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TABLE OF CONTENTS:-

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DEVELOPMENT OF HVAC VIRTUAL LABORATORY (HV-LAB VERSION 1.0)

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ABSTRACT
Laboratory-based assessment is one of the crucial assessments in the institution of higher learning especially the engineering technology programme. Simulated laboratories are changing the nature of laboratory activities, and there is a long-running debate about the value of hands-on versus simulated laboratories. Hands-on advocates emphasise design skills, while simulated laboratories advocates focus on conceptual understanding. Interest in simulated laboratories versus hands-on has increased based on two factors: advancement in technology and cost pressure. Educational goals of hands-on laboratories activities focus on conceptual understanding, professional skills, design skills and social skills, but not all the equipment provide professional skill to the students. Most equipment are designed and built to explain the conceptual understanding only. Due to this, this paper presents the Development of HVAC Virtual Laboratory (HV-Lab); Recirculation Air Conditioning System Training Unit (RACSTU) using MATLAB/Simulink. RACSTU is located at the Fundamental HVAC Laboratories, Department of Mechanical Engineering Technology, Universiti Teknikal Malaysia Melaka (UTeM). The HV-Lab system was designed as the laboratory experimental setup. General equations were defined separately for each state of air property in RACSTU then experiments were conducted based on fifteen (15) different cases. Using these equations and experimental data MATLAB/Simulink models for every state of air property were created. The MATLAB/Simulink models were combined and verified with experimental results. The simulation results show that the experimental results are compatible with the experimental results for each state.

Keywords: HVAC, laboratories, hands-on, MATLAB and virtual.

INTRODUCTION

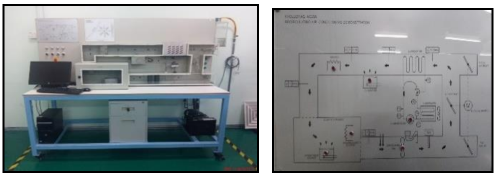
Laboratories are the necessary part of any engineering course. From the laboratories, there is equipment or training unit that is provided for the students to learn and study that are related to their course (Ibrahim, 2011). Laboratories are important components of education to enable students to gain experience (Tuysuz, 2015). Laboratories have distinctive roles especially in engineering education as recommended by science educators that there are benefits gained from laboratory education. However, despite the advantages of laboratories there are also disadvantages such as the cost of setting-up the equipment, maintenance cost, and the limited in class student ratio in using the equipment (Ibrahim, 2011). Regarding to this problem, the use of MATLAB/Simulink software is increasing in these fields (Scientifique & Jaurès, 2005). An issue related to thermal systems modelling, such as HVAC systems is the use of an appropriate simulation tool (Simulink, Novak, Mendes, & Oliveira, 2005). Therefore, by defining simplified models of each HVAC component, a group of mathematical equations can be generated using the MATLAB/Simulink software (SystemAir, 2007). MATLAB is a tool of mathematical programming that is suitable in creating the air properties mathematical model for RACSTU. An interesting application such as Graphical User Interface (GUI) can be used to design the interface model of the software which is easy to handle by clicking and dragging the mouse. From the combination of mathematical model and user interface model, the software can be created to simulate the air properties of RACSTU and get the data output. The aim of the study is to validate the air properties of the mathematical model against the experimental data.

MATLAB/Simulink and Graphical User Interface (GUI)

MATLAB is the high-level language and interactive programme utilised by a lot of engineers and scientists around the world. It is a capable tool of mathematical programming that can perform many programming applications. MATLAB makes it easier to use built GUI by providing them with a consistent appearance and with intuitive controls like pushbuttons, list boxes, sliders, menus, and so forth (Andreatos, Force, Zagorianos, Air, & Academy, 2018). The GUI should behave in an understandable and predictable manner, so that a user knows what to expect when performing an action (Tibor, Fedák, & František, 2011). In HVAC, there is a tool in MATLAB to study IAQ (Indoor Air Quality), comfort, energy consumption as well for the air flow (Scientifique & Jaurès, 2005) .This software also provided the tool of dynamic simulation which is Simulink. The usage of Simulink is for the control and automation application which will help this software to become a powerful tool (Scientifique & Jaurès, 2005). There is also a modelling toolkit in MATLAB known as HAMLab (Heat, Air and Moisture). SIMBAD is also one of the tools from MATLAB that provides HVAC models and simulation on HVAC plants. One of the latest technology developments in simulation using Simulink is HAMBase. This improvement numerical model has a continuous part and solved with a variable time step and a discrete part (Van Schijndel & Hensen, 2005). This shows that in HVAC field, the usage of simulation helps in the improvements of the systems or for study purposes.

Definition of Recirculation Air Conditioning System Training Unit (RACSTU)

There are many heating, ventilating, and air-conditioning (HVAC) systems, but only a few of them are appropriate for undergraduate education (Abu-mulaweh, n.d.) The RACSTU in this study is used for the teaching and learning of undergraduate students. It can perform cooling, heating, humidifying, sensible and latent heat. The picture of the RACSTU is shown in Fig.1. The RACSTU consists of 5 states. Each state is defined by general equations, related with energy and mass balance. Simulation of the system is created with MATLAB/Simulink, using these equations. The RACSTU discussed a mixture of gases that are usually above critical temperatures and not concerned about any of the gases condensing during the whole process. Not having to deal with two phases greatly simplified the calculation analysis. Dealing with gas-vapour mixture however, the vapour may condense out of the mixture during a process, forming a two-phase mixture. This may complicate the calculation analysis considerably. The laboratory equipment used a ventilating system that consists of parts such as evaporator (cooling coil), heater, humidifier, and fan. The cycle of the air started from the outdoor (fresh air) and supplied through the cooling coil and performed the cooling and dehumidifying process. The air also is passed through the humidifier to humidify the air before it went through the heater for the reheating process. Through the usage of fan, the air can be blown to the outdoor or by closing the damper in the system, it can recirculate. As mentioned before, in this laboratory equipment, basically the process involved is the psychrometric process which are cooling, heating, humidifying and dehumidifying processes (Koçyiğit & Şahin, 2017).

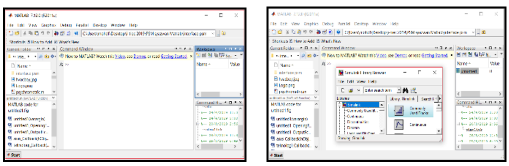


(a) (b)

Fig.1 (a) Recirculation Air Conditioning Training Unit
(b) RACSTU Simplified Diagram

SIMULATION DEVELOPMENT

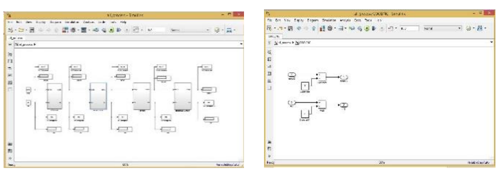
In this phase, data from fifteen (15) cases are taken to generate the result performance by using Simulink. In the Simulink development interface, the first step is to launch the command window as shown in Fig.3a.



(a) (b)

Fig.3(a) MATLAB Command Window
(b) Open Simulink Library Browser

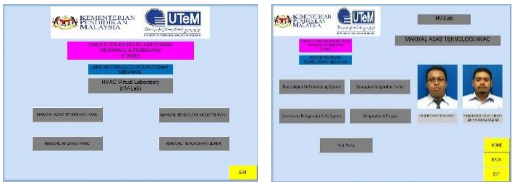
From the command window, the Simulink browser is opened by clicking the simulation library link as shown in Fig.3b. Next, generally the step creates the sub-block diagramme in Simulink, simplified by the parent block diagramme shown in Fig.4a and Fig.4b.



(a) (b)

Fig.4(a) Simulink Parent Block Diagram
(b) Simulink Sub-Block Diagram

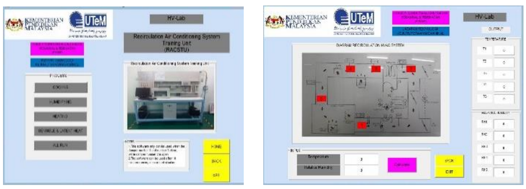
The last is to connect and synchronise between Simulink and GUI where the HV-Lab interface is shownin Fig.5. Fig.5a shows the main frame of HV-Lab by using GUI which consists of selection of laboratory. Fig.5b shows the second interface which is for choosing the equipment in the laboratory selection.



(a) (b)

Fig.5(a) Main Frame of HV-Lab Using GUI,
(b) Second Interface in Choosing Equipment

Fig.6a shows the interface of RACSTU that consists of the image of the training unit and the selection of psychrometric processes such as cooling, humidifying, heating, sensible heat, and latent heat. Fig.6b shows the diagramme of RACSTU and the inputs and outputs are identified, and the operations to be performed on inputs to generate the outputs are specified (Ferrero & Piuri, 1999). The detailed demonstration will be displayed during the presentation day.

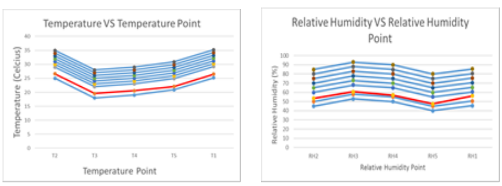


(a) (b)

Fig.6 (a) Third Interface in Choosing Process,
(b) Input Interface

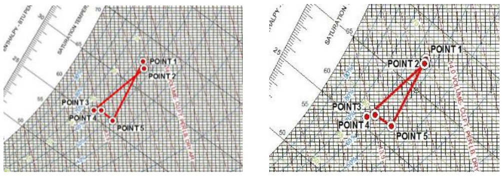
SIMULATION RESULT

The analysis of the described air properties is done by implementing the model equations in a Simulink model structure and by linking it to the HV-Lab toolkit. The overall system simulation studies of the input and output relationships are discussed. Small variations of the parameters are omitted. The data of the experimental results are examined with the simulation results. Fig.7 shows the line between the obtained experimental data and simulation data. This value does not change over time. The error should be less than 5% between the experimental data and simulation data.



(a) (b)

Fig.7 (a) Graph of Temperature During Recirculation,
(b) Graph of Relative Humidity During Recirculation



(a) (b)

Fig.8 (a) Experimental Psychrometric Chart
(b) Simulation Psychrometric Chart

Fig.8 shows that the psychrometric chart between the simulation and experimental data for complete cycle involved in RACSTU. From the starting point to the end of cycle it was proven that the simulation software had a slight error which is less than 5%. From the psychrometric chart, the psychrometric process can determine whether the simulation toolkit follows the standard of training unit in the laboratories or not.

CONCLUSION

The development of HVAC-Lab has met all the main objectives that were initially set. The objectives met are followed to develop HV-Lab of RACSTU from the experimental results. The experiment was conducted on 15 cases covering cooling, heating, humidifying, sensible and latent heat operations. General equations for RACSTU were defined separately for each state of the system. Every state was designed using the MATLAB/Simulink model. The MATLAB/Simulink models were combined and verified the experimental results. The simulation results showed that the experimental results are compatible with the simulation results. It is also user friendly where it is easier for users to see the air property in every case. This development and simulation will be used in future studies for comparison of real system results with simulations results. In addition, the simulation development process will continue with other equipment, thus completing the smart laboratory development. Compilation of the equipment simulation will be implemented in other laboratories with other equipment. It has been shown that, recently, the number of studies using MATLAB/Simulink environment has grown rapidly. More and more papers have been presented on conferences or in scientific journals. But due to the less exposure in HVAC system, the usage of tools in this field is not much known to the public. In fact, the new generation in engineering must be familiar with this due to the transformation in industrial revolution from I.R 3.0 to I.R 4.0. In millennials generation, students prefer a virtual study compared to hands-on activities since is more interactive and easier.

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