentricity, most of the holes ended up egg shaped. The brass parts also had grooves as a result of preferential flow caused by a tooling burr.

A makeshift plastic fixture was used on the small spur gears. As a result of clamping distortion and an undersize positioning pin, all of the media flowed past one side of the part causing a distorted part and numerous remaining burrs. Deburring and radiusing did occur, however.

The pinion gears were deburred in a small rigid fixture similar to that which would be used in a production operation. The parts were visually excellent, and were deburred and polished. Before extrude hone deburring, however, a burr on each part was manually thrown into the bottom of a tooth. In production, about 2 minutes would be needed for rough deburring, using a special design deburring tool. Extrude hone deburring would require an additional 2 to 3 minutes including cleaning.

Although the needed fixtures for deburring do not consist of many detailed components, a great deal of thought must be given to the fluid flow area, and construction must be sound. Efforts on the fine edge blanked pawls and the spur gear pointed out the effect of inadequate tool construction. The fixture's media guide holes for the drill and ream plates were eccentric to the part holes by roughly 0.020 inch (0.5 mm): as a result, the putty worked on one side of the hole more than the other, producing an egg-shaped hole. The miniature spur gear was similarly damaged because the locating spud was much smaller than the part center hole. Much of the inconsistency in the preliminary studies was attributed to poor quality fixturing, the short time available to run this initial evaluation, and a complete absence of data on typical process effects.

Phase 2 Testing

The second phase investigated the effects of piece part material, type of media carrier, media size and materials, volume flow past the burr, and media pressure on small drilled holes. When the second phase began, no data was available to indicate how these variables affect deburring, radiusing, and size changes.

Plates (Figure 6) were drilled and counterbored using a numerical control drill and solid carbide printed circuit board drills. Twenty-five drills 0.025 inch diameter (0.6 mm) were used to drill the 2500 small holes in

Figure 6. Escapement Plate

these brass and stainless steel plates.* Most of the deburring data was obtained using silicone oil mixed with a silicone rubber carrier. Approximately 35 parts were deburred with the "X" base media during the last part of the tests. Typical relationships between deburring effects and process variables were established (Figures 7 through 11).**

*Bendix Kansas City Material Code Numbers 750819-059 and 7340101-850.

**"Extrude Hone Deburring," a memo from L. K. Gillespie, gives details of this study.

Text continued on page 25.

Figure 7. Effect of Volume Flow on Size of 0.025 Inch (0.6 mm) Hole Using 220 SiC Abrasive and 1600 psi (10 MPa)

Figure 8. Effect of Volume Flow on Formation of Edge Radii Using 220 Grit SiC, a Ratio of 1:1 by Weight, and 1600 psi (10 MPa)

Figure 9. Effect of Abrasive Ratio on Size of 0.025 Inch Diameter (0.63 mm) Hole in 302 Stainless Steel Using Silicon Rubber Carrier, 220 Grit SiC, and 1600 psi (10 MPa)

Figure 10. Hole Size Increase Caused by Media Pressure, Using Silicon Rubber Carrier, 220 Grit SiC Abrasive, a Ratio of 1:1 by Weight, and a 6-Cubic-Inch (98 cm³) Volume Flow on 302 Stainless Steel

Figure 11. Increase in Edge Radius by Increasing Abrasive Ratio, Using Silicon Rubber Carrier, 220 Grit Abrasive, 1600 psi (10 MPa), and 6-Cubic-Inch ($98 \mu\text{m}^3$) Volume Flow

Phase 3 Testing

In the third phase, a contract with the Extrude Hone Corporation was placed to develop a process and tooling to deburr three production parts (Figures 3, 12, and 13). These are the Phase 3 results.

Base

The milled cavity in conjunction with the intersecting holes make deburring the base (Figure 3) one of the most difficult operations at Bendix. The milled cavity, presently deburred by hand, requires 54 minutes per part.

Figure 12. Actuator Housing

Figure 13. Pinion Gear

Using a 10-second cycle time in each direction, "X" base media was used with 1:1 by weight 70 grit silicon carbide abrasive. Examination of the first parts (Figure 13) showed that the majority of the burr was removed; it should be remembered, though, that the large heavy burr was manually removed prior to extrude hone deburring. This rough deburring required about 5 minutes per part; the total deburring time was 12 minutes per part compared to 54 minutes per part by hand deburring alone. No data was recorded on hole sizes or edge radii; however, all of the production parts passed inspection. Some problems were encountered with cleaning the parts because of the vendor's cleaning facilities. No problem is anticipated with present ultrasonic cleaning equipment designed for small part applications.

Pinion Gear

This part also represents a difficult hand deburring job. It is a 12-tooth gear with a pitch diameter of 0.100 inch (2.54 mm). The burrs are the result of gear hobbing and are more of a swelled burr than a hanging burr that is easily broken off. Handling the part is difficult because of its miniature size, and coupled with the burr's toughness, a difficult hand deburr operation results. Hand deburring requires approximately 20 minutes: the material is 17-4 PH H-900 stainless steel.

Extrude hone deburring of this part consisted of a rough hand deburr of 2 to 3 minutes and then a 6 second total machine cycle using the "X" base media and 320 grit silicon carbide mixed 1:1 by weight with the media. Total deburring time for the part was approximately 5 minutes instead of the 20 minutes by hand (Figure 14). A maximum of 0.0003 inch (7.6 μ m) material was removed from the pitch diameter; the average change in pitch diameter was 0.00015 inch (3.8 μ m). The total composite tooth error typically improved from 0.0008 inch TIR to 0.0002 TIR (24 μ m to 51 μ m). Because of fixture design, the burr was not completely removed in the base of the gear teeth (Figure 15). The physical size of the part may be the limiting factor of the process.

Actuator Housing

This part was included in this endeavor to study the effect of extrude hone deburring on precision thin flanges. As shown in Figure 12, the part has 6 thin flanges which will distort or break if bent. The inside edges of these flanges have a 0.003 inch (76.2 μ m) maximum edge break requirement. The material is Hiperco 50, an abrasive and brittle, high strength, highly magnetic material. The burr is extremely hard (Rc 52) compared to the base material (Rc 30). However, the part was successfully deburred with the "X" base media and 70 grit silicon carbide abrasive. The media was

BURRS FORMED BY DRILL BREAKOUT IN HARD-TO-REACH CAVITY

HARD-TO-REACH CAVITY AFTER EXTRUDE HONE DEBURRING

Figure 14. Effect of Extrude Hone Deburring on Hidden Intersection Holes

Figure 15. Gear Teeth Before and After Extrude Honing

forced over the part under 1500 psi (10.3 MPa) and flowed 40 seconds in each direction (2 cycles each of 20 seconds up and 20 seconds down). Typical edge radii of 0.002 to 0.003 inch (51 to 76 μm) were generated. Some bending of the ears--up to 0.003 inch (76 μm)--was experienced and could probably be eliminated with an improved tool design or forcing the material from only one direction.

This part is presently hand deburred in production, with the areas to be extrude hone deburred requiring approximately 20 minutes. In this study heavy burrs were removed by hand and the part was then extrude hone deburred. Total deburr time for the extrude hone process was approximately 10 minutes.

Tooling for Phase 3

The tooling used for the base consisted of a fixture (Figure 16) that "sandwiched" the part. The part was located in the bottom half of the fixture so that a media guide hole was next to each cross hole. The top half of the fixture contained two holes to guide the media from the top cavity of the part into the top cylinder. The materials in contact with the part were Nylatron, which can be compressed to obtain a good seal. The fixture containing the part was located between two tooling plates on the machine.

The pinion gear was deburred using a fixture (Figure 17) simple in design that was not completely successful. The design of the fixture did not let enough media flow at the base of the teeth, so some burrs were not removed. The vendor could not produce the precision tooling required for this part, but a workable concept was developed.

The fixture for the actuator housing (Figure 18) guided the deburr media down below the base of the slots and then out through the slots. During reverse flow, no provision was made for supporting the flanges and some were bent. Several solutions to flange bending are possible: decreasing the pressure differential by decreasing flow rate or decreasing working pressure; or forcing the media in only one direction so the flanges are supported by the fixture. This latter solution would allow deburring on the inside edge only; however, the outside burr is much easier to remove and there is more tolerance on the edge break.

ACCOMPLISHMENTS

Extrude hone deburring was found effective for removing burrs from precision miniature parts. The process does change part dimensions in some situations, but the change can be predicted and controlled. With the exception of

Figure 16. Fixture Used to Deburr Base

Figure 17. Fixture Used to Extrude Hone Deburr Pinion Gear

Figure 18. Fixture Used to Extrude Hone Deburr Actuator Housing

vibratory deburring, no other deburring process studied has the flexibility and control of extrude hone deburring.

FUTURE WORK

Additional studies will be made of extrude hone deburring, tool design concepts, and process repeatability. The effects of abrasive grain size and the feasibility of multiple fixturing also will be examined.

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