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An application of geodesics to the calculation of the rib-thickness of globoidal cam mechanisms

Shuting Ji *, Jing Zhao, Yueming Zhang

College of Mechanical Engineering and Applied Electronics Technology, Beijing University of Technology, Chaoyang District, 100124, PR China

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ABSTRACT

A systematic approach based on the geodesics in differential geometry for calculating the rib-thickness of the globoidal cam is proposed. In the proposed approach, the analytical description of the rib-thickness is derived and calculated using coordinate transformation, conjugate theory and differential geometry. In addition, the mathematical expressions for the contact curves of the conjugate surfaces, intersection curves of the ribbed surfaces with the torus, and the geodesics of the torus surface are conveniently derived. Then these curves and the ribbed surfaces are all simulated with the help of Creo Software after the calculation results are obtained using VC programming. By comparing the rib-thickness with respect to three motion curves, we find that the peak value of the velocity curve has great effects on the rib-thickness. A globoidal cam used in an automatic tool changer of CNC machines is used as an example to validate the proposed methodology. The results of this research are necessary for both the selection of motion curves, and the investigations of the rigidity and the strength of the globoidal cam mechanisms.

1. Introduction

The globoidal cam mechanism is also referred to as the roller gear cam mechanisms. Due to the advantages of high loading capacity, low noise, low vibration, and high reliability as compared with some traditional intermittent motion mechanisms, the globoidal cam mechanisms are widely used in the automatic tool changer (ATC) of CNC machines [1]. A globoidal cam mechanism is composed of a globoidal cam and a turret with rollers. Such a mechanism with six cylindrical rollers is shown in Fig. 1. The axis of the globoidal cam is perpendicular to the turret axis. The solid model of the globoidal cam with tapered ribs is shown in Fig. 2. In the working process, the rollers are driven by the ribs of the globoidal cam. For guaranteeing the rigidity and strength of globoidal cam mechanism, the selection of appropriate rib-thickness of the globoidal cam is a critical issue. However, the discussion of the rib-thickness of the globoidal cam is not available in the technical literature.

For the complexity of the surface generation of the globoidal cam, the thickness of the rib is different at different positions, so that the definition of tooth thickness of gears is not suitable for globoidal cam mechanisms. It can be seen that the surface of a globoidal cam blank is shaped in the form of a circular arc of revolution. Thus, the globoidal cam blank can be considered as a portion of a ring torus (Fig. 1). The torus is the reference torus for the rib-thickness of globoidal cam mechanisms, and is similar to the pitch circle which is the reference circle for tooth element proportions of gears [2]. A rib is composed by three surfaces: the two side ribbed surfaces that mesh with the rollers, and the top surface that is a portion of the torus surface (Fig. 2). The rib-thickness can be defined as the shortest arc length between a point of one side ribbed surface and a point of the other side ribbed surface, measured along a

* Corresponding author. Tel.: +86 15201586178.
E-mail address: yuncaishu123@163.com (S. Ji).

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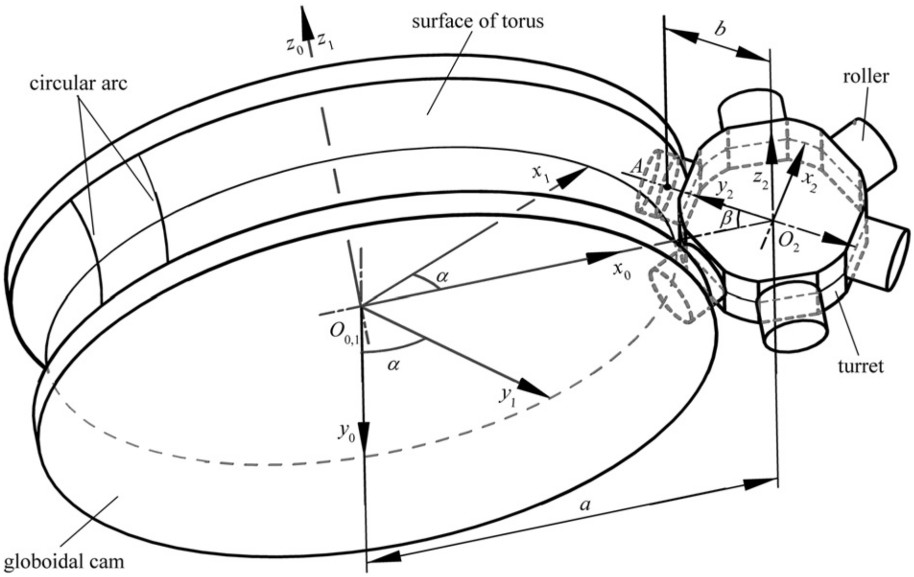

Fig. 1. The coordinate systems of the globoidal cam mechanism.

specified torus. According to the theory of differential geometry, the geodesics are locally the shortest path between two points on a surface. Along different directions at the origin point on one side ribbed surface, there are numerous geodesics on the torus surface intersected by the other ribbed surface. Under such a scenario, the rib-thickness of the globoidal cam can be taken to be the shortest length of these geodesic segments on the ring torus. Thus, we can conclude that the method applying the geodesics is the most advantageous method to calculate the rib-thickness of the globoidal cam mechanisms. The concept of geodesics and the differential equations for geodesics on a ring torus have been published in several books on differential geometry [3–5].

The first step for the calculation of the rib-thickness of the globoidal cam mechanism is to synthesize or select the follower motion curve of the turret. There are three traditional motion curves commonly selected, such as the modified constant velocity, modified sine and modified trapezoidal curves [6]. Erdman [7] gave reviews of many studies on the cam mechanisms. The four applied approaches to the derivation of cam surfaces are based on the offset surface method [8–10], the screw theory [11–13], the envelope theory [14–16] and the conjugate theory [17–21]. Among them, the method based on the conjugate theory and the offset surface method are mainly applied.

In addition to the derivation of the globoidal cam surfaces, there are many other technical considerations for the geometry of the globoidal cam mechanisms — namely, the kinematic characteristics [22–24] (pressure angles and surface curvatures), dynamic characteristics [25,26] (forces, input torque, and efficiency) and so forth. Oizumi [27] calculated the frictional loss of power in meshing of a globoidal-cam type gearing. Based on the consideration of the geometry of the globoidal cam mechanisms, some researchers have put their efforts into contact analysis between the cam surfaces and the meshing rollers. Tsay and Huang [28] analyzed the pressure angle and the principal curvature of the cam surface, and evaluated the contact forces, input torque and the reducer efficiency. Yan and Cheng [29] expressed the undercut in a concise form, which can be applied to all planar and spatial cam mechanisms. Lo et al. [30]

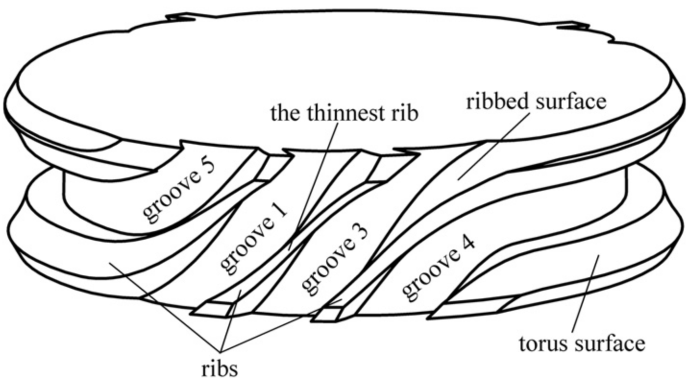

Fig. 2. The solid model of the globoidal cam.