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HOBBING RATCHET WHEELS
FOR MINIATURE MECHANISMS

By R. B. Wetherill and L. K. Gillespie

Published December 1978

Topical Report
R. B. Wetherill, Project Leader

Prepared for the United States Department of Energy
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Ratchet wheels, used in miniature electromechanical mechanisms, such as switches, actuators, and timers, have traditionally been produced by milling individual teeth or by blanking then shaving them in dies. Decreasing part size and tolerances in conjunction with the need for nearly sharp corners and fillet radii necessitated an analysis of alternative production methods. A study of hobbing as a production technique indicated that for many configurations it is a more economical approach than traditional methods. A technique for determining ratchet shapes applicable to hobbing has also been defined.

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SUMMARY

The shapes of small ratchet wheels used in miniature mechanisms are limited by corner and fillet radii requirements. Traditional methods for producing special shapes of ratchet wheels are time consuming. Continuing demands for ratchet shapes with decreasing sizes and tolerances and variable shapes necessitated an analysis of alternate production processes.

Hobbing is one alternative method for producing small ratchet wheels; however, this method is limited by spacing, number, and size of teeth. In order for hobbing to be used, a graphical technique was required to determine if a particular ratchet wheel shape could be effectively produced using the process.

Plastic, aluminum, and beryllium copper were machined to three basic teeth shapes using a variety of feeds and speeds. A graphical layout method for determining the approximate shape of the hob necessary to produce a given tooth form was developed.

DISCUSSION

SCOPE AND PURPOSE

The object of this study was to determine the suitability of hobbing for producing ratchet wheel shapes. A comparison was made between hobbing and other more traditional methods for producing small ratchet wheels.

ACTIVITY

Ratchet Wheel Shapes

Three important requirements must be met before a part can be produced by hobbing. The first and most important requirement is the spacing and number of teeth. Teeth must be evenly sized and uniformly spaced in the ratchet wheel thereby making the contour entirely uniform. The second requirement is the shape of the teeth. Although curved tooth surfaces are a possibility, all ratchet wheels studied have straight tooth surfaces, except for fillet radii or tooth crest flats or radii (Figure 1). The third consideration for hobbing is the number and size of the teeth and is dependent upon the capacity of the hobbing machine to be used.

The three basic types of ratchet teeth investigated are shown (Figure 2). All three can be used for detenting and indexing functions. Type 1 is the most common form in general use and was the one chosen for study. In its extreme form of $\alpha = \phi/2$, Type 2 is used as an escape wheel in timing mechanisms. Type 3 must be considered carefully if hobbing is to be used because when recessing becomes too severe, hobbing is not possible.

The machining portion of the study was conducted using machines limited to 6 to 390 teeth and a size approximately equal to a 26 diametral pitch involute gear tooth or about 1.905 mm (0.75 in.) wide by 2.108 mm (0.083 in.) deep in steel. Softer part materials would allow the cutting of somewhat larger teeth if the following limiting factors are not exceeded:

- The helix angle of the hob cannot exceed 4 degrees;
- The hob diameter should not exceed 31.75 mm (1.25 in.) (Hob surface footage might be excessive above this diameter as the lowest cutter spindle rpm available is 430.); and
- The combination of part and hob diameter cannot exceed 66.69 mm (2.625 in.).

Figure 1. Ratchet Wheel Nomenclature

A Type 1 part with a θ angle of 18 degrees (20 teeth) and a ϕ angle of 53 degrees was used in the initial test. The hob used for this study was designed for this specific configuration.

Three different materials were machined: a polyimide material, aluminum, and beryllium copper. A variety of feeds and speeds were used. The only significant deviation from the desired nominal tooth form was with the plastic material. The difference

TYPE 1 (RADIAL)

TYPE 2 (V FORM)

TYPE 3 (RECESSED)

Figure 2. Types of Ratchet Wheels

was apparently caused by part deflection but was still within the 50.8- μ m-wide (0.002 in.) contour band selected as the best tolerance.

The centerline was then shifted to produce Type 2 and Type 3 parts using the same cutter. Table 1 shows the results of these shifts. This ability to shift the cutter with respect to the work makes the hobber a much more versatile machine than the shaper which is restricted to centerline work only.

Samples 8 and 9 show that feed rate has little effect on tooth contour. It could, however, affect surface finish. Samples 10 and 11 and Samples 12 and 13 show the effect of cutting different materials at the same machine setting. The relatively large change on the plastic material is apparently due to part deflection.

As can be seen, the major change was in angle ϕ . The topping mentioned in Table 1 was the result of the design of the hob.

General Observations

Some parts investigated as a result of this study did not meet the requirements of having a whole number of evenly spaced continuous teeth. These segments of ratchet wheels could possibly be produced on a gear shaper. Further work in this area will be necessary to determine its feasibility.

When at all possible, teeth to be used for indexing or detenting should be evenly spaced and continuous. If it is necessary to have ratchet segments, they should be designed with the non-tooth portion lower than the root diameter of the ratchet form. In this way, unwanted teeth can be cut away in secondary machine operations. When this is not possible, a second part could be screwed, riveted, or welded to the side of the ratchet wheel to block out unwanted teeth. When none of these possibilities exist, it will be necessary to use some manufacturing method other than hobbing.

Fillet radii should be specified when defining ratchet tooth configuration. The radius should not be a part of the contour band unless absolutely necessary. A radius of about 101.6 μ m (0.004 in.) was the most common on the size parts investigated and should result in reasonable tool life from hobs. Different sizes of fillet radii can be investigated as necessary.

The crest configuration of the tooth should be formed by the outer diameter of the part. Crest radii or flats other than the outer diameter of the part must be generated by a topping hob or in secondary machining operations. When topping hobs are used, adjustments in the hobbing process are very limited resulting in the necessity of closer hob size control and shorter tool life. Secondary machining operations are expensive and should be avoided.

Table 1. Results of Inspecting Three Methods (Angle θ 18 Degrees)

Sample Number	Ratchet Type	Material	ϕ	α	β	Remarks*
11-1	3	Al	52° 40'		1° 20'	CL offset** 127 μ m (0.005 in.)
2-13	3	Al	52° 55'		2° 22'	CL offset** 254 μ m (0.010 in.)
3-15	3	Al	52° 40'		5° 14'	CL offset** 508 μ m (0.020 in.)
4-18	2	Al	52° 53'	1° 12'		CL offset 127 μ m (0.005 in.)
5-20	2	Al	52° 53'	3° 9'		CL offset 254 μ m (0.010 in.)
6-22	2	Al	53° 8'	5° 48'		CL offset 508 μ m (0.020 in.)
7-25	2	Al	52° 55'	6° 27'		CL offset 584 μ m (0.023 in.)
8-38	1	Al	52° 44'			Feed rate 71 μ m/rev. (0.0028 in./rev.)
9-45	1	Al	52° 35'			Feed rate 0.5 mm/rev. (0.020 in./rev.)
10-13	1	Plastic	51° 15'		1° 0'	
11-14	1	Al	52° 37'			Same as 10-13 settings
12-27	1	Plastic	51° 16'		0° 45'	
13-1	1	BeCu	52° 30'	9° 15'		Same as 12-27 settings
14-10	1	BeCu	52° 40'			Adjusted for nominal
*CL indicates centerline						
**topped						

Many of the limitations observed here also exist in other processes used for producing gear-like shapes.¹⁻⁴

Figure 3 shows how the hob was altered to prevent topping. Some hob tooth damage occurred when the hob was altered causing a slight deformation of the part tooth contour. This variation was disregarded when measurements were taken in later tests.

After altering the hob, further machining tests were carried out including the machining of 22, 24 and 26 tooth Type 1 ratchet wheels using ϕ angles of $50^{\circ} 20'$, $55^{\circ} 25'$, and $55^{\circ} 39'$ respectively.

ACCOMPLISHMENTS

The machining tests show that a large variety of ratchet tooth forms can be hobbled but most require a specially designed cutting tool. A layout method of determining the approximate shape of the hob necessary to produce a given tooth form is described in the Appendices. This method should be used when a new part is being designed and the configuration is still flexible; this way the optimum tooth shape to meet both functional and manufacturing requirements can be found.

Figure 3. Hob Alteration to Prevent Topping

REFERENCES

¹R. W. Stiles, *Gear Cutting* (Final Report). Bendix Kansas City: BDX-613-1392, August, 1976 (Available from NTIS).

²G. E. Volkland, "Shaper Cutters Generated by Computer," *Tooling and Production*, February, 1976, pp 36-39.

³G. E. Volkland, "Computer Designed Shaper Cutters," *Society of Manufacturing Engineers MR74-193*, 1974.

⁴R. W. Stiles, *Shaping Ratchet Teeth* (Topical Report). Bendix Kansas City: BDX-613-973, August, 1973 (Available from NTIS).

⁵W. O. Davis, *Gears for Small Mechanisms*. 2nd edition. London, England: N.A.G. Press Ltd., 1970.

⁶H. S. Seese, *Fine-Edge Blanking and Piercing* (Final Report). Bendix Kansas City: BDX-613-366, July, 1971 (Available from NTIS).

APPENDIX A

LAYOUT METHOD FOR DETERMINING SUITABILITY FOR HOBBING (Based on the technique described in Reference 5)

1. Lay out the tooth profile accurately to a convenient scale such that one pitch at the pitch circle is at least 25.4 mm (1 in.). Several teeth should be drawn.
2. A radial network as shown in Figure A-1 is drawn, dividing each pitch into five or more equal spaces. The more divisions, the more accurate will be the layout; however, too many divisions will become confusing.
3. Another network (Figure A-2) is laid out on tracing paper with parallel vertical lines having a spacing corresponding to the spacing of the radial lines (Figure A-1) at the pitch circle and a horizontal line representing the pitch line of the hob.
4. Both networks are numbered consecutively with line "0" established parallel to the bisector of angle ϕ of the tooth to be finished in this development. See Appendix B for exceptions.
5. The parallel network is now laid over the radial network, line "0" on each coinciding, and pitch line tangent to pitch circle. The contour of the tooth profile is then traced through onto the upper network. This process is repeated with each pair of the numbered lines until a rotation equal to one pitch in both directions has been made.

The resulting development is the shape of the hob required to produce the desired part profile. The offset distance on Types 1 and 2 is the amount the hob is moved off the centerline of the part in order to produce the desired shape.

This process should be reversed to verify that the hob will produce the proper part contour.

If the layout is accurate enough and to a large enough scale (50:1, 100:1) it can be measured and the dimensions used to design the hob. If the scale chosen for the layout is also a standard optical comparator magnification, the layout could be used to inspect the finished tool.

Figure A-1 shows a Type 2 tooth in which the bisector of angle ϕ is also the centerline of the part. This is the only configuration having a symmetrical tooth form (see Appendix B).

Figure A-1. Type 2 Radial Network

A multiposition hob is one in which the outside tips of the hob teeth define a cylinder and all tooth cross sections are the same shape. As each row of teeth is dulled, the hob is moved laterally to a new cutting position.

Figure A-2. Type 2 Hob Development

When Type 1 and Type 3 teeth are hobbled, a single-position hob is used. A single-position hob has a single helical row of teeth or a conical outside shape. Figure A-3 shows a Type 1 layout and Figure A-4 illustrates the hob form layout. This type of hob has only one cutting position.

Figure A-3. Type 1 Radial Network

Figure A-5 shows a Type 3 tooth. The hob tooth development is similar in shape to the Type 1 but is developed from a different point.

Figure A-4. Type 1 Hob Development

It can readily be seen in the layouts that the deeper a tooth form is with respect to its width, the thinner will be the hob tooth. When any part of the hob tooth becomes less than 8 degrees from a line perpendicular to the centerline of the hob there will be insufficient cutting clearance and the part cannot be hobbled. Figure A-2 is approximately the lower limit (16 degrees including

Figure A-5. Type 3 Hob Development

angle) of tooth thinning that can be used for most applications. Very hard materials such as some types of stainless steel may require 10 to 12 degrees of tooth width per side to provide the necessary strength to prevent breaking of the hob tooth.

APPENDIX B

LAYOUT VARIATION

In those instances where a Type 2 tooth having a fairly large angle is being laid out, it may be desirable to establish line "O" through the vertex of angle ϕ and perpendicular to the hob centerline. In this way a multiposition hob with nonsymmetrical teeth is produced. This should result in reducing tooling costs as the multiposition hob cost per part produced is usually less than the single position.

The 8 degree side angle limitation described in Appendix A still applies.

APPENDIX C

COST AND TOLERANCE COMPARISON

Blank and shave die costs for a typical ratchet shape are about \$6,600 (3 dies), and the standard hourly rate is approximately 3.210 hours per 100 parts. This hourly rate includes the cleaning operations between the three die operations.

The fine edge blanking press can produce good results in one die at a tooling cost of about \$3,500 and a standard hour rate of 0.167 hours per 100 parts. Reference 6 defines the limitations of this process. Occasionally a shaving operation will be necessary to finish fine edge blanked parts requiring close contours. Additional costs would be \$2,200 for a shave die and 1.05 hours per 100 parts for labor.

Milling of ratchet teeth (15 teeth) takes 3.540 hours per 100 parts and a tooling cost of \$550 including form milling cutters (4 parts per load).

Hobbing ratchet teeth (5 parts per load) takes 2.229 hours per 100 parts at a tooling cost of \$600 including arbors, hobs, and spacers. The spacers, which are made of brass, are used at the exit end of a stack of parts to reduce the amount of burr raised on the teeth. Stacking of parts is another economical advantage of hobbing. Part stacking is also possible when milling teeth but not when die blanking.

The parts used as cost examples of die blanking and milling do not meet some of the requirements for hobbled parts but are representative of typical costs.

Blank and shave dies can hold contour tolerances of about $50.8\text{ }\mu\text{m}$ (0.002 in.) and fine edge blanking can hold as close as $37.6\text{ }\mu\text{m}$ (0.0015 in.) in special cases. These figures are dependent to a very large degree on type and thickness of materials. Milling can hold a $101.6\text{ }\mu\text{m}$ (0.004 in.) contour. The limiting factor seems to be inaccuracy in indexing mechanisms. Hobbing and shaping can both hold very close tolerances but are dependent upon the grinding of the cutting tool. Tolerances of $50.8\text{ }\mu\text{m}$ (0.002 in.) contour are not uncommon on small parts.

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