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.
- Rohit Kumar, Sachin Kumar Verma, Janani Swaminathan and Sripad D Vantmuri (2016, Summer Interns from NITK Surathkal): Version 4.1 with graph plots for forward kinematics, dynamics of four-bar mechanism along with vector diagrams for two more mechanism, and static force analysis of five mechanisms.
- Rajeevlochana G. Chittawadigi.(M.S.(Research), IIT Delhi, Asst. Professor, Amrita University Bangalore): Architect/Framework design for Version 4, coordination and mentoring.

CONTENTS

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 **MechAnalyzerV4.1** (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 4.1 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.

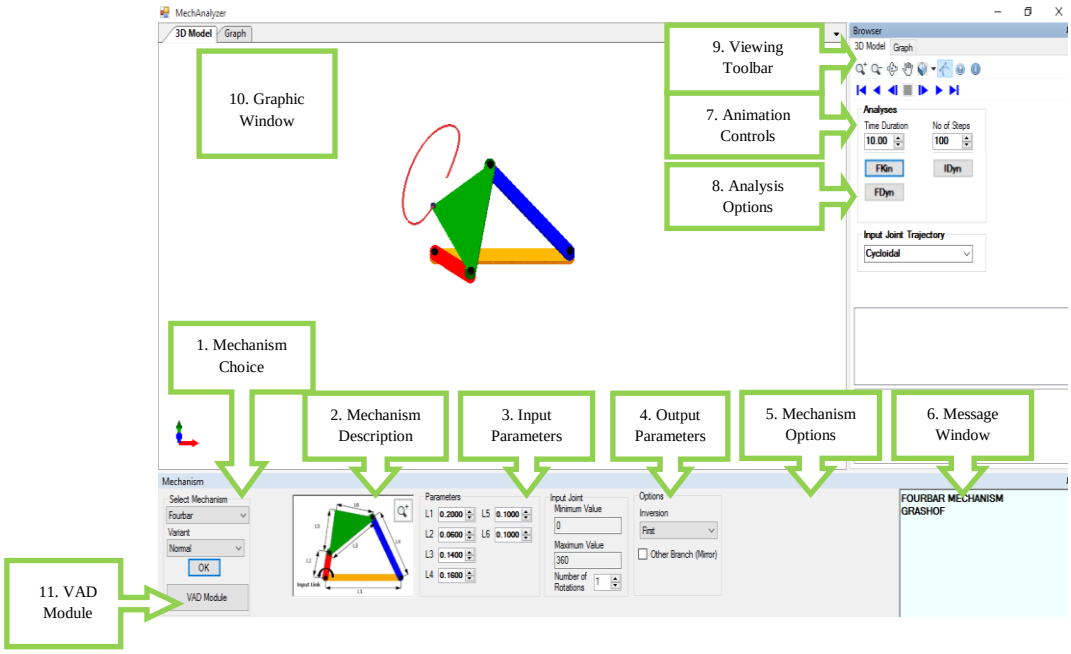

Figure 1: User Interface of MechAnalyzer V4

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.

Mechanalyzer comes with the following twelve 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.
- **Sixbar Mechanism,**
- **Geneva Mechanism.**

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.

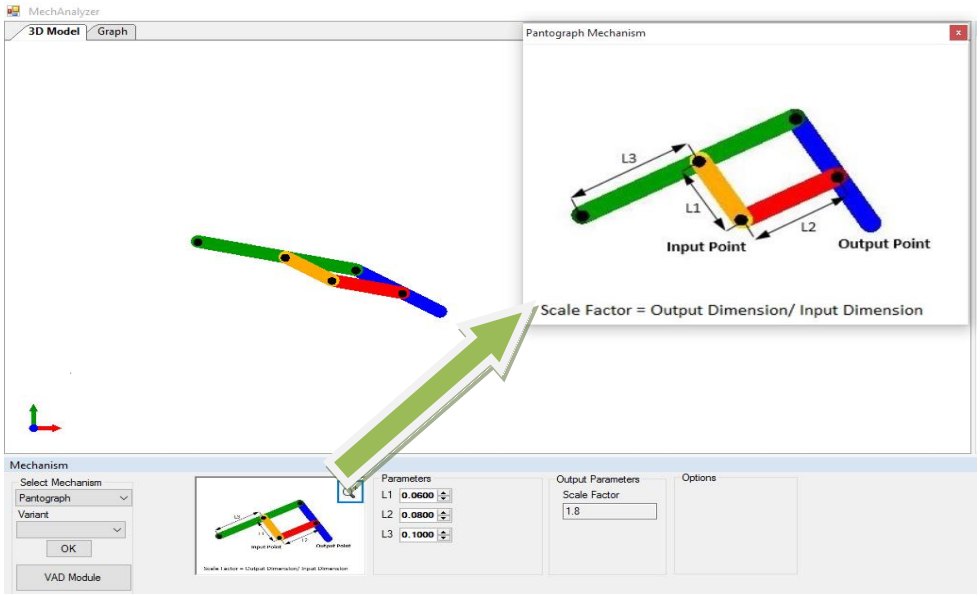

Figure 2: Mechanism description window opened by clicking the zoom button.

- Then the parameters can be defined using the **Input Parameters** numeric controls.
- Then the forward kinematic, inverse dynamics or forward dynamics analysis need to be run using the **FKin, IDyn, FDyn** buttons respectively 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.

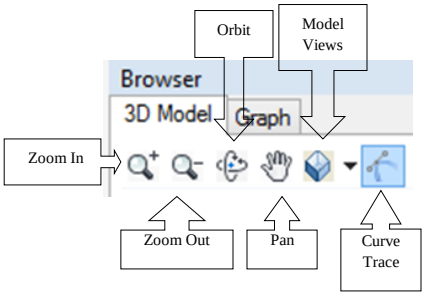

Figure 3: The 3D model view toolbar.

2.5 GRAPH PLOTS OF FKIN,IDYN, FDYN

To view the graph plots of a forward kinematics, inverse or forward dynamics (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.

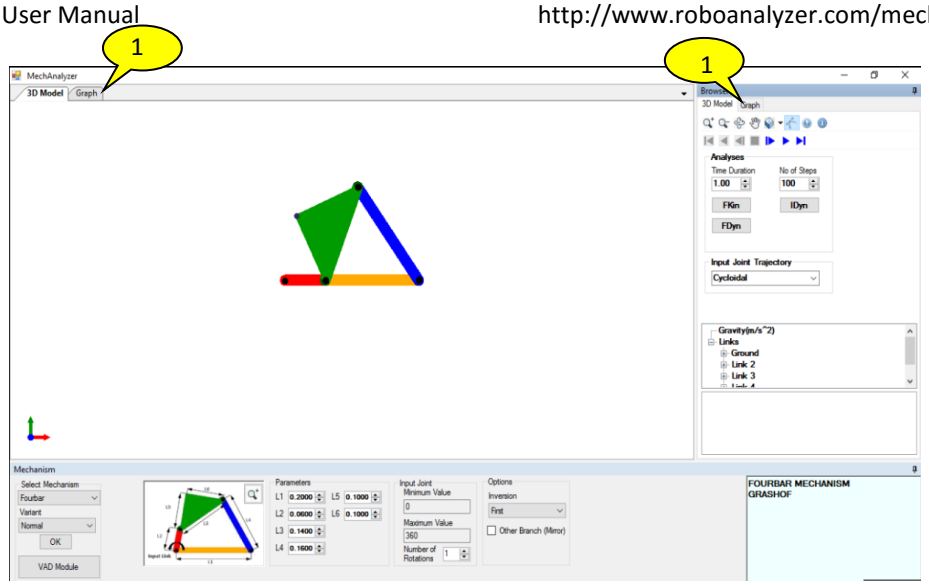

Figure 4 : Graph Plot for FKin data

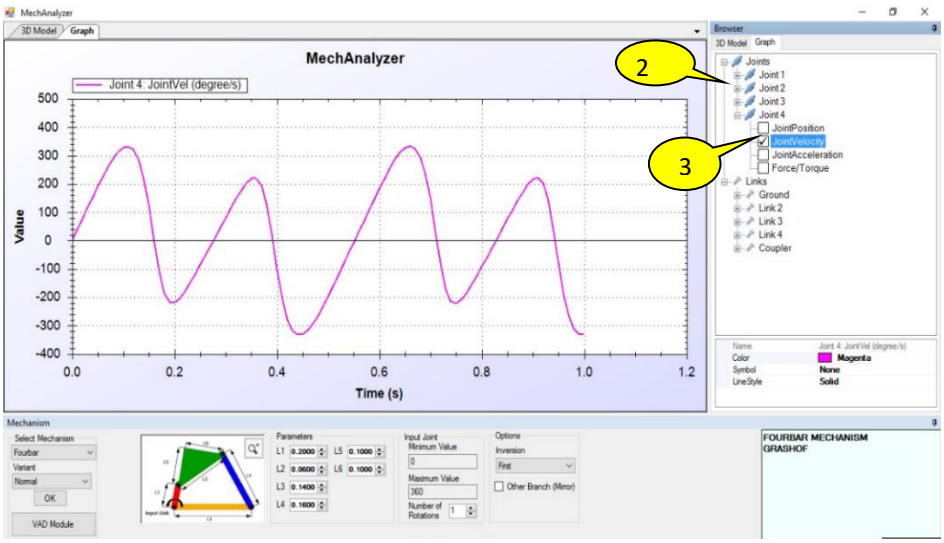

Figure 5: Graph Plots of Joint Velocity of Joint4 (Cycloidal Trajectory)

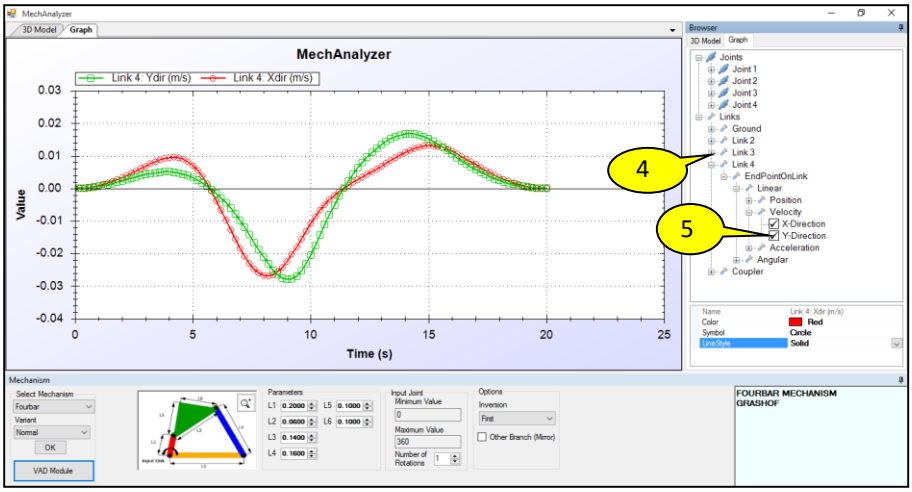

Figure 6: Graph Plots of Link4

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

3. GRAPH PLOT OPTIONS

The analyses results for FKin, IDyn, FDyn 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.

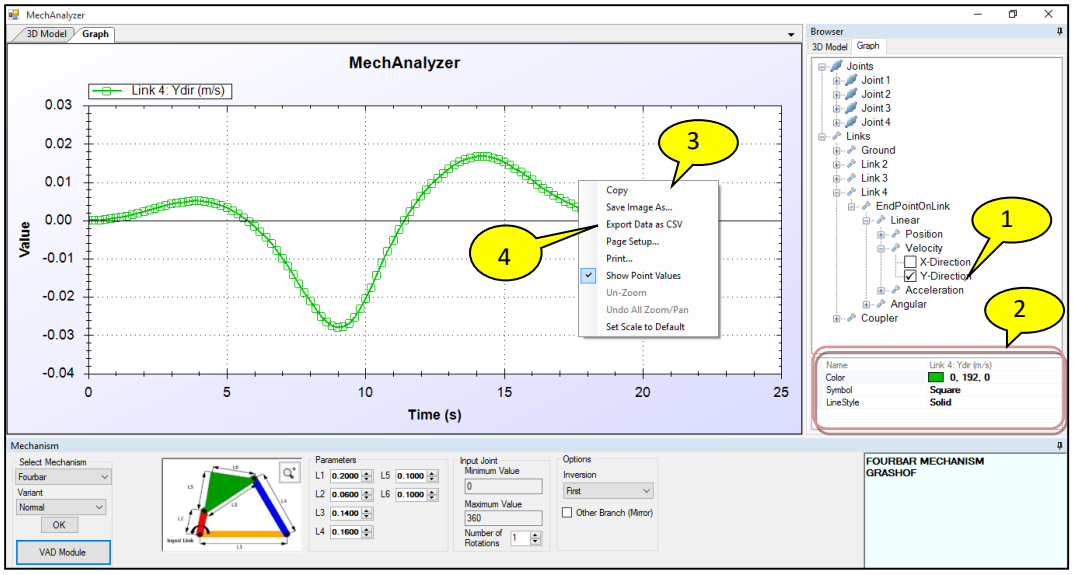

Figure 7: Graph Plot Options

4. NOTATIONS USED

The architecture of industrial mechanisms is usually represented by standard parameters and notations. The following notations are used in Mechanalyzer V4.1;

- 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).

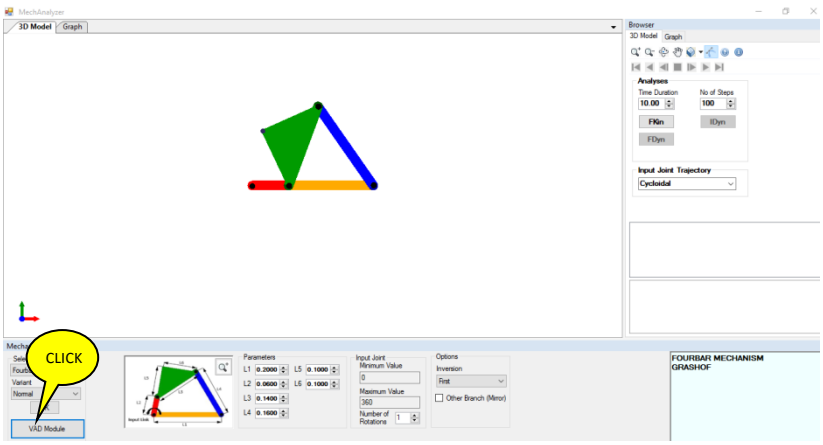

Figure 8: Interface of MechAnalyzer Highlighting VAD Module Button

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.
6. **Continuous Save Panel** – Here user can give a range and increment for the input value for which position, velocity and acceleration diagrams will be drawn and output will be stored in a file.

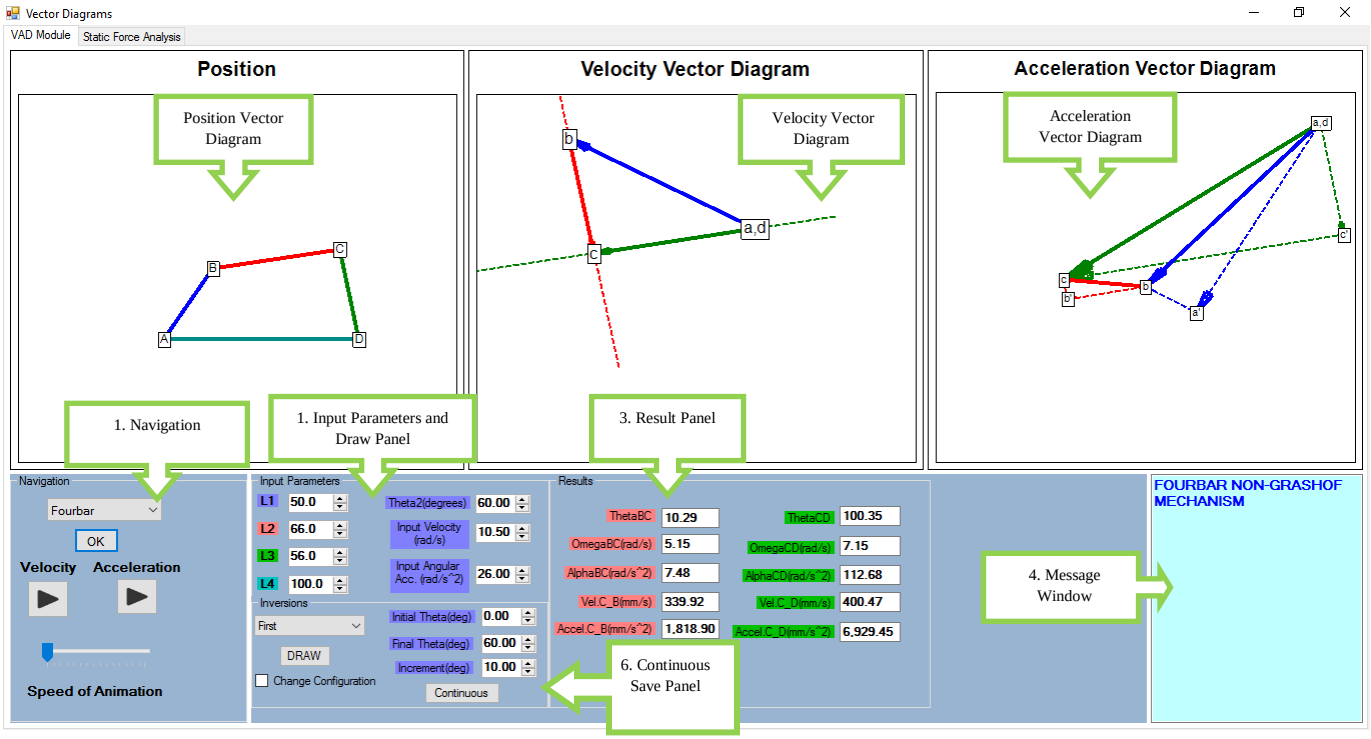

Figure 9: The User Interface of VAD Module

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).
- Store output for a given range of input and increment.

VAD module comes with nine preloaded mechanisms that are as follows

- **Four-bar Mechanism**
- **Slider-Crank Mechanism**
- **Crank and Slotted Lever Mechanism**
- **Whit Worth Quick Return Mechanism**
- **Elliptical Trammel Mechanism**
- **Scotch Yoke Mechanism**
- **Four-bar quick return mechanism**
- **Davis Steering 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 have been followed, angular velocity is positive in counter clockwise direction.
- All link lengths must be entered 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, ANIMATING VECTOR DIAGRAMS AND CONTINUOUS OUTPUT

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

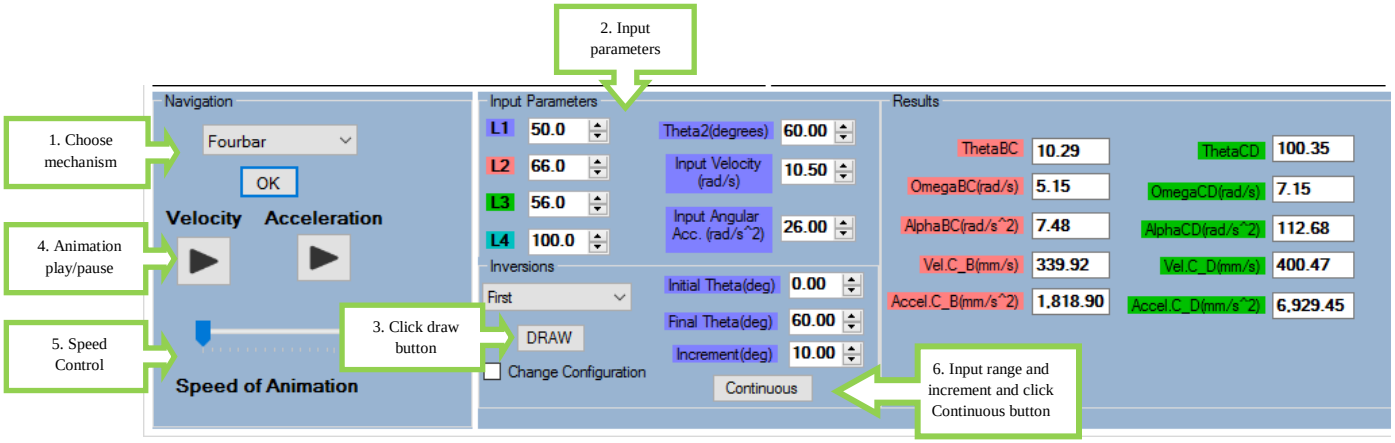

Figure 10: Guidelines for VAD Module Control

- 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.
- Input range and increment in **Continuous Save** panel and click Continuous button.

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

6. STATIC FORCE ANALYSIS (SFA) MODULE

Static Force Analysis Module (SFA Module) is a subpart of VAD Module which is a part of MechAnalyzer V4. Here in this user manual the "SFA Module" has been presented. It has been developed to do static force analysis of mechanisms graphically, which are preloaded in it. It does the analysis of mechanism by drawing free body diagrams of each link along with the force vector polygons.

6.1. OVERVIEW OF USER INTERFACE

The SFA 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 tab named **Static Force Analysis** in the VAD Module (refer Figure 8).

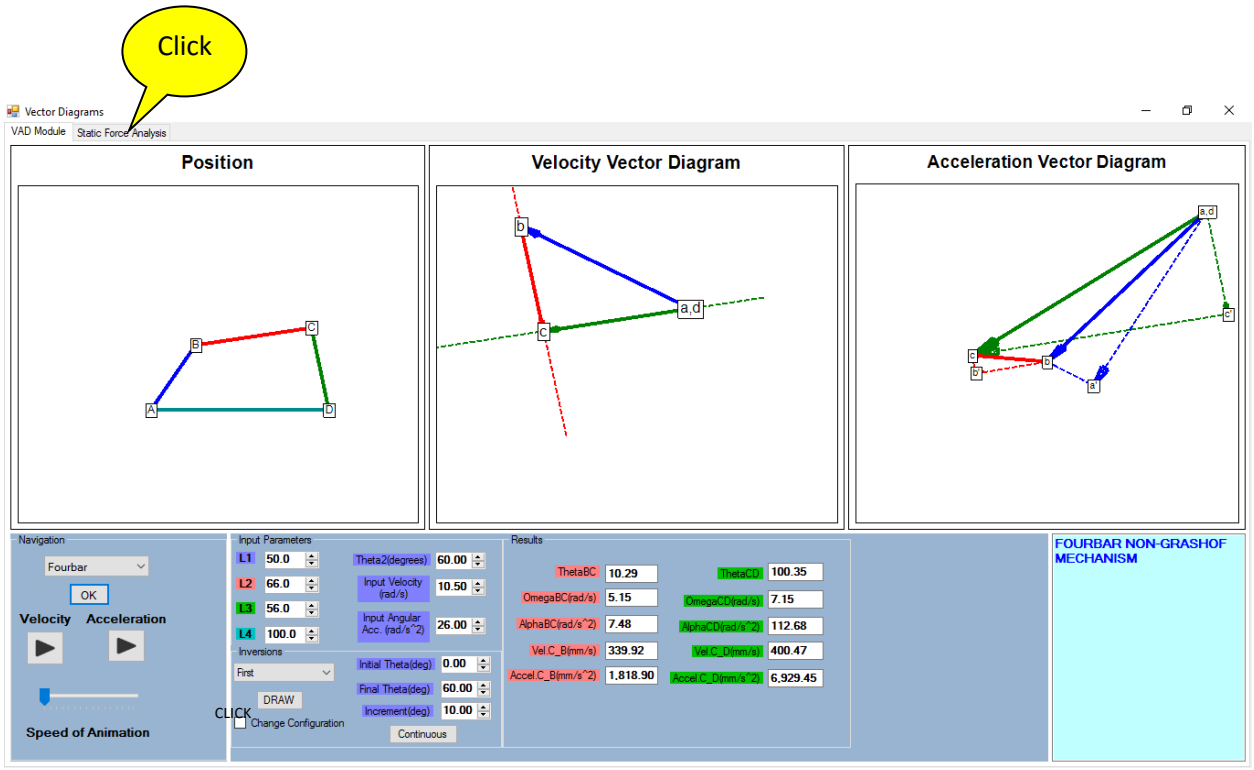

Figure 11: Interface of MechAnalyzer Highlighting SFA Module tab

After clicking the tab SFA 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 from the preloaded ones.
2. **Input Parameter and Draw Panel** – Here user can give input for length of links, crank angle and magnitude, direction and position of forces on each link. 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 i.e. torque on the crank due to force on each link and the final torque.
4. **Message Window** – Displays the name of mechanism or error message if any.
5. **Diagram Window** – This is the window where the position diagram, free body diagram and force vector polygons are drawn.

6. **Save Retrieve Panel** – When a standard input is required, this input can be saved and retrieved by clicking on the appropriate buttons.

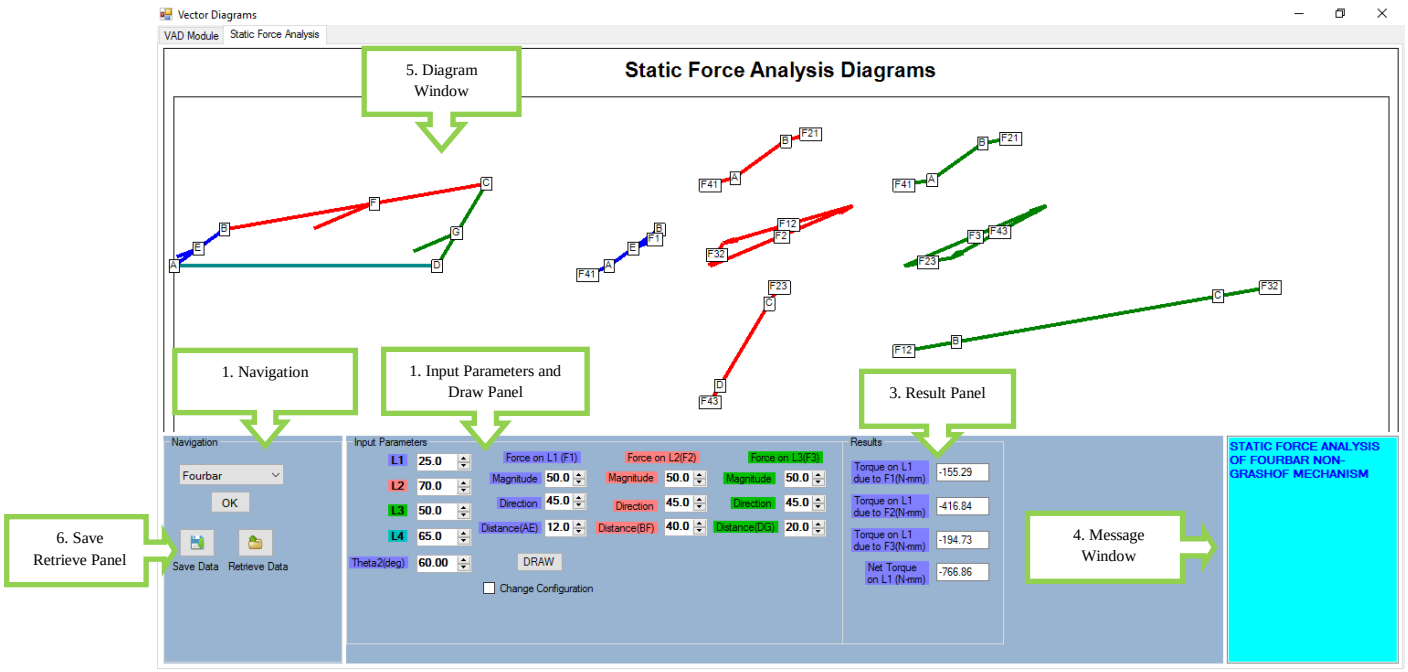

Figure 12: The user interface of SFA Module

6.2. FEATURES OF SFA MODULE

SFA module can be used to perform static force analysis of linkage mechanisms. Some features of it are as follows

- Free body diagrams for forces on each link.
- Force vector polygons.
- Store some standard input so that it can be retrieved later when required.

SFA module comes with five preloaded mechanisms that are as follows

- **Four-bar Mechanism**
- **Slider-Crank Mechanism**
- **Crank and Slotted Lever Mechanism**
- **Whit Worth Quick Return Mechanism**
- **Four-bar quick return mechanism**

6.3. INTERPRETATION OF DIAGRAMS

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

- Standard conventions have been followed.
- All link lengths must be entered in **mm** only.

- In position diagram all links are drawn in different colors to follow color code and forces on each link have the same color as that of the link.
- When the force on a link is considered, the free body diagrams of all links with the forces on them due to the external force and the force vector polygons are all drawn in the same color as that of the link in which the external force is considered.
- The links and forces are labeled appropriately.

6.4. LOADING AND SAVING STANDARD INPUTS

A desired mechanism can be loaded very easily. The procedure is described below

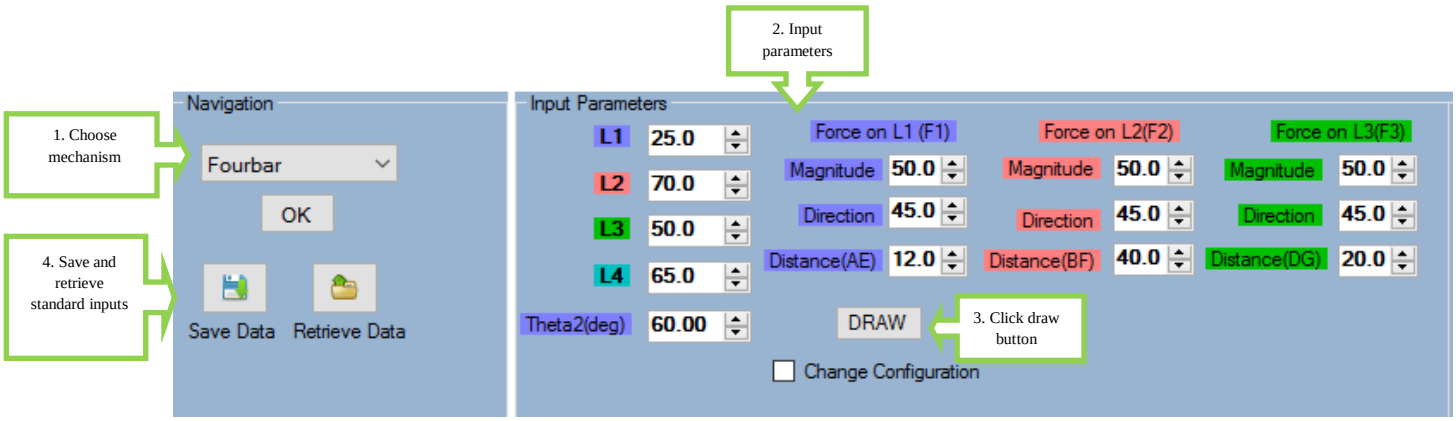

Figure 13: Guidelines for SFA Module Control

- Select the desired mechanism from dropdown menu in **Navigation** panel, and input parameters can be changed in **Input Parameter** panel (refer Figure 13).
- Now on clicking **Draw** button mechanism will be updated for corresponding inputs.
- For saving and retrieving inputs click on the corresponding buttons in **Navigation** panel (refer Figure 13).

7. REFERENCES

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