

# Design Models for Shaping of a Tooth Profile of External Fine-Module Ratchet Teeth

**O V Sharkov<sup>1,2</sup>, S I Koryagin<sup>1</sup> and N L Velikanov<sup>1</sup>**

<sup>1</sup>Immanuel Kant Baltic Federal University, 14 A, Nevskogo st., Kaliningrad, 236041, Russia

<sup>2</sup>Kaliningrad State Technical University, 1, Sovetsky ave., Kaliningrad, 236022, Russia

E-mail: osharkov@kantiana.ru

**Abstract.** Simulation of the shaping for the fine-module external ratchet teeth at which the contacting surfaces are formed by the straight segments is considered in this paper. The design schemes for shaping of the proposed ratchet teeth by a shaper cutter and a rack are obtained. It is defined that the maximum length of the straight segment of the front edge ratchet teeth will be formed at shaping by a rack cutter. The effect of a module, a gradient angle and a radius of blank circles on the length of the straight segment of the front edge ratchet teeth is investigated.

## 1. Introduction

One-way clutches are widely used in various machine drives. According to the method of load transfer one-way clutches are classified into two main types. The load transmission in these clutches can occur due to a frictional force (roller one-way clutches) or normal forces (ratchets of one-way clutches) [1-6].

Roller one-way clutches most often are applied in machine drives. However, their load capacity and durability depend on the value of the friction coefficient, which can change in a wide range of  $f = 0.04 \dots 0.20$  [2, 3].

Ratchet one-way clutches have a large load capacity and reliability. However during the operation of ratchet engagement there is a significant noise and impact loads [3, 5].

It is possible to lower these deficiencies at the expense of reduction of the size of the module. For example, in the eccentric one-way clutches of a non-friction type the fine-module ratchet teeth with module  $m_f = 0.3 \dots 1.0$  mm can be used.

In article [7] determination of geometrical parameters of fine-module ratchet engagement for the eccentric one-way clutches of the non-friction type is considered. The proposed fine-module ratchet teeth of the new profile, which provide their contact in teeth on the flat surfaces.

Modern design schemes used at shaping of involute and ratchet teeth profiles can not be applied for proposed teeth due to the peculiarities of their geometry.

## 2. Analysis of shaping methods of external fine-module ratchet teeth

Modern production methods of teeth are diverse and include more than 50 types [8-14]. One of the most efficient and widespread methods for shaping of different teeth profiles on cylindrical surfaces is tooth-cutting by continuously indexing method.



Let us analyze the methods used for shaping fine-module ratchet teeth of the described profile on the basis of a procedure for the generating of working surfaces by a continuously indexing method [8-14].

Shaping external teeth by the continuously indexing method is possible in two ways – a shaper cutter or a rack cutter [12, 14].

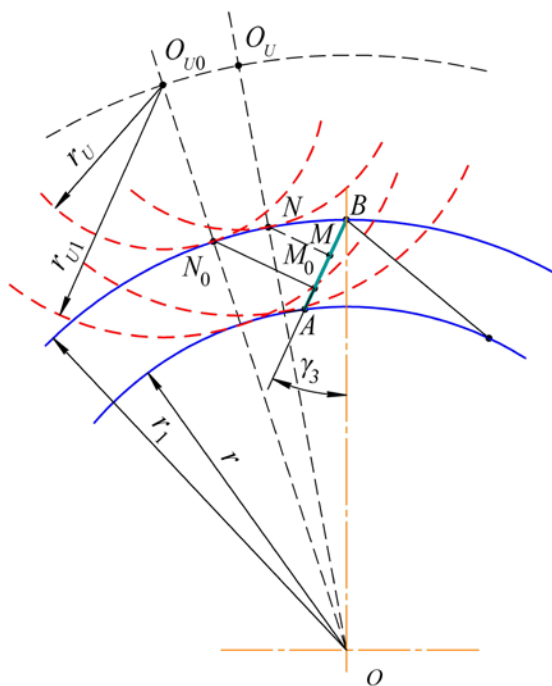
### 2.1. Simulation of shaping of the teeth by the shaper cutter

For the preparation of design models let us assume that  $r_u$  and  $r_{u1}$  – radii of dedendum and addendum circles of teeth of the edge tool;  $r$  and  $r_1$  – radii of blank circles, passing through the dedendum of external and internal of the shaped teeth ( $r = r_{f1}$  and  $r_1 = r_{f2}$ ).

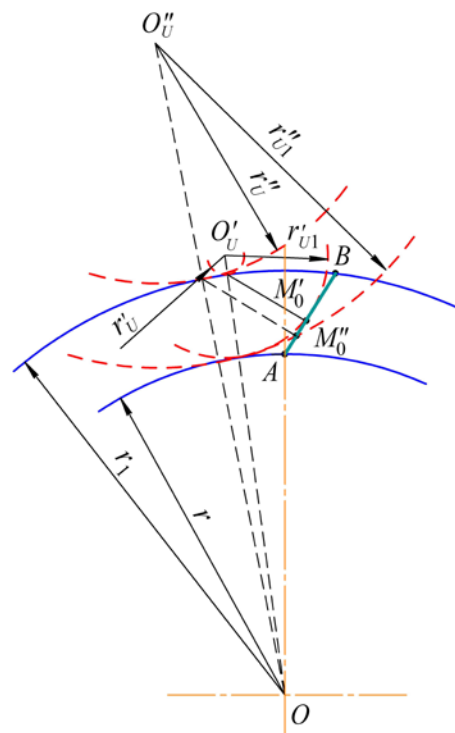
The shaper cutter with centre  $O_u$  and the blank with centre  $O$  (Figure 1) are shown in reversed motion with respect to each other with the motionless blank. During forming of point  $M$  the shaper cutter is in position  $O_u$  and a point on the shaper cutter is coinciding with point  $M$ . Because it is owned by its cutting edge.

There is point  $M_0$  (Figure 1), which is formed by the tooth point of the shaper cutter, located on the circle of radius  $r_{u1}$ .

All points located on segment  $AM_0$  do not have conjugate points on the shaper cutter, because they are formed outside the circles of radius  $r_u$  and  $r_{u1}$ . Consequently, the shape of the cutting teeth will be created at segment  $|BM_0| = l_{t11}$  by a straight line and at segment  $AM_0$  by a transition curve formed by the tooth point of the shaper cutter.



**Figure 1.** Shaping the external ratchet tooth by the shaper cutter.



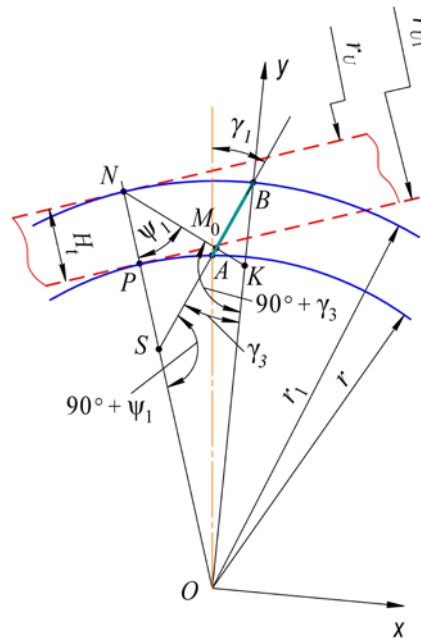
**Figure 2.** An effect of the shaper cutter diameter on the straight segment length of the tooth front edge.

When selecting the type and the size of the cutting tool for shaping external teeth it is necessary to provide a greater length of the straight segment of the tooth profile in relation to its theoretical length.

Figure 2 shows that the desire to increase the length of straight segment  $l_{t11}$  for the same tooth leads to the need of a significant increase of the radius of the shaper cutter. Therefore, for shaping the external teeth it is the most appropriate to use the rack cutter which is  $r_U = \infty$ .

## 2.2. Simulation of shaping of the teeth by the rack cutter

Figure 3 shows the position of the rack cutter and blanks when the tooth point of the rack cutter is forming extreme point  $M_0$  on the straight segment of tooth edges  $l_{t11}$ .



**Figure 3.** Shaping the external ratchet tooth by the rack cutter.

Using triangle  $OBS$  we can write

$$\frac{r_1}{\sin(90^\circ + \psi_1)} = \frac{r_1 - H_t / \cos^2 \psi_1}{\sin \gamma_3},$$

where  $H_t = |PN|$  – theoretical depth of the rack cutter tooth.

Then we obtain expression

$$r_1 \cos^2 \psi_1 - r_1 \sin \gamma_3 \cos \psi_1 - H_t = 0,$$

$$\text{where } \cos \psi_1 = \frac{r_1 \sin \gamma_3 + \sqrt{r_1^2 \sin^2 \gamma_3 + 4r_1 H_t}}{2r_1}. \quad (1)$$

Using triangle  $ONK$  we can be write

$$\frac{r_1 - l_{t11} / \cos \gamma_3}{\sin \psi_1} = \frac{r_1}{\sin(90^\circ + \gamma_3)}.$$

After the transformation we will have

$$l_{t11} = r_1 (\cos \gamma_3 - \sin \psi_1), \quad (2)$$

$$\text{where } \sin \psi_1 = \sqrt{1 - \cos^2 \psi_1} \text{ or } \sin \psi_1 = \sqrt{\frac{r_1(2 - \sin^2 \gamma_3) - \sin \gamma_3 \sqrt{r_1^2 \sin^2 \gamma_3 + 4r_1 H_t} - 2H_t}{2r_1}}.$$

After the transformation of formula (2) and taking into account  $H_t = m_t$  the length of the straight segment on the front edge of the external ratchet tooth can be expressed as

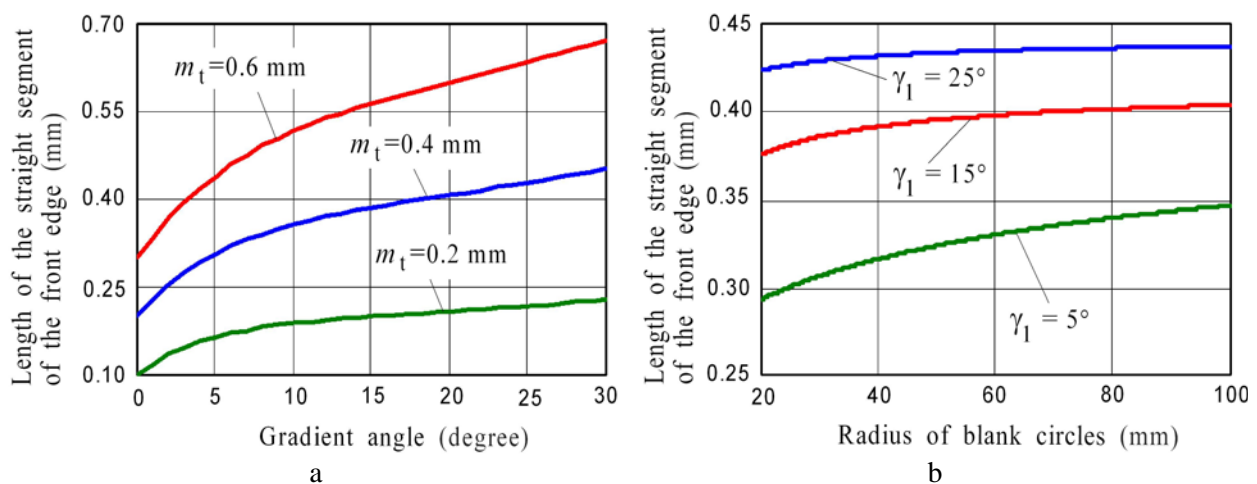
$$l_{t1} = r_1 \left[ \cos \gamma_3 - \sqrt{\frac{r_1(2 - \sin^2 \gamma_3) - 2m_t - \sin \gamma_3 \sqrt{r_1^2 \sin^2 \gamma_3 + 4r_1 m_t}}{2r_1}} \right]. \quad (3)$$

### 3. Numerical Results and Discussion

The effect of module  $m_t$ , gradient angle  $\gamma_1$  and radius  $r_1$  on the length of the straight segment of front edge  $l_{t1}$  is shown in Figure 4. Calculations are executed by formula (3).

The initial data for the calculations are accepted as:  $r_1 = 20 \dots 100$  mm;  $m_t = 0.4 \dots 0.6$  mm;  $\gamma_1 = 0 \dots 30^\circ$ . The value of gradient angle  $\gamma_3$  is defined by formula [7]

$$\gamma_3 = \arcsin \left( \frac{r_{f1} \sin \gamma_1}{r_{f2}} \right).$$



**Figure 4.** The effect of the module, gradient angle and blank circles radius on the length of the straight segment of the tooth front edge: *a* –  $r_1 = 30$  mm;  $m_t = 0.4 \dots 0.6$  mm; *b* –  $m_t = 0.4$  mm;  $\gamma_1 = 5 \dots 25^\circ$ .

The calculation results allow one to draw the following conclusions. A 1.5 time increase of module  $m_t$  causes a 2.7...3.0 time linear growth of the length of the straight segment of front edge  $l_{t1}$ . The increase of gradient angle  $\gamma_1$  in the range from 0 to  $30^\circ$  causes a 2.20...2.25 time nonlinear growth of the length of the straight segment of the front edge. The increase of radius  $r_1$  in the range from 20 to 100 mm causes a 1.02...1.17 time decrease of the length of the straight segment of the front edge.

### 4. Conclusion

For shaping ratchet teeth it is recommended to use the continuously indexing method. One can select a shaper cutter or a rack cutter as the cutting tool. The shaper cutter is a universal cutting tool because it allows shaping both external and internal fine-module ratchet teeth.

## References

- [1] Aliukov S, Keller A and Alyukov A 2015 *Jour. SAE Technical Paper* 2015-01-1130
- [2] Orthwein W C 2004 *Clutches and brakes: design and selection* (New York: Marcel Dekker) p 312
- [3] Neale M J 2001 *The tribology handbook* (Oxford: Butterworth-Heinemann) p 640
- [4] Feng Z, Gao Z and Lu W 2013 *J. Advanced Mater. Research* **823** 43–46
- [5] Bondaletov V P 2008 *Russian Jour. Russian Engineering Research* **28(9)** 845–848
- [6] Lee C J, Samie F and Kao C-K 2010 *Proceedings of the ASME Dynamic Systems and Control Conference DSCC2009* **B** 1517–1521
- [7] Sharkov O V, Koryagin S I and Velikanov N L 2015 *J. Appl. Mechan. and Mat.* **770** 264–268
- [8] Xia L, Li D and Han J 2014 *J. Key Engineering Materials* **579-580** 300–304
- [9] Stadtfeld H J 2011 *American Gear Manufacturers Association Fall Technical Meeting* pp 1–14
- [10] Huang C-L, Fong Z-H, Chen S-D and Chang K-R 2009 *J Mechanism and Machine Theory* **44(2)** 401–411
- [11] Khurmi R S and Gupta J K 2005 *Theory of Machines* (New Dehli: S.Chand & Co. Ltd.) p 1060
- [12] Radzevich S P 2012 *Theory of Gearing: Kinematics, Geometry, and Synthesis* (Boca Raton: CRC Press) p 743
- [13] Mott R L 2014 *Machine elements in mechanical design* (Upper Saddle River, New Jersey: Pearson Education) p 816
- [14] Youssef H A and El-Hofy H 2008 *Machining Technology: Machine Tools and Operations* (Boca Raton, London, New York: CRC Press) p 672