We are providing technical information on micro-drilling and the smallest diameter of ECO BRASS bars. For your information, the figure numbers in this document are those referenced in the document we last submitted if the figures are contained in the document. The figure numbers of the new figures (that are not found in the preceding document) are sequels to the figure number of the last figure in the preceding document.

1. Micro-Drilling Test

Below are the results of continuous drilling of 5 mm-deep holes with a drill of 1 mm in diameter. The materials evaluated in this testing are ECO BRASS (a CuZn21Si3P alloy; C69300), GloBrass (a CuZn36Si1 alloy; C68370), and C36000 (a CuZn38Pb3 alloy). GloBrass is an alloy developed by MMC, which was introduced in Chapter VI of the preceding document. We selected a cutting tool suitable for drilling ECO BRASS and GloBrass, and examined a variety of drilling conditions considering cutting performance and drill life before deciding which conditions to apply. The drill used in the test was a commercially available cemented carbide (Z20) drill with a function for applying lubricant internally.

In the drilling test, a vertical M/C manufactured by FANAC was used, and 5-mm deep holes of 1-mm in diameter were drilled at a drill speed of 50 m/min, a feed of 0.1 mm/rev, and a drilling depth per stroke of 0.5 mm with water-soluble lubricant supplied at P = 5 MPa.

First, **Fig. 28** shows the measurements of the thrust force and the torque taken during drilling of the tested alloys.

It took approximately 3.7 seconds to drill one hole. The maximum thrust forces were 37N for ECO BRASS and GloBrass, and 26N for C36000 respectively. That is, the thrust force of ECO BRASS and GloBrass is about 1.4 time that of C36000. No irregularity was observed in the wave profiles of the three alloys, indicating that the drilling went smoothly. Thrust force is an axial force applied in the feed direction. Therefore, it is affected by the strength of the material. The strengths of ECO BRASS and GloBrass are about 1.4 times and 1.3 times that of C36000 respectively. Considering the strengths of the alloys, it can be understood that ECO BRASS and GloBrass can be drilled almost like C36000. With respect to the torque, the wave profiles of ECO BRASS and GloBrass are more or less the same as that of C36000, indicating that ECO BRASS and GloBrass can be drilled well like C36000.

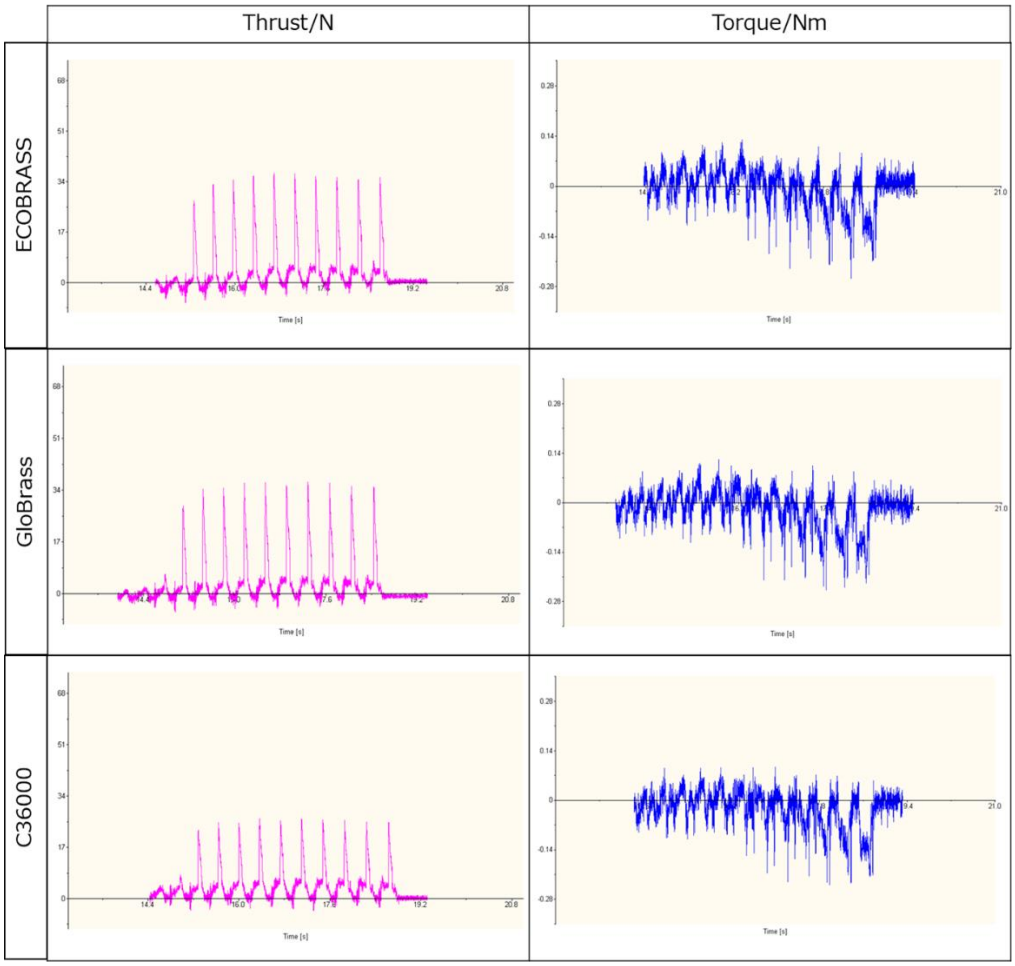


Fig. 28: Thrust Force and Torque of ECO BRASS, GloBrass, and C36000

(Drill Speed: 50 m/min, Feed: 0.1 m/rev, Hole Diameter: 1 mm, Hole Depth: 5 mm, Depth per Stroke: 0.5 mm)

Fig. 29 shows the appearances of the drills after drilling 31,806 holes in ECO BRASS, GloBrass, and C36000 materials. None of the drills were broken, and a slight wear was observed. The amount of wear (maximum flank wear) was 0.007 mm, 0.008 mm, and 0.007 mm respectively. Generally, it is said that when the maximum flank wear reaches 0.2 to 0.7 mm, the tool's life ends. Thus, it is determined that after drilling 30,000 holes, the drills were still at early stages of their lives.

Fig. 30 shows the appearance of the drill after drilling 102,114 holes continuously in a GloBrass material. The drill was not broken, and at the point when drilling of 102,114 holes was completed, the flank wear was 0.011 mm, i.e., there was only a 0.003 mm increase in the flank wear. Upon completion of drilling 102,114 holes, the test was temporarily discontinued since we determined that it would take a long time before the drill life ended. From the fact that the amount of wear was very little, the quality of drilled holes is presumed to have been maintained. It is estimated that, like GloBrass, when ECO BRASS or C36000 material is drilled, the drill will not be broken or reach the end of its life until at least 100,000 holes are drilled.

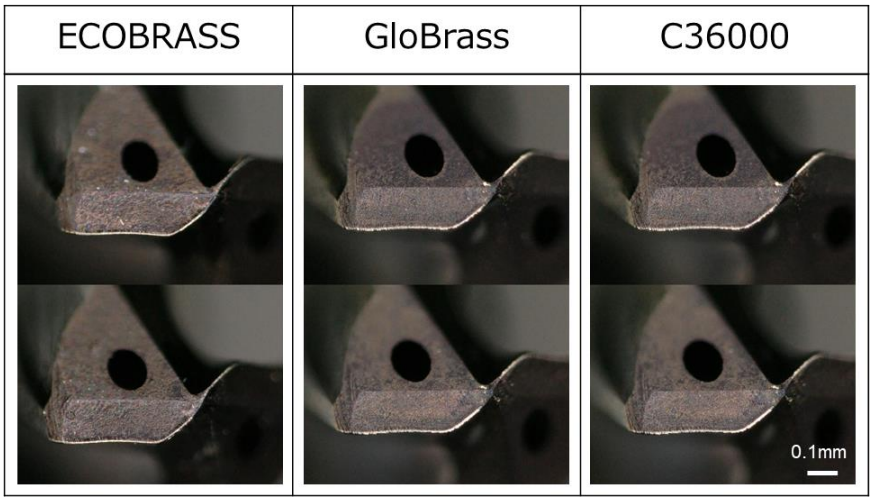


Fig. 29: Conditions of the Drills After Drilling 31,806 Holes of 5 mm in Depth and 1 mm in Diameter

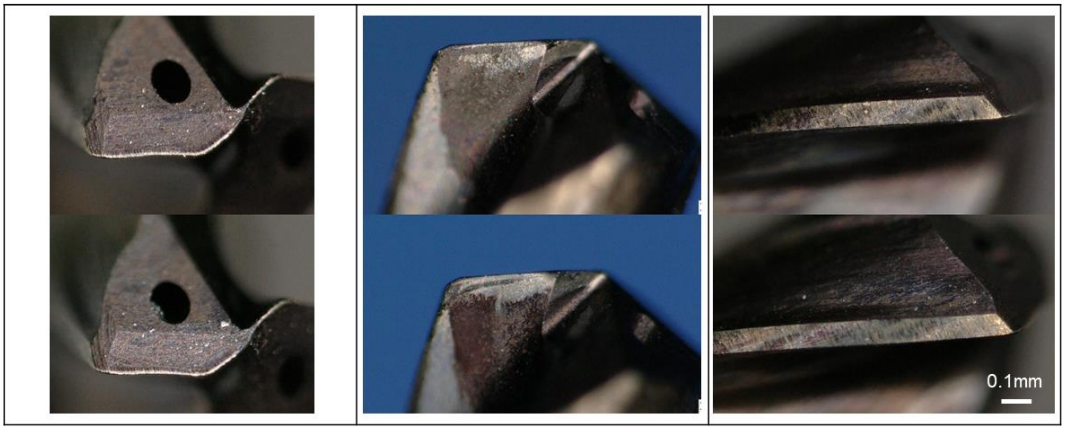
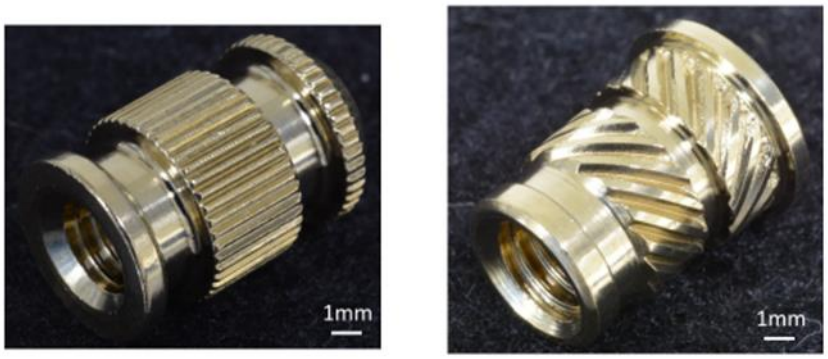


Fig. 30: Conditions of the Drill After Drilling 102,114 Holes in GloBrass

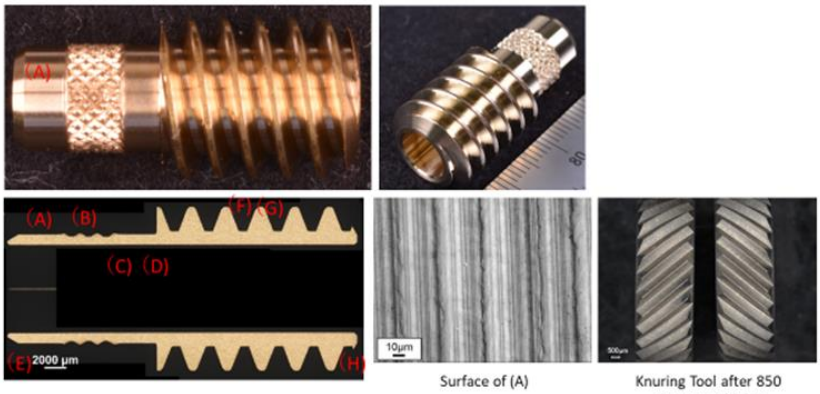
Regarding copper alloy products made by machining, like the insert nuts shown in **Fig. 6**, they are manufactured with a single machine but utilizing multiple machining methods including turning, inner threading, knurling, and grooving in addition to drilling. Then, when there are strict requirements for dimensions and surface roughness, finish cutting of the inner and outer surfaces is also added. As C36000 has superb machinability, machining time can be shortened by increasing machining speed and feed rate. With C36000, it is possible to manufacture products having a complicated shape by utilizing various machining methods, and the quality of machined surface is good. In addition, the tool life is long, the chips are easy to dispose of, and manpower is scarcely required during machining of this alloy, which are the major reasons that C36000 is chosen as a material for production of electrical/electronic components and auto parts.



Insert nut C (2.0g)　　Insert nut D (1.1g)

Fig. 6: Examples of Mass-Produced Insert Nuts for Automobiles

For example, in the mass production test of the worm gears shown in **Fig. 11** which was performed using a NC lathe, a common commercial machining facility, with the cooperation of a machining company, the machining was carried out mainly in eight steps, and it took 182 seconds to complete one cycle of machining. This 182 seconds covers not only machining itself but also fixing or turning the material, moving various cutting tools to specific positions, and the final cutting off, each of which requires several seconds. When an NC lathe, a common commercial machining facility, is used, it takes about 1 to 5 minutes to completely machine a component. For easy understanding, let us assume that it takes one minute to complete a cycle of machining operation, 60 pcs/hour, 1,440 pcs/day, 10,080 pcs/week, and 43,200/month can be machined if operated continuously without stopping the machine. In the case of C36000, machining is performed substantially without manpower, yet the machine is stopped at least for regular check-ups. The machine is also stopped for check-up of cutting tools, disposal of chips, and feeding materials, the frequency of which varies from one machining company to another. Needless to say, the longer the tool life, the better, but it is said that tool life is not a serious issue as long as tool has a long enough life so it can be replaced when the machine is stopped (as opposed to stopping the machine for the replacement). Thus, in the case machining is performed with a NC lathe that is widely used to machine C36000 on a commercial basis, it is considered that there is no problem about tool life if 30,000 holes, or further 100,000 holes can be drilled before tool life ends.



- Process :
  (A)Turning(3000rpm,0.05mm/rev.)
  →(B)Knurling→(C)ϕ7.8Drilling(1600rpm,0.07mm/rev.,6step,27sec)
  →(D)Boring (1700rpm,0.05mm/rev.,56sec)
  →(E)Chamfering→(F)Threading(40sec)→(G)Chamfering→(H)Cut off
- Cycle : 182sec
- Condition : Wet
- Machine : Citizen Machinery L-20Ⅶ
- Pieces : 850

Fig. 11: Machining Example 5 – Component Similar to Worm Gear

2. Available Sizes of ECO BRASS Materials

As shown in Figs. 3-1 and 3-2, ECO BRASS is used for Small Car Air-Conditioner Component A, and about 20 tons of ECO BRASS bars having a diameter of 5 mm (0.198 inch) were used annually on the average during the period from 2018 to 2019. Also, as the machining example shown in Fig. 7, bars of 3 mm (0.119 inch) in diameter have been commercialized already. A little more slender ECO BRASS bars can be supplied upon request.

3. Summary

The technical data and the information on available sizes of ECO BRASS bars described above can be summarized as follows:

- In the continuous drilling of 5 mm-deep holes of 1 mm in diameter, at the point 30,000 holes had been drilled, the drill was not broken and there was little tool wear. This was achieved by selecting a tool and drilling conditions suitable for ECO BRASS.
- In the case of GloBrass, upon completion of machining an increased number of holes, 100,000 holes, the drill was not broken, and there was little wear on the drill. From this test results together with the results of the machining tests previously reported, it has been confirmed that GloBrass has approximately the same machinability as that of ECO BRASS.
- ECO BRASS bars of 5 mm in diameter (0.198 inch) are commercially manufactured and widely used for auto parts that are produced by machining. More slender ECO BRASS bars can be supplied upon request.