Mechanism and Machine Theory 81 (2014) 181–192

Contents lists available at ScienceDirect

Mechanism and Machine Theory

journal homepage: www.elsevier.com/locate/mechmt

# Radius of curvature and sliding velocity in constant-breadth cam mechanisms

S. Cardona, E.E. Zayas *, L. Jordi

*Department of Mechanical Engineering, ETSEIB, Universitat Politècnica de Catalunya, Diagonal 647, 08028 Barcelona, Spain*

ARTICLE INFO

*Article history:*
Received 2 September 2013
Received in revised form 5 June 2014
Accepted 11 July 2014
Available online 1 August 2014

*Keywords:*
Constant breadth cam
Radius of curvature
Sliding velocity
Angle of inclination
Offset

ABSTRACT

In constant-breadth cam mechanisms closure of the higher kinematic pairs formed by the bilateral cam-follower contact is guaranteed by the geometry of both cam and follower. A study of the cam profile by means of its radius of curvature and the sliding velocities in the upper pair enables us to predict the correct functioning of the mechanism. This work presents the equations for calculating cam breadth when the translating follower is eccentric with an inclination, the radius of curvature of its profile and the sliding velocities of constant-breadth cam mechanisms with translating and oscillating followers. This study also analyses the influence of the angle of inclination and the offset of the flat-faced translating followers on the size of the cam and the kinematics of the mechanism. Numerical examples are given of constant-breadth cams obtained for distinct values of the mentioned parameters. Additionally, this paper describes the redesign of a cam of a conventional sewing machine and the new cam prototype, with a continuity of an order higher than the original profile, is included.



## 1. Introduction

Constant-breadth cam mechanisms belong to the class of what is known as desmodromic or positive drive cam mechanisms, which are characterised by the fact that closure of the upper kinematic pair, formed by the cam–follower contact, is guaranteed thanks to the geometry of the cam and the follower. If this is a parallel flat-faced double follower, the distance $d_c$ between them is the breadth of the cam (Fig. 1a). The constant-breadth cams may be circular arc cams or may have arbitrary geometry and can operate either translating (Fig. 1a) or oscillating follower (Fig. 8) if the appropriate desmodromic conditions are established [1].

The published studies of constant-breadth cam mechanisms normally use circular arc cam profiles and displacement functions for the double-dwell follower, basically synthesised using the cycloidal and polynomial motion curves on a monomial basis [2,3], without checking the radius of curvature or the sliding velocity. Rothbart [4] shows an example of a constant-breadth circular arc cam profile in which the follower's movement is a double-dwell function. He dedicates a section to establishing the parametric calculation equations of the radius of curvature in force-closed cam mechanisms that use flat-faced and roller followers. Chen [5] devotes a chapter of his book to obtaining the radius of curvature using different analytical methods applied to non-desmodromic cam–follower mechanisms. Koloc and Václavik [6] include a section about special cams and show a constant-breadth cam mechanism that drives an oscillating flat-faced follower; the cam profile is built from circular arcs and the corresponding displacement function has continuity $C^1$.

* Corresponding author. Tel.: +34 93 401 57 18; fax: +34 93 401 58 13.
*E-mail address:* enrique.zayas@upc.edu (E.E. Zayas).

http://dx.doi.org/10.1016/j.mechmachtheory.2014.07.005
0094-114X/

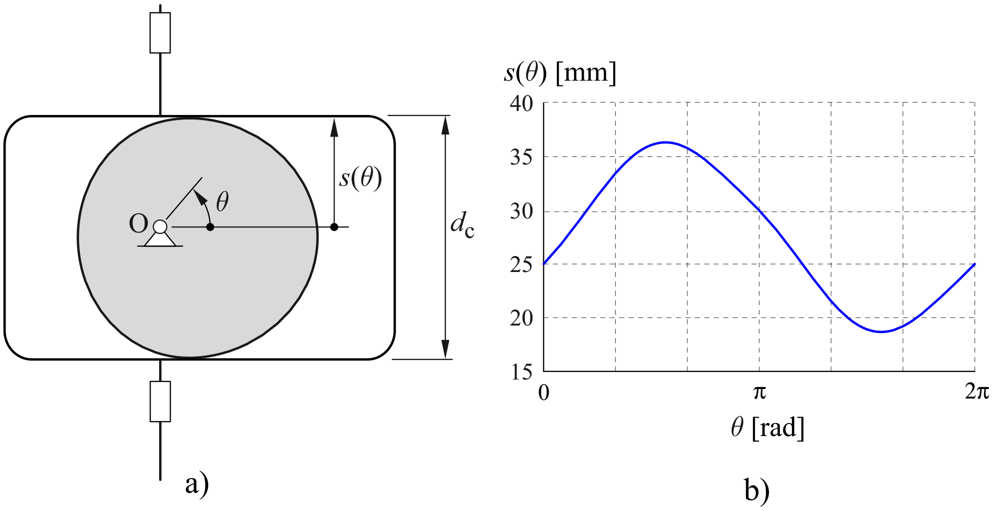


**Fig. 1.** a). Constant-breadth cam mechanism with a parallel flat-faced double translating follower. b) Displacement function of the follower.

Qian [7] looks at a constant-diameter cam mechanism that operates a double roller follower with planar movement that is joined to an output rocker arm and uses a graphical–analytical method to establish the relationship between the geometric parameters of the mechanism and the cam angles. This produces the parametric equations that generate the profile of the constant diameter cam. This work does not study how the radius of curvature of the cam profile or the sliding velocity varies. Dhande and Rajaram [8] present a kinematic analysis of certain types of constant-breadth cam mechanisms of circular arcs and, by applying the theory of conjugated curves, provide the closed form parametric equations to obtain the displacement, velocity and acceleration of the follower. Their work does not check the radius of curvature of the constant width profiles obtained or the sliding velocity at the cam–follower contact points. Other authors, such as Lanni et al. [9] and Hsieh [10], establish the importance of the design of circular arc cams, indicating the current interest in this type of cam due to its application in mini and micro-mechanisms. They are easy profiles to design, manufacture and test and consequently are cheap. Hsieh analyses the kinematics of the mechanism without studying the sliding velocity at the cam–follower contact point. Lin et al. [11] present a design method for a cam mechanism called the breadth cam mechanism. The name refers to a mechanism with a cam that drives a double oscillating follower with a constant distance between the centres of the opposite rollers. Their proposed method is based on the geometric and velocity relationships at the instantaneous velocity centres and is able to determine the coordinates at the cam–follower contact points. They also present a programme to automatically calculate and draw a two dimensional cam profile.

Norton [12] and Shigley & Uicker [13] describe the use of offset as a parameter that allows control of the pressure angle for cam–follower mechanisms with roller followers and flat-faced followers with zero angle of inclination. They also provide the equations for calculating the radius of curvature of the cam profile. Furthermore, Norton indicates that the use of offset to control the pressure angle is of little value in slotted face desmodromic cams. However, he does not explain what would happen when using offset with constant-breadth cams.

Català et al. [14] present a procedure for studying the influence that an adjustment of the predicted interference has on the fatigue life of a conjugated cam mechanism. The work shows how the radius of curvature of the cam profile influences the cam–follower contact pressure and the fatigue life of the mechanism.

In previous work [1,15], the authors of this paper presented the basic features that the follower's displacement functions and their synthesis methods must have to generate constant-breadth cam profiles that act upon both translating and oscillating followers. These works conclude that the displacement functions are composed of two segments. The first segment is designed (in the above examples, using non-parametric Bézier curves) and the second is calculated from the first. A new work by the authors [16] sets out a procedure to automatically guarantee the continuity of the displacement functions at the union between the designed and calculated segments.

The present work complements the abovementioned work [16] and studies two constant-breadth cam mechanisms. In the first mechanism, the cam operates a double flat-faced translating follower, while in the second mechanism it acts upon an oscillating follower. The work provides the equations for calculating the cam breadth $d_c'$ when the translating follower is eccentric and has a non-null angle of inclination, as well as the radius of curvature $r_c$ of the cam profile and the sliding velocity $v_{slid}$ at the cam–follower contact points due to the importance that these parameters have on the fatigue life [14] and the performance of the mechanism. In addition, it analyses the impacts that the variations of the inclination $\beta$ and the offset $\varepsilon$ of the translating follower have on the size of the cam and the kinematics of the mechanism. It provides numerical examples of constant-breadth cam profiles obtained for various values of the parameters mentioned above as well as graphics of the radius of curvature of the profile and the sliding velocities. Additionally, the study and redesign of the cam of a conventional sewing machine and the prototype of a cam proposed with a higher continuity to the original profile are presented.