An effective computational tool for teaching and learning Velocity Triangles of Hydraulic Turbines

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Abstract

This paper presents an investigation about utilizing computational tools applied to specific issues of the Turbo machinery. This subject is concentrated by third-year understudies in B.S. Mechanical Engineering Program. These understudies have previously learned the Fluid mechanics, which is required in structuring distinctive machine components. While teaching Turbo machinery, understudies frequently become overpowered by an incredible number of hypothetical ideas, loads of recipes, and references from information handbooks. In some cases it is helpful to utilize an intuitive learning condition, for example, a computing environment. In this way, activities utilizing computers are required to upgrade dynamic learning. This paper will give another method of showing the turbo machinery through Excel/VBA. A capable computer program which can change the method of your comprehension of the subject and assignments which won't be restricted to the classroom. This tool can be introduced among the students as well as among teachers. Providing students with this tool help them in getting rid of large calculations and it will also help them to see different variations in values which will help them to understand the concepts as well as it is a good way to improve the motivation of students towards the subject. It will also help teachers to teach different types of concepts not only just few concept as it takes time due to its lengthiness. Students can also use it as a tool in designing parts of the project. Besides solving the equations this tool can also provide how each parameter affects different forces. Therefore students can perform as many calculations just with a single click and without any mistake or being bored.

Keywords: *Computational tool, turbomachinery tool, Excel VBA, innovative pedagogy, engineering tool*

1. Introduction

In recent times integration of computational tools into teaching- learning has become crucial part essentially when it comes to learning of different software skills such as designing and analysis. A competent computer program is like a second instructor as students can rely and refer to it anytime they want. In particular, this integration has refrained students from lengthy calculation required to solve complex problems in engineering application. This in turn has led the students to think out of the box and analyze the end result obtained from the lengthy calculation which cannot be done without a computer. We can plot vivid graphs by varying different parameters and study its variation with only a click.

There are various platforms which allows the user to create computational tools they are

1. Pyro
2. Python
3. Sci-lab
4. Matlab
5. MS Excel/VBA
6. Wolfram CDF
7. Cycle-pad and etc.

Out of these platforms we choose Excel/VBA because it provides user-friendly environment to learn such concepts through computers by changing parameters and obtaining lively solution just in a click without worrying about the errors. This tool helps us to answer difficult questions such as why we require this modification and what outcome will it give without going to an actual industry. Scaled live graph helps in to answer such questions which are not generally mentioned in books and accelerating learning through visualisation. Excel/VBA is like a hidden treasure, we need to dig deeper into it to explore its application. It has a very user friendly interface and variety of specification which helps to create

conceptualized tools. This interface need not require any additional downloads of plug-ins for its use.

Turbo-machinery is one of the toughest subjects for mechanical as well as civil engineering sophomore students. It consists of analysis of different types of hydraulic and impulse turbines which are difficult to visualize. Engineers can only excel in their field when they have in depth knowledge of the subject and have analysed these concept with real world application. Mechanical engineers should learn every concept by putting them in shoes of an industrial person then only they can serve industry or organisation at their best. Normally, the students are informed of the effects of varying input parameters and its effect on the efficiency of turbine but due to complex calculation they could never try to analyze it. This tool bridges this gap and allows the students to play with the tool and visualize the concept.

In this paper you will get an insight of hydro-kinetic turbine followed by equations used to solve them and its specification. Finally a comprehensive problem is solved and explained by using Excel/VBA.

2. Hydraulic Turbines

The significant rule of water development is to decrease the amount of energy lost as heat. These are the significant reasons why hydropower is an alluring field for further development. (b) To work on hydropowerhydraulic turbines are needed depending on specific requirements and accessible river conditions. Hydraulic turbine is a pressure-driven turbine using the potential or kinetic energy of water and changes over it into mechanical energy in the form of runner rotation. They are a vital source of producing electricity as no fuel is required, a long lifetime of structure and machinery, and can be used on a large scale as well as small scale. They also used in industry to recycle industrial wastewater to generate electricity and in agriculture to move sprinkler trolley (a).Based on the type of stream and

head they are classified into reaction and impulse turbine.

Where, V_{r1} = jet velocity relative to bucket at inlet (m/s),

V_{w1} = velocity of whirl at inlet (m/s),

u_1 = tangential velocity of wheel at inlet (m/s),

V_2 = absolute velocity of water at outlet (m/s),

V_{r2} = jet velocity relative to bucket at outlet (m/s),

V_{w2} = velocity of whirl at outlet (m/s),

u_2 = tangential velocity of wheel at outlet (m/s),

V_{f2} = velocity of flow at outlet (m/s),

β = angle made by the absolute velocity with the direction of vane motion,

α = angle made by the relative velocity with the direction of vane motion.

2.1 Impulse Turbine

2.1.1 Pelton Wheel

The Pelton wheel is an example of impulse turbine used for its high head and low flow. The forte of the turbine is its easy manufacturing, reliability and cheap rate. The hydraulic energy of water (potential energy) is converted to kinetic energy. The water from the penstock is impinged on the blade of turbine through a nozzle as a result the runner starts moving and hydroelectricity can be produced which can be seen in (Oo, Nyi, & Khaing, 2019). The inlet and outlet velocity triangle can be observed from Figure 1(a) and the other two cases.

➤ Velocity triangle calculation of Pelton turbine

Inlet velocity calculation

From Figure 1(a) it can be seen that the inlet parameters like $\alpha = \beta = V_{f1} = 0$.

Outlet velocity triangle calculation

In Figure(c) the velocity of whirl is zero.

- Calculation of V_1

$$V_1 = K_v \sqrt{2 * g * H} \quad \text{(Equation 1)}$$

It is known that, the actual velocity of the water jet (considering friction loss in nozzle) (V_1)

Where,

K_v = Coefficient of velocity and its value is taken as 0.985 as in (Oo, Nyi, & Khaing, 2019)

H = Net Head available.

- Calculation of u

According to (Oo, Nyi, & Khaing, 2019) the tangential velocity at inlet and outlet is equal at mean pitch. Therefore,

$$u_1 = u_2 = u \quad \text{(Equation 2)}$$

And

$$u = \frac{\pi * D * N}{60} \quad \text{(Equation 3)}$$

Where,

D = Pitch circle diameter of Pelton wheel and N = RPM of turbine runner.

- Calculation of V_{r1}

From Figure 1(a) it can be written

$$V_{r1} = V_1 - u_1 \quad \text{(Equation 4)}$$

By the study of extant literature of (Oo, Nyi, & Khaing, 2019) it can be assume that the bucket surfaces is smooth and energy losses due to impact at turbine is neglected, $K=1$. So,

$$V_{r1} = V_{r2}$$

- Calculation of V_{f2}

The outlet flow velocity can be obtained by applying sine rule in all the three cases.

In outlet triangle of Figure 1(a), (b) and (c) by using (Equation 5) to find the flow velocity at outlet.

$$V_{f2} = V_{r2} * \sin \beta \quad \text{(Equation 5)}$$

The value of V_2 can be calculated in all three cases as shown in Figure 1 by using Pythagoras theorem as

- Calculation of V_2

$$V_2 = \sqrt{V_{f2}^2 + V_{w2}^2} \quad \text{(Equation 6)}$$

- Calculation of V_{w2}

In outlet triangle of (b) and (a) respectively velocity of whirl at outlet can be find out by using

$$V_{w2} = \frac{V_{f2}}{\tan 180 - \alpha} \quad \text{(Equation 7)} \quad \text{And} \quad V_{w2} = \frac{V_{f2}}{\tan \alpha} \quad \text{(Equation 8)}$$

In Figure 1 (c) the velocity of whirl (V_{w2}) is zero.

➤ A Sample Problem

The input values to our Excel/VBA program is obtained from (Oo, Nyi, & Khaing, 2019) and its output values are checked by entering the input parameters in our Excel/VBA interface. It requires a Pelton wheel which outputs power of 220kW working under a head (H) of 213m. The Rpm (N) of the turbine is 1000 and $\beta=17.14^\circ$. The angle made by relative velocity to the direction of vane motion (α) is 66° . The pitch circle diameter of 0.56m is taken and friction factor (K) =1. The above input is entered in our program to obtain a solution which is shown in Figure 2.

Input parameters

$D=0.56\text{m}$; $N= 1000$; $H= 213\text{m}$; $K=1$; $\alpha=66^\circ$ and $\beta=17.14^\circ$

Above parameters are entered in the “INPUT PARAMETERS” column shown in Figure 2 and the output values and the graph of exit velocity triangle can be calculated.

Velocity triangle gets plotted as soon as input parameters are entered in the desired cell in Excel/VBA. For better user experience and compatibility slider bars are also added. Now the user can set the values by just clicking on it.

The actual values of the velocities may differ from the solution as obtained in Figure 2 due to some assumptions. The output is intent to increase the analytical ability of students to understand the insight of velocity triangles and not just rely on numerical values of problem.

Figure 2 Solution of problem by using Excel/VBA

The numerical and graphical representation as seen in Figure 2 is obtained through following steps and method:-

Step 1: The programming is done in Excel/VBA environment to make it user friendly and compact in nature.

Step 2: Calculation of output.

- The value of “u” is calculated from (Equation 2)&(Equation 3) . The value of Mean diameter (D) and RPM (N) is entered in cell E7 and E8 respectively as shown in Figure 2 and these values gets entered in the VBA program coded with the required equations and the output is obtained in cell E16 as shown in Figure 2.
- The value of “V_{r2}” is calculated from (Equation 4) and the value of “V₁” is calculated from (Equation 1). The value of Operating head (H) is entered in cell E9 as shown in Figure 2 and its value gets entered in VBA program coded with the required equation and the output is obtained in cell E19 as shown in Figure 2.
- The value of “V_{f2}” is calculated from (Equation 5) and the value of “ β ” is entered in cell E12 as shown in Figure 2 and its value gets entered in VBA program coded with the

required (Equation 5) and the output after calculation is obtained in cell E18 as shown in Figure 2.

- The value of “ V_2 ” is simply calculated using (Equation 6) and the output after calculation is obtained in cell E17 as shown in Figure 2. The values required for calculation is automatically entered in VBA program internally and the user need not to enter any input separately.
- The value of “ V_{w2} ” is calculated from (Equation 7)&(Equation 8) depending upon the different cases of α as shown in Figure 1. The desired equation gets entered automatically as soon as user has entered the value of α in cell E11 as shown in Figure 2, Then the VBA calculates it and the result gets output in cell E20 as shown in Figure 2.

Step 3: Coordinates for plotting the velocity triangle in excel.

	A	B	C
1	Exit velocity triangle coordinates		
2			
		X co-ordinates	Y co-ordinates
3		↓	↓
4	blue- S	0	0
5	blue- E	293	0
6			
7	red- S	333.00	89.9
8	red- E	0	0
9			
10	yellow- S	333.00	0
11	yellow- E	333.00	89.9
12			
13	green- S	333.00	89.9
14	green- E	293	0
15			
16	pink- S	293	0
17	pink- E	333.00	0

Figure 3 Co-ordinates for exit velocity triangle

- Each output values in Figure 2 represent a velocity vector which has a color assigned to it as shown in Figure 1 (The same 5 colors can be seen in Figure 3 which depicts those vector's x and y coordinates).
- To plot a vector two points i.e. Start and end points (or any two points) are required. In the code it has been considered as the start and end points. So blue_S in Figure

3 represents blue color vector's starting x and y coordinate point in adjacent cells and blue_E in Figure 3 represents blue color vector's ending x and y coordinate point in adjacent cells (equals to the magnitude). For proper scaling each vector has been multiplied by the factor of 10.

- The start coordinates of V_{w2} (pink_S as shown in Figure 3) is the end coordinates of u (blue_E as shown in Figure 3) and the end of V_{w2} (pink_E as shown in Figure 3) is either $(u+V_{w2})$ or $(u-V_{w2})$ depending whether α is less than 90 or greater than 90 respectively.
- The start coordinates of V_{f2} (yellow_S as shown in Figure 3) is the end coordinates of V_{w2} (pink_E as shown in Figure 3) and the end coordinates of V_{f2} (yellow_E as shown in Figure 3) is (x co-ordinate of V_{w2} , Magnitude of V_{f2} (value in cell E 18 as shown in Figure 2)).
- The start coordinates of V_{r2} (red_S as shown in Figure 3) is the end coordinates of V_{f2} (yellow_E as shown in Figure 3) and the end coordinates of V_{r2} (red_E as shown in Figure 3) is origin as shown in Figure 1.
- The start coordinates of V_2 (green_S as shown in Figure 3) is the end coordinates of V_{f2} (yellow_E as shown in Figure 3) and the end coordinates of V_2 (green_E as shown in Figure 3) is the end coordinates of u (blue_E as shown in Figure 3).

Carefully enter the values of each coordinates as they are interrelated to each other.

Following the above mentioned steps and knowledge of Excel/VBA programming helped us to complete the interface as shown in Figure 2.

2.2 Reaction Turbine

2.2.1 Francis Turbine

As explained in (Bansal, 2010), Francis turbine is inward flow reaction turbine with radial discharge at the outlet. Modern Francis turbine is called mixed flow reaction turbine as water enters in the runner in radial direction at outlet and leaves in axial direction at inlet of the runner. Radial discharge at outlet means absolute velocity vector (V_2) and wheel's tangent (u_2) are perpendicular. Another way to interpret it is that the whirl velocity at outlet is zero

($V_{w2} = 0$). This also means limiting the three outlet cases to one case i.e. ($\alpha_2 = 90^\circ$) to reduce our kinetic losses and maximize the output efficiency which makes the flow velocity at exit (V_{f2}) equal to the exit velocity (V_2). The inlet and outlet velocity triangle of Francis turbine is shown in Figure 4(d). The other two cases of inlet velocity triangle are shown in Figure 4 (e) and (f).

2.2.2 Kaplan Turbine

Kaplan turbine is axial flow reaction turbine as direction of flow of water is parallel to the axis of the rotating shaft. It differs from propeller turbine as the vanes of the hub are adjustable in Kaplan turbine. It differs from Francis turbine as the inlet and outlet peripheral velocity is equal in case of Kaplan turbine. Kaplan turbine is known to be evolved from Francis turbine. The calculation of inlet peripheral velocity is also different in this case. The inlet velocity cases for Kaplan turbine is same as Francis turbine and is shown in figure 4 (d),(e) and (f).

Velocity triangle calculation for Kaplan and Francis turbine

Inlet velocity triangle of Francis and Kaplan turbine

There are three possible cases of inlet velocity triangle which is shown in figure 4 (d),(e) and (f) and different velocities are to be calculated according to the inlet condition.

- Calculation of u_1 (peripheral velocity)

From (Bansal, 2010) it is known that

$$u_1 = \frac{\pi * D_1 * N}{60} \quad \text{(Equation 9)}$$

Where, D_1 = outer diameter of runner and N = RPM of runner (as input by user)

- Calculation of V_{f1} (Inlet flow velocity)

From (Bansal, 2010)it is known that $V_{f1} = V_{f2}$ i.e. Inlet flow velocity is equal to outlet flow velocity and its value is equal to

$$V_{f1} = k_f * \sqrt{2 * g * H} \quad \text{(Equation 10)}$$

Where, k_f = Flow ratio and it varies from 0.15 to 0.30. In our calculation it is considered as 0.20.

H = Net head available as input by user.

- Calculation of V_{w1} (whirl velocity)

V_{w1} should be found out separately for all the cases and value of β_1 will be input by user.

Case 1:when $\beta_1 > 90^\circ$ as shown in figure 4 (d)

$$V_{w1} = u_1 + (V_{f1} \cot(180 - \beta_1)) \quad \text{(Equation 11)}$$

Case 2:when $\beta_1 < 90^\circ$ as shown in figure 4 (e)

$$V_{w1} = u_1 - (V_{f1} \cot(180 - \beta_1)) \quad \text{(Equation 12)}$$

Case 3:when $\beta_1 = 90^\circ$ as shown in figure 4 (f)

$$V_{w1} = u_1 \quad \text{(Equation 13)}$$

- Calculation of V_1 (Jet velocity)

Applying Pythagoras theorem on inlet velocity triangle following equation is obtained

$$V_1 = \sqrt{V_{f1}^2 + V_{w1}^2} \quad \text{(Equation 14)}$$

For all the three cases shown in Figure 4 (d), (e) and (f) it holds true

- Calculation of V_{r1} (Relative velocity at inlet)

Applying Pythagoras theorem on inlet velocity triangle of Figure 4 (d) and (f) equation obtained is:-

$$V_{r1} = \sqrt{V_{f1}^2 + (V_{w1} - u_1)^2} \quad \text{(Equation 15)}$$

And for $\beta_1 = 90^\circ$ as shown in figure 4 (f) it can be said that

$$V_{r1} = V_{f1} \quad \text{(Equation 16)}$$

- Calculation of α_1 (Inlet guide vane angle)

For all the three cases in Figure 4 (d), (e) and (f) it can be seen

$$\alpha_1 = \tan^{-1} \frac{V_{f1}}{V_{w1}} \quad \text{(Equation 17)}$$

Outlet velocity triangle of Kaplan and Francis turbine

By taking the no whirl condition at outlet i.e. ($V_{w2} = 0$) (as shown in Figure 4(d)) to minimize the kinetic losses and maximize the output efficiency.

- Calculation of u_2 (Peripheral velocity)

For Francis turbine,

$$u_2 = \frac{\pi * D_2 * N}{60} \quad \text{(Equation 18)}$$

Where, D_1 = inner diameter of runner ($D_2 = \frac{D_1}{2}$) and N = RPM of runner (as input by user)

For Kaplan turbine,

$$u_1 = u_2 \quad \text{(Equation 19)}$$

- Calculation of V_{r2} (relative velocity)

For Francis turbine,

Applying Pythagoras theorem in figure 4 (d) equations obtained is

$$V_{r2} = \sqrt{V_{f1}^2 + u_2^2} \quad \text{(Equation 20)}$$

For Kaplan turbine

$$V_{r_2} = \sqrt{V_{f_1}^2 + u_1^2} \quad \text{(Equation 21)}$$

- Calculation of β_2 (Outlet blade angle)

For Francis turbine,

$$\beta_2 = \tan^{-1} \frac{V_{f_1}}{u_2} \quad \text{(Equation 22)}$$

For Kaplan turbine,

$$\beta_2 = \tan^{-1} \frac{V_{f_1}}{u_1} \quad \text{(Equation 23)}$$

A Sample Problem

The following data is given for a Francis turbine as in Problem 18.24 of (Bansal, 2010)

Flow ratio (k_f) = 0.2; Working head (H) = 60m; RPM of runner (N) = 700rpm; inlet blade angle = 138.91° ; outer diameter of runner (D_1) = 0.54m. Determine guide blade angle, guide vane angle, outlet blade angle, inlet whirl velocity and relative velocity at inlet also draw the graph of inlet and exit velocity triangle.

The above values are input to our Excel interface and the solution can be seen in figure 5. It can also be seen that the velocity triangle gets plotted as soon as any input parameters are changed. Velocity triangle gets plotted as soon as input parameters are entered in the desired cell in Excel/VBA. For better user experience and compatibility slider bars are added. Now the user can set the values by just clicking on it.

The actual values of the velocities may differ from the solution as obtained in Figure 5 due to some assumptions. The output is intent to increase the analytical ability of students to understand the insight of velocity triangles and not just rely on numerical values of problem.

Figure 5

The numerical and graphical representation as seen in Figure 5 is obtained through following steps and method:-

Step 1: The programming is done in Excel/VBA environment to make it user friendly and compact in nature.

Step 2: Calculation of output

- The value of " u_1 " and " u_2 " is calculated from (Equation 9), (Equation 18) and (Equation 19) according to the type of turbine selected by the user. The value of D_1 is entered in cell G10 as shown in Figure 5 and the values get entered in our VBA program coded with the equations and the output is obtained in cell G21 and G29 respectively as shown in figure 5.
- The value of " V_{f1} " is calculated from (Equation 10) and it is same for both the turbine. The value of k_f and H is entered in cell G8 and G11 respectively as shown in figure 5 and the values get entered in our VBA program coded with the equations and the output is obtained in cell G23 and G31 respectively as shown in figure 5.
- The value of " V_{w1} " is calculated from (Equation 11), (Equation 12) and (Equation 13) and it is same for both the turbine. The value of β_1 in cell G6 as shown in figure 5 will

determine the required equation for calculation. The values get entered in our VBA program coded with the equations and the output is obtained in cell G22 as shown in figure 5.

- The value of “ V_1 ” is calculated from(Equation 14) and the output is obtained in cell G24 as shown in figure 5.
- The value of “ V_{r1} ” is calculated from(Equation 15) and (Equation 16) depending upon the type of turbine chosen by the user and the output is obtained in cell G25 as shown in figure 5.
- The value of “ α_1 ” is calculated from(Equation 17) and the output is obtained in cell G27 as shown in figure 5.
- The value of “ V_{r1} ” is calculated from(Equation 20) and (Equation 21) depending upon the type of turbine chosen by the user and the output is obtained in cell G31 as shown in figure 5.
- The value of “ β_2 ” is calculated from(Equation 22) and (Equation 23) depending upon the type of turbine chosen by the user and the output is obtained in cell G30 as shown in figure 5.

Step 3: Coordinates for plotting the velocity triangle in excel.

Inlet Velocity Triangle

Negative sign in velocity represents direction of flow of water.

- The start coordinates of u_1 (blue_S as shown in figure 6) is origin i.e. (0, 0) and the end coordinates (blue_E as shown in figure 6) are (Magnitude of u_1 , 0).
- The start coordinates of V_{w1} (pink_S as shown in figure 6) is origin and the end coordinate (pink_E as shown in figure 6) are (Magnitude of V_{w1} , 0).
- The start coordinates of V_{f1} (yellow_S as shown in figure 6) are same as end coordinates of V_{w1} and the end coordinates (yellow_E as shown in figure 6) are (Magnitude of V_{w1} , - Magnitude of V_{f1}).

- The start coordinate of V_{r1} (red_S as shown in figure 6) are same as end coordinates of u_1 and the end coordinates (yellow_E as shown in figure 6) are same as end coordinates of V_{f1} .
- The start coordinate of V_1 (green_S as shown in figure 6) is origin and the end coordinates (green_E as shown in figure 6) are same as end coordinates of V_{f1} .

	A	B	C
1			
2			
3	Inlet velocity triangle		
		X co-ordinates	Y co-ordinates
4
5	blue- S	0	0
6	blue- E	197.9	0
7			
8	red- S	197.9	0
9	red- E	276.6	-68.6
10			
11	yellow- S	276.6	0
12	yellow- E	276.6	-68.6
13			
14	green-S	0	0
15	green-E	276.6	-68.6
16			
17	pink- S	0	0
18	pink- E	276.6	0

Figure 6

OUTLET VELOCITY TRIANGLE

The velocities are multiplied by 10 for proper interpretation of graph.

Exit velocity triangle		
	X co-ordinates	Y co-ordinates

blue- S	99	0
blue- E	0	0
red- S	99	68.6
red- E	0	0
yellow- S	99	68.6
yellow- E	99	0

Figure 7

- The end coordinates of u_2 (blue_E as shown in figure 7) is origin i.e. (0, 0) and the start coordinates (blue_S as shown in figure 7) are (Magnitude of u_2 , 0).
- The start coordinates of V_{f2} (yellow_S as shown in figure 7) are (Magnitude of u_2 , Magnitude of V_{f2}) and the end coordinates (yellow_E as shown in figure 7) is start coordinates of u_2 . It is already known that $V_{f2}=V_{f1}$
- The start coordinates of V_{r1} (red_S as shown in figure 7) is the start coordinates of v_{f2} and the end coordinates (red_E as shown in figure 7) is origin i.e. end coordinates of u_2 .

3. Hypothesis results and student acceptance

Hypothesis testing is the conventional methodology that examiners use to test whether a hypothesis can be acknowledged or not with respect to a populace boundary. A hypothesis is essentially a presumption about something. During the hypothesis, we need to accumulate an ever increasing number of information with the goal to demonstrate our hypothesis one way or the other. There are several numbers of tests which are used for hypothesis testing according to population and type of data. The test which suited us the most was “t-test”.

“Two-sample t-test” is used to compare two continuous data distribution in many fields generally to check the compatibility of the product. This is done by considering a reverse hypothesis or null hypothesis in which we consider that there is no difference between the two groups. The “two sample t-test” calculate the hypothesis value by taking the mean of the individual group and compare it with null hypothesis to tell us whether the data considered for the hypothesis is acceptable or not. It generally brings out the opinion of the public regarding the product.

There is “t-test” tool in the Data Analysis tool pack in excel in which variable range is selected and it automatically gives the value of variance, mean, number of observation and P-value one tail and two tail.

P-value is an important thing in factual hypothesis testing. It is a short for probability value. It is essentially used to evaluate the possibility of factual significance of proof. It is either

expressed in percentage or decimal to reject or support null hypothesis. The P-value has been calculated with the help of in-built function in Microsoft excel.

This computational tool can be used with the course of Turbo machinery to facilitate the understanding of the course. To test the usefulness of Turbo machinery tools, the Excel/VBA file was uploaded to <https://www.drkarnteaching.com/turbomachinery-tools> and it was given access to 50 undergraduate 3rd and 4th year students.

In answering the hypothesis, the students have to give a rating from 1 to 5 (1-Strongly Disagree to 5- strongly agree). The results of the Hypothesis were analyzed by performing t-test on it. It is a familiar test and used to calculate probability and test hypothesis. The analysis of the 6 hypothesis is given below :-

1. Overall acceptance of new pedagogy -

Figure 8

It can be seen from figure 8 that a majority, 94% strongly agree (5) or agree (4) with the new way of teaching pedagogy. It concludes that the new teaching pedagogy helped their ability to visualize the principles and concepts of turbo-machinery. 6% (neither agree or disagree- 3) are unsure about the new teaching pedagogy perhaps these students found Excel/VBA difficult to operate or did not enjoy the course material. The interesting fact is that no one disagrees with our new teaching-learning pedagogy.

2. Improvement in quality of teaching

Figure 9

The figure 9 shows that students responses were split with 94% (strongly agree-5 and agree-4) obtaining positive response to improvement in quality of teaching. It states that students found this pedagogy better than teaching through power point presentation. 6% (neither agree or disagree-3) students are unsure about the pedagogy perhaps they not accustomed towards the instructor. 0% students disagree that this method of teaching learning will not improve quality of teaching. The students who find the subject useless might start studying it.

3. Retention of Students Interest

Figure 10

From figure 10 it can be seen that 94% (strongly agree-5 and agree-4) of students did not lose their interest while studying through new teaching pedagogy. High interest of students shows that they are enjoying the new way of teaching-learning. Rest 6% are neutral with their decision (neither agree nor disagree-3) perhaps they did not pay attention to it carefully. This

may be due to a boring instructor or they did not enjoy the concept at all. No one finds that this method of teaching learning will make the study of difficult concept boring.

4. Facilitate Collective and Cooperative Peer Learning

Figure 11

From figure 11 it can be seen that 90% students strongly agree (5) and agree (4) with the fact that this teaching pedagogy creates a collective and cooperative environment inside classroom. Participation of students has increased due to introduction of this method of learning. Rest 10% gave a neutral score of 3, perhaps they might not be regular in their classes and if they attend their classes they might get involved in the discussion as well. 0% students disagree that this teaching pedagogy will not facilitate collective and cooperative peer learning.

5. Reduction in difficult level of Subject

Figure 12

From figure 12 it can be seen that a majority, 93% students strongly agree (5) and agree (4) that this teaching pedagogy successfully reduces the difficulty level of subject. Now the

students can easily ponder on concepts and find it easy to grasp. 7% people responded in a neutral way and gave a score of 3, they might find the subject boring and don't find necessary to study it. If they wish to pay slight attention then they will find it less difficult than existing teaching pedagogy. No one finds that this teaching-learning method will increase the difficulty level of subject.

6. Integration of Computer in Engineering/Career Prospects

Figure 13

From figure 13 it can be seen that 83% of students strongly agree (5) and agree (4) that computers will prove to be useful in understanding difficult concepts when integrated with engineers. All complicated calculation will be done by computer and students will have time and potential to analyze the concept and draw suitable conclusion from the data. A dedicated team can work on the development of the computational tool and pursue their career for enhancing teaching learning experience. 17% students gave a neutral response, perhaps they found that developments of such tool require higher skill and it may take time for the universities to accept this idea. But from our hypothesis it is clear that these tools are easy to develop and institutions will accept it soon as students get benefit from it.

4. Combined Charts for 6 Hypothesis

Figure 14

From the figure 14 it can be clearly seen that for the entire hypothesis the p value (both one tail and two tail) is less than 0.05 which concludes that for all the above 6 hypothesis students responses were positive and the hypothesis can be successfully accepted.

Figure 8

The figure 15 compares the mean value of hypothesis and we can clearly observe that all the responses of hypothesis lies above 4.4 i.e. in between strongly agree and agree scale. It concludes that majority of students showed positive response for our innovative teaching pedagogy.

5. Conclusion

Hydraulic turbines are widely used in many industries and have troublesome concepts to grasp. Book composed knowledge is not enough to understand all the concepts from practical point of view. Engineers are known to make things simple and it is only possible if they themselves have analysed every concept and are able to apply it in real world. Mechanical engineers should learn the concepts by bringing themselves in the shoes of an industrial person and then only they can serve well in development of the organization they are working for. Visualization is the easiest and interesting way to do so.

Excel/VBA is a strong, easy and user-friendly platform which helps to build such lively tools which help in visualization and accelerate learning and answers to such mind boggling questions like why such change in particular dimensions or why we should we not use this set of values and what problem it will cause to the machine, thus saving the time and burden of tough calculation and find the best possible solution to the problem. Scaled, live graphs help to observe such changes without even bothering about mistakes to ease our understanding and by analysing the concepts our engineering will be beneficial to society.

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