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# Analysis of Crank and Slotted Lever Quick Return Mechanism by Using Powell's Optimization Technique.

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**Abstract:** *A quick return mechanism is one which that convert rotary motion into reciprocating motion at diverse rate for its two strokes i.e. working and return stroke. The working stroke is required to be greater than return stroke. Rational kinematic synthesis of quick return mechanism is the stimulus. The most constructive synthesis of mechanisms is an approach for mechanism design to satisfy all the favored characteristics of the designed mechanism. The Quick Return Mechanism is synthesized using the predictable analytical method and Powell's optimized technique. The main advantage of Powell's Optimization Method is there is no implementation of derivatives. The optimization process is done in MATLAB software. The Analytical results are compared with the results determined by Powell's Technique. The Velocity analysis is done for both the results using Relative Velocity technique. The Prototype of Mechanism is prepared using CREO Software and performance analysis is done in the same showing the difference in performance for both the models. The Experimental Validation is done by prepare the model of best optimized results of quick return mechanism and verifying the slider displacement for simulation as well as the trial model*

**Keywords:** Quick return Mechanism, Synthesis, Optimization, Powell's Technique

## I. INTRODUCTION

When two kinematic links are connected together, its called a kinematic pair and when these two kinematic pairs are connected to each other it's called as kinematic chain. When there is relative motion between these links, it's called as mechanism. Machines consist of number of mechanisms for their triumphant operation and to give preferred output. Mechanisms such as Inversion of - four bar, single slider crank, double slider crank, etc., are used for transmit motion, force, torque etc. doing well synthesis of mechanisms leads to a triumphant machine design. Hence this lead to importance of Mechanism Synthesis.

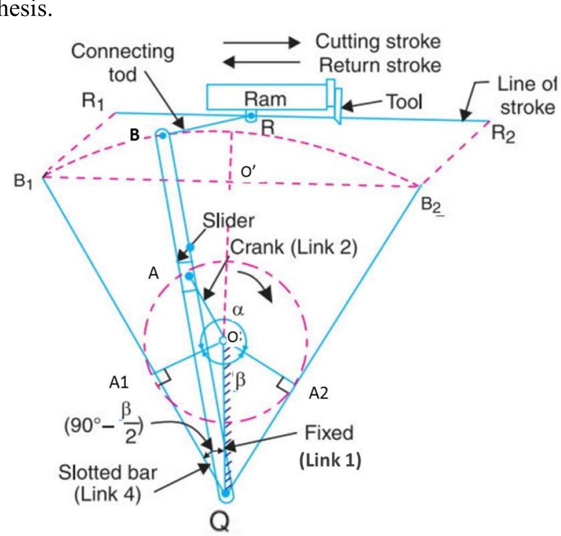


Figure 1: Crnk & Slotted Lever Quick Return Mechanism [Ref: Theory of Machines, Khurmi-Gupta]

Mechanism Synthesis has been done in various mechanisms. For last few decades Powell's technique of Optimization is been in process for optimal synthesis. This process is favorable as there is not any implementation of derivatives and Integrative.

It consists of following links.

Link 1: Fixed

Link 2: Crank

Link 4: Slotted bar

Link 5: Connecting rod.

This Mechanism is essentially used in Shaper machines, slotted machines, rotary combustion engine etc.

**PROBLEM DEFINATION**

*"To optimally synthesize quick return mechanisms using Powell's Optimization Technique"*

Optimal means selecting favorable results under certain boundaries, parameters & conditions.

Synthesis is to decide dissimilar lengths and position of links for specific function.

Powell's technique is multivariable optimization technique for unconstrained variables

In this concept, the main aim is to synthesis the quick return mechanism by the conventional methods as well as the optimized method. The conventional technique of synthesis is done for time ratio as well as the specific stroke. The optimization can be done using MATLAB programming for functioning of same parameters. There are certain objectives which are considered while synthesis process,

To obtain specific stroke.

To obtain desired time ratio.

Avoiding the violation of transmission angle.

## II. LITERATURE SURVEY

The optimal synthesis of four bar crank rocker mechanism is done by using Powell's skill of optimization by Galal. A. Hassan et. al. In this paper the optimized the four bar crank and rocker mechanism for time ratio and stroke allowing for the restrictions of maximum and minimum transmission angles The method and method has been decided using this paper[1]. The predictable method of synthesis for time ratio and stroke are premeditated using complex number methods. Descent method is showed in this paper for crank and slotted lever mechanism as well as computer aided modeling is also done [2]. There are three unusual approaches of synthesizing a quick return mechanism. This paper help to decide the kinematic analysis of quick return using analytical, graphical as well as computer aided solution. The arrangement of output slider is determined [3]. Galal. A. Hasan offset slider crank mechanism helped to verify the transmission angles for maximum and minimum. It describe the finest time ratio for single slider crank mechanism and its inversions [4].Galal. A. Hasan synthesized the planar mechanism for inversions for four bar chain, single slider crank and double slider crank chain mechanism. The transmission angles and its limitations are used to synthesize the mechanisms for time ratio and strokes [5]. Ahmad Wadollah S. Al-Sabawi states the theritical study of Quick return mechanism and its simulation in computer modelling software which further gives the kinematic analysis for velocity & acceleration [6]. Galal Hasan has described the optimal synthesis of 6-bar linkages complex mechanism. The Design requirement considered here is the and the boundary conditions applied here are transmission angles between coupler and rocker, and slider and rocker [7]. Most of the time the for any kind of mechanism whether simple or complex , the velocity analysis was done using the graphical method .. In this paper, the analysis is done using some trigonometric relations. This equations are obliging for kinematics of mechanism. The Kinematic synthesis can be done for Four bar, five bar, six bar & seven bar mechanism [8]. An efficient method for finding the minimum of several functions without calculating derivatives". This method is used to modify the Powell' method pf optimization for Quick Return Mechanism. A Simple variation of the well-known method of minimizing a function of several variables by changing one parameter [9]. OptimaLink, A MATLAB-Based Code for is prepared for Optimum Synthesis and Simulation of Mechanisms. It describes Optimum Synthesis and Simulation of Mechanisms using Matlab based programming codes. The code accommodate precision-point synthesis using the complex-number method [10].

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## III. METHODOLOGY

- Synthesis using Analytical Method.
- Synthesis using Optimized Method in MATLAB.
- Comparison of Dimensions.
- Simulation using CREO software.
- Validation of Results using Conventional Velocity Analysis
- Validation using Performance analysis in CREO software.
- Comparison of Results using Graphs.

MATHEMATICAL MODEL OF MECHNISM

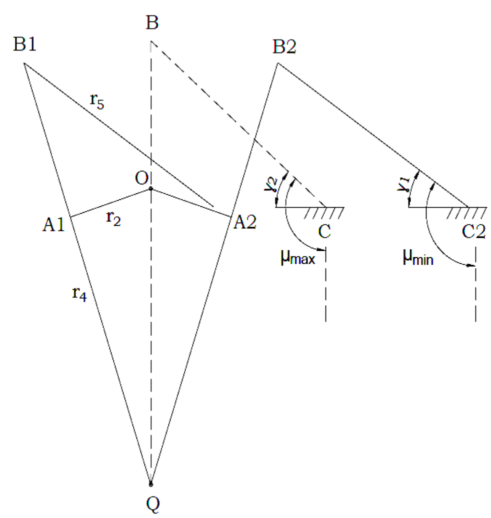


Figure 2: Kinematic Parameters of Quick Return Mechanism

Let,

| | |
|---|---|
| $r_1$ = QO = Fixed Link | $r_2$ = OA = Crank |
| $r_4$ = QB = Slotted Link | $r_5$ = BC = Connecting Rod. |
| T.R = Time Ratio | S = Stroke |
| α = Cutting Angle | β = Return Angle |

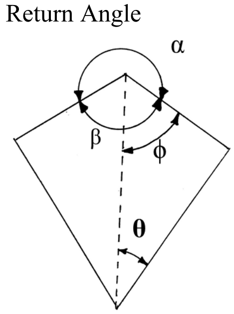


Figure 3: Cutiing & Retrun Stroke

The mechanism is to be synthesized using the following parameter :

Time Ratio : $T.R = \alpha/\beta$ (01)

Fixed Lenth : $r_1 = r_2/\cos\phi$ (02)

Stroke : $S = 2.\ r_4 \sin\theta$ (03)

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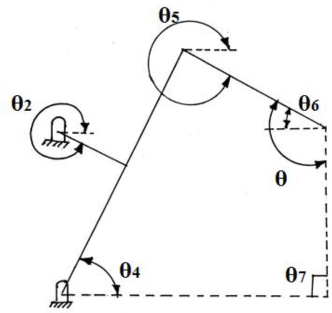

Figure 4: Position Analysis of different links

*Position of Crank*: $\theta_2 = 360 - (90 - \phi)$ (04)

*Position of Slotted Link*:

$\theta_4 = \tan^{-1}\{(r_1 \sin\theta_1 + r_2 \sin\theta_2)/(r_1 \cos\theta_1 + r_2 \cos\theta_2)\}$ (05)

*Position of other links*:

$\theta_4 + \theta_8 + \theta_7 + \theta = 360$ (06)

$\therefore \theta_6 = \theta - 90$ & $\theta_5 = 360 - \theta_6$ (07)

*Connecting Rod*:

$\sin(\theta_5 - \theta_6) = \{(r_1 \cos\theta_1 . \sin\theta_6) - (r_1 \sin\theta_1 . \cos\theta_6)\}/ r_5$ (08)

*Transmission Angles* ($\mu$) :

Min. Transmission Angle: $\mu min = 90 + \gamma_1$

where $\gamma_1 = \sin\text{-}1\{(r_4/r_5)\cos\phi - (L+r_1)/r_5\}$ (09)

*Max Transmission Angle*: $\mu max = 90 + \gamma_2$

where $\gamma 2 = \sin\text{-}1\{(r4 - r1 - L)/r5\}$ (10)

*Normalized Dimensions*:

$r_{1n} = (r_1/r_2)$ ; $r_{4n} = (r_4/r_2)$ ; $r_{5n} = (r_5/r_2)$; $S_n = (S/r_2)$

*Analytical results (Non-optimized Analytical Models) :*

TABLE 1: ANALYTICAL RESULTS FOR DESIRED STROKE & TIME RATIO

| Run No. | T.R. | $S_n$ | $r_{1n}$ | $r_{4n}$ | $r_{5n}$ |
|---|---|---|---|---|---|
| 1 | 1.45 | 2.90 | 3.5126 | 5.0933 | 3.2159 |
| 2 | 1.46 | 2.90 | 3.4538 | 5.0081 | 3.1179 |
| 3 | 1.47 | 2.95 | 3.3951 | 5.0084 | 3.0172 |
| 4 | 1.48 | 3.00 | 3.3403 | 5.0104 | 2.9471 |
| 5 | 1.49 | 3.00 | 3.2864 | 4.9282 | 2.8366 |
| 6 | 1.5 | 3.00 | 3.2361 | 4.8541 | 2.7558 |
| 7 | 1.51 | 3.00 | 3.168 | 4.7528 | 2.6702 |
| 8 | 1.52 | 3.05 | 3.1398 | 4.7865 | 2.6 |
| 9 | 1.53 | 3.05 | 3.0904 | 4.7177 | 2.5285 |
| 10 | 1.54 | 3.10 | 3.0506 | 4.72 | 2.4625 |
| 11 | 1.55 | 3.10 | 3.0083 | 4.6617 | 2.3987 |

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OPTIMIZATION APPROACH

*Design Objectives:*

Attain Specific Stroke

Attain Specific Time Ratio

Not to disobey the limit of transmission angles

*Design Parameters:*

Normalized length of fixed Link , $r_{1n}$

Normalized length of slotted bar , $r_{4n}$

Normalized length of connecting rod , $r_{5n}$

*Functional Constraints:*

There are three functional constraints,

$F_{c1}$ = Minimum Transmission Angle, $\mu_{min}$

$F_{c2}$ = Maximum Transmission Angle, $\mu_{max}$

- $F_{c3}$ = It should suit the Grasshoff's Condition,
  i.e. $r_{min} + r_{max} < r_a + r_b$

*Limits of Functional Constraints:*

$60 < F_{c1} < 90$

$90 < F_{c1} < 145$

*Powell's Conjugate Technique of Optimization:*

Powell's optimization method is used for the optimal kinematic synthesis of mechanism. This method involves the reduction of unrestrained multivariable. More over this method is widely used because it does have any achievement of derivatives and integrations.

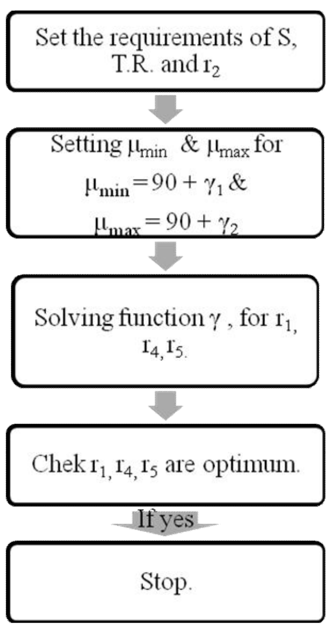


Figure 5: Powell's Conjugate Technique

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*Mechanism Design:*

The mechanism is to be design for satisfying the desired values for strokes, time ratio maximum & minimum transmission angles. For attain the objectives, following equations are to be solved,

$\mu_{min} - \mu_{mind} = 0$ (11)

$\mu_{max} - \mu_{maxd} = 0$ (12)

$T.R. - T.R_d = 0$ (13)

$S - S_d = 0$ (14)

Equations (11) (12) (13) (14) are usually nonlinear equations of genetic algorithm form. These Equations can be solved using matlab programing.

The equations can be solved using the emperical realtions as,

$\mu min = 90 + \gamma_1$ $\mu max = 90 + \gamma_2$

$\gamma_1 = \sin\text{-}1\{(r_4/r_5) \cos\phi - (L+r_1)/r_5\}$

$\gamma 2 = \sin\text{-}1\{(r4 - r1 - L)/r5\}$

$L = (r_4) - (r_1) - (\sin\gamma 2 - r_5)$

and, $T.R = \alpha/\beta$ ; $r_1 = r_2/\cos\phi$ ; $S = 2.\ r_4 \sin\theta$

The following are the results obtained using the Matlab based programming for desired time ratio and stroke length.

TABLE 2: OPTIMIZED RESULTS FOR DESIRED STROKE & TIME RATIO OBTAINED BY MATLAB PROGRAMING

| Run No. | T.R. | $S_n$ | $r_{1n}$ | $r_{4n}$ | $r_{5n}$ |
|---|---|---|---|---|---|
| 1 | 1.45 | 2.90 | 3.2299 | 5.0444 | 3.3995 |
| 2 | 1.46 | 2.90 | 3.4538 | 5.008 | 3.6615 |
| 3 | 1.47 | 2.95 | 3.3551 | 5.0096 | 3.3213 |
| 4 | 1.48 | 3.00 | 3.3003 | 4.9907 | 3.0153 |
| 5 | 1.49 | 3.00 | 3.2644 | 4.9030 | 3.2155 |
| 6 | 1.5 | 3.00 | 3.2278 | 4.8410 | 3.0092 |
| 7 | 1.51 | 3.00 | 3.1864 | 4.7797 | 2.3406 |
| 8 | 1.52 | 3.05 | 3.1292 | 4.7682 | 3.2009 |
| 9 | 1.53 | 3.05 | 3.0806 | 4.7188 | 2.9389 |
| 10 | 1.54 | 3.10 | 3.0083 | 4.6629 | 3.0835 |
| 11 | 1.55 | 3.10 | 3.0065 | 4.6533 | 3.1418 |

COMPARISON OF OPTIMAL VALUES WITH ANALYTICAL VALUES

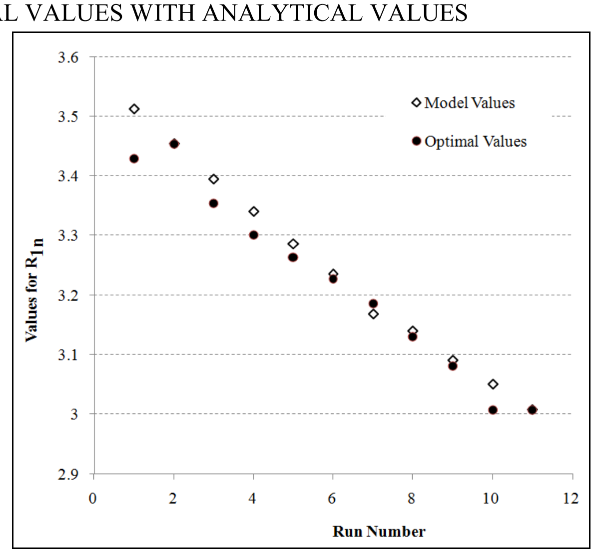


Figure 6: Optimal and Analytical value for $r_{1n}$

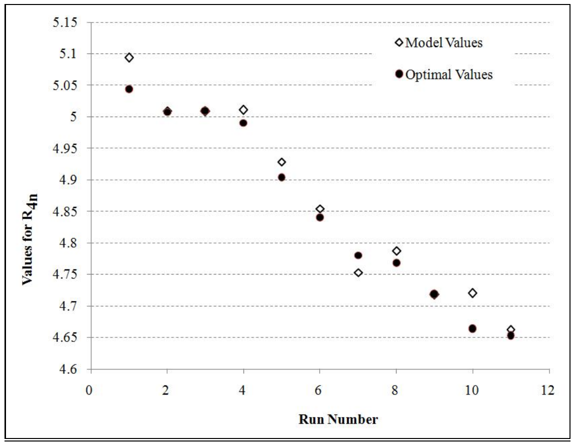


Figure 7: Optimal and Analytical value for $r_{4n}$

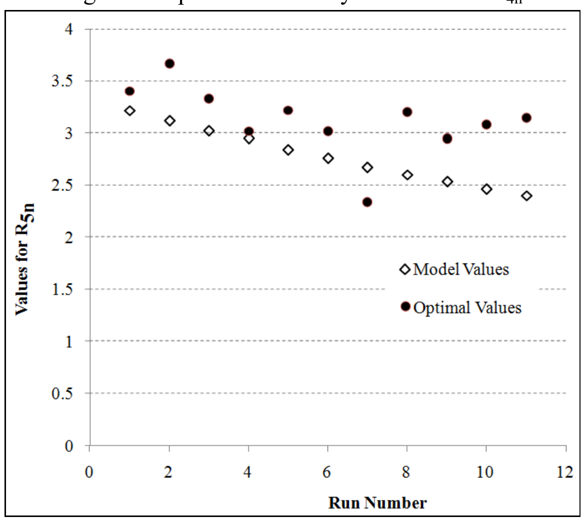


Figure 8: Optimal and Analytical value for $r_{5n}$

**SIMULATION**

The dimensions of mechanism are obtained by using the mathematical equation as well as the matlab programming. The Using the dimensions of for time ratio 1.5, both the models are prepared in creo software. The image of simulation is shown by fig. 9.

*Design Requirement:*

Stroke = 300 mm ; T.R = 1.5 ; crank ($r_2$) = 100mm

Hence from the Table 1 & 2, the dimensions for above design requirements are,

TABLE 3: DESIGN REQUIREMENT FOR DESIRED STROKE

| Parameters | $r_{1n}$ | $r_{4n}$ | $r_{5n}$ |
|---|---|---|---|
| Analytical | 3.2361 | 4.8541 | 2.7558 |
| Optimal | 3.2278 | 4.8410 | 3.0092 |

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*Computer Aided (Creo) Model:*

The model is prepared using Creo-2.0.

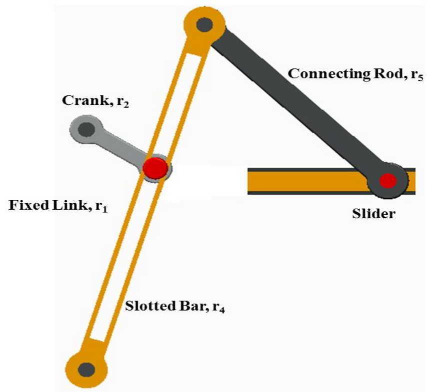


Figure 9: Creo Model of Mechanism

*Performance Analysis :*

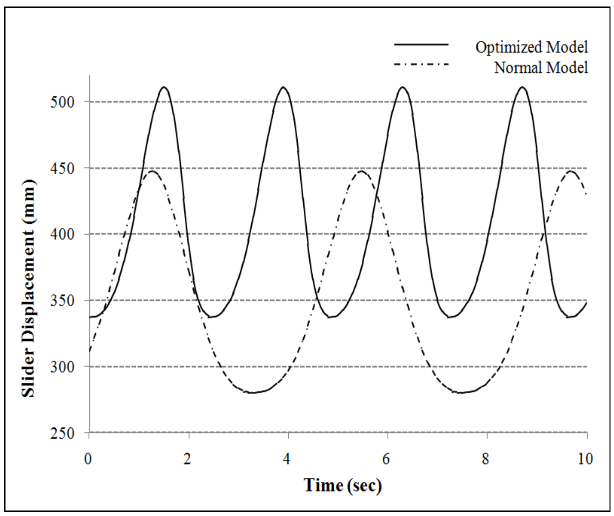


Figure 10: Slider Displacement of Optimized and Analytical Model

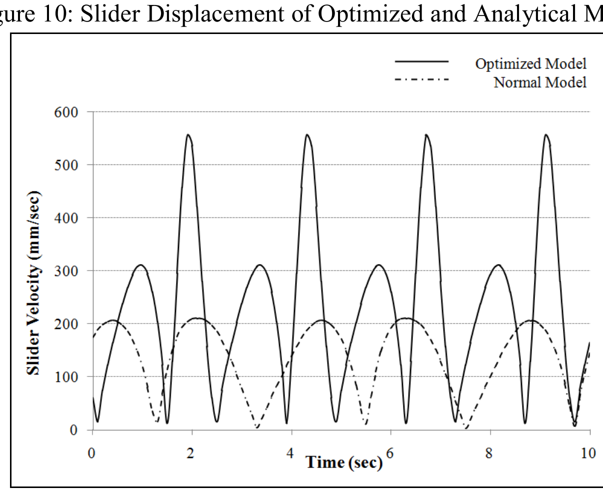


Figure 11: Slider Velocity of Optimized and Analytical replica

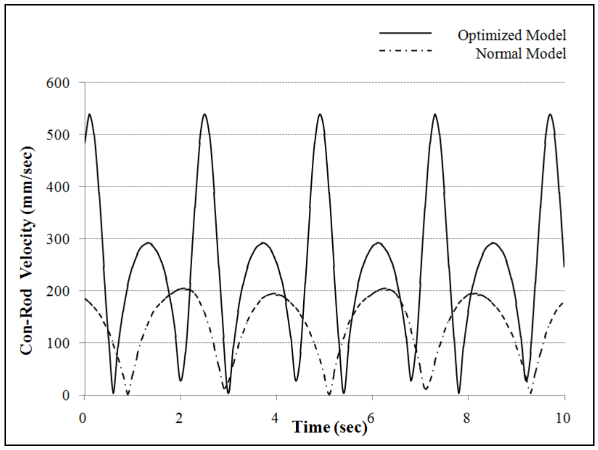

Figure 12: Con-rod Velocity of Optimized and Analytical replica

The Graph above show the performance analysis of normal as well as the optimized method. This performance analysis is carried out for Speed 150 Rpm. The Results are shown in sinusoidal graphs for Slider Velocity, Slider Displacement and the Connecting rod velocity.

## IV. RESULT AND DISCUSSION

TABLE 4: RESULTS OF VELOCITY ANALYSIS AT INPUT OF 150 RPM (C/w)

| **Velocity (mm/s)** | **$V_{BC}$ ($r_5$)** | **$V_{SLIDER}$** | **Disp. $_{SLIDER}$** |
|---|---|---|---|
| Non-Optimal | 133.18 | 136.55 | 355.29 |
| Optimal | 252.75 | 232.99 | 405.71 |
| **% Benefits** | **8.87 %** | **7.37%** | **14.21%** |

From the table 4, it shows the comparison of the velocity of slider and connecting rod, and the displacement of slider. The Table is copied from the results of Graphical values. From the table it is clear that the optimized mechanism model, which is prepared using the matlab programming shows the better results as that of mathematical model. Hence from simulation we can conclude that, the optimized model shows better results.

## V. CONCLUSION

Powell Conjugate direction technique of optimal synthesis can be implemented and can be replaced to conventional method of synthesis so as to avoid the errors upcoming in calculations just by using simple equation coding and dimensions can be obtained.

Synthesis Process for several run numbers is completed with analytical and Matlab process and 3.5% difference is calculations are observed.

A case Study is done for T.R. =1.5 and stroke= 300 is done for velocity and performance analysis and benefits in performance of optimal model is observed.

The Performance analysis graph shows the benefits in performance of Optimal Model compared to Analytical Normal Model.

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