# The Synthesis and Visualization on Tooth Profile of Swing Movable Teeth Transmission

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**Abstract.** Differing from the general gear drive, movable teeth transmission is a new type of planetary gear mechanical drive, which used to transmit rotary motion and power between two shafts with same axis. The tooth profile is very vital and the meshing quality of the central gear, shock wave device and swing movable teeth play an important role in the performance and efficiency of the transmission. It has been inferred that the tooth profile curve equation of swing movable teeth by the envelope method based on the theory of gear meshing firstly. What's more, synthesis on the tooth profile has been made in the paper and the meshing curve has been drawn by Matlab. In addition, the applicable scope and the tooth profile curve equation are discussed.

## Introduction

Differing from the general gear drive, movable teeth transmission is a new type of mechanical drive, which used to transmit rotary motion and power between two shafts with same axis[1]. It is composed of three basic parts, shock wave device H, movable teeth gear G and central gear K. The central gear which is usually fixed on the engine base is an internal gear ring with complex envelope curve tooth form. In recent years, many domestic and foreign scientists are studying continuously in the field of movable teeth transmission[2,3]. It has acquired plenty of important theoretical and practical achievements[4,5].To the driver, the tooth profile is very vital. The meshing quality of central gear, shock wave device and swing movable teeth play an important role in the performance and efficiency of the transmission. The tooth profile of central gear is complex especially, which is difficult to design and manufacture. In the paper, it will infer the tooth profile curve equation of swing movable teeth by the envelope method based on the theory of gear meshing. Furthermore, it will make synthesis and visualization on the tooth profile and draw the meshing curve by Matlab[6]. In addition, the applicable scope and the tooth profile curve equation will be discussed.

## The Mesh Joint Structure Model and Equivalent Mechanism of Swing Movable Teeth Transmission

It can choose a mesh joint as the study object when research the meshing structure theory which is independent on the phase. Fig. 1 is the mesh joint of swing movable teeth transmission. When the central gear is fixed, the joint composed with the shock wave device, the swing movable teeth and the movable teeth gear have three movable parts, three rotating joints and two high joints. It's freedom degree is one. Therefore given a driving piece, the transmission can obtain determined motion.

To solve the synthesis envelope of the movable tooth transmission with the equivalent mechanism method of the tooth profile analysis of the transmission, the first matter is to find the low joint equivalent mechanism of the swing movable teeth transmission. By the principle of high joint instead low joint, the high joint which composed with the inner profile curve of the tooth and the profile curve of the shock wave device can be changed to low joint. It must include two essential conditions.

On one hand, after the replacement, the free degree of mechanism remains unchanged. Therefore, it may be add a moving rod BC and makes two revolute joints B, C instead of high joint B. On the

other hand, after the replacement, the movement of the mechanism remains unchanged. Then two revolute joints must be put on the curvature center of two kinematic joints which form high joint.

Accordingly, the low joint equivalent mechanism is come into being, which is tooth profile synthesis positive envelope of the swing movable teeth transmission. Shown as Fig.2, it is a parallelogram equivalent mechanism of the transmission's meshing joint. In the parallelogram OBCD, the eccentricity OB of the shock wave device is equal to the eccentricity DC of the swing movable tooth, which becomes double crank of the parallelogram mechanism. The radius of the pin distribution circle OD is equal to the radius of the shock wave device with swing movable tooth radius, which amount to respectively frame and the connecting rod.

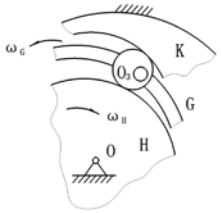



Fig. 1 The mesh joint

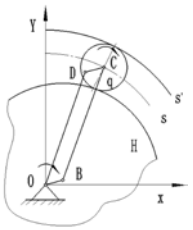



Fig. 2 The equivalent mechanism

**The Design Principles of the Movable Tooth Profile**

Any gear should follow the meshing theory. When a pair of conjugate tooth surface are conjugated, they must be contacted continuously each other and the transmission ratio of the predetermined rules must achieved. Meanwhile, the meshing joint must be ensured the good technical performance and meshing strength. The design of movable teeth profile should abide by the following design principles.

Firstly, the shock wave device, rotating constantly, pushes the movable teeth to do radial motion according to the shock wave cam curve. Tooth profile design must ensure that it is moving on its own regular pattern and movable tooth drives the outer ring with constant speed so that constant speed ratio is achieved. Secondly, it must ensure that the conjugate tooth profiles have high strength, more meshing teeth or high overlap coefficient and small sliding rate. Finally, tooth profile must have good manufacturability, in order to facilitate manufacturing and processing and have a better standardization and serialization.

**The Tooth Profile Synthesis Positive Envelope Solution of the Swing Movable Teeth Transmission**

Only the correct design of outline curve of the shock wave device, the profile curve of the swing movable teeth and the central gear can it achieve constant instantaneous transmission ratio of the transmission between the shock wave device and the swing movable teeth or between the shock wave device and the central gear. Due to the concerned mechanism has the cylindrical movable tooth and the eccentric-disc shock wave device, it comes to realize the constant speed ratio transmission as long as the curve design abides by the envelope principle. In this study, the tooth profile of swing movable teeth is designed with envelope principle.

When the high joint curve of the swing movable tooth and the shock wave device is confirmed, one of the high joint curves of the movable tooth and the central gear is given, the profile curve of the central gear is the envelope of the swing movable tooth, or the profile curve of the swing movable tooth is the envelope of the central gear, which is under the conjugate movement condition of the shock wave device and the movable teeth gear. This is tooth profile synthesis positive envelope solution of the swing movable teeth transmission. Fig.3 is the movement diagram of the movable tooth.

**The Equation of Movable Tooth Geometric Center Trajectory.** As shown in Fig.3, sets the geometry rotary center of eccentric disc to the origin, and then establishes coordinate system, the central point of movable tooth trajectory equation is obtained.

$$\rho = S \times \cos(\beta - \alpha) + \sqrt{(R+r)^2 - S^2 \sin^2(\beta - \alpha)} \tag{1}$$

For example, the number of movable teeth is one more than central gear, that is n-1=m. According to the Eqn.(4) and $\beta - \alpha = (n-1)\alpha$, it can be obtained the following:

$$\rho = S \times \cos((n-1)\alpha) + \sqrt{(R+r)^2 - S^2 \sin^2((n-1)\alpha)} \tag{2}$$

With the MATLAB software, it can undertake numerical calculations quickly, deal with visual data conveniently and intuitively and visualize data of the study. Fig.4 shows the trajectory of movable tooth geometry center moving by polar coordinates with the application of MATLAB software.

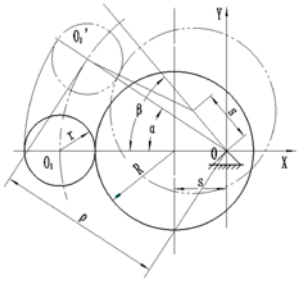


Fig. 3 Movement diagram of movable tooth

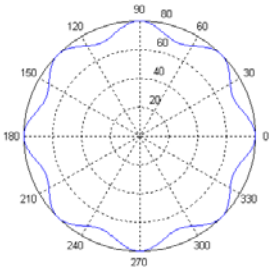


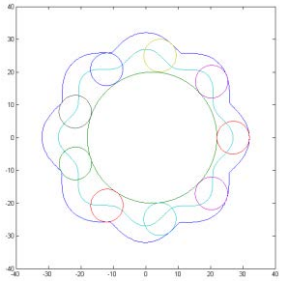

Fig. 4 Trajectory of movable tooth geometric center

**The Inner Profile Curve of Central Gear.** Envelope is a kind of effective method to solve the geometric problems of the teeth mesh transmission. When one of the tooth surfaces of two meshing transmission conjugate tooth surface is seen as generatrix, the other is formed envelope surface by the former according to certain relative motion. Their instantaneous meshing line is the tangent line between the generatrix and the envelope surface at the tangency moment in the process of movement, and then the collection of the tangent line forms the tooth surface meshing generatrix. Once one of the tooth surfaces and its relative motion in the mesh is known, the other is easily found the solution.

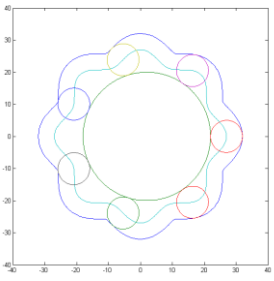
According to the above, regards the diameter curve of the movable tooth pin roller geometry center as the relative motion conditions, and also regards roller surface as the generatrix, the outer profile of the moveable tooth pin roller is obtained, which is the inner gear tooth profile of the central gear requested.

Similarly, it can obtains the profile of the central gear when the number of movable teeth is one less than the central gear according Eqn.(2). It can get the following formula.

$$\rho = S \times \cos((n+1)\alpha) + \sqrt{(R+r)^2 - S^2 \sin^2((n+1)\alpha)} \tag{3}$$



(a)



(b)

Fig. 5 The meshing curves when different number of movable teeth from central gear

Programming in MATLAB software, it can achieves the meshing curves with inner tooth profile of the central gear and the surface of movable tooth when the number of movable teeth is one more than the central gear, as shown in Fig.5 (a).As shown in Fig.5 (b), it is the meshing profile figure of the

central gear and the movable tooth when the number of movable teeth is one less than the number of the central gear in MATLAB software.

## Discussing on Tooth Profile Curve Equations

**The Applicability of Tooth Profile Equations.** Comparing Eqn. (2) with Eqn. (3), they have the same forms obviously. For this reason, it has drawn conclusion that the profile equation is exactly the same, no matter the number of movable teeth is one more or less than the teeth number of central gear. It applies to the central gear profile only for one-tooth-difference transmission, which is called the number of teeth between movable teeth and central gear differ by single. The design of tooth profile may not be affected by the integer constraints and the design of reducer will be more flexible.

**Analysis of Tooth Profile Curvature.** By geometry, only the tooth roller radius is less than the curvature radius of the center gear profile, the interference between the movable tooth and tooth profile of the central gear doesn't occurs; only the radius of curvature of the center gear profile is greater than zero, the tooth profile is not undercut. It is significant to study the curvature of any point on the central gear profile.

On one hand, the curvature of central gear tooth profile is very complex, so that it is not easier to solve directly. On the other hand, because of the radius of the shock device is much larger than the radius of movable tooth pin roller, the curvature for an arbitrary point of the movable tooth geometry center trajectory curve is only slightly larger than the corresponding point of the central gear profile. So profile curvature of central gear can be simplified to the curvature of movable tooth center track.

## Summary

At first place, this paper has inferred the tooth profile curve equation of swing movable teeth by the envelope method based on the theory of gear meshing. What's more, it drew the curve meshing tooth profile by programming in Matlab software and the meshing profile figure between the movable tooth and the central gear. In addition, the applicable scope and the tooth profile curve equation are discussed.

In addition to solving method of tooth profile curve, it can be used the equidistance method. The tooth profile curve educed in the study is the theoretical curve, but in the actual project, the design of tooth profile should also be carried out tooth profile modification on the basis of the study, in order to make the gear side clearance and improve transmission performance.

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