Applying the General Analysis Procedure in solving an Engineering Problem – an Assessment

Javeed Kittur

Department of Electrical & Electronics Engineering, KLE Technological University, Hubballi
javeed@bvb.edu

Abstract: Analysis plays a vital role in all the engineering domains. All engineering problems require a systematic procedure to be followed to obtain a reasonable solution. An engineering student learning these skills in first year of engineering would be of great help to him/her as these skills can be applied throughout the engineering program in solving any given problem. The work presented in this paper focuses on how analysis and general analysis procedure was introduced at first semester. Also it highlights how this procedure was used to come up with a solution for any engineering problem.

Keywords: analysis; assessment; engineering analysis; engineering problem

1. Introduction

Analysis is defined as separation of a whole into its component parts, or an examination of a complex system, its elements and their relationships [1]. Engineering analysis majorly relies on basic mathematics and higher level mathematics may also be used. Physical sciences laws and principles are the engineering analysis key ingredients. Finding an equation that will solve an engineering problem, substituting values in the equation and getting the result is not engineering analysis. Systematic and logical thinking relating the engineering problem is required in engineering analysis [2].

As an engineer, the primary requirement that he/she must possess is stating the problem logically, concisely and clearly [3]. For the system under study which is being analyzed, an engineer should know the systems' physical behavior and understand the various scientific principles that can be applied. Recognizing a particular mathematical tool that can be used and also its implementation is an engineer's job. Generating solution which is in line with the assumptions stated and the problem statement must be done by the engineer. The solution contains no errors and is reasonable must be ascertained by the engineer [1].

Javeed Kittur

Department of Electrical & Electronics Engineering, KLE Technological University, Hubballi
javeed@bvb.edu

One of the most important things an engineering student learns during the program of study is how to approach an engineering problem in a systematic and logical fashion [2]. Meeting the society needs by devices and system design and manufacture can be considered as problem solving process. Hence problem solving process's major part is engineering analysis. An important key skill which an engineer must possess is problem solving. Systematic and logical solution methods must be made use of by the engineers to get a thorough and accurate engineering solution of the given problem. In order to attain a successful solution to the given engineering problem, correctly applying the solution methods is mandatory. Problem solving is an integral part in the thought process of an engineer [4].

Analysis is majorly focused in many engineering courses. It therefore becomes utmost important for a first semester student to have a thorough understanding of the fundamentals of analysis and how to perform analysis [5]. This is taught to the students in the course 'Engineering Exploration' in the first year at KLE Technological University, Hubli. The experiences from the Engineering Exploration course can motivate students to learn engineering analysis techniques and also form a cornerstone for the students' learning process. The general analysis procedure learning's from this course can be applied to all the courses that the students will come across in their tenure of engineering degree.

2. Methodology

The process from identifying an engineering problem that can be solved with data to collecting, organizing, interpreting, and drawing conclusions about the data requires students to involve in making many logical and systematic calculations. This study documents that path for students during the data analysis tasks when solving an engineering problem focused on engineering and physical science.

Specifically, this paper answers the following research questions: How do students navigate the process of formulating the problem statement and analyzing data as they work towards drawing conclusions supported by evidence in applied contexts?

The module ‘Role of Analysis in Engineering’ was taught to students starting with a question “Let's say you are a part of a team of engineers working to reduce the number of car accidents that occur during rush-hour traffic. Discuss in teams and come up with a detailed solution”. Students were then asked to share their solutions to the class and this led to discussions. When asked by the course instructor, about the entire process which students followed to come up with solutions as to what it is called then most of the students said it is ‘Analysis’. The students’ ideas and thinking process was taken in to the learning context of the module and then the text book definition of analysis was introduced.

After having discussed what exactly analysis is, the students were given another question “You are in a boat in an ocean with limited resources. Discuss in teams and give rank wise priority of the items to keep you alive until rescue arrives and **reason it out**”. To answer this question students were planning thoroughly and there was analysis involved majorly in their reasoning. Later Engineering Analysis was explained and then engineering failures and turning an engineering failure in to success was also discussed.

Before teaching the general analysis procedure, a problem statement, “Two resistors with resistances of 5Ω and 50Ω are connected in parallel across a 10V battery. Find the current in each resistor” was given to students and they just started solving in a hurry to get the answer and nobody followed any specific method in obtaining the result, no doubt their answer was correct. Later the general analysis procedure was taught (the step by step procedure shown below in fig 1) and the same problem was solved step by step following the learning’s from the general analysis procedure [1].

- **Problem Statement**
  It is writing the description of the given problem. The description written should be logical, concise and clear. The information given including the input data required to obtain the solution for the problem is summarized in the problem statement. The parameters to be determined through analysis are stated in the problem statement.

- **Diagram**
  The schematic, drawing or a sketch of the system under study is the diagram. It is a picture representing the actual system to be analyzed which includes details of the aspects of the system which are required to perform analysis. The complete information taken from the problem statement must be shown in the diagram.

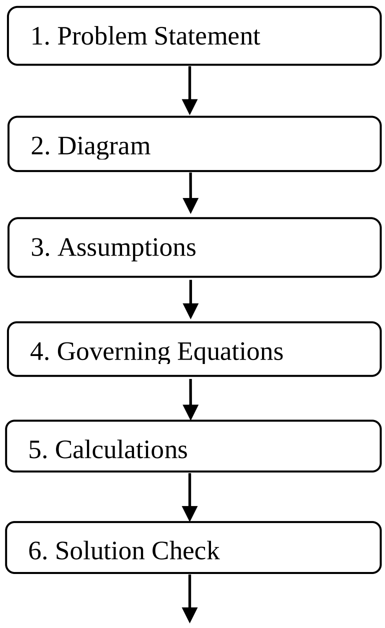
- **Assumptions**
  Few assumptions are always involved when an engineering analysis is done. Assumptions are statement of fact or belief about the given problem statement which helps in refining and simplifying the analysis. It may be very difficult to solve a complex problem without having made any assumptions.

- **Governing Equations**
  Writing mathematical equations relating the physical system is always helpful in analysis. These mathematical equations represent the basic definitions of engineering and physical laws.

- **Calculations**
  This step gives us the solution to the given problem statement. The solution is algebraically written first and then numerical values are plugged into these equations. The calculations are done using a computer or a calculator which gives the final result.

- **Solution Check**
  This step is very important. Examining the results carefully is essential after the results are obtained immediately. To check the solution’s reasonability, it is required to use common sense and knowledge of similar cases. Also each step of the analysis has to double checked, to remove errors if any.

- **Discussion**
  After obtaining the result and having it checked thoroughly, it must be discussed. Discussions generally involve the assumptions assessment, conclusion summary and experimental verification of the result.



7. Discussion

Fig. 1 General Analysis Procedure

Another example was discussed wherein, a 200kg crate was suspended by a rope and the students were asked to calculate the tension in the rope. Students followed the general analysis procedure to find the solution. As a part of homework students had to come up with a problem statement and also its solution following the analysis procedure. Most of the students came up with similar examples as discussed in class. After few weeks an assessment was done in the class to find out how many students are following the general analysis procedure taught in class.

The problem given to students during the assessment is as follows “A company manufactures boxes with 200 x 300 x 400 mm dimensions, and the cardboard is of 5mm thickness. Calculate how much space is available inside this cardboard box? If thickness is reduced to 4mm thickness, then what % of volume is increased?”

Students were asked to solve this problem in a team of four and once the team was ready with their answer, the solution to this problem was displayed to the students. Later a checklist was passed to the students which looked like this,

KLE Technological University, Hubballi **Centre for Engineering Education Research**

CHECKLIST	
Semester/Division: I /	Date:
Course Title: Engineering Exploration	Team Number:

Tick which of the following steps you used in arriving at a solution to the given problem

1. Formulating Problem Statement ☐
2. Drawing the Schematic/Diagram ☐
3. Making Assumptions ☐
4. Listing Governing Equations ☐
5. Performing Calculations ☐
6. Having Solution Check ☐
7. Verifying through Discussions ☐
8. Is your solution matching the exact solution: Yes/No

3. Results

Table 1. Priority wise ranking of general analysis procedure steps of each division

Rank	Division A	Division B	Division C	Division D	Division E	Division F	Division G
1	Calculation (15)	Calculations (17)	Calculations (18)	Calculations (16)	Calculations (16)	Problem Statement (16)	Calculation (17)
2	Discussion (14)	Equations (15)	Equations (17)	Discussion (16)	Problem Statement (15)	Assumptions (14)	Assumption (13)
3	Solution Check (13)	Discussion (13)	Problem Statement (17)	Problem Statement (16)	Equations (14)	Calculations (14)	Discussion (13)
4	Assumptions (12)	Assumptions (12)	Assumptions (16)	Equations (13)	Discussion (12)	Diagram (14)	Equations (13)
5	Equations (12)	Problem Statement (11)	Diagram (14)	Solution Check (13)	Assumptions (9)	Discussion (12)	Problem Statement (13)
6	Problem Statement (11)	Diagram (8)	Discussion (14)	Diagram (12)	Diagram (9)	Solution Check (11)	Diagram (10)
7	Diagram (8)	Solution Check (5)	Solution Check (13)	Assumptions (10)	Solution Check (8)	Equations (10)	Solution Check (5)

No. of Correct Solutions (71)	14/15	5/17	10/18	12/16	8/15	12/16	10/18

From table I, the following comments can be made,

Division A: The maximum teams have followed the step ‘Making Calculations’ and the step that is least followed by the teams is the step ‘Drawing Diagram’. 14 teams out of 15 have got the correct answer to the given problem.

Division B: The maximum teams have followed the step ‘Making Calculations’ and the step that is least followed by the teams is the step ‘Solution Check’. 05 teams out of 17 have got the correct answer to the given problem.

Division C: The maximum teams have followed the step ‘Making Calculations’ and the step that is least followed by the teams is the step ‘Solution Check’.10 teams out of 18 have got the correct answer to the given problem.

Division D: The maximum teams have followed the step ‘Making Calculations’ and the step that is least followed by the teams is the step ‘Making Assumptions’. 12 teams out of 16 have got the correct answer to the given problem.

Division E: The maximum teams have followed the step ‘Making Calculations’ and the step that is least followed by the teams is the step ‘Solution Check’. 08 teams out of 15 have got the correct answer to the given problem.

Division F: The maximum teams have followed the step ‘Formulating Problem Statement’ and the step that is least followed by the teams is the step ‘Equations’. 12 teams out of 16 have got the correct answer to the given problem.

Division G: The maximum teams have followed the step ‘Making Calculations’ and the step that is least followed by the teams is the step ‘Solution Check’. 10 teams out of 18 have got the correct answer to the given problem.

Table 2. Priority wise ranking of general analysis procedure steps of all divisions (cumulative)

Rank	**For all divisions**
1	Calculations (113)
2	Problem Statement (100)
3	Discussion (94)
4	Equations (94)
5	Assumptions (86)
6	Diagram (75)
7	Solution Check (68)

The data of all the divisions was combined and is as shown in table II, it is found that the most common followed step is ‘Making Calculations’ and the least followed step is ‘Solution Check’. 71 teams out of 115 teams have got the correct solution to the given problem.

4. Discussion

This activity was carried out with the assumption that the teams which follow all the steps of the general analysis procedure are bound to get a solution which may not be the exact solution but at least very close to the exact solution. A brief summary of division A is given below;

Out of fifteen teams, as per the checklist, four teams did not use the first step (formulating problem statement) and out of these four teams, three teams have got the correct solution and one team could not arrive at the correct solution. The three teams may have not checked the first step in the checklist due to ignorance or they might have missed it or it may be intentional. Three teams did not use the fourth step (using governing equations) and out of these three teams two teams have arrived at the right solution and one team failed to get the correct answer to the given problem. The two teams which said that they did not use fourth step is not genuine as obtaining the solution without using the equations is impossible.

Out of the seven divisions, the least number of teams who have got the correct answer are from division B and the number is five out of seventeen. The students might have not understood the problem statement or the instructions given to the students were not very clear. The reason might also be the students disinterest as the session in which the data collected was post lunch session.

Combining the data of all the divisions, it is found that most used step is ‘making calculations’, Seventy one out of one hundred and thirteen teams have got the correct solution. Seventy one out of one hundred teams who have used the step ‘formulating Problem Statement’ have got the correct solution. Seventy one out of ninety four teams who have used the step ‘Discussion’ have got the correct solution. Seventy one out of ninety four teams who have used the step ‘Governing Equations’ have got the correct solution. Seventy one out of eighty six teams who have used the step ‘Making Assumptions’ have got the correct solution. Seventy one out of seventy five teams who have used the step ‘Discussion’ have got the correct solution. The least step used is ‘Solution Check’ and even though sixty eight teams have used this step, seventy one teams have got the correct solution.

The data that was collected for this activity during this current semester is quantitative. In the next semester the authors would like to also gather some qualitative data in the form of video recording.

5. Conclusions

This paper gives a summary of implementation of the general analysis procedure for the freshman engineering students in the course ‘Engineering Exploration’. The data has been collected for seven divisions and from this data it can be concluded that seventy one teams out of one hundred and fifteen teams have arrived at the right solution, i.e., 61.74% teams have got the right solution for the given problem . Almost all these seventy five teams have followed most of the steps involved in the analysis procedure.

Acknowledgment

The author would like to thank the Head of the department, Electrical and Electronics Engineering of KLE Technological University, Hubli, for providing the necessary support to carry out the work. Also, the author would like to thank Centre for Engineering Education Research (CEER) for helping in collecting the required data for this activity.

References

[1] Syed Ahmad Helmi Syed Hassan, et’al, “An Instrument to Assess Students’ Engineering Problem Solving Ability in Cooperative Problem-Based Learning (CPBL)”, American Society for Engineering Education, 2011

[2] Ryan Fries, Ryan W Krauss, “An Analysis of First Year Students’ Changing Perceptions of Engineering Design and Practice”, 121st ASEE Annual Conference & Exposition, 2014

[3] Aran W Glancy, et’al, “How Fifth Grade Students Apply Data Analysis and Measurement in Engineering Design Challenges (Fundamental)”, 122nd ASEE Annual Conference & Exposition, 2015

[4] Donald Elger, et’al, “Performance Criteria for Quality in Problem Solving”, American Society of Engineering Education Annual Conference and Exposition, 2003

[5] David Jonassen, et’al, “Everyday Problem Solving in Engineering: Lessons for Engineering Educators”, Journal of Engineering Education, 2006