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MATLAB Simulator can support student learning for Fluid Mechanics courses in the Mechanical Engineering Department

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Abstract

The purpose of this study is to find out the impact of using the Matlab software on students' academic achievement in the Mechanical Engineering Department at Near East University. This paper presents an example of designing an airfoil and estimates the aerodynamic characteristics of it in the field of Mechanical Engineering (ME) using the Matlab software. The study was structured as an educational design experiment, which used the Matlab software in teaching some mechanical courses in ME degree program at Near East University (NEU). The same project was given to the all group. The first group was used traditional methods to analysis aerodynamic characteristics of the developed airfoil. The second and the third groups were used Matlab code developed by the researchers and potential flow simulator to analyze the project. The last group (group 4) was used in both Matlab software and traditional methods to estimate the aerodynamic characteristics of the developed airfoil. Based on the analyzing results, the Matlab software proved to be an efficient method for supporting the students' ability to improve and understand the concept of some selected courses. Moreover, the analysis result of the test showed that there are statistically significant differences between the experimental group (who used Matlab software) and the control group (used traditional methods) at a significance level of 0.05 for the interest of the experimental group. Consequently, it can be concluded that students used Matlab software to demonstrate deeper learning and understanding the course compared to the traditional method.

Keywords: Academic achievement; Educational technology; Matlab Software; Teaching method

1. INTRODUCTION

Education encounters, in modern times, challenges in all aspects of social, economic, engineering and cultural life; the most important of which are over-population, over-knowledge, education philosophy development & the change of teacher's role, the spread of illiteracy, lack of the staff & the technological development and mass media [1]. This drove the teaching staff to use the modern teaching technologies to face some of the main problems, which education & its productivity encounter, by increasing the learning level which may be achieved through providing equivalent opportunities for all people whenever and wherever they are while taking into account the individual differences between learners. To improve educational productivity, some of the teaching staff sought to mainstream technology within education, developing traditional techniques and using new educational methods [2-6].

Integrating mathematical simulation software such as Matlab in various engineering curricula has been attracting widespread interest during recent decades, especially for courses involve process design [7-10]. Matlab is regarded as an excellent tool intended for mathematical modeling, very few studies were performed previously about using Matlab for supporting the student learning for the courses. For example, Ibrahim (2011) [2] conducted a study entitled as ‘‘Engineering simulation with MATLAB: improving teaching and learning effectiveness’’. The study aims to show that Matlab/ Simulink is one of the most important tools in engineering education and can be an be very useful in teaching the working principles of various engineering instruments and devices. The researcher used a tuned RLC circuit as an example to show the importance of simulation and also to show how easily simulation can be carried out using a Matlab package and the simulation values are close to the experimental values carried out in a real physical laboratory.

Li& Huang (2017) [3] carried out a study entitled as ‘‘An inverted classroom approach to educate MATLAB in chemical process control" The aim of this study was to examine the effectiveness of the inverted-classroom approach in developing MATLAB/Simulink skills of upper-division undergraduates in Villanova's chemical process control course. The survey results showed that students' experience became more positive with the inverted-classroom approach as they become more familiar with MATLAB and the inverted-teaching approach.

Moussavi & Fazly (2010) [4] found out that students can be used Matlab/Simulink to guess the behavior of actual induction machine drive.

Casini & Garulli (2016) [5] discussed Matlab simulator for mobile robotics experiments. They concluded Matlab simulator allowed the student to easily design control laws for team robotics and to simulate their behavior through suitable animations.

1.1 Study problem

The study problem is focused in finding out the influence of

Matlab/Simulink in teaching Fluid courses and undergraduate project, which related to design a wind turbine on the students' academic achievement, especially the students of the Mechanical Engineering Department at Near East University, in comparison with their department who benefit from this curriculum through traditional education. This problem is made more specific in the following question: What is the impact of using Matlab/Simulink in supporting and understanding the concept of the courses & its uses in education on the students' academic achievement?

1.2 Study objectives

This paper describes a technology that can provide students learning to solve and design complex engineering problems in their efforts. In the present study, the effect of using Matlab/Simulink on the Mechanical Engineering students' academic achievement in the energy courses specially Fluid course and supporting the student to design or to study the flow characteristics for any object, particularly who is in the third-year and fourth-year Bachelor's degree. Several MATLAB modules were used in the Fluid courses. The modules demonstrate how to estimate the aerodynamic forces and coefficients of any object including four-digit airfoil. Two anonymous surveys were conducted for the two teaching modules to evaluate the improvement of students' technical knowledge and skills through solving the assignments. In addition, the goal of this paper is to show the advantages of using Matlab/Simulink to develop interactive resources to support teaching and learning in the Mechanical Engineering Department. Thus, the idea is to help the students to understand the concept of the main courses in Mechanical Engineering Department courses with which students can validate their designed and understand the real world.

1.3 Study significance

The importance of the subject study is a result of the following issues:

1. It allows reaching a simplified strategy which leads to easy understanding the concept of the courses.
2. It raises the Mechanical students' academic achievement in using Matlab software.
3. It develops the Mechanical teachers' and students' ability to use Matlab package in teaching the other mechanical courses like heat transfer, thermodynamics, static, dynamic and so on.
4. It encourages the last fourth years' students to study the effect of the flow passing anybody including the airfoil.

1.4 Study limits

The study limits are confined to the following:

1. Spatial limits and educational stage

The category of students who is third-year and fourth-year Bachelor's degree. A sample, consisting of 60 students distributed on four groups, see section 7, (third-year Bachelor's degree students studying Fluid Mechanics I and fourth-year Bachelor's degree students studying Fluid Mechanics II and taking undergraduate project related to design a horizontal wind turbine) taught in the Mechanical Engineering Department at Near East University.

2. Temporal limits

Studying starts by the beginning of the first and second semester of the University year 2016-2017 and it wraps up by its end.

1.5 Study terminology

1. Matlab simulator: It is a tool intended for mathematical modeling.
2. Student's academic achievement: It is the result of what the students learn after the learning process.

1.6 Study equations

The presented study is based on data collected from third-year and fourth-year Bachelor's degree students especially Mechanical Engineering Department students. Computer Aided Designing applications including Matlab software, have been applied in the world in order to reduce the number and cost of experiments and obtain more information before designing subjects.

The subject study provides an answer to the following main questions:

Q1. Can Matlab software help the mechanical students to understand the real world?

Q2. Is Mechanical Engineering students' willingness to use Matlab software related to their use of computer technology for understanding the courses very well?

Q3. Are there any statistically significant differences between the average marks of the groups in the T-test measurements?

2. COURSE DESCRIPTION AND TEACHING METHODS

In both 2016 and 2017, the Fluid mechanics I and II were taught during a fall and spring semesters period to third and fourth-year Bachelors degree students majoring in Mechanical Engineering Department. During the period, the number of students actively participating in the course was 35 students in Fluid Mechanics I and 26 students in Fluid Mechanics II. The course included 60 h of contact teaching, which combined lectures and exercises. The topics covered in both courses included physical properties of fluids, fluid flow concepts, and basic equations in terms of continuity, energy and momentum principles, viscous effects in fluid flow, Potential flow theory and Boundary Layers. The courses grade were derived from the scores earned on three group assignments, each of which included teacher and peer evaluation. Table 1 illustrates the intended learning outcomes for both course and their alignment with the teaching methods used.

Table 1. Meeting the intended learning outcomes with the chosen teaching methods

After the module the student	Lectures and exercises	Assignment I	Assignment II	Assignment III
Can derive the mathematical model to describe the velocity distribution over a fixed plate	X	X		
Can derive the mathematical model to describe the velocity distribution between two parallel plates	X	X		
Can derive the mathematical model to describe the velocity distribution around the object	X		X	
Can estimate the aerodynamic coefficients around an airfoil to describe the effect of attack angle on them	X		X	X
Can know how the pressure and velocity distribution around the airfoil	X		X	X
Can the low or high velocity affect the aerodynamic coefficient and pressure distribution around the airfoil	X			X

2.1 Assignment I and II

The course's first assignment was a closed problem that focused on derived a mathematical equation to describe the velocity distribution over a thin plate or between two parallel plates. Its purpose was to find the exact solution for the simple problem when (1) flow passed over a fixed plate (2) the flow passed between two fixed plates (3) the flow passed between two plates: the lower plate was fixed while the upper plate was moving. In addition, the assignment demonstrated the results derived theoretically from the lectures by showing effect velocity distribution with boundary condition in three cases.

The second assignment considered the case of a complex example (around the object such as a sphere, cylinder, and NACA airfoil) for compressible flow. The task was to estimate the drag and friction forces and coefficients for known the velocity profile. Also, the assignment was to determine the aerodynamic coefficient theoretically (lift and drag coefficient) for the symmetric and unsymmetrical airfoil. The aim of this assignment was to let the student know: (1) the type of flow (laminar or turbulent) will affect the boundary layer thickness, (2) the effect of the velocity profile of the drag and friction forces. Furthermore, the purpose was to gain an understanding of the theoretical relationship between aerodynamic coefficients, forces, and shape of the object. The lectures, the exercises, and the two above mentioned assignments were designed to prepare the students for the third assignment. This third assignment was conducted during the last month of the courses after the first two assignments had been handed in, graded and discussed in the classroom.

2.2 Assignment III

In the third assignment, the students worked in groups and used Matlab software. The tasks were to (1) develop and sketch an airfoil of high cambered section (2) show the relationship between attack angle and the aerodynamic coefficient for three different airfoils (3) show the velocity distribution around the airfoil using numerical methods and potential flow simulator.

3. ESTIMATION AERODYNAMIC FORCE OF AIRFOIL

The aerodynamic force and coefficients of the airfoil, which can be considered as a complex problem and important example to show the velocity and pressure distribution on the airfoil. Also, in order to design a wind turbine especially the horizontal turbine or Darrieus turbine for producing electricity, the undergraduate students need to calculate the aerodynamic forces and estimate the pressure and velocity distribution around the airfoil. Thus, this section shows the exact and numerical solution for aerodynamic forces, velocity and pressure distributions.

3.1 Exact solution (Textbook)

If a horizontal wing is cut by a vertical plane parallel to the centerline, the shape of the resulting section is usually like Figure 1 [11]. This is an airfoil section.

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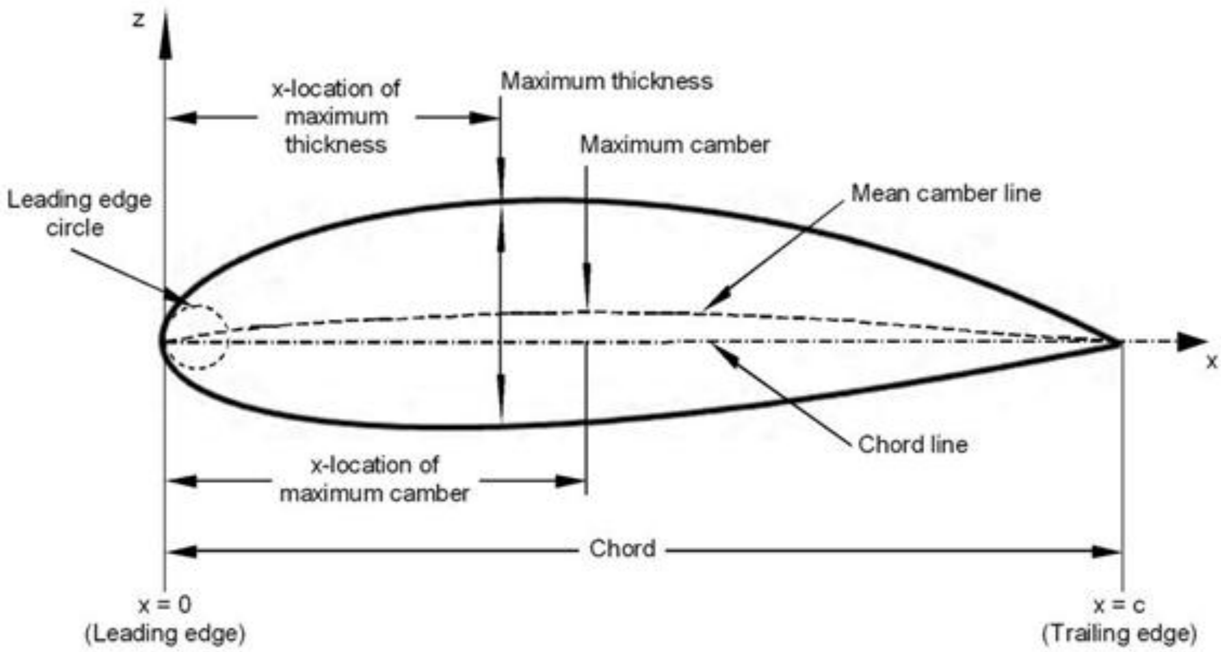

Figure 1. Airfoil-section geometry and it is nomenclature [11]

The airfoil shape (Figure 1) is expressed analytically as a function of some design parameters. Geometric parameters that have an important effect on the aerodynamic characteristic of an airfoil section include: (1) the leading-edge radius, (2) the mean camber line, (3) the maximum thickness and the thickness distribution of the profile and (4) the trailing edge angle. An airfoil is a body of such a shape that is placed in an airstream in order to produce an aerodynamic force as shown in Figure 2 [12]. The lift and drag forces depend on n the airfoil's shape, the angle of attack, air viscosity. Thus, they are characterized by a single variable in the lift and drag equations, called the lift and drag coefficients. Due to the complexities of both coefficients, it is generally found via experimental or numerical study. Therefore, the lift (F_L) and drag (F_D) equations given by [13, 14]:

$$F_L = \frac{1}{2} V_\infty^2 \rho C_L A \tag{1}$$

$$F_D = \frac{1}{2} V_\infty^2 \rho C_D A \tag{2}$$

where ρ is the density of air, V_∞ is the relative velocity of the airflow A is the area of the airfoil as viewed from an overhead perspective, C_L is the lift Coefficient and C_D is the drag Coefficient. Eq. (3) shows the relationship between drag and lift coefficient [15]

$$C_D = C_{D,0} + \frac{C_L^2}{\pi ar} \quad , \quad ar = \frac{b^2}{A_p} \tag{3}$$

where, $C_{D,0}$ is drag coefficient at zero lift, ar is aspect ratio, b is wingspan or is the distance from one wingtip to the other wingtip of the airplane and A_p is planform area.

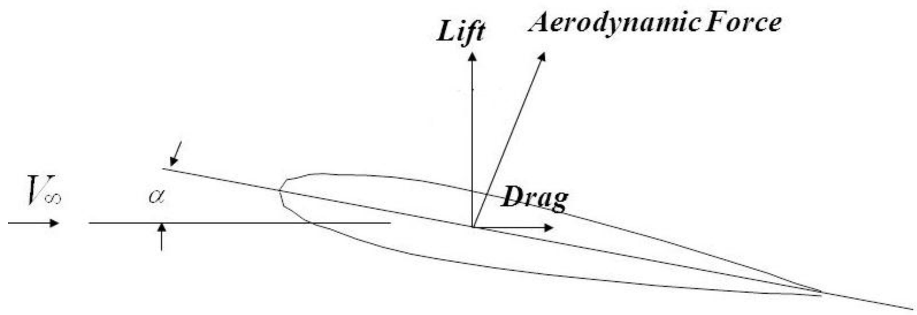

Figure 2. Aerodynamic forces [12, 14]

The pressure and velocity on the surface of an airfoil in flight are not uniform. Figure 3 shows typical pressure distributions for a given section at various angles of incidence. It is convenient to deal with non-dimensional pressure differences using P_∞, the pressure far upstream, as the datum. Thus the coefficient of pressure (C_p) is introduced as

$$C_p = \frac{P - P_\infty}{\frac{1}{2}\rho V_\infty^2} \tag{4}$$

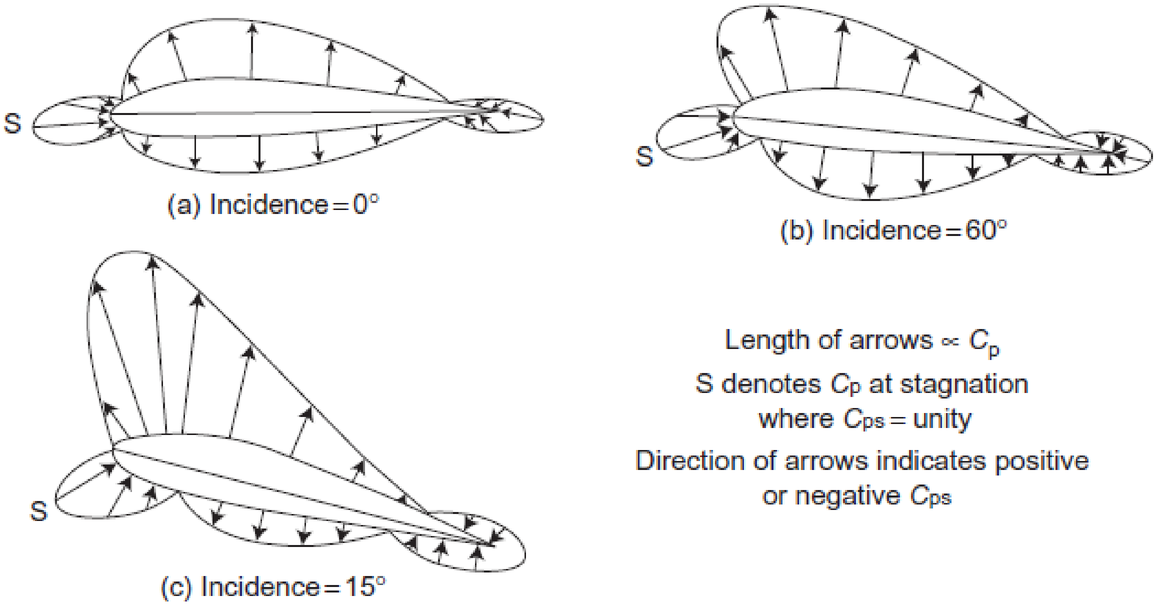

Figure 3. Typical pressure distributions on an airfoil section [15]

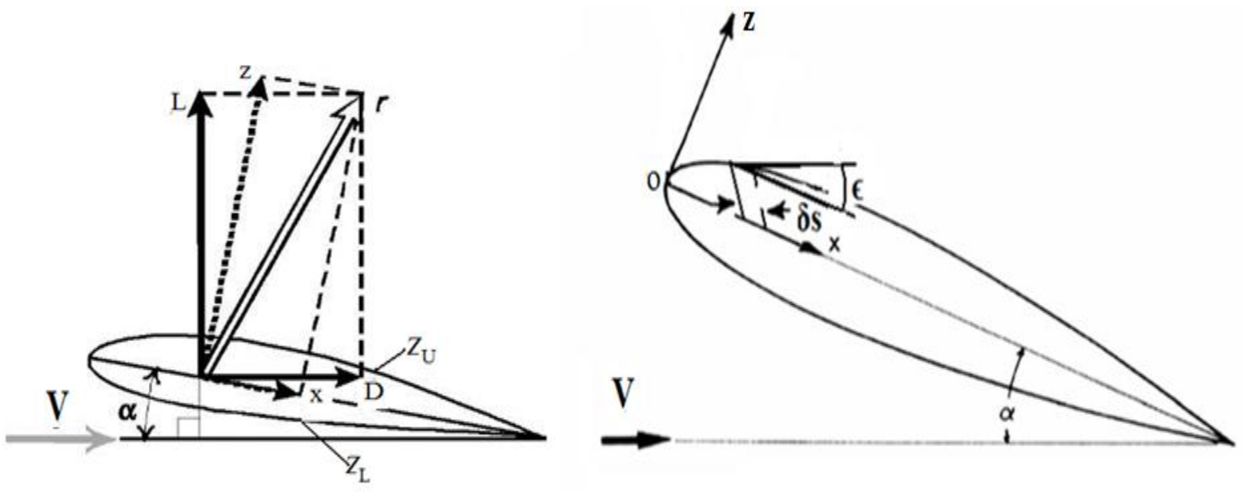

Figure 4. Normal pressure force on an element of the airfoil surface [15]

Let Figure 4 represent an aerofoil at an angle of incidence α to a fluid flow traveling from left to right at speed V_∞**.** The axes O_x and O_z are respectively aligned along and perpendicular to the chord line.

Taking the aerofoil to be a wing section of constant chord and unit spanwise length, let us consider the forces acting on a small element of the upper aerofoil surface having length δs. The inward force perpendicular to the surface is given by P_Uδs**.** This force may be resolved into components δXand δZ in the x and z directions. It can be seen that

$$\delta Z_u = -P_u \cos \varepsilon \tag{5}$$

and from the geometry

$$\delta s cos\epsilon = \delta x \tag{6}$$

so that

$$\delta Z_u = -P_u \delta x \qquad per\ unit\ span \tag{7}$$

Similarly, for the lower surface

$$\delta Z_l = -P_l \delta x \qquad per\ unit\ span \tag{8}$$

We now add these two contributions and integrate with respect to x between x = 0 and x = **c** to get

$$Z = -\int_0^c P_u dx + \int_0^c P_l dx \tag{9}$$

But we can always subtract a constant pressure from both $P_u$and P_l without altering the value of Z**,** so we can write

$$Z = -\int_0^c (P_u - P_\infty)dx + \int_0^c (P_l - P_\infty)dx \tag{10}$$

Where P_∞ is the pressure in the free stream (we could equally well use any other constant pressure, e.g. the stagnation pressure in the free stream). Eq. (10) can readily be converted into coefficient form. Recalling that the aerofoil section is of the unit span, the area *A= 1* x **c** = *c* so,

$$C_Z = \frac{Z}{\frac{1}{2}\rho V_\infty^2 c} = \frac{1}{\frac{1}{2}\rho V_\infty^2 c}\left[-\int_0^c (P_u - P_\infty)dx + \int_0^c (P_l - P_\infty)dx\right] \tag{11}$$

Remembering that *(l/c) dx = d(x/c)* and that the definition of pressure coefficient is

$$C_p = \frac{P - P_\infty}{\frac{1}{2}\rho V_\infty^2 c} \tag{12}$$

We see that

$$C_Z = -\int_0^1 (P_u - P_l) d\left(\frac{x}{c}\right) \tag{13}$$

Similar arguments lead to the following relations for X**.**

$$\delta X_u = P_u \delta s \sin\epsilon\, \delta X_l = P_l \delta s \sin\epsilon\, \delta s sin\epsilon = \delta z \tag{14}$$

Giving

$$C_X = \oint_c C_P d\left(\frac{Z}{c}\right) = \int_{Z_{ml}}^{Z_{mu}} \Delta C_P d\left(\frac{Z}{c}\right) \tag{15}$$

Where Z_{mu} and Z_{ml} are respectively the maximum and minimum values of z, and ΔC_P, is the difference between the values of C_P acting on the fore and rear points of an aerofoil for a fixed value of z. [16]

Aerodynamic coefficients of Airfoil can be obtained from Eqs. (16) and (17)

$$C_L = C_Z cos\alpha - C_X sin\alpha \tag{16}$$

$$C_D = C_Z sin\alpha + C_X cos\alpha \tag{17}$$

3.2 Numerical Solution

Houghto & Carpenter (2003) [17] describes NACA four digits series and presents the equations for constructing NACA four digits series, which describe the thickness distribution and camber lines of the four digits series.

The airfoil of four-digit wing sections defines the profile by:

1. One digit describing maximum camber as a percentage of the chord.
2. One digit describing the distance of maximum camber from the airfoil leading edge in tens of percents of the chord.
3. Two digits describing the maximum thickness of the airfoil as a percent of the chord.

The formula for the shape of a symmetrical airfoil, 00XX , with "XX" being replaced by the percentage of thickness to chord, is:

$$z = \frac{t/c}{0.2} c\left[a\sqrt{\frac{x}{c}} - b\left(\frac{x}{c}\right) - c\left(\frac{x}{c}\right)^2 + d\left(\frac{x}{c}\right)^3 - e\left(\frac{x}{c}\right)^4\right] \tag{18}$$

where c is the chord length, x is the position along the chord from 0 to c, z is the half thickness at a given value of x, t/c is relative thickness (thickness ratio) and a, b, c, d, and e are constants (Table 2).

Table 2. Constants of four digit symmetrical airfoil

a	*b*	*c*	*d*	*e*
0.2969	0.1260	0.3516	0.2843	0.1015

Now the coordinates (x_u, z_u) of the upper airfoil surface and (x_L, z_L) of the lower airfoil surface are:

$$z_u = +z \quad and\ \ z_L = -z \quad for\ x_u = x_L = x \tag{19}$$

The formula used to calculate the mean camber line for a un-symmetric NACA 4-digit is

$$z = \begin{cases} h\dfrac{x}{{x_h}^2}\left(2x_h - \dfrac{x}{c}\right) & ,from\ x = 0\ to\ x = x_h c \\ h\dfrac{c - x}{(1 - x_h)^2}\left(1 + \dfrac{x}{c} - 2x_h\right) & ,from\ x = x_h c\ to\ x = c \end{cases} \tag{20}$$

where h is the maximum camber, x_h is the location of maximum camber, c is the chord length and x is the position along the chord from 0 to c.

The calculations of the velocity distribution and the aerodynamic coefficients have been derived through the singularity method in the previous section. Now, these parameters can be evaluated in a convenient way through the numerical summation formulas. The details of the calculation are referred to the work of F.Riegels and E. Truckenbrodt [18]

For the numerical quadrature the coordinates of the profile at the N-discrete nodes is determined as;

$$X_m = \tfrac{1}{2}\left(1 + cos\frac{\pi m}{N}\right),\ m = 0,1, \ldots, N \tag{21}$$

The velocity distribution on the profile contour at discrete points Xn is obtained through the following summation formula;

$$\frac{V_k(X_n)}{U_\infty} = \frac{1}{X_n^*}\left[a_n + 2\sum_{m=1}^{N-1} A_{nm} Z_m^t \pm 2\sum_{m=1}^{N-1} C_{nm} Z_m^s \pm \alpha\left(b_n + 2\sum_{m=1}^{N-1} H_{nm} Z_m^t\right)\right] \tag{22^1}$$

Where

$$X_n^* = \sqrt{C_n + \left(\frac{dZ^t}{d\varphi}\right)_n^2} \qquad (23^1)$$

and an ,bn , cn, Anm, Cnm and Hnm are Fourier series coefficients, and N is the number of discrete nodes.

The pressure coefficient distribution on the profile contour is obtained through the following summation formula;

$$\mathrm{C_p} = 1 - V_k^2(X_n) \qquad (24)$$

The aerodynamic coefficients are obtained through Eqs. (23) and (24)

$$C_L = C_Z cos\alpha - C_X sin\alpha \qquad (25)$$

$$C_D = C_Z sin\alpha + C_X cos\alpha \qquad (26)$$

where

$$C_Z = \left[\sum_{I=1}^{\infty}\left(\frac{C_{p\,i} + C_{p\,i+1}}{2}\right)\left|\frac{x_i}{c} - \frac{x_{i+1}}{c}\right|\right]_{upper} - \left[\sum_{I=1}^{\infty}\left(\frac{C_{p\,i} + C_{p\,i+1}}{2}\right)\left|\frac{x_i}{c} - \frac{x_{i+1}}{c}\right|\right]_{lower} \qquad (27)$$

$$C_X = \left[\sum_{I=1}^{\infty}\left(\frac{C_{p\,i} + C_{p\,i+1}}{2}\right)\left|\frac{x_i}{c} - \frac{x_{i+1}}{c}\right|\right]_{FRONT} - \left[\sum_{I=1}^{\infty}\left(\frac{C_{p\,i} + C_{p\,i+1}}{2}\right)\left|\frac{x_i}{c} - \frac{x_{i+1}}{c}\right|\right]_{AFT} \qquad (28)$$

4. MATLAB SOFTWARE

MATLAB is a fourth-generation programming language and numerical analysis environment [19].

4.1 General Matlab code

The instructor wrote a general Matlab code for determining the aerodynamic forces, velocity and pressure distribution for any four-digit NACA airfoil. The purposes of this code are

1. To draw any four digit airfoil.
2. To calculate the aerodynamic coefficients at a various angle of attack.
3. To show the velocity and pressure distribution over the airfoil.

By assuming the student learned the concept of aerodynamic fundamentals through the lecture and textbook. The code focuses exclusively on helping students estimate the forces and coefficients of any four-digit airfoil problems while maintaining the ability to interpret student work.

4.2 Potential flow simulator

2D Potential Flow Simulator calculates and simulates a potential flow based on given combination elementary flows. User can put a combination of uniform flow, source/sink flow, vortex flow, and doublet flow, define its strength and position, and 2D Potential Flow Simulator will calculate and generates the resulting potential flow.

5. EXAMPLE

A NACA 2412 airfoil with a 2 m chord and 5 m span is being tested in a wind tunnel at standard sea level condition and Reynolds number of 4×10^5 at an angle of attack of 10°. Estimate the lift force of the airfoil?

This example is a simple problem to let the student calculate the aerodynamic forces. It has been chosen because the lift and drag coefficients for different Reynolds number are available in textbooks.

5.1 Textbook

Figure 5 shows the lift and drag coefficients at different attack angles of NACA 2412. The student must find the lift coefficient (Figure 5) at the attack angle of 10° then finding drag coefficient of NACA2412. To find the aerodynamic forces

1. *Calculate the stream velocity*

$$Velocity = \frac{kinematic\ visocisty. Reynolds\ number}{chord} = 3.11\ m/s \qquad (27)$$

2. *By using Eq. (1)*

$$Lift\ force = \frac{1}{2} \times 1.225 \times (3.11)^2 \times 1.3 \times 2 \times 5 = 77.01\ N \qquad (28)$$

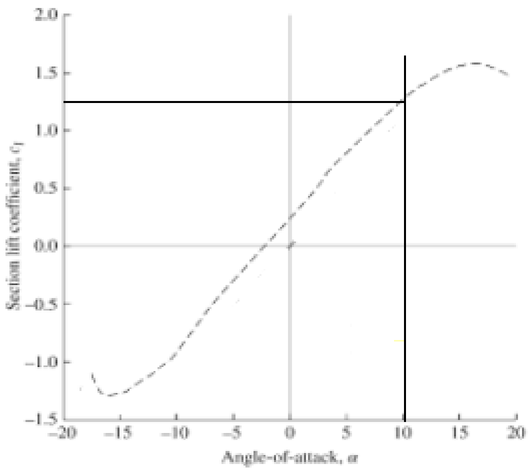

Figure 5. Lift coefficient vs. attack angle of NACA2412

5.2 General Matlab Code Developed by Researchers

The assignment for students is aims to (1) calculate the lift force (previous example) of NACA 2412 and compared with numerical solution obtained from general Matlab code which developed by the instructor, (2) estimate the lift force for reshaping an airfoil with high chamber line and (3) compare the velocity and pressure distribution obtained through the Matlab code and potential flow simulator.

Instructional manual content: the procedure and steps for using both Matlab code and potential flow simulator for this example and for assignment III. The first part of the manual

[1] Coefficients a_n ,b_n , c_n , A_{nm} , C_{nm} , H_{nm} are to calculate the velocity distribution on the contour profile according to Eq. 3 for N = 12 are given in [18]

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introduces the functions used in Matlab code to determine the aerodynamic forces and aerodynamic characteristics in terms of velocity and pressure distribution and shows the parameters that the students should change them according to four digit airfoil.

The first part of the instructional manual contains all essential information for the student to make full use of the Matlab code. The steps description of determination the aerodynamic forces and characteristics using the code can be given as

a. Airfoil parameter

The code contains all functions that can be used to draw 2D four digit airfoil (symmetrical and unsymmetrical airfoil, Eqs. (18) and (20). Depending on the type of airfoil and status of the project, the user (student) should change the four digit of the airfoil (see Figure 6).

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%% Four Digit Airfoil%%%%%%%%%%%%%%%%%%%%%%
% NACA XYWZ airfoil has a maximum camber of X% located (Y*10)%
%(0.Y chords)from the leading edge with a maximum thickness of WZ%
%of the chord
%%%%%%%%%%
% f_L: maximum camber
f_L=0.02;
% Xf_L: location of maximum camber
Xf_L=0.4;
% d_L: maximum thickness
d_L=0.12;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

First digit

Second digit

Third and fourth digit

Figure 6. Four-digit of airfoil

b. Projection area and wind speed

Depending on the questions, the student can change the dimensions (chord and span) of the airfoil, the wind speed and attack angle as shown in Figure 7.

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%% Dimension of airfoil %%%%%%%%%%%%%%%%%%%%%%
%chord of airfoil
c=2;
%span
S=5;
%projection area
aera=(c*S);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%% wind velocity and air dinsioty %%%%%%%%%%%%%%%
% wind velocity
U_infin=3.11;
%air density
density=1.225;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%% attack angle  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% alpha: angle of attack
alpha=(10*pi)/180;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

Figure 7. Details about dimensions of an airfoil, wind speed, and air density

c. Solver

The solver is the heart of the program system. It calculates the aerodynamic forces, coefficients and aerodynamic characteristics in terms of velocity and pressure profiles for upper and lower surfaces of the airfoil at various wind speed and attack angle (Figure 8).

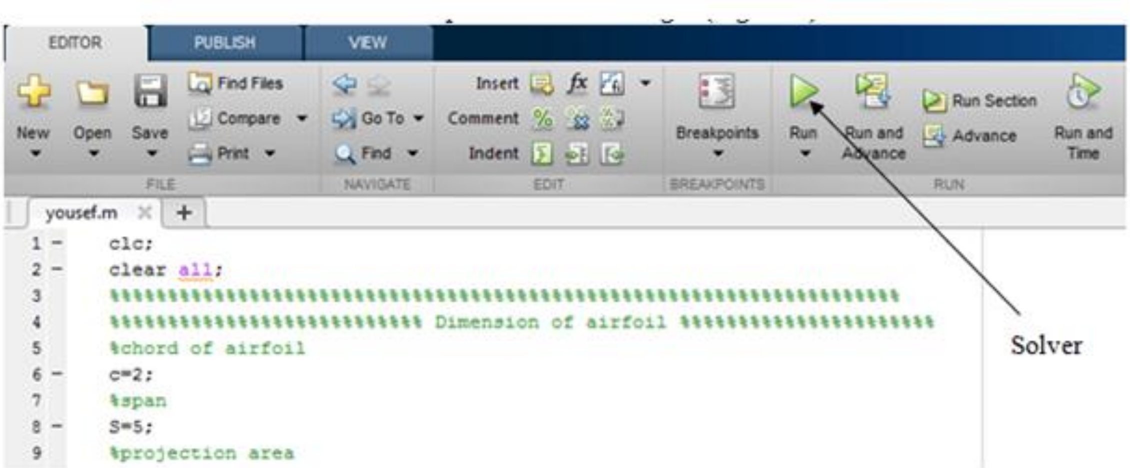

Figure 8. Solver

After running the code, the calculation has been carried out, the results can be displayed as shown in Figure 9.

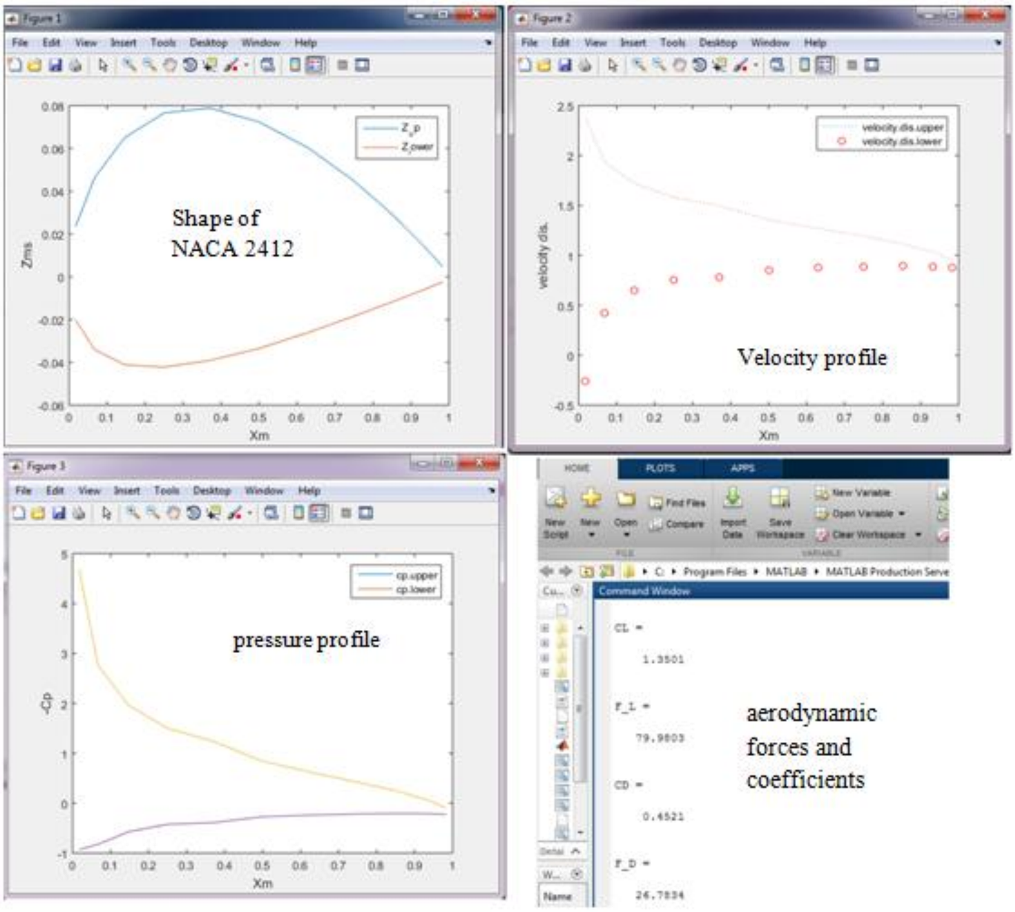

Figure 9. Result of the previous example of NACA 2412

The second part of the manual establishes the functions used in potential flow simulator to determine the aerodynamic forces. coefficients and aerodynamic characteristics in terms of velocity and pressure distribution. This potential flow simulator simulates the flow past bodies of arbitrary shape including airfoils. With this simulator, Students can do the following tasks

- Compute and plot the Velocity Vector Plot of the flow past the selected body.
- Compute and plot the Pressure Distribution.
- Compute and plot the aerodynamic coefficients in terms of lift and drag.

The steps description of determination the aerodynamic forces and characteristics of any selected body including airfoil using the potential flow simulator are discussed as follow

a) Starting the Advanced Potential Flow Simulator

The application can be run via the MATLAB command line by using the command *AdvancedPotentialFlowSimulator*.

b) Elements of the User Interface

It contains the following items (Figure 10)

1. Add elements: To add an element, the type has to be selected in the drop-down menu. After the parameters are inserted in the corresponding text fields, the choice is confirmed by clicking Add. By using the button Load Airfoil airfoils can be loaded.
2. Table of elements: All manually or automatically created elements appear inside the element table. Every parameter can be changed afterward. (
3. Menu bar: Tools for navigating the plot are placed in the menu bar.
4. Plot: The plot shows different visualizations of the current problem according to

   the settings.
5. Export: The potential, the vector field as well as the plot figure can be exported. Furthermore, particle animation can be started here.
6. Settings: Reset resets the element table to its original state. The settings are not altered. Settings open the settings where the visualization can be configured.

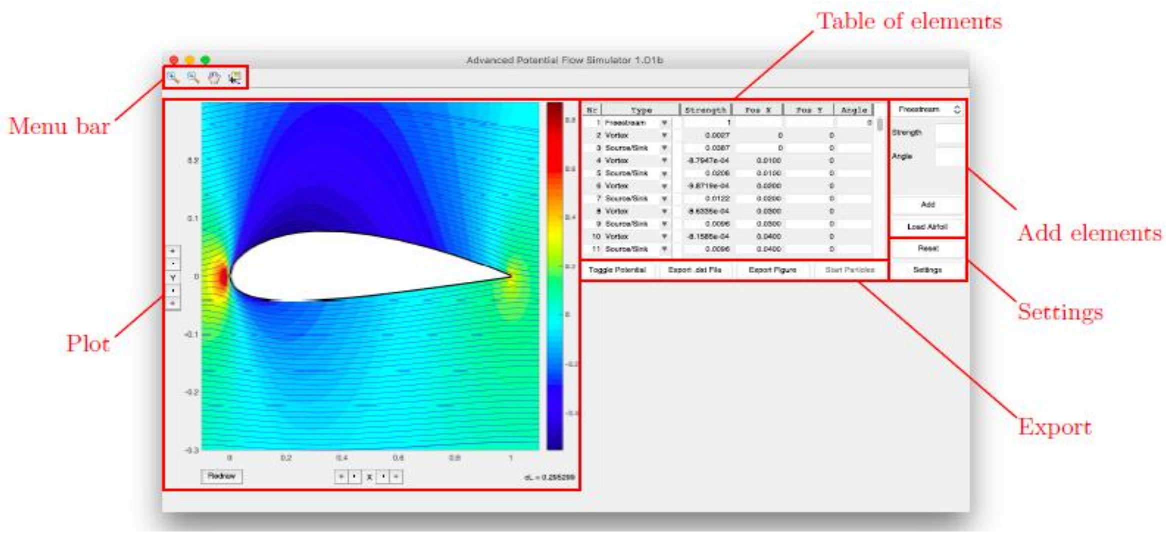

Figure 10. User interface

6. STATISTICAL PROCESSING

The researchers in the following statistical processing used the Statistical Package (SPSS) for analyzing all processes:

- Calculating the median.
- Calculating the standard deviation.
- T-test to examine the difference between the performance of control and experimental groups.

7. STUDY TOOLS

In this section, the researchers designed 6 undergraduate projects to fourth-year Bachelor's degree students. The aim of these projects to show how Matlab software will help and support the students to understand the concept of energy courses in terms of Fluid Mechanics, Boundary layer, Aerodynamic courses. Also, They aim to let the students understand the real world.

In general, these projects were to (1) estimate the effect of wind speed on the aerodynamic characteristics of symmetrical and unsymmetrical airfoil, (2) develop and sketch an airfoil of high cambered section and show the relationship between attack angle and aerodynamic coefficient for airfoil (3) show the velocity distribution around the airfoil using numerical methods, Matlab code developed by the researchers and potential flow simulator.

Therefore, the researcher divided students into four groups as follow;

i. The first group will use general Matlab code(developed by the researchers)
ii. The second group will use advanced potential flow simulator
iii. The third group will use the traditional method
iv. The fourth group will use all methods (Matlab software and traditional method)

They were conducted during a six-week period to fourth-year Bachelors degree students of the course especially who were taking Fluid Mechanics II and Wind Engineering courses, after the all groups assignment had been handed in, graded and presented in the classroom.

After the presentation for these project, The researchers conducted an academic achievement test, with the help of the curriculum instructors, which covers all aspects of the projects to measure the different levels of academic achievement not memorizing. The test included 20 questions divided into two kinds of questions:

i. Fundamental questions (5 questions)
ii. True and False (5 equations)
iii. Multiple-choice (10 questions), each one included four answers and the student choose the right one.

The test was made in an objective way and it was submitted to a group of arbitrators to judge it scientifically and pedagogically, in terms of the scientific material, its suitability to students and the clarity of its form (the arbitrators were teachers of the curriculum).

8. THE STUDY RESULTS AND ITS DISCUSSION

After applying the experiment, the researcher conducted a post-academic achievement test then they analyzed the study outcomes to figure out the impact of using SW-P on Mechanical Engineering students' academic achievement and the results were as follows:

8.1 Results related to the first and second questions

Q1. Can Matlab software help the mechanical students to understand the real world?

Q2. Is Mechanical Engineering students' willingness to use Matlab related to their use of computer technology for understanding the courses very well?

After getting the statistical results of the test (T-test) of the groups, the positive impact of using Matlab software was clear on teaching and understanding the real world and on better scientific academic achievement of groups who used Matlab software compared to other group who used traditional method, which proves that using Matlab software in education is an effective means of reaching a better learning.

8.2 Results related to the third question

Q3. Are there any statistically significant differences between the average marks of the groups in the T-test measurements?

To answer this question the mean and the standard deviation of the academic achievement test for the groups were extracted as shown in Table 2.

Moreover, Figure 11 shows the effect of using Matlab software and traditional methods on the score of the groups. It is observed that the fourth group (used all methods, Matlab software, and traditional methods) has the maximum mean score compared to group 2 and 3, while Group 1 has a minimum mean score. In addition, it can be noticed that there is no significant difference between group 2 and 3 in term of the mean score of the test.

It can be concluded that Matlab software helped the student to understand the concept of the courses and to increase their ability to understand the real world.

Table 2. Results of the pre-academic achievement test for the control and experimental groups

Descriptive

Group	Number of question	Mean	Standard Deviation	Standard Error	Between- Component Variance
1	20	6.0500	2.41650	.54035	1.59357
2	20	7.7500	1.77334	.39653	
3	20	7.9000	2.10013	.46960	
4	20	9.3000	.92338	.20647	

ANOVA

Parameters			Degree of freedom (df)	Mean Square	F	P-value
Between Groups	**(Combined)**		3	35.433	9.948	.000
	Linear Term	Contrast	1	98.010	27.517	.000
		Deviation	2	4.145	1.164	.318
	Quadratic Term	Contrast	1	.450	.126	.723
		Deviation	1	7.840	2.201	.142
	Cubic Term	Contrast	1	7.840	2.201	.142
Within Groups			76	3.562		

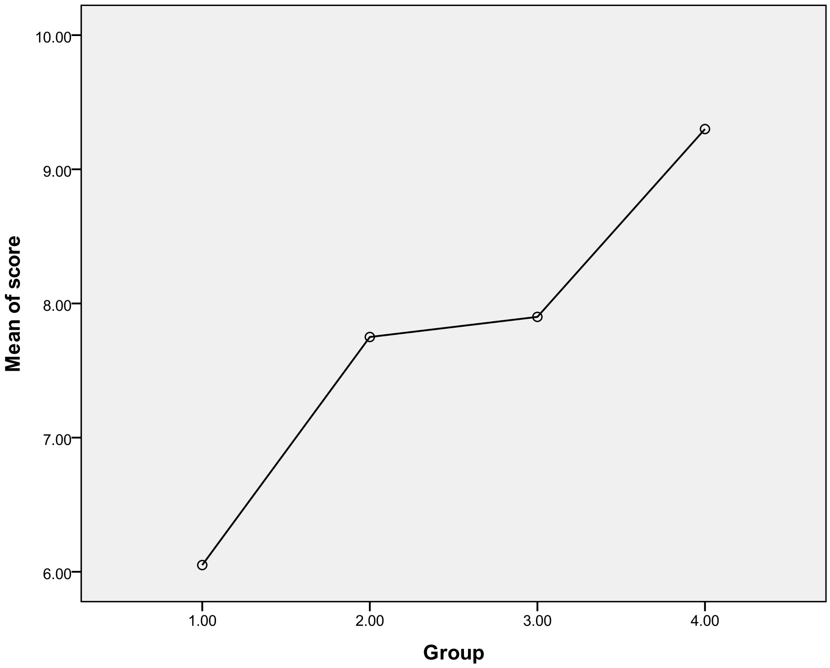

Figure 11. Mean plot of score vs. group

9. STUDY RECOMMENDATIONS

According to the study results which indicated the effective use of multimedia compared to the traditional methods of teaching, the study recommends the following:

- Using Matlab software in other courses for Engineering Department especially Mechanical Engineering Department.
- Giving training courses to the teachers regarding the use of Matlab software in teaching educational subjects provided that these courses will be available over the academic year.
- Conducting more studies on using Matlab software in the academic curriculum at the University.

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Conflict of Interest

All authors have no conflict of interest in this study.

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