The Use of MATLAB in Learning the Velocity Analysis with Relative Velocity Method on Slider Crank Mechanism

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Abstract In the subject of kinematics, velocity analysis is the fundamental concepts in studying motions in the machines. Graphically velocity analysis, might be difficult to understand by the students, especially if the concepts is explained by conventional teaching method. In this study, development a computer program for velocity analysis of slider crank mechanism is presented. The purpose is to assist the learning process of slider crank kinematics, so the students will easily understand the concept. The computer program is written by using MATLAB. Graphical User Interface is used, so the users are allowed to change the input parameters such as angle of linkage bar, the magnitude and direction of angular velocity etc. Based on the inputs, the computer program displays the outputs such as linear and angular velocity, steps of velocity analysis graphically and its mathematical computations. This computer program has been validated by theoretical calculations. In the future, the application will be developed for other complex mechanism and be implemented in learning of kinematics.

1. Introduction

Kinematics is one of the subjects taught in mechanical engineering department. Kinematics is the branch of mechanics which deals with the description of motion. It does not deal with the causes of motion [1]. Kinematics analysis purposes to predict future values of position and velocity of a system in terms of its present values of position, velocity and its accelerations [1]. Kinematics involves velocities and acceleration analysis on several mechanisms such as slider crank mechanism, four bar mechanism, powell engine etc. The relative velocity method is the most frequent method used in kinematics analysis. The relative velocity method involves drawing of vectors graphically. Implementation of relative velocity method on mechanisms might be difficult to understand by the students, in particular, if the explanations are delivered by conventional teaching method. Drawing many velocities vectors make this subject tedious and uninteresting. A breakthrough is required in kinematics learning, in order to make the concept of kinematics is easily explained and understood. In this case, innovation in the use of learning media is indispensable.

Learning media is anything that can be used to transmit messages from the sender to the recipient, so that it stimulates thoughts, feelings, attention and interest that lead to the learning process. Technological developments have created many breakthroughs in the development of learning media. Computer programs are often used as a learning media that involves simulations. Computers simulations may combine colors, sounds and display animated graphics.

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment. MATLAB is often used in calculations
in mechanical engineering subjects. Several studies have also use MATLAB as a tool in learning process. Rahemi and LaVergne [2] implement MATLAB programming as a computing tool in Engineering Analysis Course in order to stimulate student’s critical thinking and problem-solving skills. It also makes the students understand the behavior of an engineering system easily. Yang et.al [3] implement and assess the use of MATLAB into the instruction of an Introductory Circuit Analysis Course. The purpose is to enhance student learning by delivering relevant course materials using MATLAB’s graphical representation and problem’s solving capabilities. The results indicate that integration of MATLAB into course instruction, promotes learning and enhances students’ computer skill. A MATLAB computer model of finite element analysis (FEA) is used by Zhao [4] in teaching FEA methodology. The aim is to introduce the finite element formulation to sophomore who does not know about deformation theory. He found that implementation of MATLAB also strengthens the student programming’s skills. A teaching–learning tool based on MATLAB for elementary psychrometric processes is developed by Gupta PK and Patel [5]. The results show that the tool increases the performance of students over the conventional approach. Niazzkar and Afzali [6] create MATLAB code for solving water distribution networks. This computer application is developed not only for enhancing teaching and but also for researching on analysis of water distribution networks. In order to motivate and inspire learning in Media Signal Processing, Sturm and Gibson [7] use MATLAB to create a collection of exploratory demonstrations and applications (SSUM). They found that the application is proved can be used for quickly and effectively illustrating concepts. Kassem et.al [8] compare a learning process of Fluid Mechanics by traditional method and by using MATLAB. They conclude that MATLAB is proved to be an efficient method for supporting the students’ ability in understanding the concept. A new educational simulation tool is created by Sanguino and Marquez [9] in robotic arms kinematics with the purpose to make attractive and practical teaching and learning. This tool enables studying and evaluating different aspects related to kinematics of serial robotic arms.

In this study, the objective is to create a learning media to assist the kinematics learning process, particularly for velocity analysis on slider crank mechanism. A computer program based on MATLAB is chosen as learning media as MATLAB enables integration of programming, engineering computation and visualization in explaining the kinematic concept.

2. The implementation of relative velocity method on slider crank mechanism.

Figure 1 shows mechanism of slider crank. The velocity analysis involves determining the velocity of point of A \((V_A)\), B \((V_B)\) and C \((V_C)\). The linkage bar of \(O_2A\) rotates about a rotation center, \(O_2\) with the angular velocity of \(\omega_2\), while the slider of B moving back and forth during the rotation. The length of linkage bar of \(O_2A\), BA and CA are given. The velocity of A \((V_A)\) is calculated by using (1)

\[
V_A = \omega_2 \cdot O_2A
\]  

(1)

The velocity of B \((V_B)\) and C \((V_C)\) are determined graphically by using (2) and (3)

\[
V_B = V_A + V_{BA}
\]  

(2)

\[
V_C = V_A + V_{CA}
\]  

(3)

\(V_{BA}\) is defined as relative velocity of B with respect to A with the magnitude as shown in (4)

\[
V_{BA} = \omega_3 \cdot BA
\]  

(4)

\(V_{CA}\) is defined as relative velocity of C with respect to A with the magnitude as shown in (5)

\[
V_{CA} = \omega_3 \cdot CA
\]  

(5)

The magnitude of \(V_{BA}\), \(V_B\) and \(V_C\) are determined graphically as shown in Figure 2.
3. Materials and Methods

A computer program for velocity analysis on slider crank mechanism is created by using MATLAB. This computer program can be used after installing MATLAB on the computer. The graphical User Interface (GUI) is utilized to enable the users changing the input parameter such as angle of linkage bar \( O_2 A \), magnitude and direction of angular velocity etc. Based on the inputs, the computer program displays the outputs such as linear and angular velocity of other linkage bars, steps by step of velocity analysis graphically and the related mathematical computations in every step. The program also displays animation of the motion, trajectory and the graph showing the change of position of the observed point. The flowchart of the program is given by Figure 3.

![Flowchart](image)

**Figure 3. Flowchart**

4. Results

The display of the computer program can be seen in Figure 4. In the section of Input, the users give the magnitude and direction of angular velocity of linkage bar 2 and the angle of bar 2. After clicking ‘Hitung’, the program will calculate and displays the results. The magnitude of velocity of A, B, C and the angular velocity of bar 3 will be displayed in section Output. The program will show the figure of slider crank based on the given angle and the steps of diagram vector drawing for velocity analysis. By clicking number of steps (1,2,3, etc), the figure below will display the corresponding drawing of vectors, its mathematical calculation and the concept about the vector drawing. On the right side of

![Diagram](image)

**Figure 1. Slider crank mechanism**

**Figure 2. Vector diagram**
panel, section of animation shows the motion of the mechanism, trajectory and graph of position change of A and B.

**Figure 4.** Display of the computer program

**Figure 5.** Displays of velocity analysis step 2
Figure 6. Displays of velocity analysis step 3

Figure 7. Displays of velocity analysis step 4
Mekanisme Engkol Peluncur

Figure 8. Displays of velocity analysis step 5

Figure 9. Displays of velocity analysis step 6
Figure 10. Displays of velocity analysis step 7

Figure 5 to Figure 9 show the steps in drawing the vectors to obtain velocity of A, B and C. Figure 10 displays the isolated bar with its velocity vector, so the users understand the meaning of vector diagram. The drawing of vector diagram consists of several steps as follows:

1. Drawing of $V_A$, the application will draw vector $V_A$ which is perpendicular to bar 2. The magnitude is calculated based on (1). As the steps imitate the procedure in solving the vector summation graphically, the application will specify the scale used (Figure 4)
2. Drawing the line of $V_{BA}$, the line is created perpendicular to bar 3 (Figure 5)
3. Drawing the line of $V_B$, the line is created according the direction of slider (B) movement, horizontal (Figure 6)
4. Drawing the direction of $V_{BA}$ and $V_B$, based on (2). The length of line $V_{BA}$ and $V_B$ represents the magnitude of vectors. The measurement results of those length will be multiplied with the scale, and the magnitude of $V_{BA}$ and $V_B$ are obtained. (Figure 7)
5. To obtain $V_C$, first, the $V_{CA}$ is calculated by using (5). The line $V_{CA}$ is drawn at the end of $V_A$ with the length of line is scaled by using the used scale. (Figure 8)
6. Drawing of $V_C$, based on (3), the line is drawn from the beginning of $V_A$ to the end of $V_{CA}$. The line is measured, then by multiplication it with the scale, $V_C$ is obtained. (Figure 9)
7. Drawing of isolated bar with its velocity vector to display the meaning of vector diagram.

5. Discussion

The results of the application have been validated by theoretical calculation. Table 1 shows the comparison between the results of this MATLAB application with the results of theoretical calculation. The difference between these results are less than 1%, so the application/computer program is considered acceptable and valid.
Step by step of drawing of vectors together with its mathematical calculation is expected to make the concepts is easy to understand and to remember. This application can be utilized by teachers and students in kinematic learning process. It allows the user to change the magnitude and direction of input variables. Hence, the users can repeat the process with different input and the application will show the problem solving. By varying the kinematic problems, the students will have a good understanding about the concepts. The animation shown by this application is also expected to make the learning process more interesting and boost the learning motivation. The conventional teaching method of kinematic by drawing the vectors on the board using the ruler and protractor, limit the ability to vary the kinematic problems and to repeat the teaching process for solving problems. It also takes more time and not efficient. Similarly, the use of power point for explaining these concepts is also not practical, as it involves a direct measurement and calculation. This application is expected to help the learning process of kinematic. In the future, the application will be developed for other complex mechanism and the impact in learning of kinematics will be investigated.

6. Conclusion
In this paper, MATLAB programming is developed to assist the learning process of slider crank kinematics. Step by step of drawing of vector diagram with mathematical calculation are displayed to make the kinematic concept easy to understand and to remember. The use of GUI enables the user to vary the input and to repeat the learning process. Next, other more complex mechanism will be included in the program. Evaluation of the influence of this application/computer program on the student learning outcomes will be carried out to see its effectiveness as a kinematics learning media.

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