Calculation of the Contours of a Radial Double Cam Based on an Approximate Course of the 2nd Derivative of the Displacement Law of a Working Link

P. Jirásko and M. Václavík

Abstract This paper deals with requirements for the production of cam mechanisms or cams that reliably operate in manufacturing machines even for several decades and currently, it is necessary their replacement due to wear. Those machines are usually unique in their construction and they meet the demanding technological requirements of the production even today. The effort of producers or users is to overhaul those machines and so continue to use them. We meet today with the requirements for the manufacture of years proven cam mechanisms with an insufficient or incomplete production documentation. The paper focuses on one such characteristic case.

Keywords Radial cam and double cam · Cam mechanism · Kinematic analysis and synthesis · Approximation

1 Introduction

A significant expansion of cams and cam mechanisms occurred in the seventies and eighties of the last century with the mass deployment of NC machine tools. At that time, the use of computer technology was very limited and it concentrated in research centers or at major manufacturers, for example, at those producing machine tools. The situation in computer technology corresponded to that time with its unique hardware and software components. The conventional and today widespread PC was not in the world. At that time, VÚTS used calculators and first computers from Hewlett-Packard and Olivetti. The same situation was also among

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major manufacturers of machines using cam mechanisms. In such a way, on specific HW computing means, there were developed unique and therefore non-transferable programs with calculation algorithms of production coordinates of the contours of cams. Production data were archived and transferred to machines through punched tapes. After the rapid development of computer technology in the following decades, there often occurred both a loss of production data and "forgetting" of special algorithms and analytical relations describing unique technological movements that were implemented by cam mechanisms.

The special customer's requirement was therefore the manufacture of a cam based on the schematic description of the 2nd derivative of motion function of the working link of a cam mechanism. The paper depicts a methodology for calculating the production coordinates of a radial double cam of that business case.

1.1 General Calculation Methodology of Cam Mechanisms in VÚTS

VÚTS developed the methodology and the associated software to address these cases. It is a system of two communicating sw means that are APROX programs (approximation of a discreetly or numerically defined displacement law with an equidistant step) and KIN (kinematic analysis and synthesis of compound cam mechanisms).

Using the *APROX* program, it can be approximated a function which is defined in a one or several discrete intervals—*blocks*. Inside the selected block, there are chosen *intervals* or *boundary* of intervals. In the intervals, the given function will be approximated using a polynomial of the fifth or seventh degree. The courses of the polynomials can be influenced by the position of *boundary points* or interval boundaries, *boundary values* of polynomials or a degree of a polynomial. The position of the boundary points will be chosen, the boundary values are determined by the program and they can be then corrected. The correction is to be performed in the boundary points of the blocks always there when it is necessary to ensure the mutual sequence of the blocks (in all derivatives according to the degree of the polynomial).

By *kinematic analysis* of the basic cam mechanism with conventional cam it is understood determination of the movement (kinematic quantities) of the working link with rotary (rocker) or sliding (follower) movement for the given movement at the *input* and the defined dimensions of a cam mechanism including the theoretical profile (path of the roller center). Thus, by an *analysis* it is determined the *motion function* of the working link (rocker, follower) in dependence on time or *displacement law* depending on the angle of rotation of the cam at a constant angular velocity equal to 1 (rad/s). The block diagram is in Fig. 1.

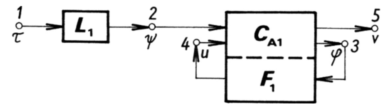

Fig. 1 Block diagram of kinematic analysis [1, 2]

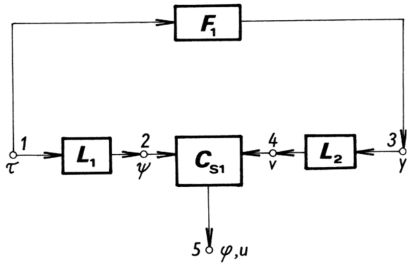

Fig. 2 Block diagram of kinematic synthesis [1, 2]

By *kinematic synthesis* of a basic cam mechanism with conventional cam it is meant the design of a mechanism for the prescribed rotary (rocker) or sliding (follower) movement of the working link and for the given movement of a cam. The result is usually determination of the polar coordinates of the theoretical profile of a cam (path of the roller center of the basic cam mechanism) following the displacement law of the working link or the rocker or follower depending on the constant rotation of the cam. The block diagram is in Fig. 2.

In both assignments, linear constraint L_1 defines the sense of the cam rotation. Function block F_1 in the case of *analysis* it is function relation $u = u(\varphi)$ of the polar coordinates of the theoretical profile of the radial cam and in the case of *synthesis* it is displacement law $y = y(\tau)$ of the working link (rocker, follower) depending on the non-oriented uniform angle of rotation τ or time. Linear constraint L_2 in the case of synthesis it is transformation (translation, scaling) of displacement law F_1. The result of the calculation of *analysis* is according to Fig. 1 *kinematic quantities of the working link* (rocker, follower). The result of the calculation of *synthesis* according to Fig. 2 is *polar coordinates* (φ, u) *of the theoretical profile of a cam* (generally radial, axial, and globoid) iterated to the specified equidistant step of coordinate φ.

2 Specification of the Assignment

By the customer, as production documentation, it is delivered a production drawing according to which the production technology of the blank of a double cam is determined, a cutout is in Fig. 3. (For the reasons of the confidentiality of the customer, merely illustrative cutouts are listed). Other documentation is records for the calculation and for clarity, they are again given partial cutouts in Figs. 4 and 5.

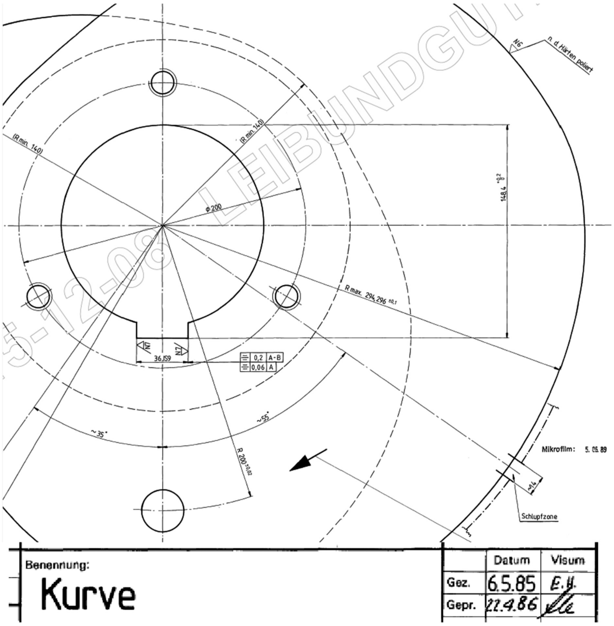

Fig. 3 Cutouts from the drawing of a double cam

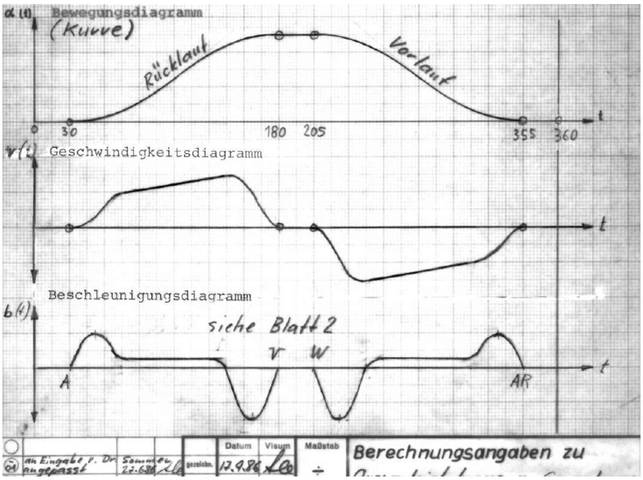

Fig. 4 Scheme of the motion function of the working link

Therefore, it is a schematic representation of the motion function of the working link, which is the rocker of a double cam. Specific usable data for the calculation are only the values of the acceleration polygon with a very course non-equidistant step

Fig. 5 Setting values of the acceleration polygon (partial view)

Bewegungsgesetze		Δ t°	Δ α°	b/b max	$\dot{\alpha}$		
Rast		30			0		
Beschl. - Polygon		150	+32,5966				
Zwischenwerte	A	0		0			
	B	4		0,2409			
	C	8		0,4511			
	D	11		0,5812			
	E	14		0,6913			
	F	18		0,7613			
	G	22		0,7613			
	H	26		0,6913			

of the independently variable and the geometry of the double cam mechanism (length of the frame, lengths of the rockers of the master and slave cams, roller diameters).

3 The Methodology of Calculation of the Production Coordinates

Due to a limited extent of the paper, we will present only essential documents. Data of the acceleration polygon (see Figs. 4 and 5) are interpolated and subsequently per sections twice numerically integrated. The thus obtained data file is to be approximated per selected sections (sw APROX) by polynomials of the 5th or 7th degree with the check of a positional deviation according to Fig. 6. The file of analytic relations describing the displacement law of the rocker (15 sections of the polynomials) enters the kinematic synthesis of the KIN program according to Fig. 7. The result of the synthesis is the polar coordinates of any arbitrary equidistances of both cams (master and slave) according to the scheme in Fig. 2.

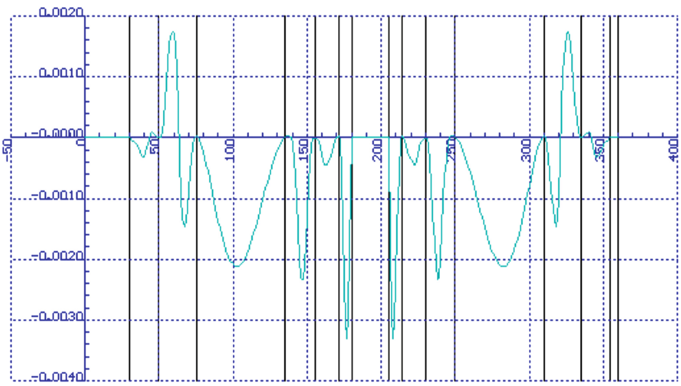

Fig. 6 Positional error with respect to the course of the 2nd derivative of the displacement law of the double cam rocker (15 sections), X-axis (deg), Y-axis (mm)

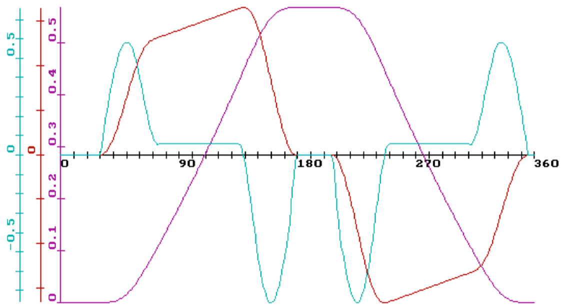

Fig. 7 Displacement law of the double cam rocker entering sw KIN, X-axis (deg), Y0-axis (mm), Y1 (rad/rad), Y2 (rad/rad^2)

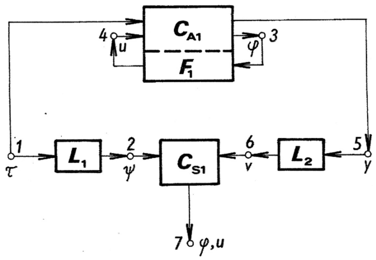

Fig. 8 Task of the analysis of the master cam (sw APROX, sw KIN) with the synthesis of the slave cam (sw KIN) [2]

4 Conclusion

The double cam was produced in the required quality and delivered to full satisfaction of a customer from Western Europe who requires maximum quality. The contract value was in the order of thousands of euros. It was a double cam made from the blank of a diameter of 600 (mm) and a weight of about 350 (kg). The mentioned case is not unique, contracts of a similar type on the basis of insufficient documentation or based on specific worn cams are becoming more common. According to Fig. 8, the creation of the double cam production coordinates is from the measured contour of the master cam by combining *kinematic analysis and synthesis*. This can be done even with worn double cams to which no drawing and calculation documentation is available.

References

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