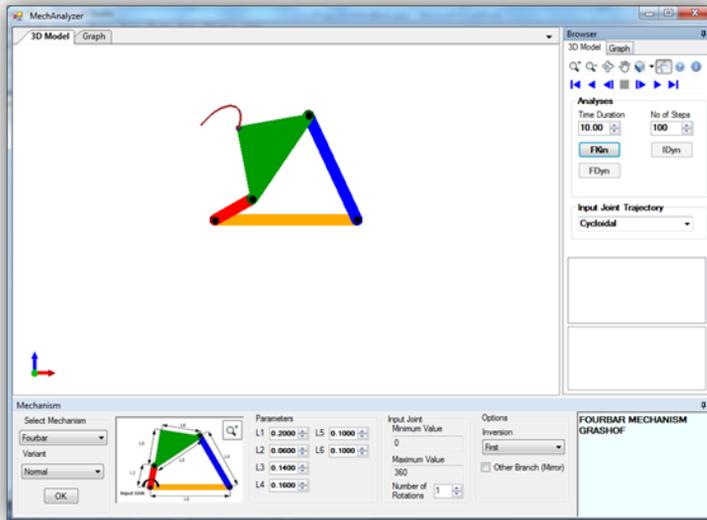


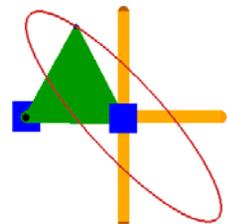
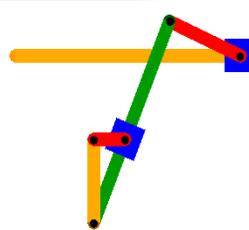
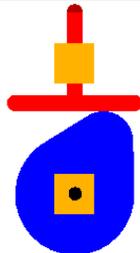
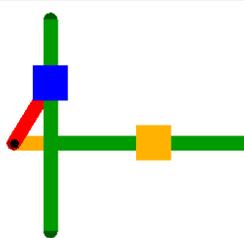
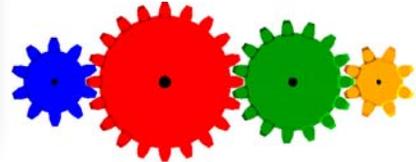
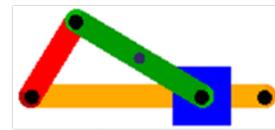
MechAnalyzer

3D Model Based Mechanisms Learning Software
User Manual (Version 4)



Features:

Forward Kinematics
More than 10 Mechanisms
Inversions
Velocity and Acceleration
Module (VAD)



Freely Available for Academic Use !!!



September 2015

Developed by Prof S. K. Saha & Team

Mechatronics Lab, Mechanical Engineering Department, IIT Delhi, New Delhi, India

<http://www.roboanalyzer.com/mechanalyzer.html>

PREFACE

Study of various planar linkages is covered in Mechanism design, which is a basic course taught to most mechanical engineering students. Starting with the theory behind them, students learn the dynamic equations to analyze different types of mechanisms, and eventually solve design problems. A computer-based approach to solve these equations becomes imminent when the number of equations increases and also for a quick and better understanding through visualization. Currently, there are many commercially available software which can help students in this matter. Unfortunately, a considerable time has to be spent to train a student to use these programs. Hence, there is a need for a Mechanism learning software.

In this user manual, the third version of the educational computer software “Mechanalyzer” is presented. It has been developed to simulate and analyze the mechanisms that are already preloaded. Developed in C#, Mechanalyzer renders 3D OpenGL graphics with an easy-to-use interface. Presently, Mechanalyzer can simulate ten mechanisms. After selecting a mechanism, its link lengths can be easily changed the same is reflected instantly in the 3D model of the mechanism. One can also switch between its different inversions and select variants of the mechanisms. Mechanalyzer was developed in the Mechatronics Lab, Department of Mechanical Engineering at IIT Delhi, India under the guidance of Prof. S. K. Saha. The following students are given due credits in its development.

- Shamanth Hampali (2013, Summer Intern from NITK Surathkal): Version 2 comprising of kinematic and dynamic analysis of four-bar, slider crank and five-bar mechanisms.
- Rakshith Lokesh (2014, Summer Intern from NITK Surathkal): Version 3 with forward kinematics of around 10 mechanisms.
- Rohit Kumar and Sachin Kumar Verma (2015, Summer Intern from NITK Surathkal): Version 4 with graph plots for forward kinematics and vector diagrams for 6 mechanisms.
- Rajeevlochana G. Chittawadigi.(M.S.(Research), IIT Delhi, Asst. Professor, Amrita University Bangalore): Architect/Framework design for Version 4, coordination and mentoring.

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1. GETTING STARTED

This section helps you get started with the installation of MechAnalyzer, a 3D Model Based Mechanisms Learning Software. It has been developed using OpenGL and Visual C#.

1.1. MINIMUM SYSTEM REQUIREMENT

- Processor: Atleast 1.5 GHz
- RAM: Atleast 512 MB
- Operating System: Windows XP, Windows Vista, Windows 7, Windows 8.
- Dependencies: Microsoft .Net 2.0 framework

1.2. INSTALLATION

MechAnalyzer can be installed on a computer by downloading it from our website. The fourth version of the software is available for free at <http://www.roboanalyzer.com/mechanalyzer.html>. The following are the steps to install MechAnalyzer:

Step 1: Visit <http://www.roboanalyzer.com/mechanaylzer.html>

Step 2: Look for **Downloads** section on the webpage

Step 3: Click on download link for **MechAnalyzerV4** (or latest version) to download a .zip file

Step 4: A popup window will appear. Select the folder where the file has to be saved and click on **Save**

Step 5: After downloading is complete, unzip MechAnalyzer.zip to any folder on your computer. Open the folder MechAnalyzer

Step 6: Double-click on MechAnalyzer.exe to start MechAnalyzer (No need to install to use)

2. INTRODUCTION TO MECHANALYZER

MechAnalyzer is a 3D Model Based Mechanisms Learning Software. It has been developed to help the faculty to teach and students to learn the concepts of Mechanisms.

2.1. OVERVIEW OF USER INTERFACE

The version 4 of MechAnalyzer has been presented to the user in such a way that the user can easily get started with it. The user interface of the software as shown in Figure 1, can be divided into the following sections:

1. Mechanism Selection Panel – The desired mechanism and its corresponding variant can be loaded.
2. Mechanism Description Window – Displays a labeled image of the mechanism showing its various parameters. An enlarged image is shown in a separated window when the zoom button is clicked.
3. Input Parameters Panel – The user can set the input parameters pertinent to the mechanism.
4. Output Parameters Box – Some of the important output parameters related to the mechanism are displayed.
5. Mechanism Options – Other options related to the mechanism if any are shown here.
6. Message Window – Displays the name of the mechanism, its variant and warning messages if any.
7. Animation Controls – The speed, play forward, play backward controls are enabled in this toolbox.

8. Analysis Options – The analysis needed to be performed can to selected.
9. Viewing Toolbar - The basic CAD viewing options like zoom, pan, orbit etc. are provided.
10. Graphic Window – This is the window where the mechanism is rendered and simulation is shown.
11. VAD Module – Opens new window of velocity acceleration diagram module.

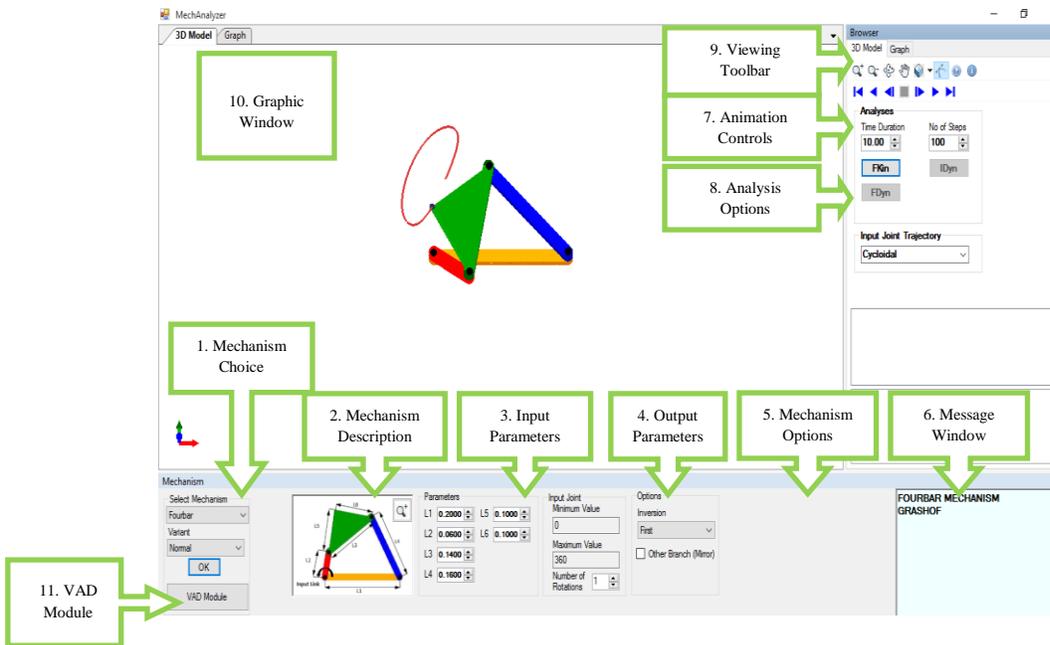


Figure 1: User Interface of MechAnalyzer V4

2.2. FEATURES OF MECHANALYZER

MechAnalyzer can be used to perform kinematic analyses of linkage mechanisms. The following are the main features of MechAnalyzer:

- Mechanism Animation
- Curve Trace for coupler point.
- Inversions for Fourbar and Slider Crank.

Note : Graph Plot, Inverse Dynamics and Forward Dynamics haven't been incorporated yet. They will be reported in the future versions of the software.

Mechanalyzer comes with the following ten preloaded mechanisms and the mentioned special variants of the respective mechanism;

- **Fourbar Mechanism**, its inversions and the following straight line mechanisms derived from Fourbar; Robert's Mechanism, Watt's Mechanism, Evan's Linkage, Tchebyshev's Mechanism and Hoeken's Linkage.
- **Slider Crank Mechanism**, its inversions and a straight line mechanism derived from slider crank; Scott Russel Mechanism.
- **Double Slider Mechanism**, variations of double slider; Elliptical Trammel, Oldhams Coupling and Scotch Yoke Mechanism.

- **Steering Mechanism**, Ackermann Steering and Davis Steering.
- **Wiper Mechanism**.
- **Whitworth Quick Return Mechanism**.
- **Fourbar Quick Return Mechanism**.
- **Pantograph Copier Mechanism**.
- **Cam Follower Mechanism**, Flat Face follower and Knife Edge Follower.
- **Spur Gear Mechanism**, Simple Gear Train, Compound Gear Train.

2.3. LOADING AND ANIMATING A MECHANISM

- The desired mechanism can be selected from the **Select Mechanism** (refer Figure 1) dropdown menu. The corresponding variant if it applies to the mechanism needs to be selected from the **Variant** (refer Figure 1) dropdown menu.
- The mechanism parameters window using the zoom button as shown in Figure 2 can be opened to relate the various lengths to the parameters of the mechanism. The window also defines any output parameters of the mechanism.

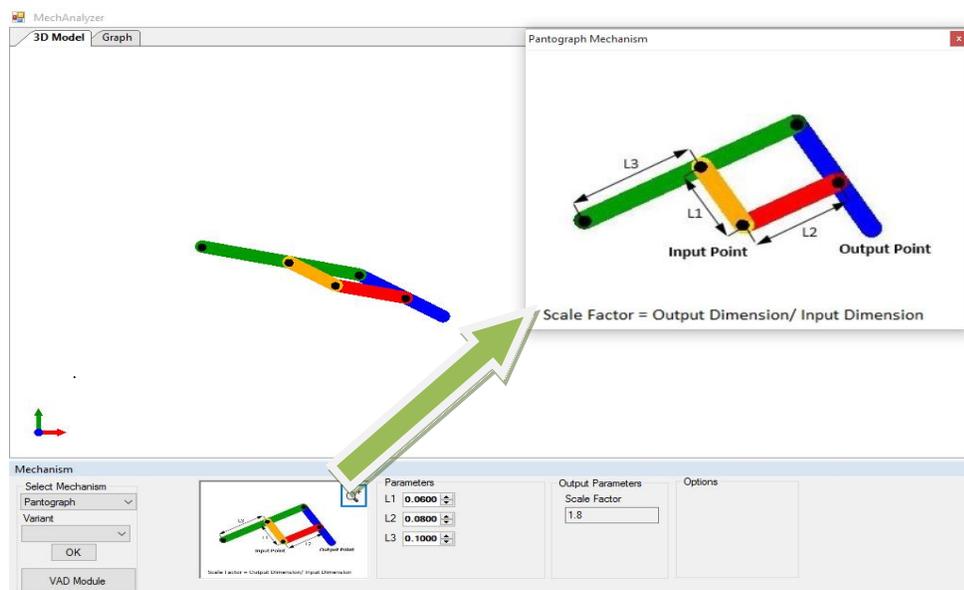


Figure 2: Mechanism description window opened by clicking the zoom button.

- Then the parameters can be defined using the **Input Parameters** numeric controls.
- Then the forward kinematic analysis needs to be run using the **FKin** button in the **Analysis Option** box after which the animation can be observed using the animation controls.

2.4. 3D MODEL VIEW OPTIONS

MechAnalyzer lets the user to zoom, rotate and pan the 3D model to have better visualization. These can be used as explained below and shown in Figure 3.

- **Zoom:** Use the zoom in and zoom out buttons to enlarge or diminish respectively.
- **Rotate:** Click on **Rotate** button to make it active. Place the mouse cursor anywhere on the 3D Model View and rotate the model by clicking on left-mouse button and dragging the mouse.
- **Pan:** Click on **Pan** button to make it active. Place the mouse cursor anywhere on the 3D Model View and translate the model by clicking on left-mouse button and dragging the mouse.
- **Model Views:** The dropdown can be used to quickly move to a different view; front view, side view, isometric view etc.
- **Curve Trace:** Click on **curve trace** button to draw trace and click on it again to disable trace.

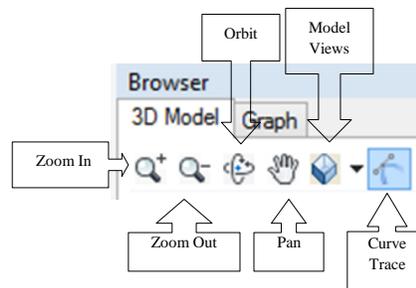


Figure 3: The 3D model view toolbar.

2.5 GRAPH PLOTS OF FKIN

To view the graph plots of a forward kinematics (animation) analysis, the following are the steps as shown in Figures 4, 5 and 6.

1. Click on Graph tab.
2. Click on + next to the joint of which the plots are to be viewed.
3. Click on box to plot graph of a particular node to see joint value (joint angle for revolute joint and joint offset for prismatic joints), joint velocity and joint acceleration.
4. Click on + next to the link of which the plots are to be viewed.
5. Click on box to plot graph of a particular node to see plots of the end points on the link for linear and angular position, velocity and acceleration. Linear node gives an option to plot graphs in either X or Y direction.

NOTE: The graphs are plotted for some selected mechanisms like four bar, slider crank, elliptical trammel, scotch yoke and quick return mechanism.

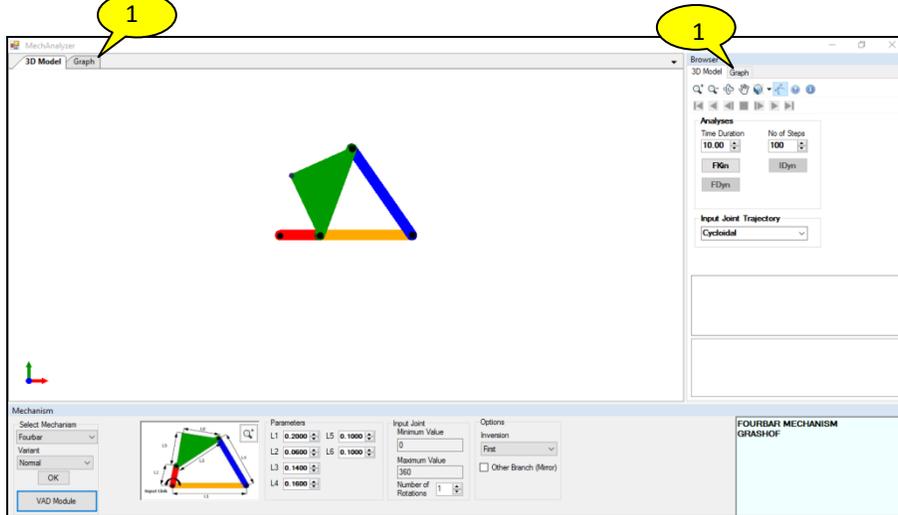


Figure 4 : Graph Plot for FKIn data

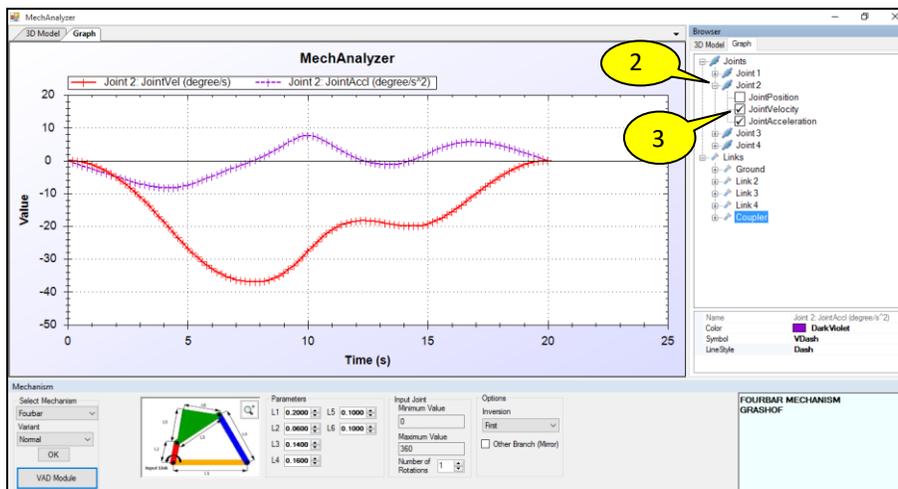


Figure 5: Graph Plots of Input Trajectory to Joint2 (Cycloidal Trajectory)

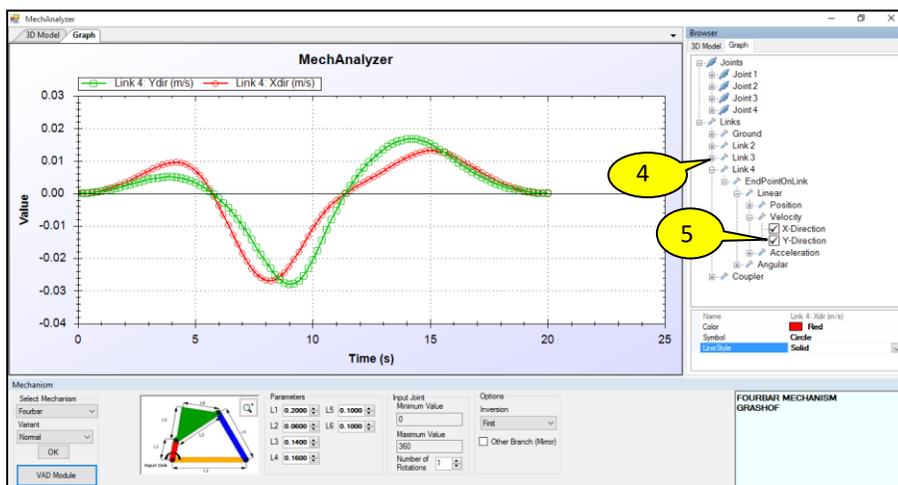


Figure 6: Graph Plots of Link4

More details and information on the Graph Plot options can be found in Section 3.

3. GRAPH PLOT OPTIONS

The analyses results for FKIn can be viewed as graph plots as explained in Sections 2.5. Several options for graph plot functionalities are explained below and as shown in Figure 7 .

1. Select a graph plot node.
2. Set the plot color, symbol and line style.
3. Right click on graph to show a menu. Here you can use various options to zoom, print etc.
4. Export Data as CSV: Export plot data that can be opened in a spreadsheet such as MS Excel.
5. Use Mouse wheel to zoom in and out.
6. Press Mouse wheel and drag the mouse to pan around the graph.
7. Hover over the curve to see the coordinates of the point.

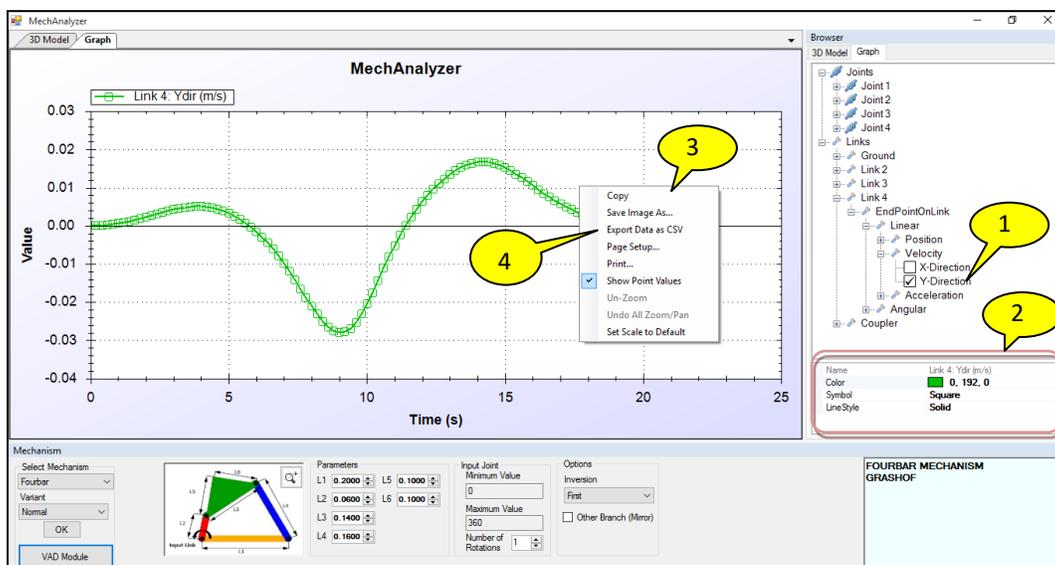


Figure 7: Graph Plot Options

4. NOTATIONS USED

The architecture of industrial mechanisms is usually represented by standard parameters and notations. The following notations are used in MechAnalyzer V4;

- The fixed link is represented yellow in color apart from mechanism when showing inversions.
- Black circles on links represent pin joints at that location and links penetrating into cubes represent prismatic joint at that location.
- The coordinate marker shown at the bottom left corner of the screen uses standard colors, i.e., red for x, green for y and blue for z axes, respectively.

- Lines shown in dotted represent axis lines to show extension of links and do not form a part of the mechanism.
- Fkin implies Forward Kinematics, IDyn implies inverse dynamics.

5. VELOCITY AND ACCELERATION DIGRAM (VAD) MODULE

Velocity and Acceleration Module (VAD Module) is a part of MechAnalyzer V4. Here in this user manual the “VAD Module” has been presented. It has been developed to do kinematic analysis of mechanisms graphically, which are preloaded in it. It does the analysis of mechanism by drawing vector diagrams for velocity and acceleration, and then shows the animation (stepwise drawing of vector diagrams).

5.1. OVERVIEW OF USER INTERFACE

The VAD module has been presented to the user in such a way that the user can easily get started with it. To access this click on the button named **VAD Module** (refer Figure 8).

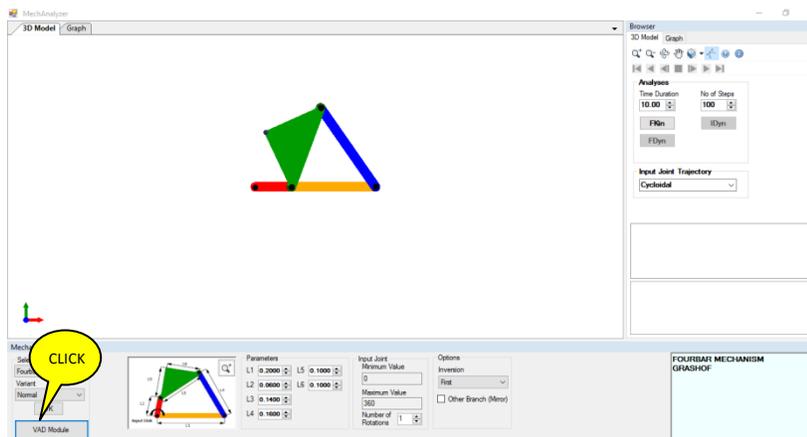


Figure 8: Interface of MechAnalyzer Highlighting VAD Module Button

After clicking the button VAD Module window appears. The user interface as shown in Figure 9 can be divided into the following sections:

1. **Navigation Panel** – Here user can select desired mechanism, play animation for vector diagram, and can also control the speed of animation.
2. **Input Parameter and Draw Panel** – Here user can give input for length of links, crank angle, crank velocity and acceleration. A draw button is provided here to draw vector diagrams for updated values.
3. **Result Panel** – it displays the output parameters associated with the mechanism like orientation, angular and linear velocity, and acceleration for links other than crank link.
4. **Message Window** – Displays the name of mechanism or error message if any.

5. **Diagram Window** – This is the window where the vector diagrams are drawn, and animation can be seen. It has three sections consisting of position, velocity, and acceleration vector diagram.

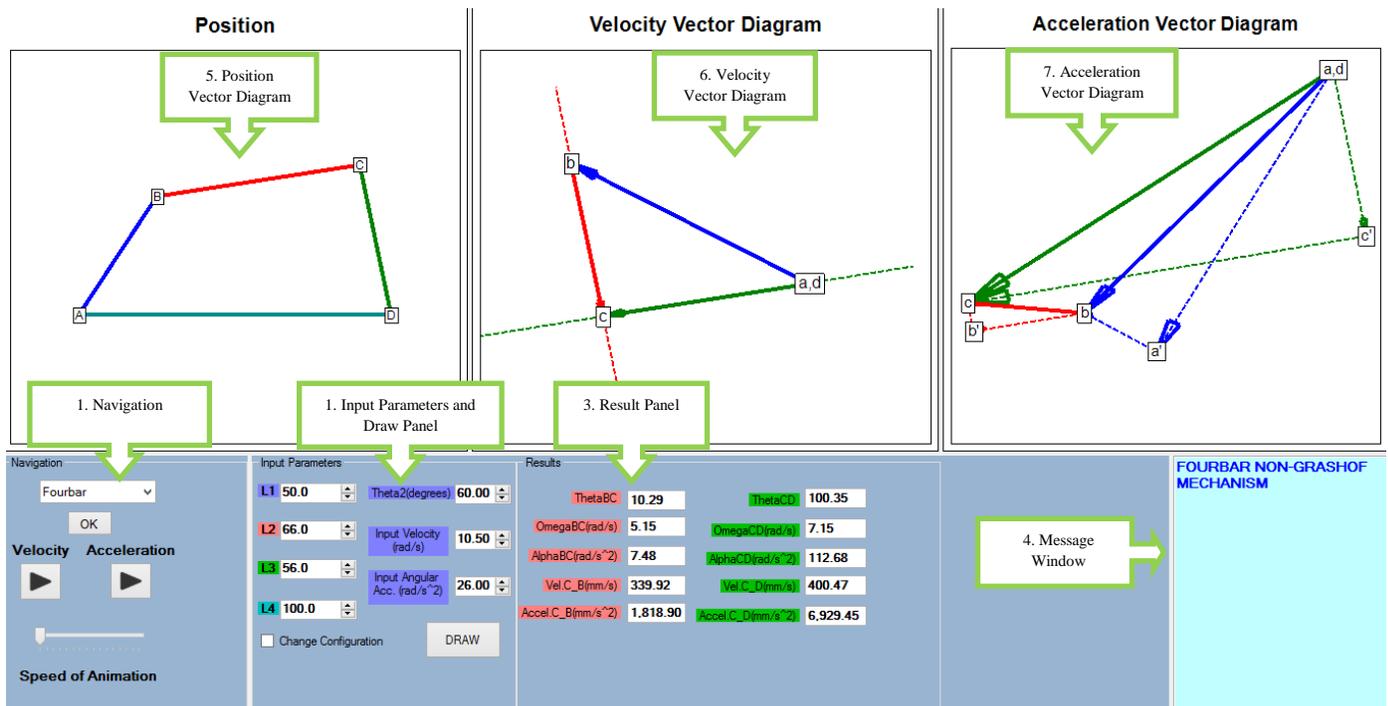


Figure 9: The User Interface of VAD Module

5.2. FEATURES OF VAD MODULE

VAD module can be used to perform kinematic analysis of linkage mechanisms. Some features of it are as follows

- Velocity, and acceleration vector diagram.
- Animation of vector diagrams (stepwise formation).

VAD module comes with six preloaded mechanisms that are as follows

- **Fourbar Mechanism**
- **Slider Crank Mechanism**
- **Crank and Slotted Lever Mechanism**
- **Whit Worth Quick Return Mechanism**
- **Elliptical Trammel Mechanism**
- **Scotch Yoke Mechanism**

5.3. INTERPRETATION OF VECTOR DIAGRAMS

In the development of VAD module a proper color code has been followed in order to make it easy for users to interpret. Vector diagrams can be interpreted very easily, the procedure for interpretation is as follows

- Standard conventions has been followed, angular velocity is positive in counter clockwise direction.
- All link lengths must be inputted in **mm** only.
- In position vector diagram all links are drawn in different colors to follow color code.
- In velocity vector diagram the vector of a color, same as link color in position diagram will show its velocity that is normal to the vector in position diagram (the blue color vector in velocity diagram shows the velocity vector for link corresponding to blue color in position diagram).
- In the acceleration vector diagram two types of line are shown solid and dashed.
- The solid line represents resultant acceleration for the link which is of same color in position diagram.
- The dashed lines represent angular, and tangential acceleration for the link which is of same color as in position diagram.

5.4. LOADING AND ANIAMTING VECTOR DIAGRAMS

A desired mechanism can be loaded and seen its animation very easily. The procedure is described below

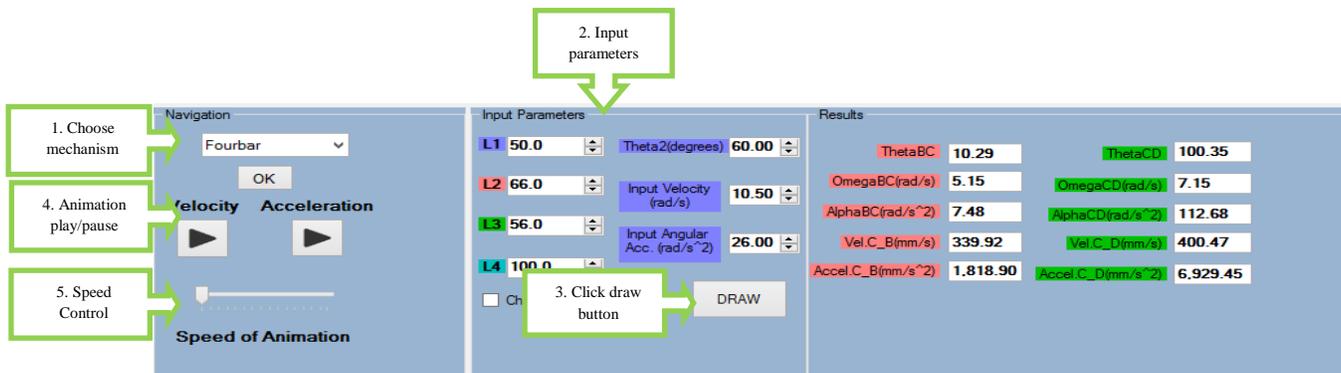


Figure 10: Guidelines for VAD Module Control

- Select the desired mechanism from dropdown menu in **Navigation** panel, and input parameters can be changed in **Input Parameter** panel (refer Figure 10).
- Now on clicking **Draw** button mechanism will be updated for corresponding inputs.
- For playing animation for velocity or acceleration vector diagram click on the corresponding buttons in **Navigation** panel (refer Figure 10).
- Speed of animation can be controlled with the help of track bar provided in **Navigation** panel.

Note - For better performance play animation for one vector diagram at once.

6. REFERENCES

- [1] Robert Norton , “Design of machinery 2nd Edition”

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1

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- Select a Skeleton Model and Vary the Denavit-Hartenberg (DH) Parameters
- Learn and Visualize DH Parameters
- Visualize End-Effector Transformations

2

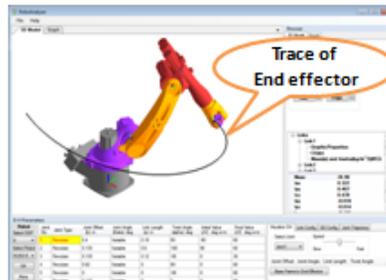
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- Forward and Inverse Dynamics*
- Animation and Trace
- Virtual Robots Module *Uses ReDySim
- MATLAB Interface

3

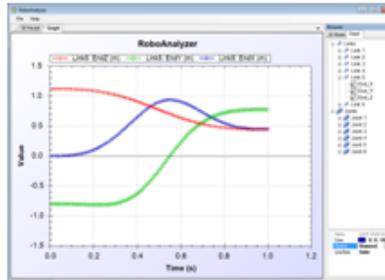
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- Learn the Physics of Robot First and then its Mathematics
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- Create Custom Robot Models



3D Model of Robot
DH Parameters



Trace of End effector



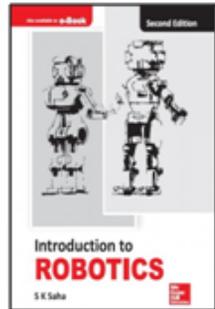
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Website: <http://www.roboanalyzer.com>

Book Explains Robots



Introduction to ROBOTICS
S.K. Saha

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