An Educational Computer Aided Heat Exchanger Design Software

Mohamed Edali, Asma Milad, Walid Alaswad, Zaed Sahem, Faraj BenRajeb
Department of Chemical and Petroleum Engineering, Elmergib University, Elkhoms, Libya.
Creativity Group for Technical Services, Ottawa, Ontario, Canada
dredalicreativitygroupts@gmail.com, asma.aga2009@gmail.com, walaswadzo@gmail.com, sahemzaed@gmail.com, fabr67@mun.ca

Ali Elkamel
Department of Chemical Engineering, University of Waterloo, Waterloo, Ontario, Canada
aelkamel@uwaterloo.ca

Abstract

This paper presents an advancement of an academic computer-aided design software system tool for the shell and tube heat exchanger project. The project is teaching a Visual Basic, user-friendly Application (VBA) programming in chemical engineering at Elmergib University with a focus on a unit operation project selected from chemical engineering design core courses. The course is designed to teach not solely the way to program, however additionally on problem-solving and the way to convert a chemical engineering problem into an operating software package program. Many chemical engineering issues were designated as either projects or demonstrations to permit students to gain expertise and advantages of programming in VBA. The central importance of sensible provision and style project, and also the approaches adopted by new suppliers to deliver these parts, are reviewed, alongside the role of software system tools in chemical engineering education, and measures to facilitate business input into courses. As to inhibit innovation, the certification process provides constructive steerage and leverage for universities developing new chemical engineering programs. Most chemical engineers getting into the work spend a minimum of half of their workday at their computers, which principally involves the utilization of easy industrial software.

Keywords
Computer aided design tool, Unit operation, Heat Exchanger, Microsoft excel, Visual Basic for Applications (VBA).

1. Introduction
Academic teaching has been traditionally focused on the theoretical instruction delivered in classroom lectures. However, chemical engineering design course tasks and their data processing and model evaluation are time-consuming. They are not adding much value to the student's learning experience as they reduce the available time for result analysis, critical thinking, and report writing skills development. In addition, a well-known issue that processing experimental knowledge and examination of results against theoretical models are often time-consuming because of repetitive and complicated calculations. That holds back the student's available time for analysis and discussion resulting into a poor-quality report. This project aims to initiate the teaching of Excel VBA programming in chemical engineering, with the emphasis on relevant examples/projects. The programming paradigm behind this project is structural programming with a divide and conquer strategy (Albright 2001). VBA has both procedural and object-oriented features. The Excel VBA programming part has been run as a trial within some chemical engineering undergraduate courses. Therefore, this project addressed this issue by selecting several experiences of the design process namely: applied theories behind thermo-hydraulic design analysis with practical mechanical design details required for costing and production and developed programming skills using individual spreadsheets (Serth and Lestina 2010). These spreadsheets are organized in such a way to process a design algorithm, evaluate complex analytical and numerical graphs models and correlations (Chapra 2003), and convey results in tables and plots. Chemical engineering students that tested the spreadsheets were surveyed and expressed the added value of the sheets, being user-friendly. They helped them to fulfil engineering design objectives by reducing their hand calculation workload. They allowed them to complete detailed analyses that instructors could not request before as they were able to quickly evaluate, compare and validate different model assumptions and correlations (Chapra 2003). Students also

provided valuable suggestions to improve the spreadsheet experience through these sheets, where the students' lab learning experience was updated. Using Visual Basic for Applications (VBA) in conjunction with the Excel spreadsheet, the user has the convenience of a spreadsheet for neatly formatted input/output and the graphical display of results, to function as a graphical user interface (GUI) (Norton et. al. 2008). In the meanwhile, well structured, readable, line-oriented code is often used for complex sophisticated calculations.

1.1 Objectives

This project is a short course within the process design courses in chemical engineering as a part of students' course projects. Since it has been conducted in fifth-year courses, most of the students have already taken computer programming courses in their first year with another computer programming language. Therefore, in this Excel VBA programming task, we include fundamental Excel VBA syntax; a case study on how to convert a chemical engineering problem into a working program; and projects related to chemical engineering problems. There are also some demonstration programs on certain chemical engineering problems selected from core chemical engineering courses since the programming is considered a practical knowledge that students learn from tutorials, projects, and demonstrations. The programing task mainly focuses on the following kinds of computation problems: (1) to find a numerical solution by solving ODEs, matrices. (2) to handle repetitive, simple calculations, and (3) to calculate procedures that involve flexible options or complicated decision making. The course employs structural programming as a programming paradigm and flow charts for program design with an emphasis on the object-oriented programming feature of VBA. It is a fact that chemical engineering graduates would be more efficient when equipped to contribute to industrial software packages, if they were instructed in such a way effectively to use Microsoft excel and, especially, Visual Basic for Application programming. That instead of just writing a computer program in a coding language, they may never use any more. Also, it is a favourable setting for them to learn programming skills since they are already working in excel.

In a fluid mechanics course, fluid flow in a pipe is a classic problem. Based on given fluid properties, flow rate, etc., students can calculate the pressure drop with the aid of the friction factor. To find the friction factor for turbulent flow, we need to solve the Colebrook equation using the Reynolds number, which is known since the velocity is already known. in the process of solving the Colebrook equation for the friction factor, an iteration loop is required. Such a job could be performed by the built-in Excel function, Goal Seek. If this problem is implemented using programming, one iteration loop will be required to solve the Colebrook equation. However, such a problem could be structured with a given pressure drop, and either the fluid flow rate or pipe diameter as the unknown. For such cases, a trial-and-error strategy is required to solve such a problem. An iteration is used to find the corresponding flow rate or pipe diameter after the initial guess of the flow rate or pipe diameter is made. For these cases, those problems contain two nested iteration loops: one iteration loop is for a trial-and-error to estimate fluid flow rate or pipe diameter and the other iteration loop is for solving the Colebrook equation.

The solution of the equation by iteration using the programming of Excel VBA is demonstrated, as well as creating appropriate functions in a program to make the program source code easy to read and easy to maintain. This also shows that, if students are going to solve a single iteration loop problem, the Excel Goal Seek feature is an appropriate solution. Also, programming is a more appropriate tool when students need to solve a multiple iteration loops problem. In this way, students are taught to select the most suitable software tool for a particular application.

2. Case study: converting a chemical engineering problem into a working program with basic numerical techniques - Heat Exchanger

This paper describes the development of a stand-alone, user-friendly programming package for designing shell and tube heat exchanger using visual basic. The program is called Heat Exchanger Design (HED) and validated via comparison of its design and analysis results with benchmark problems from design textbooks on heat exchanger design. The HED addresses two main heat exchanger issues: the rating issue, in which the designer must determine whether a fully specified exchanger performs a given heat transfer duty specifications as required. There are numerous methods available for the design and analysis of heat exchangers, but the best established are Kern (Sinnott et. al. 2005) and stream analysis methods. The development of HED through this project is based on the Kern method for the thermo-hydraulic design analysis. The mechanical design is based on the TEMA standard (Sinnott et. al. 2005). The detailed analysis of heat exchangers, the log mean temperature difference (LMTD) method presented in the textbook authored by Serth (Serth and Lestina 2010) is used.

To get HED works, a design team of instructors and a group of fifth-year undergraduate students were involved in detailed preparation tasks. The typical program development cycle included some steps. First, defining the problem represented on the input/output data. Second, planning the solution to the problem by using a logical sequence of precise steps as an algorithm where it is built into the program with a simple logical sequence for the design of heat exchangers. The HED design logic is illustrated in Figure 1 (Sinnott et. al. 2005). Third, graphical user interface (GUI) was built using objects buttons, text boxes, command tabs, and more of those to obtain the inputs and display the outputs. Forth, writing the computer program by translating the design algorithm into the VBA script. Fifth, debugging the program and testing and correcting the execution errors. A team effort results in preparing a help manual to help users to use the package.

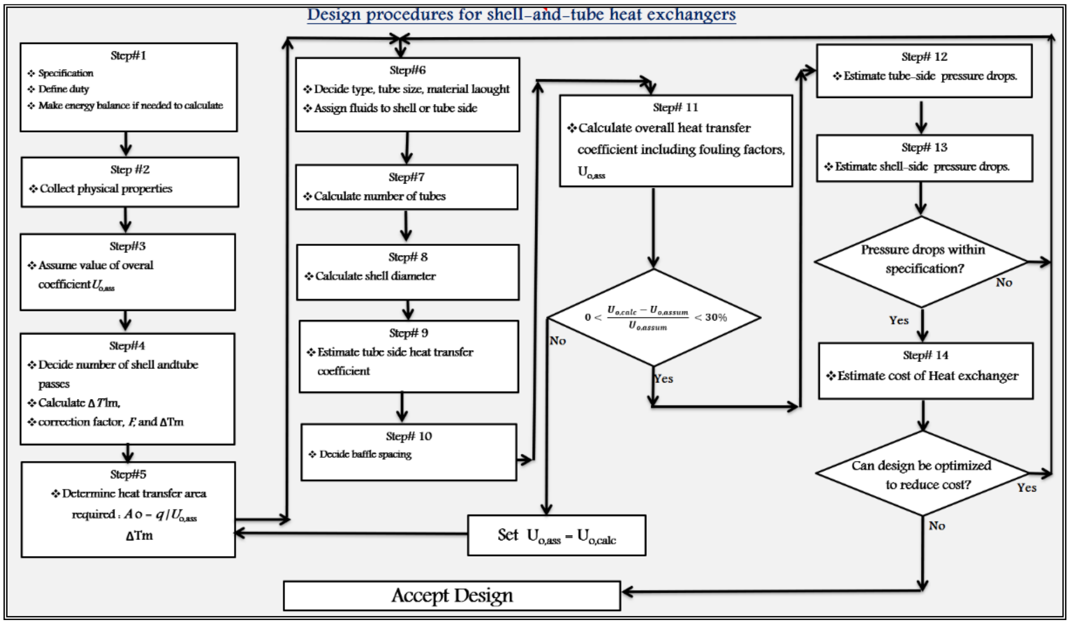

Figure 1. Design procedures for shell-and-tube heat exchangers (Sinnott et. al. 2005)

3. Results and Discussion

The coding part of VBA under excel environment was put in a Module to be accessible from any of the worksheets and can be easily exported to any other projects where it may be reused. Object control, e.g., a command button that activates a subroutine on a particular worksheet, then coding for the event calls the subroutine and may appear in the coding for that form. The simulation results generated by HED software depend on the data input by the user. Figure 2 shows the software HED explorer window of the project objects, forms Modules used.

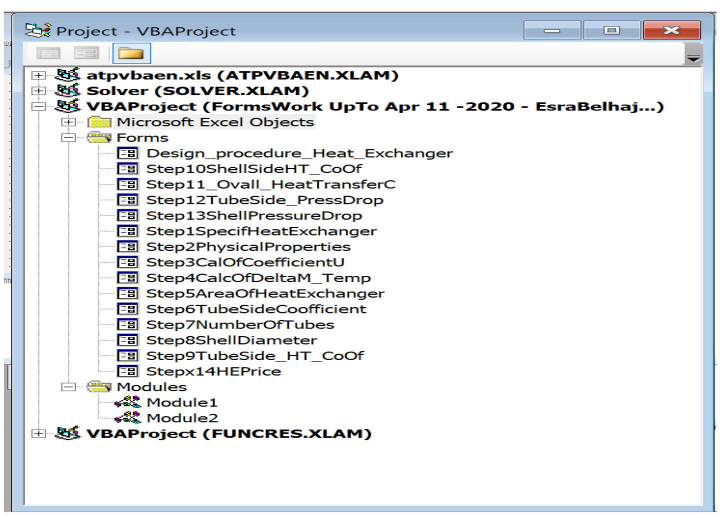

Figure 2. Project Explorer Window of HED

The user is required to key in the input values for the exchanger configuration, fluid properties and conditions, using the HED design interface in figure 3 following the algorithm steps. The following example was used to validate the design of shell and tube heat exchangers simulating the parameters. Data in figure 4 from Example 12.2 from Vol 6, Sinnott's textbook (Sinnott et. al. 2005) used to illustrate the validation of HED design software.

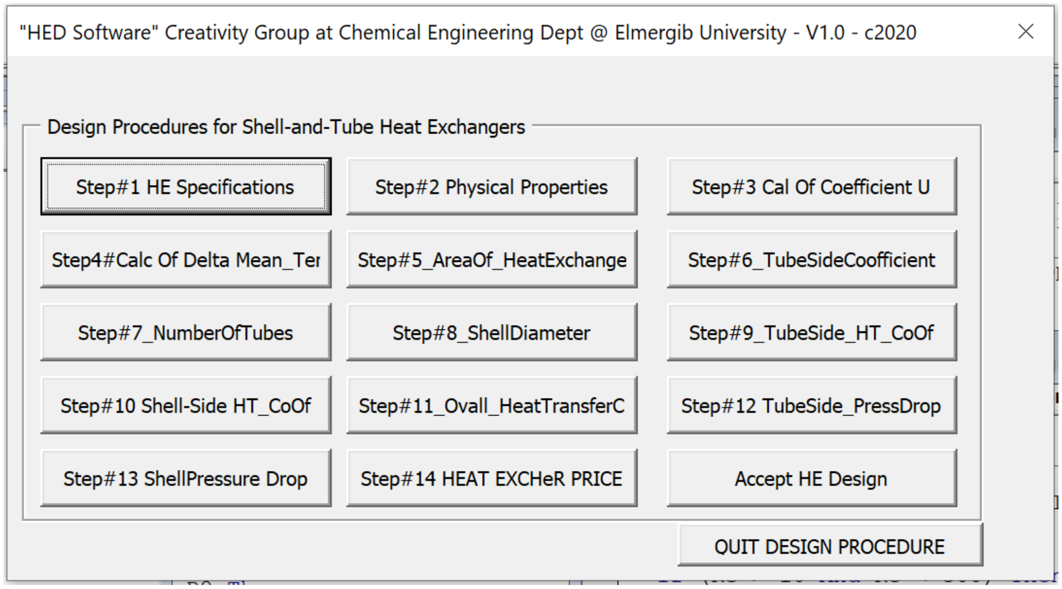

Figure 3. HED design interface

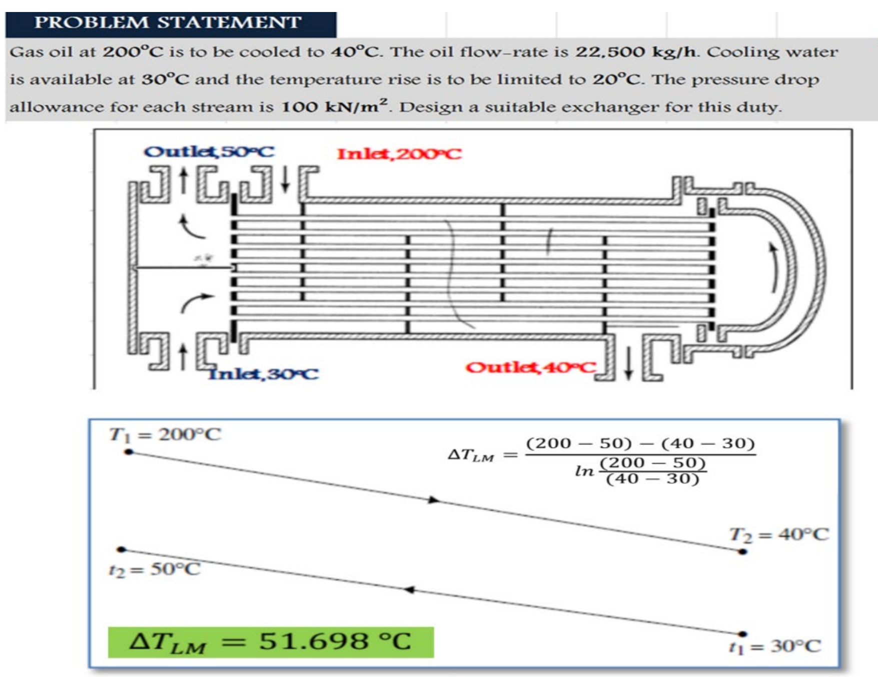

Figure 4. Example 12.2 from Vol 6, Sinnott's textbook (Sinnott et. al. 2005)

The HED execution steps illustrated in figure 5 are the first, second, third, and fourth window step interfaces used to key in the input data. The fifth, sixth, and fourteenth window interfaces are shown as illustrations in figure 6.

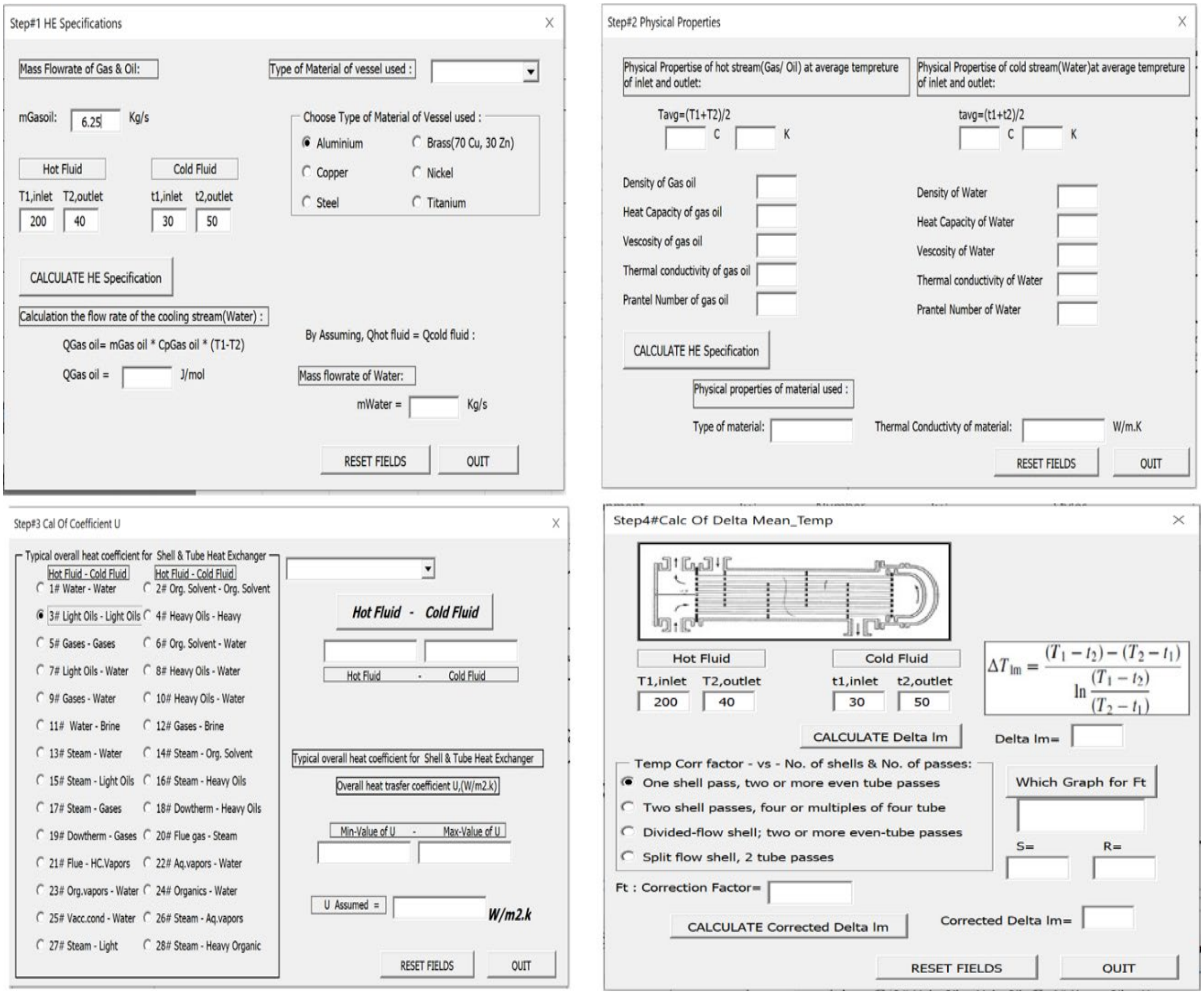

Figure 5. HED deign - first four steps window interfaces

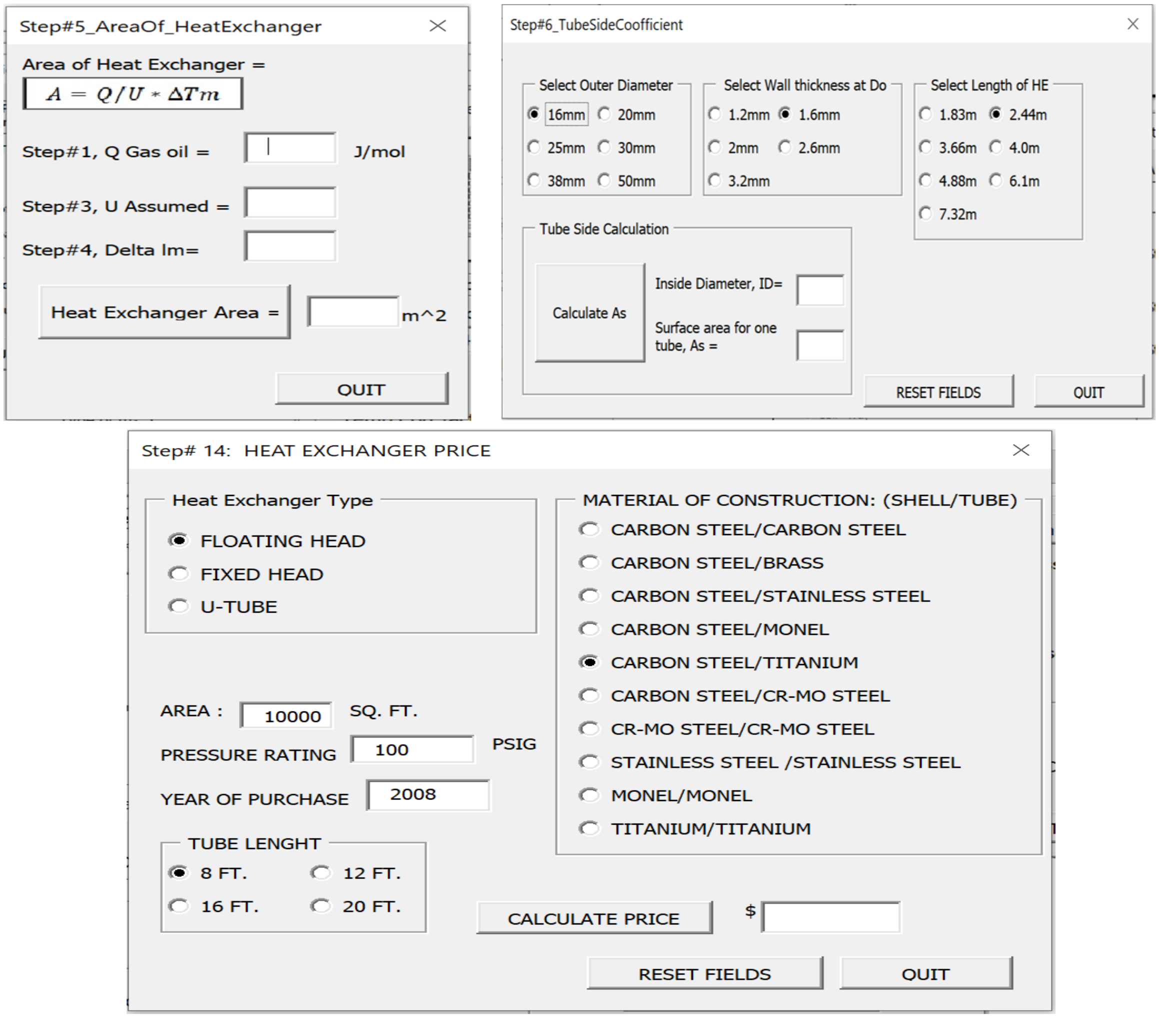

Figure 6. HED deign – illustrations of the fifth, sixth, and the fourteenth steps interfaces

The general equation for heat transfer across a surface is:

$$Q = U\,A\,\Delta T_m \qquad (1)$$

where
- Q = heat transferred per unit time, W,
- U = the overall heat transfer coefficient, W/m^2 °C,
- A = heat-transfer area, m^2,
- ΔTm = the mean temperature difference, temperature driving force, °C.

Determining the surface area required for the rate of heat transfer specified duty using the temperature differences available was the ultimate objective in this heat exchanger design project. The reciprocal sum of the overall of several individual resistances to heat transfer

represents the overall coefficient. The physical arrangement of the heat-transfer surface, the heat transfer process whether conduction, convection, condensation, boiling, and radiation are the bases of the magnitude of the individual coefficients. That as well will depend on the nature of the physical properties of the fluids, on the fluid flow-rates. As of the heat exchanger physical layout cannot be determined until the area is known. Therefore, the design of an exchanger is of the necessity of a trial and error procedure. Before equation 1 can be used to determine the heat transfer area required for a given duty, an estimate of the mean temperature difference ΔTm must be made. The fluid temperatures at the inlet and outlet of the exchanger are to be keyed in as inputs and ΔTm will be calculated from that terminal temperature difference. The well-known "logarithmic mean" temperature difference calculation was produced by using the HED design step 4 as an illustration in figure 7, solving for the ΔTm from data inputs of example 12.2 (Sinnott et. al. 2005) as shown above in figure 4, to validate the accuracy of HED simulation results.

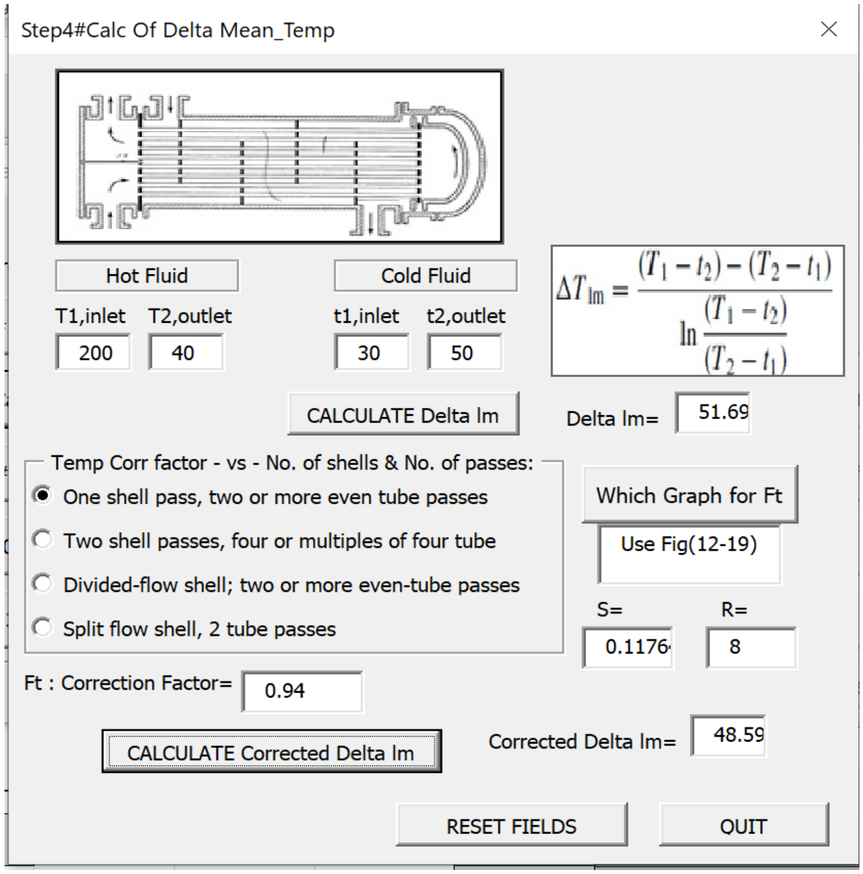

Figure 7. Solution as illustration and comparison with HED results from page 680 (Sinnott et. al. 2005)

Within the chemical engineering program at Elmergib University, students are trained to use Excel-VBA in the Computing and Numerical Methods lecture courses. They are also acquainted to use the programming to solve different engineering problems from the basic level, learning to plot experimental data and perform some simple cell operations. This author team ran into an attempt to address such deficiency and help students meet the job market requirements and decided to use spreadsheets as the programming environment for developing the required tools for the chosen laboratory design experiments and teaching more advanced levels based on the fundamentals of the numerical method. Figure 8 shows the results of using curve fitting numerical techniques into the HED design project Module to calculate the Shell side pressure drop in HED design "step13", where friction factor value is needed, from the correlation graph of friction factor -vs- Reynolds Number.

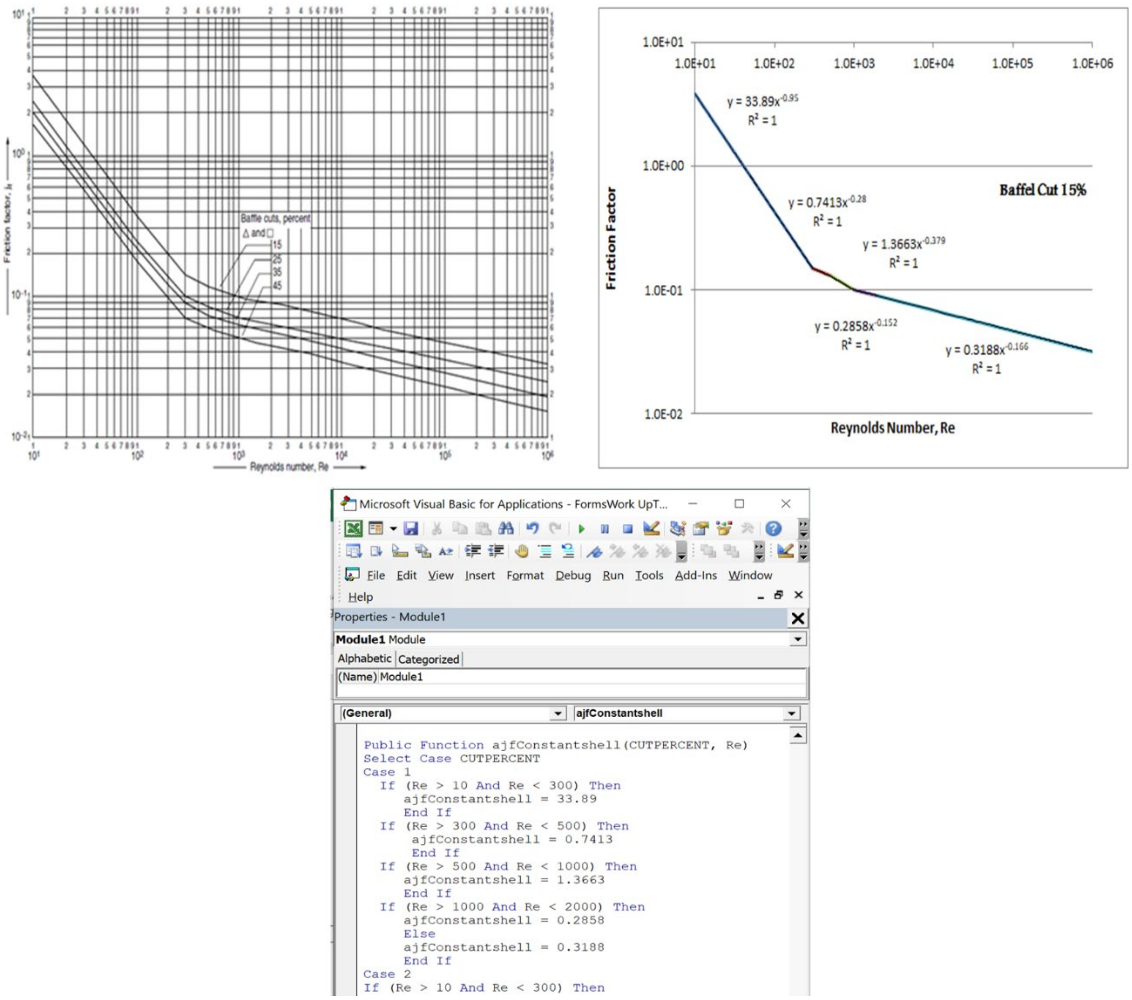

Figure 8. HED design project step 13 Module program to calculate the Shell side pressure drop

4. Conclusion

The engineering student team of HED design response to the use of VBA within this project has been excellent. Great welcome the opportunity of adding a new package to their credit of proficiencies. The spreadsheets that were presented in this project were well-programmed, for assisting the data processing of the complex heat exchanger model design evaluation tasks. Analytical and numerical solutions of different models were well comprised of those spreadsheets, as well as correlations available in the literature. A survey was conducted on the five chemical engineering students group who tested the spreadsheets, showing that spreadsheets were considered useful for reducing workload and boosting analyses quality where they earned the expertise of possibility of quickly rehearsing with diverse correlations and models. The students also gave valuable suggestions and feedback to improve the spreadsheet experience, such as incorporating more correlations and models and examples into the user manuals, which will be considered for the next stage of this project by creating a spreadsheet for each unit in the design laboratory course. Finally, the goal of updating the teaching and learning experience of chemical engineering students at the design course through computers was fulfilled by the introduction of these spreadsheets, without the need for students to acquire any more programming skills courses. This can be considered a practical advantage, as it would allow other fellow communities to benefit from this work into their graduation project proposals.

Acknowledgment
The instructors and authors team wish to thank Professor Elkamel of Waterloo university for his academic and finacial support. Appreciation goes as well to Assistant Professor of Elmergib University, Abdualnaser Almagrbi, and to the five undergraduate chemical engineering students, Abdel Moez Al-Dubbouss, Asraa Balhaj, Yousuf Alsileeni, Serag Alshrif, and Abdulrraziq Alazqal, who were involved in the preparation of this HED software project. The research team valuable contributions is highly appreciated in producing this first version 1.0 of the heat exchanger design HED software development of the HED spreadsheets project at the Chemical and Petroleum Engineering Departement at Elmergib University. Thanks to the other instructors that participated in the assessment process of the HED spreadsheets.

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Biography

Mohamed Edali is Assistant Professor of Chemical and Petroleum Engineering at Elmergib University. He holds a BSc in Petroleum Engineering, MS in Mechanical / Chemical Engineering Lab from Concordia University, and PhD in Process and Industrial Engineering from Regina University. His specific research interests are in computer-aided modeling, optimization, and simulation. The aim of his scientific work is to deepen and consolidate the students' knowledge by using simulation techniques and tools as an advanced engineering teaching aid using APPS which were created by COMSOL Multiphysics using the built-in APP builder features. The engineering teaching project includes the fields of heat transfer, fluid mechanics, mass transfer, transport phenomena, and Engineering design. Member, APEGS (Professional Engineer), Member of the Canadian Society for Chemical Engineering (CSChE), and Member, Chemical Institute of Canada (MCIC).

Asma Milad is Assistant Professor of Chemical and Petroleum Engineering at Elmergib University. She holds a BSc, MSc, and PhD in Chemical Engineering. Her research interests are in computer-aided modeling, optimization, and simulation.

Walid Alaswad is the Head of Department of Chemical and Petroleum Engineering at Elmergib University. He holds a BSc and MSc in Chemical Engineering from Elmergib University. His research interests include fundamental studies of heat and mass transfer, fluid mechanics teaching strategies.

Zaed Sahem is the founder of Creativity group Engineering Simulation R&D Smart teaching APPS in Engineering and Science fields using COMSOL & CAD SolidWorks. Host Institutions: University of Waterloo & Elmergib University. He holds a BSc in Mechanical Engineering from Nasser University, and MEng in Mechanical Engineering from University of Ottawa.

Faraj Ben Rajeb is PhD candidate in process Engineering at Memorial University of Newfound. He holds a BSc in Chemical Engineering from Bright Star University of Technology, and MSc in Chemical Engineering from University of Tripoli. His research interests are fluid mechanics, Newtonian, and non-Newtonian multiphase flow.

Ali Elkamel is Professor of Chemical Engineering at the University of Waterloo. He holds a BSc in Chemical Engineering and BSc in Mathematics from Colorado School of Mines, MS in Chemical Engineering from the University of Colorado-Boulder, and PhD in Chemical Engineering from Purdue University (West Lafayette), Indiana.

His specific research interests are in computer-aided modeling, optimization, and simulation with applications to energy production planning, sustainable operations, and product design. He has supervised over 70 graduate students (of which 30 are PhDs) in these fields and his graduate students all obtain good jobs in the chemical process industry and in academia. He has been funded for numerous research projects from government and industry. His research output includes over 190 journal articles, 90 proceedings, over 240 conference presentations, and 30 book chapters. He is also a co-author of four books; two recent books were published by Wiley and entitled Planning of Refinery and Petrochemical Operations and Environmentally Conscious Fossil Energy Production.