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Improvement of cam performance curve using B-Spline curve

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Abstract. The mathematical modeling approach has been applied in order to increase the cam profile curve of Modenas CT115s performance by using MATLAB software as a programmed to calculate the mechanism of the cam profile. Cam is used inside the engine to push the rocker and consequently open and close the engine valve that allows the fuel-air mixture to be entered during the combustion process. The B-Spline curve was implemented in order to enhance the current performance of the cam profile. The calculation had been done by using manual and MATLAB software. The results obtained has been analyzed and interpreted in plotting the graphs. From the analysis, the profile that had the highest displacement factor, sk produced higher cam curve performance of the engine. Thus, it can be concluded that the increase of the displacement factor, sk can increase the engine performance as the valve displace further in which allow higher fuel-air mixture entrance during the combustion process.

1. Introduction

Cam is a component that works to transmit a power by the motion of mechanical from a speed constant to a variety of speeds and widely used in the automotive industry due to the superior properties for high speed in operation, accuracy in motion, the rigidity of the structure and low cost production. The location and shape of the lobe will determine the timing of the valve opening-closing motion, its lifting height and valve movement rate of one complete cycle which could affect the performances of the MODENAS motorcycles.

In an automotive engine, the cam does not work individually because it attaches with follower, camshaft, valve and others. The follower is the element in which direct contact with the cam [1]. Cam also can be classified into two types which are eccentric and concentric based cam. An eccentric cam is a cam that has symmetrical lift location and in contrast, concentric cam has offset lift location in which can be



adjusted in order to achieve a greater lift of the valves during internal combustion. Generally, profiles of the cam can affect the engine performances. It is because the profiles it can manipulate the intake duration, intake opening and closing angle, exhaust opening and closing angle, lobe separation angle and the valve lift of the cam. Thus, by using proper mathematical modeling all of the combustion process parameters can be manipulated successfully. The B-Spline method is more suitable and advantage because of its effectiveness and has no problem with the stability of numerical in the parameterization of cam shape. By then, the performance of MODENAS Motorcycle engine can be enhanced by several percentages than before.

2. Methodology

The main objective of this study to increase the cam performance by enhancing the cam profile curve by implementing the B-Spline method. Cam curve performance analysis will be conducted based on its several displacement factors, sk from 6th orders of the B - spline method and all possible engineering parameters. This is necessary to determine the best cam design that will produce high performances throughout. The analysis of the cam will be done by using computerized engineering software such as CATIA and MATLAB. This analysis is designed so that optimization of the cam profile can be done and thus, the factor affecting the optimization of the cam can be determined [2]. The collected data will be analyzed properly so that the pattern graph of displacement, velocity, acceleration and jerk versus angle of cam rotation can be established. Then, the results from the analysis could contribute in enhancing the engine performance for the MODENAS motorcycles.

The dimension and parameters of the cam that impact the motion of cam are measured by using 3D Scanner and CMM machine. This is necessary to calculate cam profile curve. Due to shining properties of cam, 3D Scanner facing a problem in cam measurement. Apart from that, the camshaft does not have the assembly part and cannot measure the cam lobe only. 3D Scanner more suitable to do the improvement design.

Therefore, CMM machine was used in order to obtain the dimension of the existing cam lobe profile due to the function that can give all dimensions of assembly parts. The dimension is in 3 axis, x, y, and z-axis, but the dimension that had been obtained are not very precise and accurate due to the obtained reading is in a wide range. There is also some error when taking the dimension because of condition changes of the cam while cam measurement. Besides, sometimes the condition of the cam is not correct or unstable. As a solution, CATIA software had been used to get any existing parameter that's needed in calculating the displacement, velocity, acceleration and jerk.

The fundamental principle of B-Spline is the number of splines can be mingled together in knots to get the desired cam function and it has been confirmed with the classical spline of 6th orders [3]. Figure 1 shows that the displacement spline and knot curve. In producing a smoother curve, four polynomials are put together at the three knot intermediate. This is because the intermediate knots are specifications consider for a single dwell cam displacement by using classical spline with 6th orders. By constructing the curve of the classical spline, the polynomial pieces and knots can be defined.

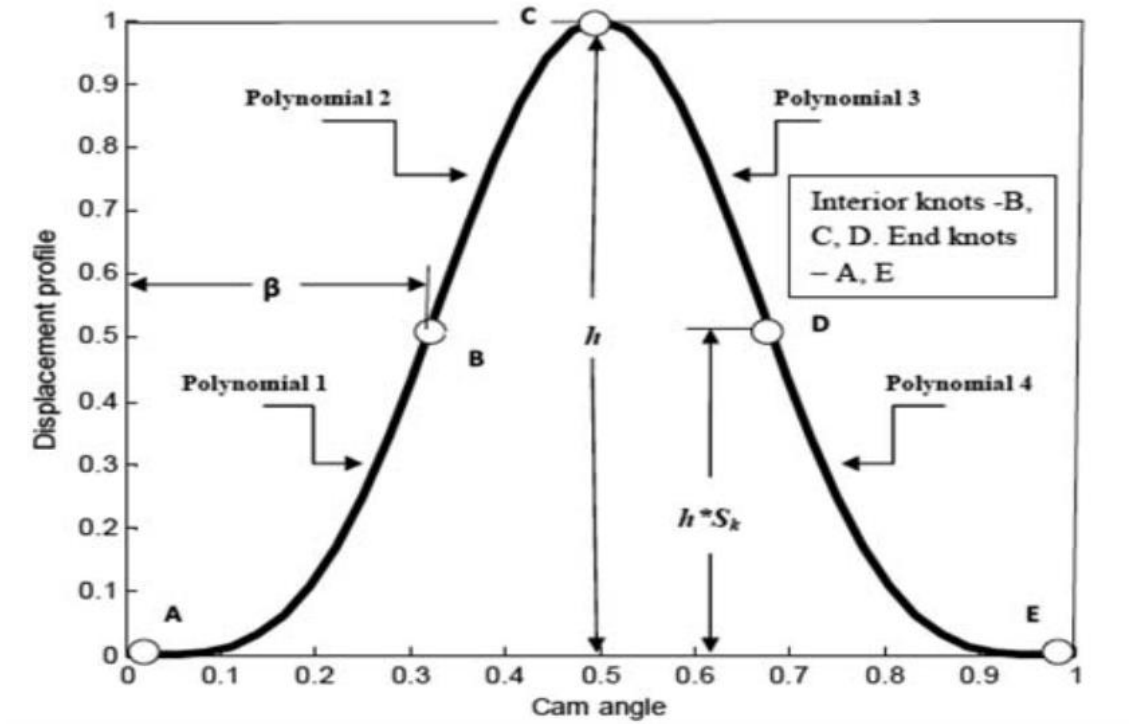


Figure 1. Displacement spline and knot curve [4].

The calculation involved in this research is the maximum rise of the cam is h , the rise of the cam rotation angle (2β) and fall cam rotation angle h is in next 2β . The balance of cam dwells rotation angle is $(2\pi - 4\beta)$ and the angular velocity of the camshaft is taken as constant due to not enough parameter obtain. The starts and closure angle of cam rotation is 0 and 4β , while the intermediate angle is β , 2β , and 3β . A formulation that involved in this research is [5]:

Displacement Profile:

$$s(\theta) = \left\{ \begin{array}{l} \left[C_{nj} \left(\frac{\theta}{\beta}\right)^{\bar{m}-1} + C_{nj} \left(\frac{\theta}{\beta}\right)^{\bar{m}-2} + C_{nj} \left(\frac{\theta}{\beta}\right)^{\bar{m}-3} + C_{nj} \left(\frac{\theta}{\beta}\right)^{\bar{m}-4} + C_{nj} \left(\frac{\theta}{\beta}\right)^{\bar{m}-5} + C_{nj} \right], \\ \quad 0 \leq \theta \leq \beta \\ \left[C_{nj} \left(\frac{\theta - \beta}{\beta}\right)^{\bar{m}-1} + C_{nj} \left(\frac{\theta - \beta}{\beta}\right)^{\bar{m}-2} + C_{nj} \left(\frac{\theta - \beta}{\beta}\right)^{\bar{m}-3} + C_{nj} \left(\frac{\theta - \beta}{\beta}\right)^{\bar{m}-4} + \right. \\ \quad \left. C_{nj} \left(\frac{\theta - \beta}{\beta}\right)^{\bar{m}-5} + C_{nj} \right], \\ \quad \beta \leq \theta \leq 2\beta \\ \left[C_{nj} \left(\frac{\theta - 2\beta}{\beta}\right)^{\bar{m}-1} + C_{nj} \left(\frac{\theta - 2\beta}{\beta}\right)^{\bar{m}-2} + C_{nj} \left(\frac{\theta - 2\beta}{\beta}\right)^{\bar{m}-3} + C_{nj} \left(\frac{\theta - 2\beta}{\beta}\right)^{\bar{m}-4} + \right. \\ \quad \left. C_{nj} \left(\frac{\theta - 2\beta}{\beta}\right)^{\bar{m}-5} + C_{nj} \right], \\ \quad 2\beta \leq \theta \leq 3\beta \\ \left[C_{nj} \left(\frac{\theta - 3\beta}{\beta}\right)^{\bar{m}-1} + C_{nj} \left(\frac{\theta - 3\beta}{\beta}\right)^{\bar{m}-2} + C_{nj} \left(\frac{\theta - 3\beta}{\beta}\right)^{\bar{m}-3} + C_{nj} \left(\frac{\theta - 3\beta}{\beta}\right)^{\bar{m}-4} + \right. \\ \quad \left. C_{nj} \left(\frac{\theta - 3\beta}{\beta}\right)^{\bar{m}-5} + C_{nj} \right], \\ \quad 3\beta \leq \theta \leq 4\beta \end{array} \right. \quad \text{a)}$$

Velocity Profile:

$$s'(\theta) = \left\{ \begin{array}{l} \frac{1}{\beta} \left[5Cnj \left(\frac{\theta}{\beta} \right)^4 + 4Cnj \left(\frac{\theta}{\beta} \right)^3 + 3Cnj \left(\frac{\theta}{\beta} \right)^2 + 2Cnj \left(\frac{\theta}{\beta} \right)^1 + Cnj \right], 0 \leq \theta \leq \beta \\ \frac{1}{\beta} \left[5Cnj \left(\frac{\theta-\beta}{\beta} \right)^4 + 4Cnj \left(\frac{\theta-\beta}{\beta} \right)^3 + 3Cnj \left(\frac{\theta-\beta}{\beta} \right)^2 + 2Cnj \left(\frac{\theta-\beta}{\beta} \right)^1 + Cnj \right], \beta \leq \theta \leq 2\beta \\ \frac{1}{\beta} \left[5Cnj \left(\frac{\theta-2\beta}{\beta} \right)^4 + 4Cnj \left(\frac{\theta-2\beta}{\beta} \right)^3 + 3Cnj \left(\frac{\theta-2\beta}{\beta} \right)^2 + 2Cnj \left(\frac{\theta-2\beta}{\beta} \right)^1 + Cnj \right], 2\beta \leq \theta \leq 3\beta \\ \frac{1}{\beta} \left[5Cnj \left(\frac{\theta-3\beta}{\beta} \right)^4 + 4Cnj \left(\frac{\theta-3\beta}{\beta} \right)^3 + 3Cnj \left(\frac{\theta-3\beta}{\beta} \right)^2 + 2Cnj \left(\frac{\theta-3\beta}{\beta} \right)^1 + Cnj \right], 3\beta \leq \theta \leq 4\beta \end{array} \right. \quad \text{b)}$$

Acceleration Profile:

$$s(\theta) = \left\{ \begin{array}{l} \frac{1}{\beta^2} \left[20Cnj \left(\frac{\theta}{\beta} \right)^3 + 12Cnj \left(\frac{\theta}{\beta} \right)^2 + 6Cnj \left(\frac{\theta}{\beta} \right)^1 + 2Cnj \right], 0 \leq \theta \leq \beta \\ \frac{1}{\beta^2} \left[20Cnj \left(\frac{\theta-\beta}{\beta} \right)^3 + 12Cnj \left(\frac{\theta-\beta}{\beta} \right)^2 + 6Cnj \left(\frac{\theta-\beta}{\beta} \right)^1 + 2Cnj \right], \beta \leq \theta \leq 2\beta \\ \frac{1}{\beta^2} \left[20Cnj \left(\frac{\theta-2\beta}{\beta} \right)^3 + 12Cnj \left(\frac{\theta-2\beta}{\beta} \right)^2 + 6Cnj \left(\frac{\theta-2\beta}{\beta} \right)^1 + 2Cnj \right], 2\beta \leq \theta \leq 3\beta \\ \frac{1}{\beta^2} \left[20Cnj \left(\frac{\theta-3\beta}{\beta} \right)^3 + 12Cnj \left(\frac{\theta-3\beta}{\beta} \right)^2 + 6Cnj \left(\frac{\theta-3\beta}{\beta} \right)^1 + 2Cnj \right], 3\beta \leq \theta \leq 4\beta \end{array} \right. \quad \text{c)}$$

Jerk Profile:

$$s(\theta) = \left\{ \begin{array}{l} \frac{1}{\beta^3} \left[60Cnj \left(\frac{\theta}{\beta} \right)^2 + 24Cnj \left(\frac{\theta}{\beta} \right)^1 + 6Cnj \right], 0 \leq \theta \leq \beta \\ \frac{1}{\beta^3} \left[60Cnj \left(\frac{\theta-\beta}{\beta} \right)^2 + 24Cnj \left(\frac{\theta-\beta}{\beta} \right)^1 + 6Cnj \right], \beta \leq \theta \leq 2\beta \\ \frac{1}{\beta^3} \left[60Cnj \left(\frac{\theta-2\beta}{\beta} \right)^2 + 24Cnj \left(\frac{\theta-2\beta}{\beta} \right)^1 + 6Cnj \right], 2\beta \leq \theta \leq 3\beta \\ \frac{1}{\beta^3} \left[60Cnj \left(\frac{\theta-3\beta}{\beta} \right)^2 + 24Cnj \left(\frac{\theta-3\beta}{\beta} \right)^1 + 6Cnj \right], 3\beta \leq \theta \leq 4\beta \end{array} \right. \quad \text{d)}$$

3. Results And Discussions

3.1 Cam Curve Performance

In this research, cam specification used data the maximum lift $h = 0.009\text{m}$, the rise and fall of cam angle $2\beta \times 2 = 146^\circ$, roller radius $rr = 0.0065\text{m}$ and base circle radius is $rb = 0.025\text{m}$. By using all the information, the displacement, velocity, acceleration, and jerk graph are obtained after calculation. In improves the cam curve performance part, the displacement factor, sk was used to optimize the current graph. The displacement factor, sk use in this improvement part is $sk=0.25$, $sk=0.35$, $sk=0.45$, $sk=0.5$ and $sk=0.6$.

Figure 2 shows that the significant effect on the displacement curve performance. The area under the displacement curve graph increase with the increment of the displacement factor, sk . Figure 2 shows the existing cam curve performance is not in the best condition yet compare to the improvement cam curve performance using displacement factor, $sk=0.6$.

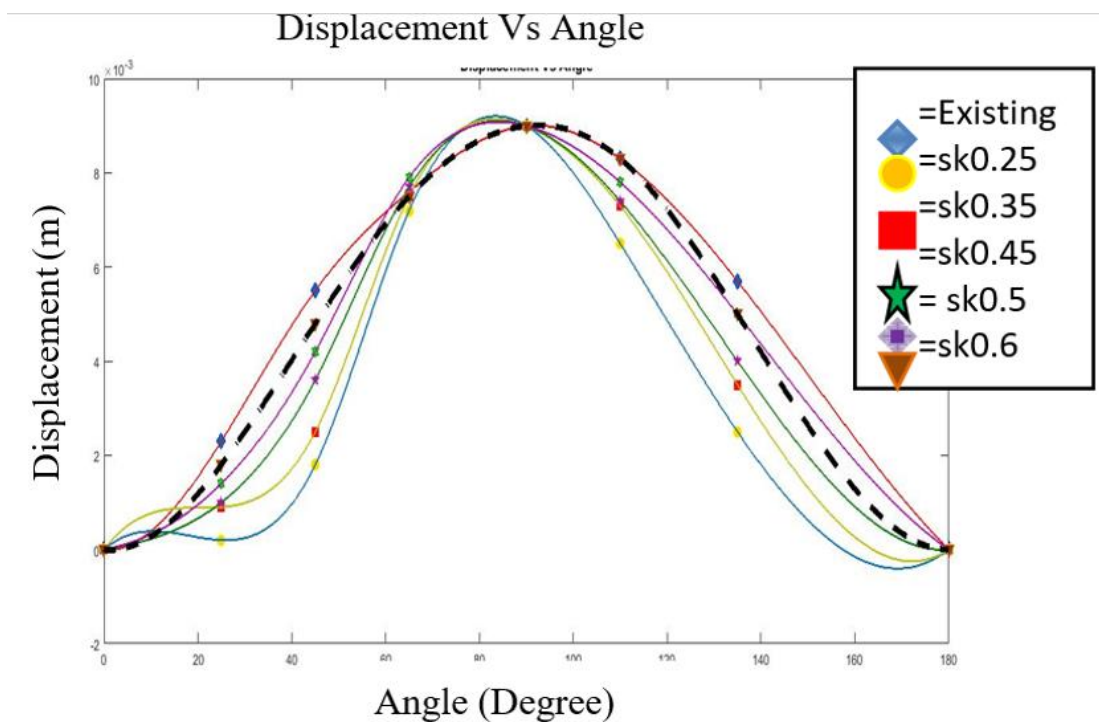


Figure 2. Displacement curve for all designs.

Comparison between existing and improvement cam curve performance for velocity can be seen in Figure 3. In the graph, it is shown that the velocity curve lowers with an increment displacement factor, sk and it remains constant at intermediate knots. $Sk=0.6$ is the best cam curve performance due to almost the same with the ideal velocity cam curve. The existing velocity cam curve performance for MODENAS CT115s did not optimize yet due to more different with ideal and improvement cam curve performance.

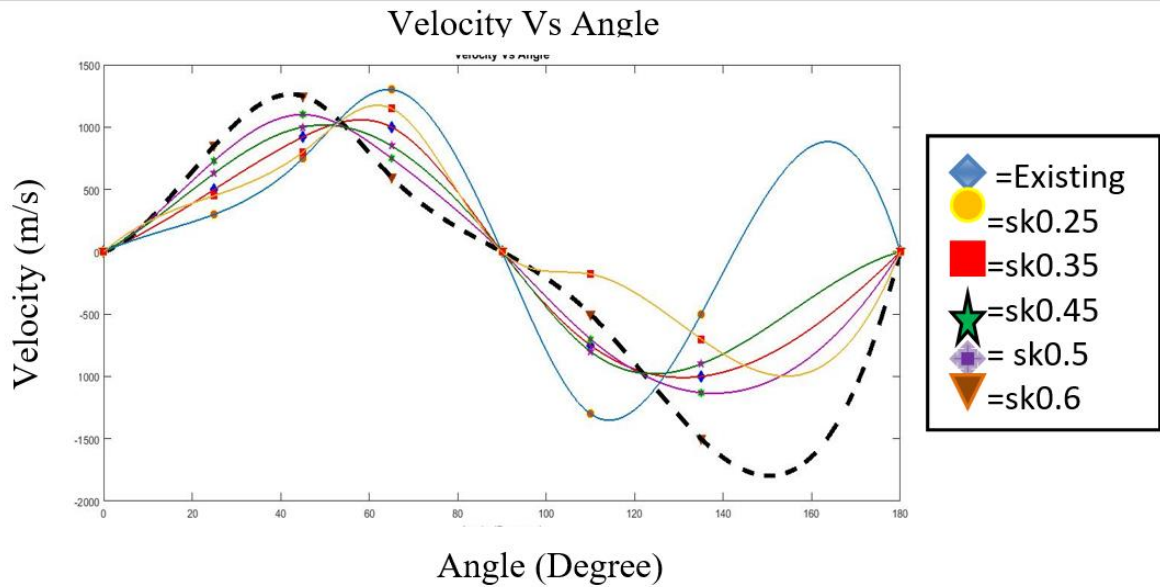


Figure 3. Velocity curve for all designs.

Figure 4 shows the effect of having different displacement factor, sk on the acceleration curve. The graph shows drastic changes in each displacement factor also to the existing acceleration curve. By using different knot the important observation can be clearly seen that negative acceleration decrease with the increment of displacement factor, sk . This is good for improvement due to less negative acceleration will reduce the tendency follower to jump. In order to improve the acceleration curve performance, negative acceleration should be less than the existing. One of the methods to reduce negative acceleration and minimize jump of the follower is by choosing the higher displacement factor, sk but it cannot be too much higher because it will tend to have more negative acceleration. Increasing displacement factor reduces negative peak acceleration.

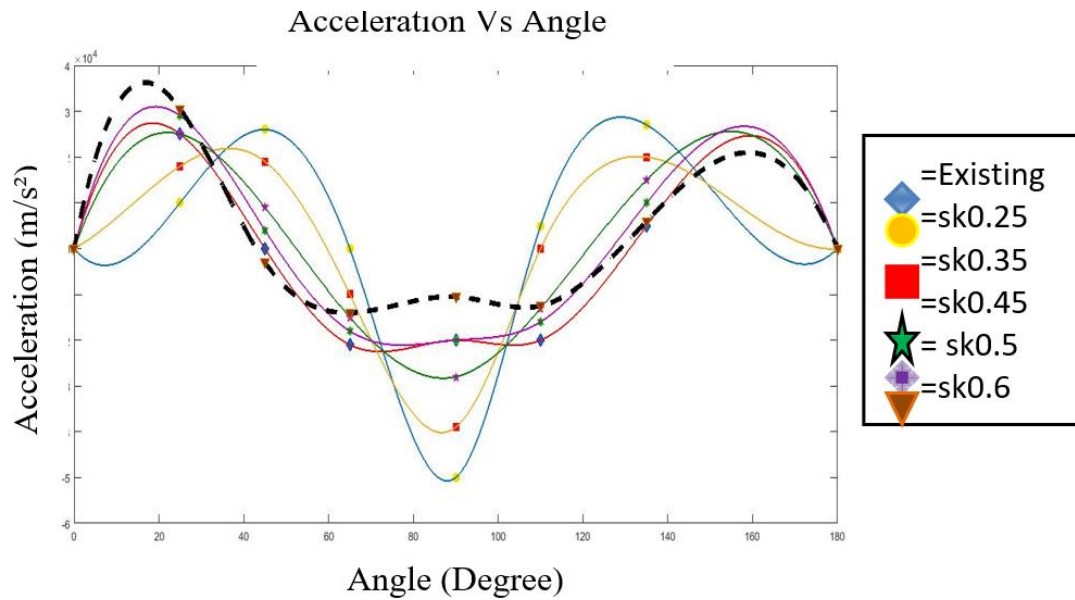


Figure 4. Acceleration curve for all designs.

Smother jerk profiles will reduce the residual vibrations in cam system. In any profile with continuity, the curve will begin and ends at zero amount in each cycle but not for jerk profile. This is because jerk profile does not disregard the principal law of cam plan and rather desirable for smooth operation of cam driven mechanisms. In Figure 5, the graph showed the statement is correct which is jerk profile does not disregard the principal law of the cam. Thus, there is an exchange off between reducing the peak of acceleration and increasing the peak of a jerk. Therefore, in order to optimize the cam curve performance, cam systems with excessive jerk need to be avoided.

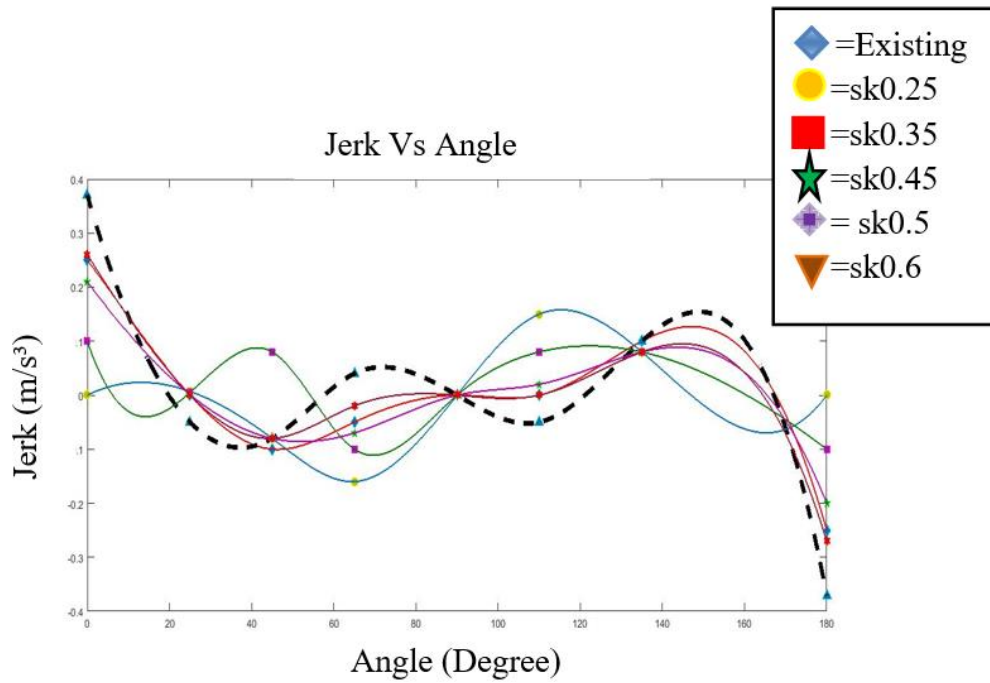


Figure 5. Jerk curve for all designs.

In order to optimize cam curve performance of MODENAS CT115s, there is few methods need to follow such as a B-Spline method. This is because, in the B-Spline method, knot specification and displacement factor, sk need to choose wisely to produce the great cam curve performance. To optimize the cam curve performance using B-Spline is important to know the meaning of negative acceleration, the peak of a jerk, and how it affects the performance of the cam.

The higher displacement factor, sk , was used in order to optimize the acceleration profile. This is to reduce the percentage of the follower to jump during high speed cam rotation condition. This is because higher negative acceleration will tend the follower to jump in the operation. It will give a bad impact on the cam curve performance. Apart from that, by increasing the peak of jerks it will give smooth operation in cam system and reduced the high vibration [6].

Large positive acceleration against load will make the cam follower interfaces forces that can bring about inordinate wear. Negative acceleration has a tendency to lessen the cam adherent interface constraints and if the negative acceleration is adequately worn bounce between the cam and follower can happen. A single dwell cam displacement function is characterized by a B-Spline method that is comprised of four polynomial sorts that tied it out at their closures and called as a knot. The particulars of these branches are considered for combination and investigation of Cam supporter followers. The mathematical connection between interface force and knot area is displayed as wear and jump models. These models are valuable to decrease wear [4].

4. Conclusions

The B-Spline method was implemented in calculating the overall cam performance. By the aid of MATLAB software, the performance curve that consists of displacement, velocity, acceleration, and jerk were plotted. The increasing displacement factor, sk produced the better cam curve performance in terms of displacement, velocity, acceleration and jerk profile. The selection of displacement factors is decided in investigating the effect of displacement factor, sk to the cam performance curve. The value of displacement factor must not exceed 0.60. This is because the value over 0.60 will reduce the performance of cam. This is because 0.60 was the ideal value in plotting the cam performance. Therefore, the increasing value of displacement factor, sk will improve the cam performance but the value of displacement factor must not exceed 0.60.

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6. References

- [1] Hansong Xiao, Jean W. Zu, Cam profile optimization for a new cam drive, *Journal of Mechanical Science and Technology* 23, 2009, pp 2592-2602.
- [2] A.K.Jamkhande, S.S.Tikar, S.S.Ramdasi, N.V. Marathe, Design high speed engine's cam profile using B-Spline functions for controlled dynamic, *SAE Technical Paper* 2012-28-0006
- [3] Vu-Thinh Nguyen, Do-Joong Kim, Flexible cam profile synthesis method using smoothing spline curves, *Mechanism and Machine Theory* 42, 2007, pp 825-838
- [4] Jose De Miguel, How to Build a Bobber on a Budget, <http://xorl.wordpress.com>, March 2011.
- [5] Cobalt327, Crashfarmer, Crosley, Curtis73, Jon, The inspector 1, The right curve, Valkyrie 57, How to Choose a Camshaft, www.crankshaftcoalition.com, 2013.
- [6] Harold k. Rothbart, *Cam Design Handbook*, McGraw-Hill Companies, 2004, pp 90-150