IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 4, June 2023

Optimal Kinematic Synthesis of Crank and Slotted Lever Quick Return Mechanism for Specific Stroke and Time Ratio

Mr. Naresh A. Jadhav, Mr. S. V. Kasar, Mr. S. A. Patil, Mr. K. P. Suryawanshi
Department of Mechanical Engineering
Guru Gobind Singh Polytechnic, Nashik, India

Abstract: *A quick return mechanism is one which that converts rotary motion into reciprocating motion at different 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 motivation. The optimal synthesis of mechanisms is an approach for mechanism design to satisfy all the desired characteristics of the designed mechanism. The Quick Return Mechanism is synthesized using the conventional analytical method and Powell's optimized method. 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 Method. 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 preparing the model of best optimized results of quick return mechanism and verifying the slider displacement for simulation as well as the experimental 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 successful operation and to give desired output. Mechanisms such as Inversion of - four bar, single slider crank, double slider crank, etc., are used for transmitting motion, force, torque etc. Successful synthesis of mechanisms leads to a successful machine design. Hence this lead to importance of Mechanism Synthesis.

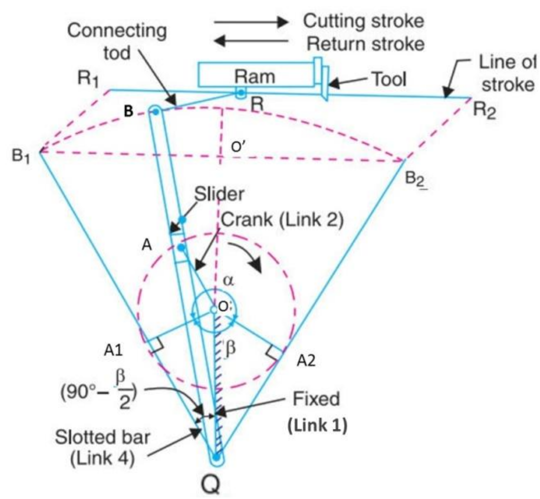

Figure 1: Crank & Slotted Lever Quick Return Mechanism [Ref: Theory of Machines, Khurmi-Gupta]

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 4, June 2023

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 mainly 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 determine different 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 method 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 technique 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 considering the limitations of maximum and minimum transmission angles The methodology and procedure has been decided using this paper[1]. The conventional method of synthesis for time ratio and stroke are calculated using complex number methods. Descent methodology is showed in this paper for crank and slotted lever mechanism as well as computer aided modeling is also done [2]. There are three different approaches of synthesizing a quick return mechanism. This paper helped to determine the kinematic analysis of quick return using analytical, graphical as well as computer aided solution. The position of output slider is determined [3]. Galal. A. Hasan offset slider crank mechanism helped to determine the transmission angles for maximum and minimum. It describes the optimal 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 helpful 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 methodology is used to modify the Powell' Technique 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 accommodates precision-point synthesis using the complex-number method [10].

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 4, June 2023

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.

IV. MATHEMATICAL MODEL OF MECHNISM

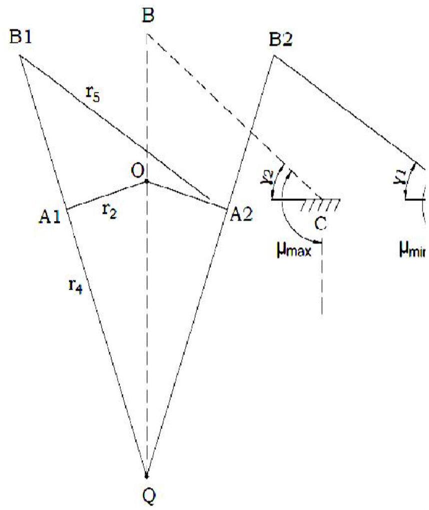

Figure 2: Kinematic Parameters of Quick Return Mechanism

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

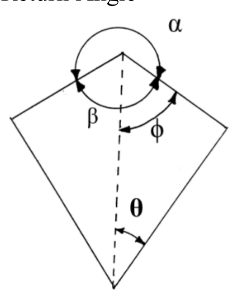

Figure 3: Cutiing & Retrun Stroke

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)

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 4, June 2023

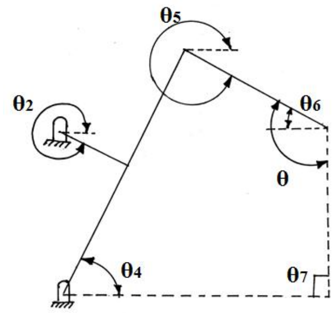

Figure 4: Position Analysis of different links

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 (μ) :

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

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 4, June 2023

OPTIMIZATION APPROACH

Design Objectives:

Attain Specific Stroke
Attain Specific Time Ratio
Not to violate 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, μ_{min}
F_{c2} = Maximum Transmission Angle, μ_{max}
- F_{c3} = It should satisfy 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 technique is used for the optimal kinematic synthesis of mechanism. This process involves the reduction of unconstrained multivariable. More over this technique is widely used because it does have any implementation of derivatives and integrations.

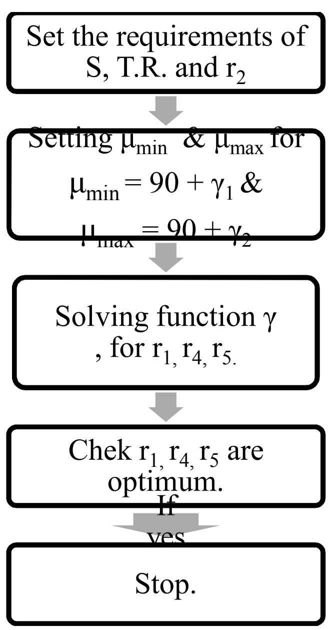

Figure 5: Powell's Conjugate Technique

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 4, June 2023

Mechanism Design:

The mechanism is to be design for satisfying the desired values for strokes, time ratio maximum & minimum transmission angles. For attaining 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 generally nonlinear equations of genetic algorithm form. These Equations can be solved using matlab programing.

The equations can be solved using the emperical realtions as,

$\mu min = 90 + \gamma_1$

$\mu max = 90 + \gamma_2$

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

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

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

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

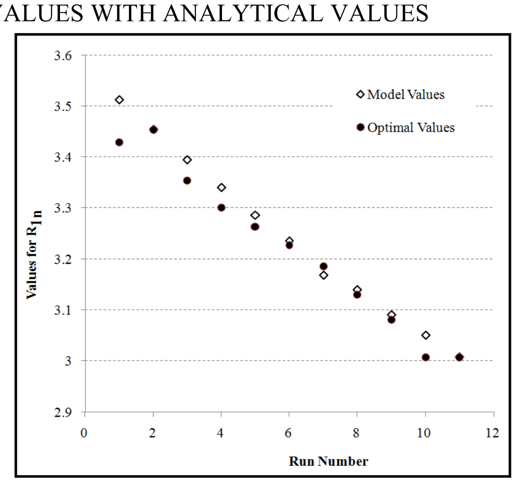

Figure 6: Optimal and Analytical Values for r_{1n}

IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.301

Volume 3, Issue 4, June 2023

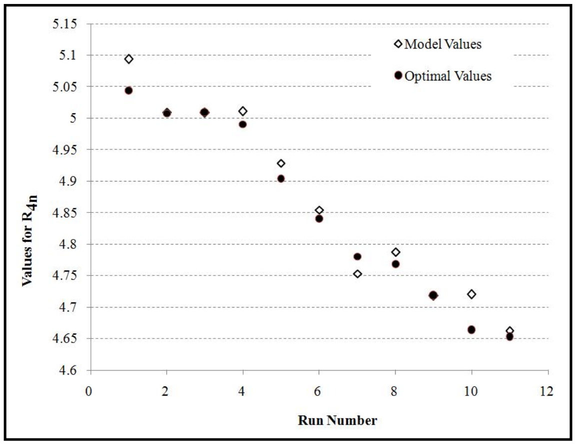

Figure 7: Optimal and Analytical Values for r_{4n}

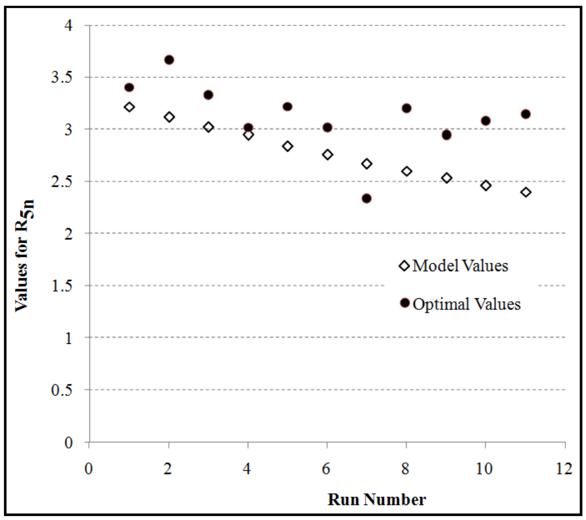

Figure 8: Optimal and Analytical Values for r_{5n}

V. 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

Computer Aided (Creo) Model:

The model is prepared using Creo-2.0.

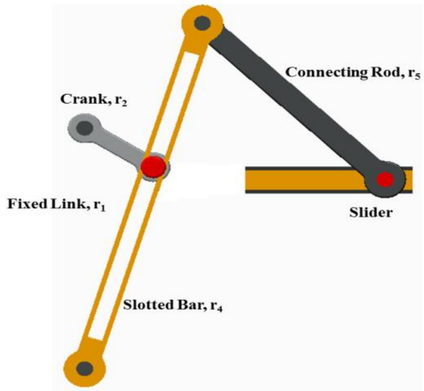

Figure 9: Creo Model of Mechanism

Performance Analysis :

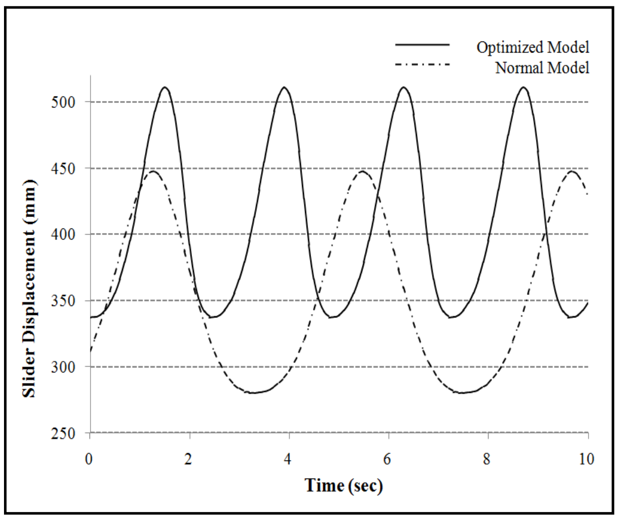

Figure 10: Slider Displacement of Optimized and Analytical Model

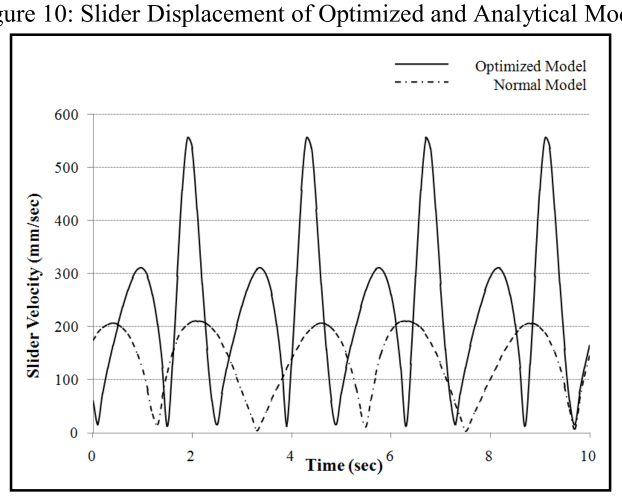

Figure 11: Slider Velocity of Optimized and Analytical Model

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 4, June 2023

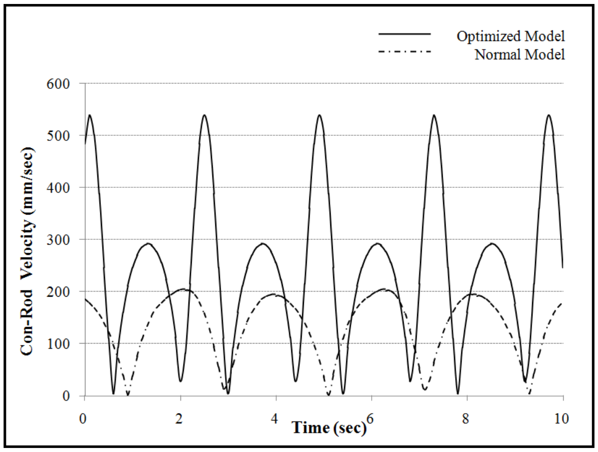

Figure 12: Con-rod Velocity of Optimized and Analytical Model

The Graph above shows the performance analysis of normal as well as the optimized mechanism. 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.

VI. 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 derived 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.

VII. 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.

ACKNOWLEDGMENT

The report is outcome of guidance, moral support and devotion bestowed on me throughout my work. For this I acknowledge and express my profound sense of gratitude and thanks to everybody who have been a source of inspiration during the experimentation. First and foremost I offer my sincere phrases of thanks with innate humility to **Dr. S.V.Sadhawani,** (H.O.D) Mechanical Engineering Department, S.N.D.College of Engineering & Research Centre Yeola, Nashik for providing help whenever needed.

The consistent guidance and support provided by **Prof. Londhe.V.D** is very thankfully acknowledged and appreciated for the key role played by him in providing me with his precious ideas, suggestions, help and moral support that enabled me in shaping the experimental work.

REFERENCES

[1]. Galal A. Hassaan, Mohammed A. Al-Gamil & Maha M. lashin "Optimal kinematic synthesis of 4-bar planar crank-rocker Mechanisms for a specific stroke and time ratio." International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) Vol. 3, Issue 2, Jun 2013

[2].S.D. Shelare, P.S. Thakare, Dr. C.C. Handa "Computer Aided Modelling And Position Analysis of Crank And Slotted Lever Mechanism" International Journal of Scientific & Technology Research Volume 1, Issue 5, June 2012.

[3].Katarína Monková, Peter Monka, Sergej Hloch, Jan Valíček. "Kinematic analysis of quick-return mechanism in three various approaches" Technical gazette.

[4].Galal Ali Hassaan "Optimal Kinematic Synthesis of Planar Mechanism, Part I: Offset Crank-Slider Mechanism" International Journal of Computer Techniques – Volume 2 Issue 1, 2015.

[5].Galal Ali Hassaan "Synthesis of Planar Mechanisms, Part II: Specified Stroke, Time Ratio and Transmission Angle" International Journal of Computer Techniques - Volume 2 Issue 3, May - June 2015

[6]. Ahmad Wadollah S. Al-Sabawi "Theoretical Study and Computer Simulation of a Modified Quick Return Mechanism" Al-Rafidain Engineering Vol.20 No. 5 October 2012.

[7]. Galal A. Hassan "Optimal Synthesis of Single Dwell 6 Bar linkage mechanism" International Journal of Computational Engineering Research, Vol, 04 Issue, 2 Feb 2014.

[8]. Pravin S. Ghawade, Nilesh D. Shirgire "Analytical Method for Velocity Analysis of Simple and Compound Mechanisms Using Simple Trigonometry" International Journal of Emerging Technology and Advanced Engineering Volume 3, Issue 4, April 2013.

[9]. Powell M., "An efficient method for finding the minimum of several functions without calculating derivatives" The Computer J., Vol.7, 1964, p.155.

[10]. AhmaD Smaili, Naji Atallah and Firas Zeineddine "OptimaLink: A MATLAB-Based Code for Teaching/Learning Precision-Point and Optimum Synthesis and Simulation of Mechanisms" Int. J. Engg. Ed. Vol. 21, 2005