IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 5 Issue 11, November 2018
ISSN (Online) 2348 – 7968
www.ijiset.com

Performance Optimization of Spline Based Cam Follower System

Shivangi Umrao[1], Laxmi Kant Sahu[2] and Anoop Kumar[3]

[1] Department of mechanical engineering, Raipur Institute of Technology, Raipur, Chhattisgarh, India.

[2] Department of mechanical engineering, Government polytechnic college, Korba, Chhattisgarh, India.

[3] Department of mechanical engineering, Raipur Institute of Technology, Raipur, Chhattisgarh, India.

Abstract

This paper presents a new synthetic five degree B spline with eight control points for smooth and uniform velocity and acceleration of Cam-follower system which reduces the jerk during motion. The B-spline curve is used to approximate the basic Cycloidal curve which has better motion characteristics. Performance characteristics of the proposed curve are compared with other basic CAM motion curves. Comparison results demonstrate the effectiveness of the proposed curve.

Keywords: *Cam follower Mechanism, Splines, Cycloidal Curve, Approximation.*

1. Introduction

A Cam is the mechanical component of a machine which is used to convert cam motion to its follower through a certain motion direct contact.

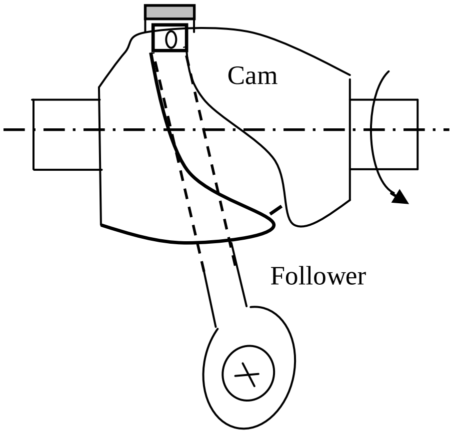

Fig 1 Globoidal Cam

As a machine component to transmit a mechanical motion from a constant speed to a periodic variable speed, Cam mechanisms are widely used modern machines because of their excellent properties.

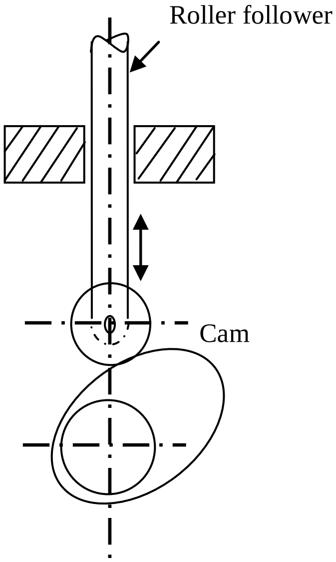

Fig 2 Follower Configuration

In the past two decades several works have been reported on the design of Cam-follower mechanism. Earlier researchers used many forms of curves which include basic motion curves, polynomial curves and trigonometric series curves to synthesize the Cam [1-2]. Basic motion curve and freeform curve have been widely used in various engineering applications. One of the applications using these curves is CD which plays an important role to automate the machines and design jerkless / vibration free motion of the machine [3-5].

Since the polynomial curve has some limitations like its harmonic content is not explicitly known and can be high

enough to vibration problem. To overcome these problems Splines have been used by many researchers to develop Cam profiles. Splines are the mathematical equivalent of a French curve. It provides almost unlimited flexibility. Splines represent the lift curve as a number of functions, usually polynomials that are pieced together. Synthetic curve includes Bezier, B-spline and Non Uniform Rational B-splines (NURBS).
Firstly the periodic splines in the synthesis of planar curves expressed in function form or parametric form, with local geometric constraints at a set of finite points are used by Angeles [6]. A recently developed family of curve refers to as Bernstein– Bezier harmonic curves, as opposed to polynomial curves, for kinematic synthesis of Cam displacement curves are used by Srinivasan and Ge [7]. One of the most versatile tools for modeling curves is the B-splines [8].

A CAD/CAM system is developed for the design and production of complex profiles for high performance drum Cams within the specified tolerance by Masood [9]. Developed system graphically generates the Cam profile on the cylindrical drum after performing an analysis of the kinematic performance for eight different types of follower motion, using a B-spline representation of follower curves.

The kinematic performance is based on the criteria of achieving the lowest levels of velocity and acceleration for each curve. The optimal synthesis for a Cam with non-constant angular velocity has been presented by Kim et al. [10] based on the dynamic model of a complete spring-actuated Cam system. They have optimized the follower motion using a cubic spline to satisfy asymmetric constraints and guarantee continuous contact at the Cam-follower interface. They have verified that the dynamic behavior of the optimized Cam is superior to polynomial Cams. Dynamic equations of the intermittent motion of a Globoidal Cam driven system are developed by Kuang et al. [11]. A new follower velocity curve is generated by using cubic B-spline with six control points by Sateesh et al. [12]. They have approximated various basic curves which have better motion characteristics in design of follower velocity curve. The generated velocity curve is defined by following equations in the three segments of Cam and follower motion:

The Paper is organized as following the introduction, Section 2 describe the Cam follower motion synthesis using B-spline. Section 3 illustrates the results obtained from simulation of Cam follower mechanism. In Section 4 simulation results are compared with the basic motion cureves and discussed. Finally conclusions are drawn in Section 5.

2. Approximation of Cam Follower motion using B-spline

In a Cam-follower mechanism, the load produced by inertia forces induces deflections and creates vibrations. These affect the operating life of the Cam. So to reduce the dynamic loading, the Cam function i.e. first and second derivative of displacement must be uniform and continuous, also the peak value (i.e. jerk) must be as small as possible. Representing the curves by B-spline may be a better method to improve the motion characteristic of the follower.

2.1 B-Spline Curve

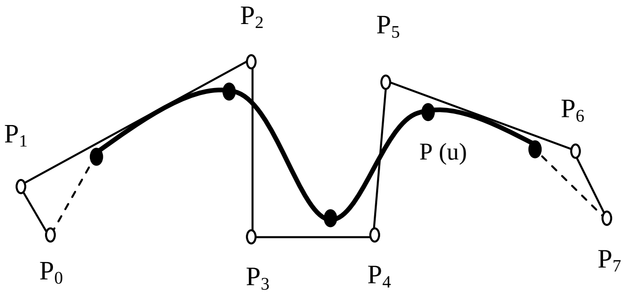

Fig. 3 B-Spline curve

Mathematically B-splines can be defined by having (k-1) degree and n+1 control point as:

$$P(u) = \sum_{i=0}^{n} N_{i,k}(u) P_i \ , \qquad 0 \le u \le u_{max} \tag{1}$$

where P (u) = Position on the curve at parameter u,

Pi = Control points,

$N_{i,k}$ (u) = Blending function and defined as

$$N_{i,k}(u) = \frac{[(u-u_i)N_{i,k-1}(u)]}{[u_{i+k-1}-u_i]} + \frac{[(u_{i+k}-u)N_{i+1,k-1}(u)]}{[u_{i+k}-u_{i+1}]}$$

$$\begin{aligned} N_{i,1}(u) &= 1 \qquad \text{if } u_i < u < u_{i+1} \\ N_{i,1} &= 0 \qquad \text{otherwise} \end{aligned} \tag{2}$$

where, k= Order of curve,

u_i= Knot values and defined as

$$\begin{cases} u_j = 0 & \text{if } j < k \\ u_j = j - k + 1 & \text{if } k \le j \le n \\ u_j = n - k + 2 & \text{if } j > n \end{cases} \qquad \text{with} \quad 0 \le j \le n + k,$$

number of knot values (m) = n+ k+ 1, i.e. $u_j = [u_0, u_1, u_2, u_3, \ldots \ldots \ldots, u_{n+k}]$. (3)

2.2 Approximation of B-Spline Curve

The first task in the design of Cam is to select a suitable basic curve which will satisfy the constraints of motion. Here the constraints are the relationship of the motion curves with the Cam rotation angle. Once the basic follower motion curve has been specified, then it can be approximated by B-splines. During approximation following steps are carried out:

1. Create the basic curve of selected follower motion (Cycloidal, parabolic etc.)
2. Divide the angle of interval of the curve into seven equal parts. This will create eight points v0, v1, v2, v3, v4, v5, v6, and v7 lying on the curve. These eight control points are selected for specified rise angle of return Cam angle.
3. The point on the curve is then defined by using the equation
4. $V(u) = \sum_{i=0}^{n} N_{i,k} V_i$, $0 \le u \le 3$

Using equations (1) to (4), the parametric equations for velocity curve for three segments can be defined as:

For $0 \le u \le 1$,

$$V_1(u) = (-u^5 + 5u^4 - 10u^3 + 10u^2 - 5u + 1)v_0 + \left(\frac{31u^5}{16} - \frac{75u^4}{8} + \frac{35u^3}{2} - 15u^2 + 5u\right)v_1 + \left(\frac{425u^4}{72} - \frac{575u^5}{432} - \frac{55u^3}{6} + 5u^2\right)v_2 + \left(\frac{37u^5}{72} - \frac{65u^4}{36} + \frac{5u^3}{3}\right)v_3 + \left(\frac{5u^4}{18} - \frac{5u^5}{36}\right)v_4 + \left(\frac{u^5}{54}\right)v_5 \qquad (5)$$

for $1 \le u \le 2$,

$$V_2(u) = \left(-\frac{u^5}{16} + \frac{5u^4}{8} - \frac{5u^3}{2} + 5u^2 - 5u + 2\right)v_1 + \left(\frac{73u^5}{432} - \frac{115u^4}{72} + \frac{35u^3}{6} - 10u^2 + \frac{15u}{2} - \frac{3}{2}\right)v_2 + \left(-\frac{17u^5}{72} + \frac{35u^4}{18} - \frac{35u^3}{6} + \frac{15u^2}{2} - \frac{15u}{4} + \frac{3}{4}\right)v_3 + \left(\frac{17u^5}{72} - \frac{115u^4}{72} + \frac{15u^3}{4} - \frac{15u^2}{4} + \frac{15u}{8} - \frac{3}{8}\right)v_4 - \left(\frac{73u^5}{432} - \frac{15u^4}{16} + \frac{15u^3}{8} - \frac{15u^2}{8} + \frac{15u}{16} - \frac{3}{16}\right)v_5 + \left(\frac{u^5}{16} - \frac{5u^4}{16} + \frac{5u^3}{8} - \frac{5u^2}{8} + \frac{5u}{16} - \frac{1}{16}\right)v_6 \qquad (6)$$

and for $2 \le u \le 3$,

$$V_3(u) = \left(\frac{5u^4}{18} - \frac{u^5}{54} - \frac{5u^3}{3} + 5u^2 - \frac{15u}{2} + \frac{9}{2}\right)v_2 + \left(\frac{5u^5}{36} - \frac{65u^5}{36} + \frac{55u^3}{6} - \frac{45u^2}{2} + \frac{105u}{4} - \frac{45}{4}\right)v_3 + \left(\frac{425u^4}{72} - \frac{37u^5}{72} - \frac{105u^3}{4} + \frac{225u^2}{4} - \frac{465u}{8} + \frac{189}{8}\right)v_4 + \left(\frac{575u^5}{432} - \frac{225u^4}{16} + \frac{465u^3}{8} - \frac{945u^2}{8} + \frac{1905u}{16} - \frac{765}{16}\right)v_5 + \left(\frac{315u^4}{16} - \frac{31u^5}{16} - \frac{635u^3}{8} + \frac{1275u^2}{8} - \frac{2555u}{16} + \frac{1023}{16}\right)v_6 + (u^5 - 10u^4 + 40u^3 - 80u^2 + 80u - 32)v_7 \qquad (7)$$

$V_1(u)$, $V_2(u)$, and $V_3(u)$ are the three segments of desired velocity curve of follower with respect to Cam angle in the range of specified Cam rise and return angle.

Considering θ = angle of rotation of Cam, r_1 = rise angle and r_2 = return angle, the parameter $u = \left(\frac{\theta}{r_1}\right)$ where θ varies from 0 to r_1 or $u = \left(\frac{\theta}{r_2}\right)$ where θ varies from 0 to r_2.

Now displacement (S) of the follower is obtained by integrating above three segments of velocity equations (5) to (7) with respect to time (t).

$$S(u) = \int V(u)dt = \left(\frac{r_1}{w}\right) \int V(u)du + C \qquad (8)$$

where w = angular velocity of follower, $w = \left(\frac{2\pi N}{60}\right)$, N= Cam speed (RPM) and C= a constant.

The equations for the three segments of the displacement curve ar

$$S_1(u) = \left(\frac{r_1}{w}\right) \int V_1\,(u)du + C_1 \qquad \text{for } 0 \le u \le 1$$

$$S_2(u) = \left(\frac{r_1}{w}\right) \int V_2\,(u)du + C_2 \qquad \text{for } 1 \le u \le 2$$

$$S_3(u) = \left(\frac{r_1}{w}\right) \int V_3\,(u)du + C_3 \qquad \text{for } 2 \le u \le 3 \tag{9}$$

Now, for finding the integrating constants (C_1, C_2 and C_3) for all the three parts, following three conditions are considered.

1. Initial displacement is zero i.e.
$$S_1(u) = 0 \qquad \text{at } u = 0 \tag{10}$$
2. End point of the first part curve and starting point of the second part curve are same i.e.
$$S_1(u) = S_2(u) \qquad \text{at } u = 1 \tag{11}$$
3. End point of the second part curve and starting point of the third part curve are same i.e
$$S_2(u) = S_3(u) \qquad \text{at } u = 2 \tag{12}$$

The three integrating constants obtained by substituting the values of S_1 (u), S_2 (u) and S_3 (u) into equation (10) to (12) from equation (9) are:

$$C_1 = 0$$

$$C_2 = \left(\frac{1}{R_{11}}\right)(0.167v_0 - 0.33v_1 + 0.25v_2 - 0.125v_3 + 0.0625v_4 - 0.03125v_5 + 0.0104v_6$$

$$C_3 = \left(\frac{1}{R_{11}}\right)(0.167v_0 + 0.333v_1 - 1.75v_2 + 3.875v_3 - 7.9375v_4 + 15.96v_5 - 21.3196v_6 + 10.667v_7) \tag{13}$$

where $R_{11} = \left(\frac{180w}{\pi r_1}\right)$ and the parameter $u = 3\left(\frac{\theta}{r_1}\right)$

The equations for the three parts of the displacement curve are obtained by substituting these three integrating constants into the equation 3.10 and can be written as:

For $0 \le u \le 1$,

$$\begin{aligned}S_1(u) = \left(\frac{1}{R_{11}}\right)\Bigg[&\left(u^5 - \frac{u^6}{6} - \frac{5u^4}{2} + \frac{10u^3}{3} - \frac{5u^2}{2} + u\right)v_0 + \\ &\left(\frac{31u^6}{96} - \frac{75u^5}{40} + \frac{35u^4}{8} - 5u^3 + \frac{5u^2}{2}\right)v_1 + \\ &\left(\frac{85u^5}{72} - \frac{575u^6}{2592} - \frac{55u^4}{24} + \frac{5u^3}{3}\right)v_2 + \left(\frac{37u^6}{432} - \frac{13u^5}{36} + \right. \\ &\left.\frac{5u^4}{12}\right)v_3 + \left(\frac{u^5}{18} - \frac{5u^6}{216}\right)v_4 + \\ &\left(\frac{u^6}{324}\right)v_5\Bigg]\end{aligned} \tag{14}$$

for $1 \le u \le 2$,

$$\begin{aligned}S_2(u) = C_2 + \left(\frac{1}{R_{11}}\right)\Bigg[&\left(\frac{u^5}{8} - \frac{u^6}{96} - \frac{5u^4}{8} + \frac{5u^3}{3} - \frac{5u^2}{2} + \right. \\ &\left. 2u\right)v_1 + \left(\frac{73u^6}{2592} - \frac{115u^5}{360} + \frac{35u^4}{24} - \frac{10u^3}{3} + \frac{15u^2}{4} - \right. \\ &\left.\frac{3u}{2}\right)v_2 + \left(\frac{7u^5}{18} - \frac{17u^6}{432} - \frac{35u^4}{24} + \frac{15u^3}{6} - \frac{15u^2}{8} + \right. \\ &\left.\frac{3u}{4}\right)v_3 + \left(\frac{17u^6}{432} - \frac{23u^5}{72} + \frac{15u^4}{16} - \frac{15u^3}{12} + \frac{15u^2}{16} - \right. \\ &\left.\frac{3u}{8}\right)v_4 + \left(\frac{3u^5}{16} - \frac{73u^6}{2592} - \frac{15u^4}{32} + \frac{15u^3}{24} - \frac{15u^2}{32} + \right. \\ &\left.\frac{3u}{16}\right)v_5 + \left(\frac{u^6}{96} - \frac{u^5}{16} + \frac{5u^4}{32} - \frac{5u^3}{24} + \frac{5u^2}{32} - \right. \\ &\left.\frac{u}{16}\right)v_6\Bigg]\end{aligned} \tag{15}$$

and for $2 \le u \le 3$,

$$\begin{aligned}S_3(u) = C_3 + \left(\frac{1}{R_{11}}\right)\Bigg[&\left(\frac{u^5}{18} - \frac{u^6}{324} - \frac{5u^4}{12} + \frac{5u^3}{3} - \frac{15u^2}{4} + \right. \\ &\left.\frac{9u}{2}\right)v_2 + \left(\frac{5u^6}{216} - \frac{13u^5}{36} + \frac{55u^4}{24} - \frac{15u^3}{2} + \frac{105u^2}{8} - \right. \\ &\left.\frac{45u}{4}\right)v_3 + \left(\frac{85u^5}{72} - \frac{37u^6}{432} - \frac{105u^4}{16} + \frac{75u^3}{4} - \frac{465u^2}{16} + \right. \\ &\left.\frac{189u}{8}\right)v_4 + \left(\frac{575u^6}{2592} - \frac{45u^5}{16} + \frac{465u^5}{32} - \frac{315u^3}{8} + \right. \\ &\left.\frac{1905u^2}{32} - \frac{765u}{16}\right)v_5 + \left(\frac{63u^5}{16} - \frac{31u^6}{96} - \frac{635u^4}{32} + \right. \\ &\left.\frac{425u^3}{8} - \frac{2555u^3}{32} + \frac{1023u}{16}\right)v_6 + \left(\frac{u^6}{6} - \frac{10u^5}{5} + \right. \\ &\left.10u^4 - \frac{80u^3}{3} + 40u^2 - 32u\right)v_7\Bigg]\end{aligned} \tag{16}$$

Similarly acceleration (A) of the follower is obtained by differentiating velocity equation V (u) with respect to time (t):

$$A(u) = \frac{dV(u)}{dt} = \left(\frac{w}{r_1}\right)\left(\frac{dV(u)}{du}\right) \qquad \text{for } 0 \le u \le 3 \tag{17}$$

So after differentiating the equations (14) to (16), the acceleration equation obtained for the three parts of the curve are:

For $0 \le u \le 1$,

$$\begin{aligned} A_1(u) = {} & R_{11}(-5u^4 + 20u^3 - 30u^2 + 20u - 5)v_0 + \\ & \left(\frac{155u^4}{16} - \frac{75u^3}{2} + \frac{105u^2}{2} - 30u + 5\right)v_1 + \\ & \left(\frac{425u^3}{18} - \frac{2875u^4}{432} - \frac{55u^2}{2} + 10u\right)v_2 + \\ & \left(\frac{185u^4}{72} - \frac{65u^3}{9} + 5u^2\right)v_3 + \left(\frac{10u^3}{9} - \frac{25u^4}{36}\right)v_4 + \\ & \left(\frac{5u^4}{54}\right)v_5 \end{aligned} \tag{18}$$

for $1 \le u \le 2$,

$$\begin{aligned} A_2(u) = {} & R_{11}\left[\left(\frac{5u^3}{2} - \frac{5u^4}{16} - \frac{15u^2}{2} + 10u - 5\right)v_1 + \right. \\ & \left(\frac{365u^4}{432} - \frac{115u^3}{18} + \frac{35u^2}{2} - 20u + \frac{15}{2}\right)v_2 + \\ & \left(\frac{70u^3}{9} - \frac{85u^4}{72} - \frac{35u^2}{2} + 15u - \frac{15}{4}\right)v_3 + \\ & \left(\frac{85u^4}{72} - \frac{115u^3}{18} + \frac{45u^2}{4} - \frac{15u}{2} + \frac{15}{8}\right)v_4 + \\ & \left(\frac{15u^3}{4} - \frac{365u^4}{432} - \frac{45u^2}{8} + \frac{15u}{4} - \frac{15}{16}\right)v_5 + \\ & \left.\left(\frac{5u^4}{16} - \frac{5u^3}{4} + \frac{15u^2}{8} - \frac{5u}{4} + \frac{5}{16}\right)v_6\right] \end{aligned} \tag{19}$$

and for $2 \le u \le 3$,

$$\begin{aligned} A_3(u) = {} & R_{11}\left[\left(\frac{10u^3}{9} - \frac{5u^4}{54} - 5u^2 + 10u - \frac{15}{2}\right)v_2 + \right. \\ & \left(\frac{25u^4}{36} - \frac{65u^3}{9} + \frac{55u^2}{2} - 45u + \frac{105}{4}\right)v_3 + \\ & \left(\frac{425u^3}{18} - \frac{185u^4}{72} - \frac{315u^2}{4} + \frac{225u}{2} - \frac{465}{8}\right)v_4 + \\ & \left(\frac{2875u^4}{432} - \frac{225u^3}{4} + \frac{1395u^2}{8} - \frac{945u}{4} + \frac{1905}{16}\right)v_5 + \\ & \left(\frac{315u^3}{4} - \frac{155u^4}{16} - \frac{1905u^2}{8} + \frac{1275u}{4} - \frac{2555}{16}\right)v_6 + \\ & \left.(5u^4 - 40u^3 + 120u^2 - 160u + 80)v_7\right] \end{aligned} \tag{20}$$

Also Jerk (J) of the follower is obtained by differentiating velocity equation A (u) with respect to time (t):

$$J(u) = \frac{dA(u)}{dt} = \left(\frac{w}{r_1}\right)\left(\frac{w}{r_1}\right)\frac{dA}{du} \qquad \text{for } 0 \le u \le 3 \tag{21}$$

So after differentiating the equations (18) to (20), the jerk equations obtained for the three segments of the curve are:

For $0 \le u \le 1$,

$$\begin{aligned} J_1(u) = {} & R_{11}R_{11}\left[(-20u^3 + 60u^2 - 60u + 20)v_0 + \right. \\ & \left(\frac{155u^3}{4} - \frac{225u^2}{2} + 105u - 30\right)v_1 + \left(\frac{425u^2}{6} - \frac{2875u^3}{108} - \right. \\ & \left. 55u + 10\right)v_2 + \left(\frac{185u^3}{18} - \frac{65u^2}{3} + 10u\right)v_3 + \left(\frac{10u^2}{3} - \right. \\ & \left.\left.\frac{25u^3}{9}\right)v_4 + \left(\frac{10u^3}{27}\right)v_5\right] \end{aligned} \tag{22}$$

for $1 \le u \le 2$,

$$\begin{aligned} J_2(u) = {} & R_{11}R_{11}\left[\left(\frac{15u^2}{2} - \frac{5u^3}{4} - 15u + 10\right)v_1 + \right. \\ & \left(\frac{365u^3}{108} - \frac{115u^2}{6} + 35u - 20\right)v_2 + \left(\frac{70u^2}{3} - \frac{85u^3}{18} - 35u + \right. \\ & \left. 15\right)v_3 + \left(\frac{85u^3}{18} - \frac{115u^2}{6} + \frac{45u}{2} - \frac{15}{2}\right)v_4 + \left(\frac{45u^2}{4} - \frac{365u^3}{108} - \right. \\ & \left.\left.\frac{45u}{4} + \frac{15}{4}\right)v_5 + \left(\frac{5u^3}{4} - \frac{15u^2}{4} + \frac{15u}{4} - \frac{5}{4}\right)v_6\right], \end{aligned} \tag{23}$$

and for $2 \le u \le 3$,

$$\begin{aligned} J_3(u) = {} & R_{11}R_{11}\left[\left(\frac{10u^2}{3} - \frac{10u^3}{27} - 10u + 10\right)v_2 + \right. \\ & \left(\frac{25u^3}{9} - \frac{65u^2}{3} + 55u - 45\right)v_3 + \left(\frac{425u^2}{6} - \frac{185u^3}{18} - \frac{315u}{2} + \right. \\ & \left.\frac{225}{2}\right)v_4 + \left(\frac{2875u^3}{108} - \frac{675u^2}{4} + \frac{1395u}{4} - \frac{945}{4}\right)v_5 + \\ & \left(\frac{945u^2}{4} - \frac{155u^3}{4} - \frac{1905u}{4} + \frac{1275}{4}\right)v_6 + (20u^3 - 120u^2 + \\ & \left. 240u - 160)v_7\right] \end{aligned} \tag{24}$$

3.3 Cam profile calculations

Considering the translating radial follower, the rectangle coordinates (X, Y) for the Cam pitch profile are given as

$$X = (R_p + S)\sin\theta,$$
$$Y = (R_p + S)\cos\theta \tag{25}$$

where, Rp = Prime circle radius, and

S = Displacement with respect to Cam angle θ.

3. Result and discussions

The main objective of all Cam design optimization methodologies is to make the motion acceleration characteristic uniform, continuous and minimum as much as possible. Also the jerk characteristic should be minimized during the motion. In the past, several motion curves like SHM, Parabolic, constant acceleration, Cycloidal motion etc have been used to design the Cam-follower mechanism for uniform acceleration and minimum jerk. But all these motion curves are used for certain specific applications due to some speed limitations of the Cam-follower. To overcome this problem an attempt has been made in this work by representing the motion curve in terms of higher order B-spline. For approximation, the smoothest Cycloidal motion curve has been selected from among all regular basic curves.

Higher degree B-spline developed in this work has been compared with the results obtained by other authors'. Figure 4 illustrated the comparison of motion characteristic curves of the Cam-follower for the maximum acceleration and Figure 5 illustrated that the comparison of motion characteristics curves of the Cam-follower for the maximum jerk.

By the analysis of the motion characteristics curves of the Cam-follower for the maximum acceleration and maximum jerk, it is found that performance of spline based Cam Follower systems can be improved by increasing its degree and by adjusting control points. Numerical values obtained by developed methodology using fifth order B-spline are also compared with the numerical value obtained by Sateesh et al. (2009) in Table 1. By the analysis it is found that the developed fifth order B-spline (approximation of cycloidal) with eight control points has reduced the maximum acceleration by 6.28% as compared to the basic cycloidal motion and 1.85% as compared to the Cycloidal approximated cubic B-spline with six control points.

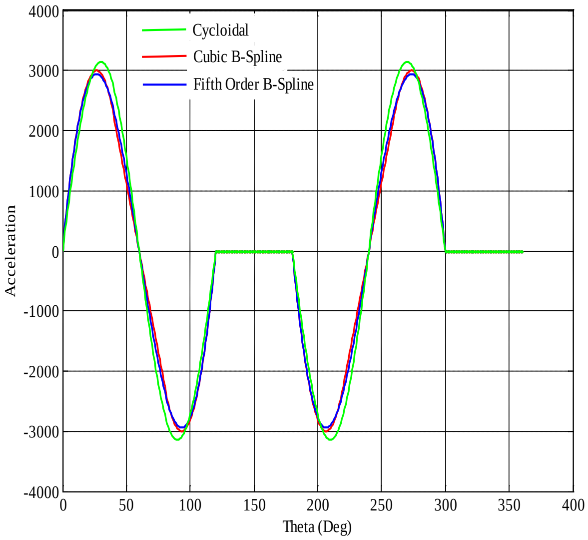

Fig.4 Comparison of maximum acceleration between basic Cycloidal, cubic B-spline and fifth order B-spline

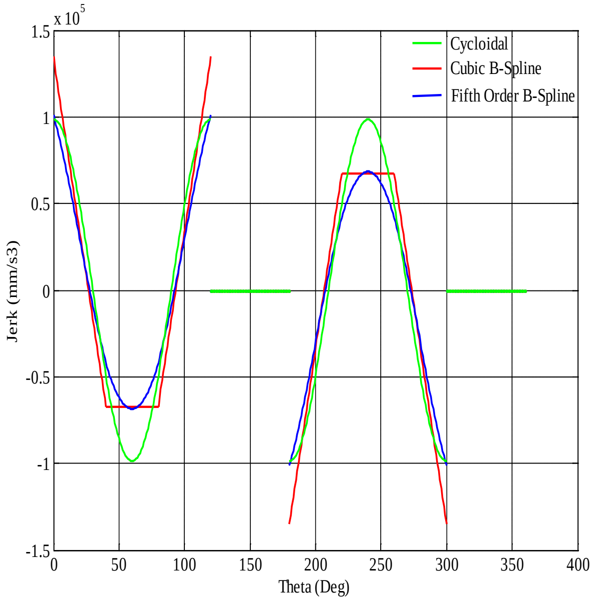

Fig. 5 Comparison of jerk between basic Cycloidal, cubic B-spline and fifth order B-spline motion

Table 1 Comparison of maximum acceleration for various follower motions

Type of motion Cam speed (RPM)	Maximum acceleration (mm/s^2)		
	100	200	500
Simple harmonic motion	2467.4	9869.6	61685.0
Cycloidal	3141.2	12566.3	78539.8
4-5-6-7 polynomial	3756.4	15025.6	93910.3
Double harmonic motion	4934.8	19739.2	123370
Cubic B-spline (approximation to Cycloidal)	2999.5	11998.1	74988.2
5th degree B-spline (approximation to Cycloidal)	2944.0	11776.0	73601.0
% Reduction over Cycloidal motion	6.28%		
% Reduction over Cubic B-spline motion	1.85%		

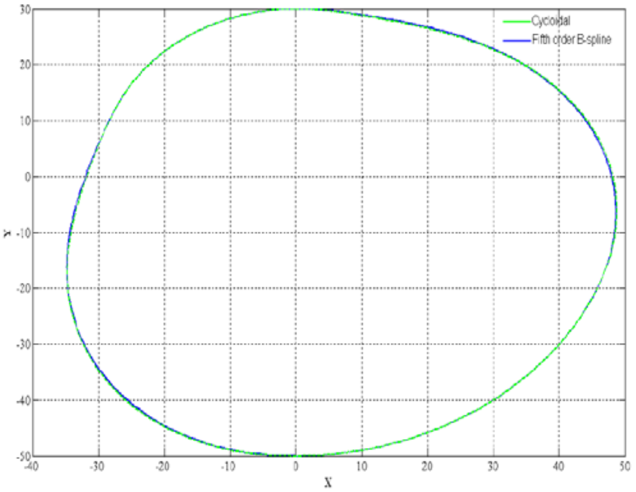

Figure 6: Comparison of Cam profiles between basic cycloidal and B-spline motion

Figure 6 shows the comparison of generated Cam profiles through them. From the above results five degree B-spline with eight control points are thus, found to be more advantageous than the basic Cycloidal and cubic B-spline even in the high speed applications. Users can choose the proposed five degree B-spline with eight control points instead of regular basic curve and cubic B-spline to improve the design of Cam profile and motion characteristics of Cam-follower mechanisms. They can select the desired velocity and can change the shape of the velocity curve by changing the control points.

4. Conclusions

From theoretical, numerical and simulation analysis it is found that the nature of curves play an important role in design of Cam-follower mechanism. By mathematical analysis it is clear that Performance parameter of spline based cam follower systems can be improved by increasing the degree and by adjusting the control points

References

[1] J. Angeles and C. S. Lopez-Cajfin, "*Optimisation of Cam Mechanisms*", Kluwer Academic Publishers, (1991).

[2] Norton, R. L., "*Cam Design and Manufacturing Handbook*", Industrial Press, New York, (2002).

[3] Roth Bart, H.A., "*Cams: Dynamics and Accuracy*". New York: John Wiley.(1956).

[4] Neklutin, C. N., "Mechanisms and Cams for Automatic Machines: Influence of Dynamic Forces on High-speed Machine Components", American Elsevier, New York. (1969).

[5] Makino, H., "*Universal Cam Curve and its Applications*", Reports of Faculty of Engineering, Yamanashi University, Vol. 28, pp. 48-58, (1977).

[6] Angeles, J., ''Synthesis of Plane Curves with Prescribed Local Geometric Properties Using Periodic Splines'', Computer-Aided Design, Vol. 15, No. 3, pp. 147– 155, (1983).

[7] Srinivasan, L.N. and Jeffrey Ge, Q., "*C^2 Piecewise Bezier Harmonics for Motion Specification of High Speed Cam Mechanisms*", Proceedings of ASME Design Engineering Technical Conferences, Irvine, California, (1996).

[8] Cox, M. G., "*The Numerical Evaluation of B-Splines*," Journal of Institute of Mathematics and its Application, Vol. 10, pp. 134–149, (1972),

[9] Masood, H.S., "*A CAD/CAM System for High Performance Precision Drum Cams*", International Journal of Advanced manufacturing Technology, Vol. 15, pp 32–37, (1999).

[10] Kim, J., Ahn, K. and Kim, S., "*Optimal Synthesis of A Spring-Actuated Cam Mechanism Using A Cubic Spline*", Journal of Mechanical Engineering Science, Vol. 216, pp 875-883, (2002).

[11] Kuang, J. H., Lin, A. D. and Ho., T. Y., "*Dynamic Responses of a Globoidal Cam System*". ASME Journal of Mechanical Design, Vol. 126, pp909–915, (2004).

[12] Sateesh, N., Rao, C.S.P. & Janardhan, T. A., "*Optimisation of Cam-follower motion using B splines*", International Journal of Computer Integrated Manufacturing, Vol. 22, No. 6, pp 515-523, (2009).

Shivangi Umrao received the Bachelors of Technology degree in Mechanical Engineering from Institute of Technology Korba, Chhattisgarh Swami Vivekananda Technical University, Bhilai, Chhattisgarh, India in 2014 She is currently M tech Scholar in Raipur Inswtitute of technology, Raipur with specialization of Machine Design in Mechanical Engineering department.

Laxmi Kant Sahu received the Bachelors of Technology degree in Mechanical Engineering from Government Engineering College, Bilaspur, Chhattisgarh Swami Vivekananda Technical University, Bhilai, Chhattisgarh, India in 2010 and Masters of Technology in Machine Design from Guru Ghasidas Vishwavidyalaya (A central university), Bilaspur, Chhattisgarh, India in 2014. He is currently working in Government Polytechnic College, Korba as an Assistant Professor in Mechanical Engineering department.

Anoop Kumar received the Bachelor of Engineering degree in Mechanical Engineering from C.S.I.T.Durg, Chhattisgarh Swami Vivekanand Technical University Bhilai, Chhattisgarh, India in 2011 and Masters of Technology in Machine Design from Guru Ghasidas Vishwavidyalaya (A Central university), Bilaspur Chhattisgarh, India in 2014. He is currently working in RITEE Raipur, as an Assistant Processor in Mechanical Engineering Department.