Distribution of the contact pressure in the cam-follower mechanism

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Abstract- Educational A disc cam is studied that drives a roller follower whose law of displacement has been designed through the use of Bezier grades 5, 7 and 9, the roller undergoes a full upward and downward movement. The equations for finding the contact pressure in a parallel cylinder system are presented, then the variation of the contact pressure in mechanism during a complete rotation cycle is presented, the theory of contact in the cam-follower mechanism is explained by silvering the formulas of Contact footprint and Contact Pressure. The distribution of the contact pressure variation for the study of the full motion cam-follower will be shown in a graph.

Keywords – Contact Pressure, Bezier Curve, Contact Footprint, Variation.

I. INTRODUCTION

Cam-follower systems are applied in many of the machines used in engineering. Cam-followers comply with the principle of a four-bar linkage mechanism that has a non-circular motion. Compared to four-bar mechanisms, cams are easier to design to give a specific output function, however, the production process is more complex and costlier [1]. The cam-follower mechanism, being in permanent contact, experiences pressures on its surface as a result of this contact. This pressure is caused by the force of contact between the elements, which is related to the assembly closing system [2]. In the case of disc cams with translation roller, the most used closing system is that of force closing which, by means of a spring, exerts an overload on the mechanism so that there is no separation between the elements due to negative accelerations [3]. The contact pressure present in the cam mechanisms can cause deformations in the elements, with adequate load analysis, the magnitudes of the pressures only cause small deflections in the plastic limit of the material, but if the necessary safety parameters are not considered, these pressures would cause cracks, pitting or flaking in the surface of the material which represents the end of the useful life of the mechanism [4].

New theoretical knowledge of the design of the cam-follower mechanism is proposed, especially the study of the distribution of pressures present at the point of contact between them. This pressure generates as a consequence a series of efforts that vary along the whole circular perimeter (cam profile); considering these efforts that can synthesize a good system with better efficiencies and therefore lower maintenance costs. The following issues are considered successively: what the contact theory studies and why it should be considered, how the contact force acts on the contact footprint and thus creating infinite areas where the contact pressure is generated, then it is shown through a graph the results according to the Bezier Curves.

II. Methodology

2.1 Theory of contact

This theory studies the efforts generated in the contact zone between two elements with rotational motion, depending on the properties, geometry and load applied to the bodies. It also allows a three-dimensional study of the contact forces acting inside a body as the contact pressures in a cylinder. In cams with a thickness less than the radius of the primary circle, it experiences a state of two-dimensional stress or commonly called plane stress with their respective main stresses and the cams with a greater experimental thickness, three-dimensional or plane deformation stresses. In this study a short cam is taken [5].

2.2 Bezier curves

They are nonparametric curves that have the advantage of an intuitive nature in which the curve follows the control polygon and also has ease of continuity in straight sections thus generating curves of displacement, speed and acceleration [6]. They use a degree n and their equation is expressed as follows.

$$B_i^n(u) = \binom{n}{i} u^i (1-u)^{n-i} = C_n^i u^i (1-u)^{n-i}; \quad i = 0, \ldots\ldots, n \tag{1}$$

The grade analyzes the study of the cam according to its number (i) [7], then:

$$\binom{n}{i} = C_n^i = \frac{n!}{i!\,(n-i)!} \tag{2}$$

$$B_i^n(u) = 0 \tag{3}$$

$$\square \nexists \; 0, \ldots., \square \tag{4}$$

These curves must have properties of symmetry, positivity and also establish a numerical base [8].

2.3 Contact footprint

The contact force creates finite areas due to deflections, being these areas small in comparison with the compressive stresses that are high [9], this contact area has a semielipsoidal shape, but in the case of cams is represented by a rectangular area, with respect to its theoretical area (2* α * l), Where α is wide and l is the depth of the contact footprint [10], obtained from the following expression:

$$\alpha = \sqrt{\left(\frac{4F_c}{\pi l} * \frac{\frac{1-\gamma_1^2}{E_1} + \frac{1-\gamma_2^2}{E_2}}{\frac{1}{R_1} + \frac{1}{R_2}} \right)} \tag{5}$$

Where R_1 and R_2 are the radio that press together with a contact force F_c. Designating E_1, γ_1 and E_2, γ_2 as the respective elastic and Poisson constants in the two cylinders [11].

The contact force is determined by the following expression:

$$F_c(t): \frac{am + \vartheta c + sk + F_{pl}}{cos\, \emptyset} \tag{6}$$

Where:
a: Acceleration of the tracker
ϑ: speed of the follower
s: displacement of the tracker
m: mass of the tracker including the spring
k: the constant of the follower-spring system
c: the damping constant.

2.4 Contact pressure

In the contact fingerprint the distribution of pressures can be seen semi-ellipse, the maximum value is presented in the center line and the zero value in the edges of the fingerprint [12], as can be seen in figure 1.

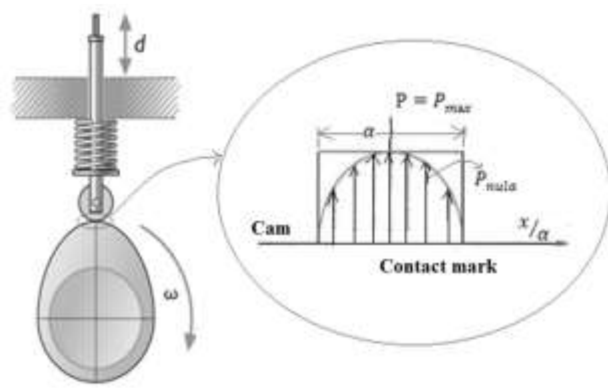

Figure 1. Distribution of the pressure in the contact footprint.

Then the contact pressure can be calculated with the following equation:

$$\mathrm{P} = P_{máx}\sqrt{1-\left(\frac{x}{\alpha}\right)^2} \tag{7}$$

Since P is the value of the pressure for which the values of x are distributed ($-\alpha \leq x \leq \alpha$), α is the width of the semielipse and $P_{máx}$ the maximum value of the pressure and is defined:

$$P_{máx} = \frac{2F_c}{\pi\alpha l} \tag{8}$$

It is analyzed that the maximum pressure depends on the radius of curvature of the surfaces in contact, so, in a cam its value varies along the profile [13]. Its application can be seen in the pressure cylinders that are studied by hertzian stresses (compressive, tensile, shear and axial forces).

III. Results and discussion

The analysis will be made to a cam-follower that is preloaded with a spring to drive a cam with a greater force. Table 1 shows the corresponding data used for this study.

Table 1. Data for the study of preloaded cam-follower with a spring

Parameter	Value
Cam mass	$m_l = 0,5\ kg$
Mass of the follower	$m_r = 0,2\ kg$
Roller radius	$R_r = 0,01m$
Radius of primary circle	$R_o = 0,02m$

Equivalent stiffness factor of the system	$k = 800\,{}^{N}/_{m}$
Thickness of cam	$l = 0{,}01m$
Poisson ratio of both materials	$\upsilon = 0{,}3$
System preload	$F_{pl} = 1500N$
Damping constant	$c = 0{,}06\,c_c$
Angular speed of the cam	$\omega = 20\pi\,{}^{rad}/_{seg}$
Maximum elevation of the tracker	$L = 0{,}01m$

With this data you can determine the contact force that has a constant speed and this in turn is connected to the preload of the system.

$$F_c(t): \frac{am\omega^2 + \vartheta c\omega + sk + F_{pl}}{cos\,\emptyset} \quad (9)$$

With a preload on the compressed spring and the displacement being zero the values of acceleration and speed can be positive or negative, the constancy of the spring k and the preload F_{pl} have positive values, because of this the value of the preload must be higher than the three previous values in equation 9 in order to obtain the positive contact force [5]. In figure 2. The preloaded cam-follower can be seen with a screw that is being analyzed.

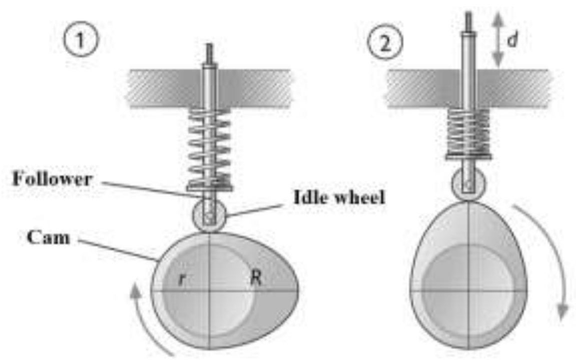

Figure 2. The cam-follower preloaded with a spring as indicated on the model.

With the model in figure 2 and replacing the data in the Bezier Curve equations in degrees 5, 7 and 9, contact footprint and contact pressure and using a graphical method [11], for a complete rotational motion of the cam-follower, the following graph was generated. As expressed in [14] and [15], the main voltages can be replaced by a voltage that generates the same effects in the mechanism.

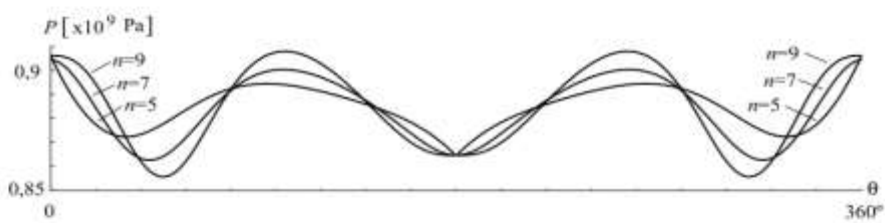

Figure 3. Comparison of the contact pressure variation for degrees n = 5, n = 7 and n = 9 of the model described

IV.CONCLUSION

In this It was presented the variation of the contact pressure in a disc cam mechanism that rotates with constant speed with a roller follower whose law of displacement was designed by means of Bezier curves of degrees 5, 7 and 9.

It was observed that as the degree of each of the curves increases, the greater is the magnitude of the pressure experienced in the mechanism.

It was determined that the Bezier curve of grade 5 is the one that presents better behavior due to the fact that it presents less values of contact pressure which means that this mechanism experienced smaller efforts due to the direct relation of these with the pressure, unlike the Bezier curve of grade 9 that presents greater values of pressure what would be caused in the mechanism greater probability of degassing.

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