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# Computer Assisted Computation Of Compound Linkage Machine Mechanism Using Matlab

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***ABSTRACT***

The compound linkage is a modified closed loop mechanism and has numerous uses in industry and for simple devices found in automobiles, todays, spacecraft etc. The computer assisted computation of different mechanisms has been actively studied since the last century. The pioneering work in this field was explored by Reuleaux in the 1870's, and continues to be a field of active research. It can't be dependent totally on manual working of anything in the universe, it leads thing to take much time with less accuracy. So such thing must be developed to overcome this. All the mechanisms in the universe are modified form of four bar mechanism, now in this paper; it explains developed such design software developed in MATLAB for computational analysis of compound linkage which will be helpful for the undergraduate students in the academic work. Also it helps for the design engineer to carry out the research work in the industry. Traditionally, there are two methods for computational analysis of compound linkage as graphical method and analytical method, but these methods are having certain limitations due to which desired results are not possible. These are very complex and time consuming and do not provide actual motion of links i.e. proper visualization is not possible. In this paper, analysis of each and every link of 6 bar linkage is possible with proper visualization at every position of crank and gives the required output in short span of time. This design software is prepared in MATLAB and gives the results within the fraction of second. The focus of this paper is on the design and computational analysis of compound linkages and practical implementation of software enables to find displacement, force, velocity and acceleration. The computer assisted computational task and implementation to practical applications are carried out to select the best possible according to its performance parameters and also their results shown in tabular form.

***Keywords*** - 6-bar linkage mechanism, MATLAB, experimental analysis, performance parameters

## I. INTRODUCTION

Machines are mechanical devices used to accomplish work. A mechanism is a heart of a machine. It is the mechanical portion of the machine that has the function of transferring motion and forces from a power source to an output. The six bar mechanism is the compound mechanism consist of five links and one slider. It has numerous uses in industry and for simple devices found in Robotics, Simple press, Lift platform.

## II. DESIGN CONSTRUCTION

Links 1 is a ground link (sometimes called frame or fixed link), and it assumes to be motionless. Link 2 and 4 each rotates relative to the ground link about fixed pivots A and D. Link 2 is the crank which operates the mechanism. Link 3 is called coupler link and is the only link and the only link that can trace paths of arbitrary shape and transfers motion to link 4 (follower) and link5(connecting rod). Link 4 is called the follower link, because its rotation merely follows the range of motion as determined by the input and coupler link.

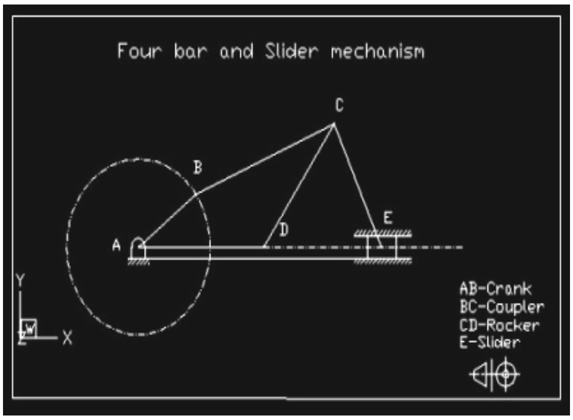


Fig.1. Compound linkage Mechanism

The connecting rod (link5) is connected to slider which oscillates in horizontal direction according to rotation of crank. The objective of this paper is to analyze the compound linkage mechanism from the application point of view using computer programming. In computational analysis of compound linkage mechanism includes, finding out velocities and acceleration of different links, obtaining various inertia and static forces acting on the links. The traditional methods of computational analysis are Graphical and analytical may be limited when they are applied to complicated problems. Graphical methods, although they provide a good understanding of kinetics, lack of accuracy and tend to be time consuming. These are the reasons why not used for repetitive or three dimensional analyses. Analytical or closed form methods can be extremely efficient, although they are application dependent, and may suffer from excessive complexity problems. Now, to overcome above difficulties, the design analysis concept of six bar linkage mechanism is thought of which would be very useful for analyzing the machines containing six linkages. The developed working model includes sensors (angular sensor) and RPM sensor and interfacing kit. In computational analysis, it is required to give the motion to input crank. The interfacing kit is major part which is linked between mechanically fabricated assembly and computer set up. Now, we will give input to computer by rotating the crank, this input is in analog form (from sensor to kit) and give to analog digital converter which will convert this input into digital form and give to MATLAB software program .Now, software program will calculate the velocities, acceleration of different links, for different positions of crank.

The application considered for analysis purpose is as shown in fig.2

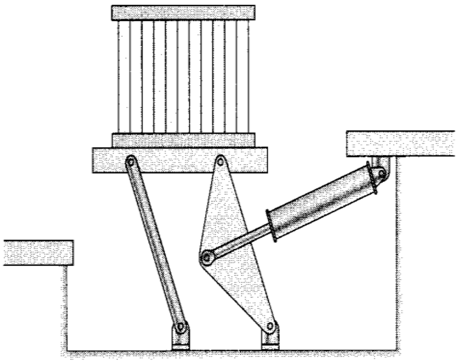


Fig.2. Lift platform

Similarly the compound linkage mechanism has found wide application in Simple press, Microwave carrier to assist people on wheelchair, Moves packages from an assembly bench to a conveyor.

## III. BUILDING OF MODEL FOR ANALYSIS

**Design section-**

*A.* Link Dimensions- For providing a better aesthetic look we have used Aluminium as material for the fabrication of link with required dimensions. All the five links are made of same material and slider is made up of wooden block for simplicity. The fabricated model is mounted on plywood sheet of 4mm thickness & dimensions of 2*3 feet.
- Crank- length: 15 cm, Width: 2cm, Thickness: 0.2cm
-Coupler- length: 30cm, Width: 2cm, Thickness: 0.2cm


Fig.3. Crank and Coupler

-Rocker: length: 25cm, Width: 2cm, Thickness: 0.2cm
-Fixed Link: 30cm,
-Connecting rod: length: 35cm, Width: 2cm, Thickness: 0.2cm
-Slider


Fig.4. Rocker and connecting rod

*B.* Model dimensions-A fabrication model along with electronic hardware kit (interfacing kit) is mounted on the PLYWOOD Sheet of dimension 2*3 feet. On the sheet there is one hole through which wires are connected from sensor to interfacing kit.

Fig.5.Actual Model of Compound linkage Mechanism

*Design of Electronics Components-*

1. Voltage regulators
2. Proximity Sensor (TSOP)-For R.P.M. measurement
3. Potentiometer (10 k type):- For angle sensing
4. Micro-Controller (Ardiunon uno)
5. Interfacing Kit

In this paper, a software program for coordinating activities of compound mechanism model is developed in MATLAB. It is interfaced with model through computer system with the help of electronics hardware kit for directing and monitoring the mechanism activities. The electronic hardware consists of micro-controller board (arduino-uno), serial port connectors, resistors, sensors mainly angular and rpm sensor, & interfacing kit. An analog signals are coming out from various sensors are provided to Analog-Digital Convertor where signal conversion is carried out and further sends to a microcontroller which processed that digital signal and send to CPU through serial port.


Fig.6. Block diagram of system layout

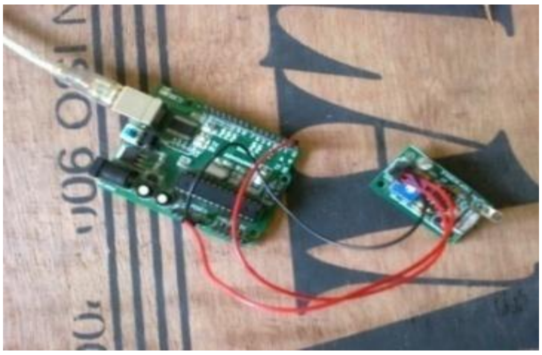


Fig.7 Interfacing Kit

Electronic Section-
1. Voltage regulators
2. Sensors- TSOP, 10k potentiometer
3. Microcontroller (arduino uno)
4. Serial communication cable
5. Pin to pin connectors

*1. Voltage regulators*-It is used for regulating and maintaining the voltage which is to be provided to further devices such as sensors, ADC, Microcontroller etc. on PCB. Initially 230V AC supply is converted into 9V AC Supply with the help of transformer. This 9V AC supply is further moves towards the rectifier where its conversion is done into 9V DC supply. Through a filter (Capacitor) a purely 9V DC Supply is proved to a Voltage regulator which regulates the 9V DC Supply and maintain it at 5V DC supply and supplies to various devices on PCB & sensors as per their requirement i.e. Maximum 5Volt.

*2. Sensors-*

- *TSOP*- It is basically object detection sensor which acts as proximity sensor detecting the revolution done by crank during the working of mechanism. When crank comes in front of the sensor the LED on sensor glows and increases count in ardiuno software giving RPM of rotating motor. This data of RPM is taken by MATLAB as input which helps in further calculation of Velocities& acceleration.

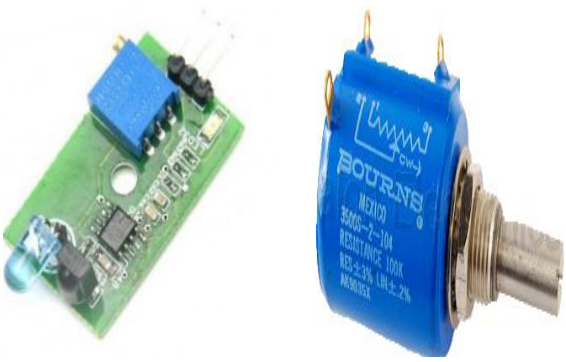



Fig.8. TSOP and Potentiometer 10k type

- *Potentiometer 10k type*-It is nothing but a potentiometer which works as a sensor. It is three terminal resistors with a wiper & resistive strip. It is constructed using a semicircular resistive element with a sliding contact wiper. The wiper is connected through another sliding contact to another terminal. It is manually adjustable resistor. It has three terminals, one terminal is connected to the power source, another one terminal is hooked up to ground (a point which have no voltage or resistance & which serves as a neutral reference point) while third terminal runs across a strip of resistive material. This resistive strip generally has a low resistance at one end; its resistance is gradually increased or decreased to maximum resistance at other end. Third terminal is usually interfaced to user by means of knob or lever. Users can adjust the position of third terminal along a resistive strip in order to manually increase or decrease resistance. By controlling resistance, a potentiometer can determine how much current flow through a circuit. When used to regulate current, a potentiometer is limited by maximum resistivity of strip. Fig. 8 shows the potentiometer mounted at four different positions on model. When we are providing a motion to a link (crank) all links will also move through certain degree and due to which knob (through a rotation of spindle) providing a sliding motion to wiper on resistive strip. If the knob controlling the resistance is positioned at exactly halfway point on resistive strip then output voltage will drop by exactly 50%, no matters how high the potentiometer input voltage.

3. *Microcontroller (ATMEGA 8)*

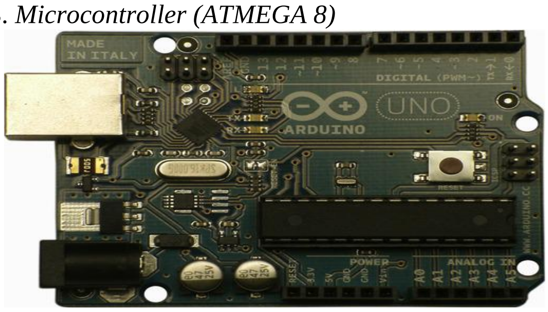



Fig.9. Microcontroller

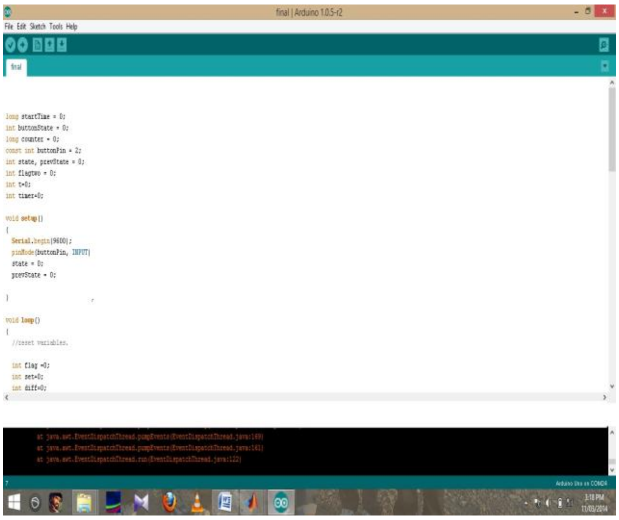
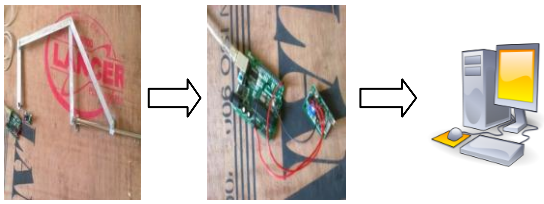


Fig.10. Microcontroller Processing

## IV. WORKING SETUP FOR COMPUTATIONAL ANALYSIS

For taking a trial on the actual working of mechanism-a demonstrative model, we have two options by which analysis can be possible. We can go for either automatic method or manual method. As compared to traditional method this approach give the required output in less time and better accuracy along with better visualization of various links of mechanism.

Fig.10 shows the experimental setup for analysis of 6-bar mechanism which consists of fabrication model, interfacing kit and software program inside a computer system.



Compound bar linkage    Interfacing kit    Software Program

Fig.11. Set up for Computational Analysis

For operation, it is required to give motion to a crank by operating switch. While operating, the revolution of motor will be calculated by object detection TSOP sensor and on switching off the motor the position of crank at that instant will be calculated by Rotary Encoder. Due to motion of crank other links will also move through certain degrees. The Corresponding change in position will be calculated in software using *Freudenstein's equation*. These two parameters (Angles and RPM) are then provided to the MATLAB software program which will finally give output as velocity, acceleration, Inertia & static Forces for all the links of mechanism. Also we can manually input the data of RPM and angle to Software which will generate the required output.

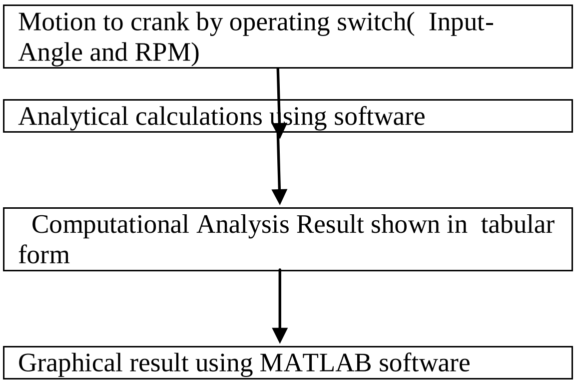



Fig.12. Flow chart of experimentation

***Comparison between Theoretical Drawn and Computer Assisted Velocity diagram, Acceleration Diagram***

Traditionally we have two methods for the analysis of 6- bar mechanism as graphical method and analytical method, but these methods are having certain limitations due to which desired results are not possible. These are very complex and time consuming and do not provide actual motion of links i.e. proper visualization is not possible. In this paper, computational analysis of each and every link of linkage is possible with proper visualization at every position of crank and gives the required output in short span of time. In this the comparison between outputs given by traditional method and that given by a demonstrative model approach by doing so, we came to know that compared results are 95% correct.

## V. COMPUTATIONAL ANALYSIS

Following are some problems which gives the comparison between traditional (Graphical manual method) method and demonstrative model approach using MATLAB.

Example- Analyze a six bar mechanism having following given data and Space diagram as follows

Crank Length (AB):-0.15m, Coupler (BC):-0. 46m, Rocker (CD):-0.30m, Fixed Link (AD):-0.30m, Connecting Rod:-0.45m,& Slider and

Angle between crank and fixed link is 90, when crank is rotating with 600rpm.

Solution-

*-Graphical Method- manual method*

We know that

Crank length (r2) = 0.15m.

Angular Velocity of crank (w2) = 62.83 rad/sec.

So Velocity of crank = r2 * w2

V2 =0. 15* 62.83 = 9.42m/sec

Take scale as 1cm. = 1m/sec. for drawing velocity diagram.

By Measurement: V3 = 5.9768m/sec

V4 =11.95m/sec

V5=5.0m/sec

Now Radial comp. of acceleration of crank is given as

ar2 = V2^2 / r2

ar2= 88.7364 /0.15 = 591.576m/sec.

Similarly,

ar3 = 5.9768*5.9768 /0.46 =77.85m/s2,

ar4 = 11.95*11.95 /0.30 = 476.00 m/s2

ar5= 5.0*5.0/0.45=55.55m/s2

Tangential comp. of acceleration of crank as

at2= r2*a =0,

at3=68.79m/sec2,

at4=176.5m/sec2

at5=462.26m/sec2

*-Static and inertia force analysis using MATLAB software*

1. Inertia Force- The **f**orce opposite in direction to an accelerating force acting on a body and opposite to the product of the accelerating force & the mass of body.

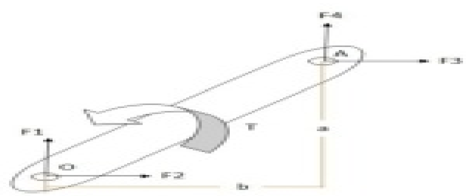
FI2 =m2*ag2 (force on crank), FI3 =m3*ag3 (coupler)

FI4 =m4*ag4 (rocker), FI5 =m5*ag5 (connecting rod)

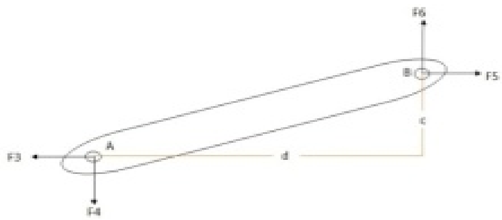
FP = m*ω^2*R3 $[\cos\theta 4 + (\cos 2\theta 4/n)]$

2. Static Force-If the body is under equilibrium condition, then this equilibrium is known as static equilibrium

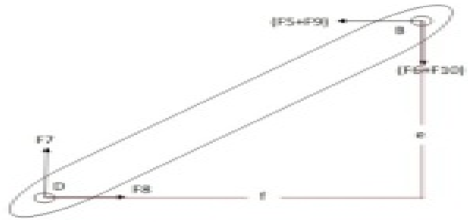
*Condition 1-F1+F3=0, F2+F4=0*



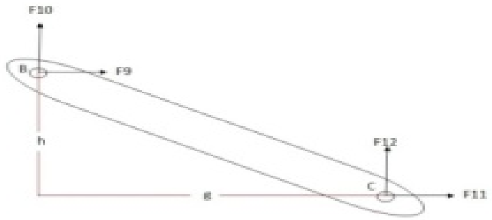
*Condition 2 --aaF3+bbF4+T=0, -F3+F5=0, -F4+F6=0*



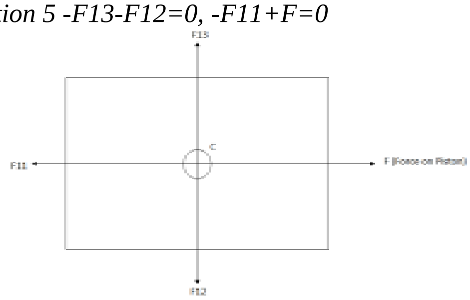
*Condition 3 - -cc*F5+dd*F6=0, F8-F5-F9=0*
*F7-F6-F10=0, -ff (F6+F10)+ee(F5+F9)=0*




*Condition 4 -F11+F9=0, F12+F10=0, gg*F12+hh*F11=0*




*Condition 5 -F13-F12=0, -F11+F=0*




## VI. RESULT OF COMPUTATIONAL ANALYSIS

The analytical calculations for compound linkage mechanism application are calculated and shown in tabular form. Also the comparison of analytical and software analyzed values is shown in table I and table II and the results obtained are on the window, as shown in fig 13 and fig. 14

TABLE I.

| NO. | LINK NAME | LENGTH OF LINK | VELOCITY | ACCELERATION | | INERTIA FORCES | STATIC FORCES |
|---|---|---|---|---|---|---|---|
| | | | | *Radial* | *Tangential* | | |
| 1. | CRANK(2) | 0.15 | 9.424778 | 592.1762 | 0.0000 | 5.921763 | F1=4.0604<br>F2=-1.019<br>F3=4.060422<br>F4=1.01917 |
| 2. | COUPLER(3) | 0.46 | 6.303837 | 86.38773 | 70.502265 | 1.643167 | F5=4.0602<br>F6=1.019 |
| 3. | ROCKER(4) | 0.30 | 12.549607 | 524.9754 | 177.278949 | 7.874632 | F7=0<br>F8=-1.7542 |
| 4. | FIXED LINK(1) | 0.30 | 0 | 0 | 0 | 0 | 0 |
| 5. | CONNECTIN G ROD(5) | 0.45 | 5.013364 | 55.85293 | 466.3646 | 1.641367 | F9=-5.8147<br>F10=-4.1636 |
| 6. | SLIDER | 5 | 6.581326 | -97.388 | - | Axial-5.814722 | F11=5.8147<br>F12=4.163<br>F13=4.1636<br>Torque on Crank=-0.13162 |

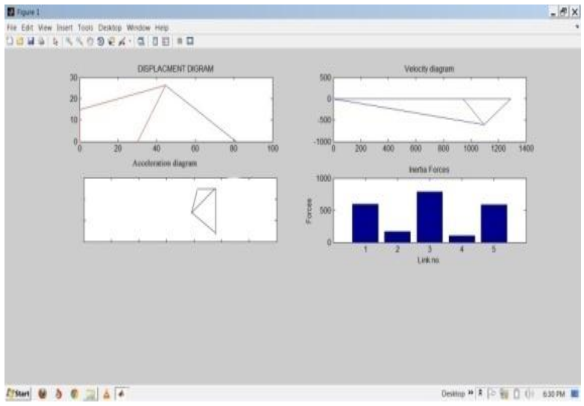



Fig.13. Computational Analysis (6-bar) in MATLAB Software

TABLE II

| Parameters / Iterations | Iteration no. 1 | Iteration no. 2 | Iteration no. 3 | Iteration no. 4 | Iteration no. 5 |
|---|---|---|---|---|---|
| INPUTS | | | | | |
| Theta | π/2 | Π | π/3 | π/7 | π/4 |
| Crank speed (RPM) | 600 | 300 | 100 | 30 | 50 |
| OUTPUTS | | | | | |
| Velocity of crank | 9.424778 | 4.712389 | 1.570796 | 0.471239 | 0.785398 |
| Velocity of coupler | 6.303837 | 4.817109 | 1.029173 | 0.607612 | 0.569402 |
| Velocity of rocker | 12.549607 | 3.141593 | 2.346098 | 1.049435 | 1.272750 |
| Radial accln of crank | 592.176264 | 148.044066 | 16.449341 | 1.480441 | 4.112335 |
| Radial accln of coupler | 86.387737 | 50.444645 | 2.302603 | 0.802592 | 0.704823 |
| Radial accln of rocker | 524.975454 | 32.898681 | 18.347249 | 3.671043 | 5.399641 |
| Tangential accln of crank | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Tangential accln of coupler | 70.502265 | 31.685177 | -1.826069 | -7.137439 | 2.041353 |
| Tangential accln of rocker | 177.278949 | --82.784698 | -6.037946 | -7.212968 | -2.784058 |
| Inertia force on crank | 5.921763 | 1.480441 | 0.164493 | 0.014804 | 0.041123 |
| Inertia force on coupler | 1.641367 | 0.958448 | 0.043749 | 0.015249 | 0.013392 |
| Inertia force on rocker | 7.874632 | 0.493480 | 0.275209 | 0.055066 | 0.080995 |
| Static forces | | | | | |
| F1 | -4.060422 | -0.922315 | 0.307593 | 0.008791 | 0.001023 |
| F2 | -1.019174 | -0.733057 | 0.041632 | -0.000204 | 0.000078 |
| F3 | 4.060422 | 0.922315 | -0.307593 | -0.008791 | -0.001023 |
| F4 | 1.019174 | 0.733057 | -0.041632 | 0.000204 | -0.000078 |
| F5 | 4.060422 | 0.922315 | -0.307593 | -0.008791 | -0.001023 |
| F6 | 1.019174 | 0.733057 | -0.041632 | 0.000204 | -0.000078 |

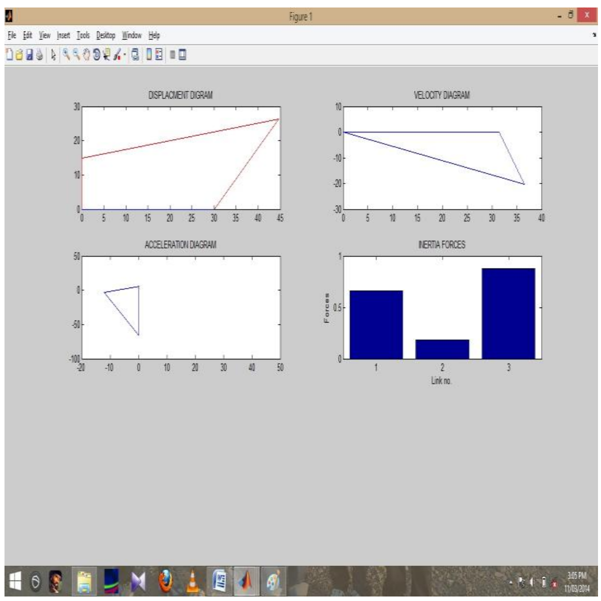



Fig.14. Computational Analysis (4-bar) in MATLAB Software

## VII. CONCLUSION

In concluding statements it can be claimed that this paper "Computational setup for analysis of compound linkage mechanism- a demonstrative model approach" is successful in great extent to reduce the complexity in computational analysis of compound linkage mechanism, with the application point of view ,obtaining accurate and faster results in terms of displacement, velocity, acceleration and force analysis of compound linkage mechanism which also results in saving of time, visualization of actual motion of links for different mechanisms obtaining from the mechanism. We have compared the analysis outputs obtained from computational setup approach and graphical method which are found to be approximately 99% correct.

## VIII. ACKNOWLEDGEMENTS

"Completing a task is never a one man's effort. Several prominent people in production, academics, and administrative field have helped in the development of computational set up to analyze the compound linkage mechanism for this present research work. Their collective support has led in successful design and development of this work. To name them all is impossible." I am thankful to colleagues, at, Government College of Engineering, Awasari, Pune, and various other institutions for cooperation provided by them. Special thanks to the Principal and teaching staff of GCOEAR, Awasari, for needful support and encouragement for making successful.

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