Proceedings of the
International Conference on Mechanical Engineering 2009
(ICME2009) 26- 28 December 2009, Dhaka, Bangladesh

ICME09-RT-15

AUTOMATION OF TESTING FACILITIES USING MATLAB

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ABSTRACT

MATLAB is a powerful tool for engineering and scientific analysis. Experimental analysis and testing is must for engineers and researchers to carry on advanced engineering and scientific research works as well as to take decisions on different practical aspects. Thus it is obvious the result of any experimental analysis should be error free and well presented. This paper examines how to develop an automated testing facility using MATLAB with the help of a parallel port and as well as com port in PC and microcontroller with proper sensory arrangement. **The forced convection over a flat plate** experimental setup has been taken as a model. Software with MATLAB GUI has been developed to make the system more user-friendly. The total system contains the hardware arrangement for the data acquisition from the setup and to control the setup via MATLAB and an automated report generation based on the data received from the DAQ part. The system also has emergency data saving capability if the PC somehow fails to work or shut down unexpectedly. The developed automated system has the capability of starting the whole testing facility itself, check the required parameters needed to carry out the experiment, control the inputs given by the experimenter and finally take the result. The automated system also provides the experimenter, the facility for the statistical analysis of the result.

Keywords: MATLAB, GUI, Auto Calibration, Automation.

1. INTRODUCTION

Engineers and researchers frequently need to carry out numerous experiments within a very short time. A highly automated testing facility [1] widens the scope of achieving an error free result and also acute analysis of the result. Moreover, sensors used during the experiment may require calibration from time to time, to ensure minimum error in the result.

The automation of a testing facility should be such that, it encompasses all the aspects of testing process, from the test planning to the test execution, storage of results for statistical analysis, and finally to print out the data tables, graphs, and results.

The endeavor of our work was to show, the detailed hardware and software arrangement for automation of a testing facility and to depict the advantages, obtained due to this automation. There are numerous important engineering applications in which heat transfer for flow over bodies such as flat plate, a sphere, a circular tube or tube bundle are needed. That's why in our present work, we have taken '**Forced Convection over a Flat Plate**' as a model. The testing panel is interfaced with PC, and is programmed, using MATLAB. GUI has been used to make the system more user-friendly. Microcontroller is used for the storage of results, if the PC fails to work or shut down unexpectedly. For the permanent storage of the results, we have used Microsoft Excel, in affiliation with MATLAB.

The hardware & software arrangement facilitates the experimenter, to start/stop and control the air velocity, to regulate the heat input to the plate, and to auto-calibrate the sensors, by means of computer control. The system arrangement also enables the experimenter, to perform the experiment, at different angles of the heated plate.

2. SENSOR ARRANGEMENT

Sensors are generally used to convert a physical signal into a corresponding electrical signal, which by proper amplification or attenuation is converted into a numeric quantity. Forced convection analysis over a flat plate consists of temperature sensors in the plate that is under experiment. The sensors (Fig 1) are connected to the control unit. The experimental setup contains two types of sensors, a pressure sensor and temperature sensors. Piezo-electric [2] sensor is used to measure pressure inside the duct. For temperature sensing, two types of sensors are used, namely DS18b20 (-55^{o}C to 125^{o}C) and LM34 (-45^{o}C to 145^{o}C) and the ultimate working range of the testing facility is from -45^{o}C to 125^{o}C. DS18b20 acts as the primary temperature sensor, which provides output in °C. LM34 acts as the secondary temperature sensor, which provides output in milli volt (mv). ADC channels of a Microcontroller chip ATMEGA 8 connected to the secondary sensors convert milli volt (mv) unit into a suitable 10 bit digital value. Secondary sensors are calibrated by comparing it with the primary sensor output value during calibration. The components used in the experiment can be listed as below:

1) Piezo-electric pressure sensor.
2) DS18b20 temperature sensor.
3) LM34 temperature sensor.
4) ATMEGA 8-microcontroller chip

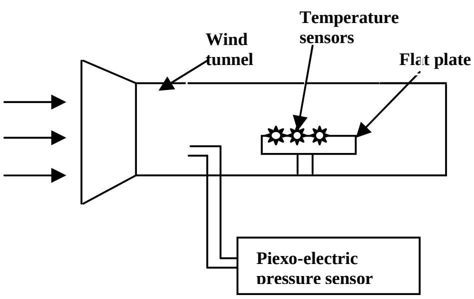


Fig 1. Sensor arrangement

3. HARDWARE ARRANGEMENT

The hardware part of the system covers the whole electrical system apart from the hardware of the testing facility itself. Hardware sections used here can be divided into following parts,

A. Circuit to control testing equipments.
B. Circuit for intermediate processing and feedback control.
C. Circuit for storing transferring and monitoring data (Data logging circuitry).

Well developed hardware arrangement is the backbone of automation. The hardware part should contain control unit, feedback unit, and processing unit. The feedback unit and the intermediate processing unit contains microcontroller which is programmed by C/C++. All these units should have interconnection with one another. PC sends primary control data associated to the experiment and fixed by the experimenter to both the intermediate processing unit and the feedback unit. Intermediate processing unit then processes the data and sends command to the control unit. And based on the command, control unit controls fan speed and heat input to the plate. The feedback unit receives feedback from the velocity and pressure sensors, and sends it to both the PC and control unit. Once the test is started, intermediate processing unit takeover all the task for processing and controlling based on user input and sends data to the PC where MATLAB based software shows the ongoing data for monitoring and controlling of parameters, if needed, by the user. To make the software more user friendly, GUI has been introduced. The software facilitates the experimenter, to store the data in **(.xls)** file. Finally, the experimenter has scope to print out the data table, graphs and also to generate a detailed report based on the experimental data.

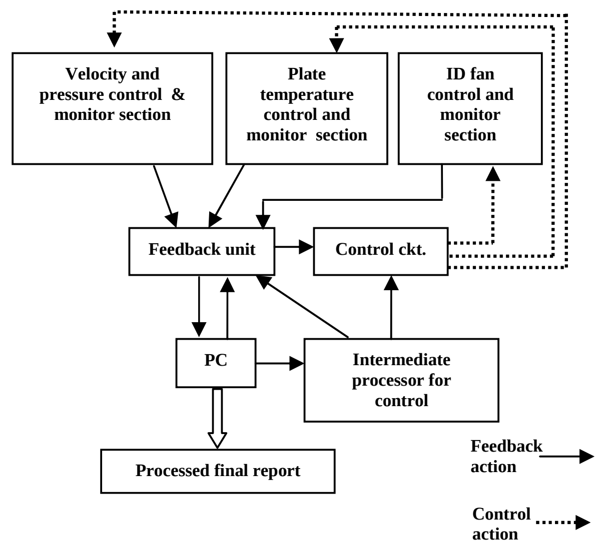


Fig 2. Schematic diagram of hardware arrangement.

3.1 Inter-Connection between Fan* Speed and Velocity/Pressure Sensing Arrangement

In this work, the endeavor was to develop a highly atomized testing set-up. The hardware and software arrangement facilitates the experimenter to perform the experiment at different air velocity (Fig 3). The experimenter sets the air velocity in which he needs to perform the experiment. And based on the given air velocity, the control unit changes the fan speed to achieve that air velocity. Until the system reaches the desired given velocity (steady state) it takes the feedback from the pressure sensor which in turns calculate the instantaneous velocity of air in the tunnel and sends it back to the control unit. Control unit, based on the feedback changes the fan speed until the desired velocity is achieved.

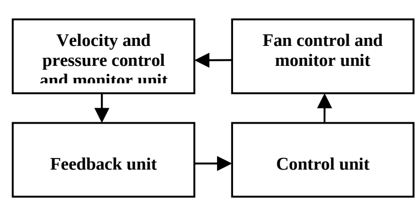


Fig 3. Schematic diagram to set air velocity

***ID Fan has been used in this model**

3.2 Inter-Connection between Plate Temperature and Control Section

The hardware and the software setup facilitate the experimenter to perform the experiment at different plate temperatures (Fig 4). The experimenter has option to select the plate temperature. And based on the selected plate temperature, the control unit changes the heat flux to the plate. Until the system reaches the desired plate temperature (selected by the experimenter), it takes the feedback from the temperature sensors. Control unit, based on the feedback, changes heat flux to the plate until the desired plate temperature is achieved.

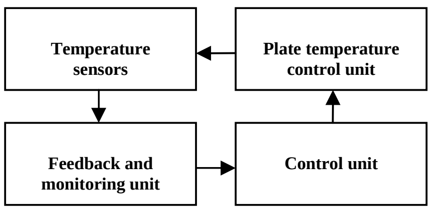


Fig 4. Schematic diagram to control the plate temperature

4. SOFTWARE DEVELOPMENT

To make the testing facility more efficient and user-friendly, an object oriented GUI based software has been developed (Fig 5) using MATLAB GUIDE tool and the MATLAB programming and mathematics tool for the setup. To decrease the complexity and to make the testing procedure conspicuous, experimenter has been given the privilege to stop control and change the parameters at any time and if necessary shutdown the whole process. The object oriented analysis is a faster and efficient way, to develop software and systems. The object-oriented software divides the system into well defined units. For example as in this study: setup checking, data recording [3], initialization, graph plotting etc. are the different units present in the system with the capability of each unit performing independently.

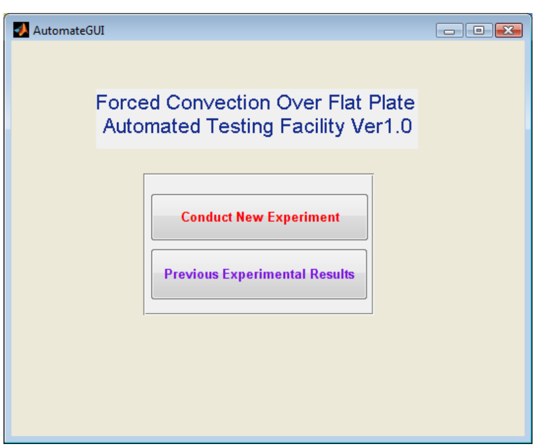


Fig 5. Initial GUI of the software

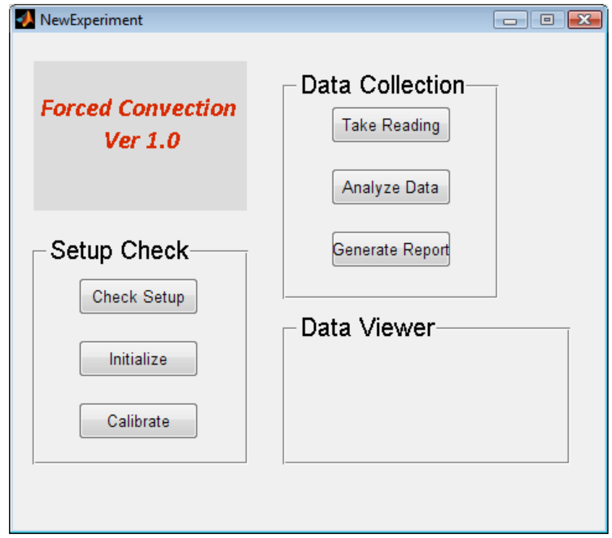


Fig 6. GUI of the software when a new experiment would be conducted

4.1 Setup Checking

The very first task of an experiment is to check the setup. (i.e. if any of the functional components of the setup is ok or not). The GUI for the setup checking has been developed with a proper arrangement to check the availability and the functionality of the equipments (Fig 7).The software provides a pictorial view of the setup, and each of the components, along with their specifications. The software facilitates the experimenter, to check the availability of all the components. Such as: copper plate, blower, temperature sensors, etc. And if any of the components does not respond, then the software apprises the experimenter to check that specific component.

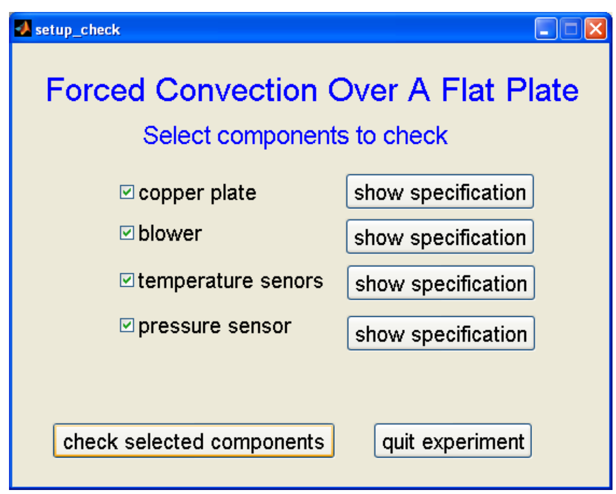


Fig 7. GUI for setup check

4.2 Auto-Calibration

To record the temperature, at different points of the plate, two types of temperature sensor have been used. **DS18b20** has been used as the primary sensor and **LM34** has been used as the secondary sensor. The primary sensor has good accuracy level (±0.5 °C). And it provides the temperature in digital unit. The secondary sensors are calibrated by comparing it with the primary sensor. GUI for auto-calibration has been developed (Fig 8). The software contains built-in auto- calibration code to simplify the calibration process.

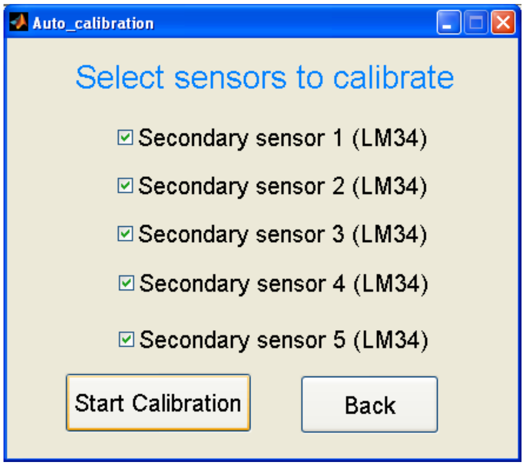


Fig 8. GUI for auto calibration

4.2.1 Advantages of Auto-Calibration

Every sensor shows fluctuation in performance. So for better accuracy the sensors used in an experiment needs calibration from time to time. The conventional process of calibration needs physical access to the sensors which usually means disassembling the system, which is an inconvenient and time consuming process. Moreover in auto-calibration process all the sensors are calibrated simultaneously. Auto calibration shows far better performance than the conventional calibration process. Auto-calibration reduces the error level to a significant level [4]. In this model, specifically Dallas semiconductor designed DS18b20 has been used but if needed other primary sensors can also be used with a proper transducing arrangement to employ auto- calibration in the system.

4.2.2 Method of Auto-Calibration

MATLAB code has been developed to auto calibrate the secondary sensors. Each secondary sensor is connected to ADC channels of a Microcontroller chip **ATMEGA 8** which converts milli volt (mv) input to a suitable 10 bit digital value. To calibrate the secondary sensors, the copper plate is heated to a higher temperature (about 100 °C) and the software records the actual temperature and digital values for each secondary sensor at an interval of 250 milli second. Based on these data, the software plots the temperature vs. digital output curve (Fig 9) and generates equation for each secondary sensor. However, for higher accuracy and low response time, LM34 can be replaced by thermocouples or other temperature sensors [5] such as **TSIC-301**(response time 0.1 second) can also be used. Following table shows the data recorded to calibrate 2(two) **LM34** (secondary sensor) sensors automatically, the program itself generates the table and generates necessary curve for the calibration purpose.

Table 1: Digital values of the sensors at different temp.

DS18b20 (°C)	**LM34** (sensor 1) (Digital value)	**LM34** (sensor 2) (Digital value)
50	122.16	123.2
55	127.45	126.56
60	130.54	129.85
65	133.25	134.26
70	136.88	137
75	139.90	140.12
80	143.25	144.4

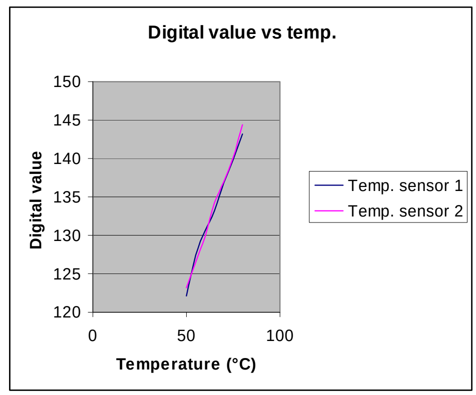


Fig 9. Digital value vs. temp. graph

4.3 Initializing the Process

In every experiment, the experimenter has to provide some standard test data, based on which the experiment is performed. GUI for the initialization of the test has been developed (Fig. 10). The experimenter has to initialize the specifications of the plate which is going to be used in the experiment i.e. plate material, plate length, thickness etc. The software provides option to change the air velocity and plate temperature.

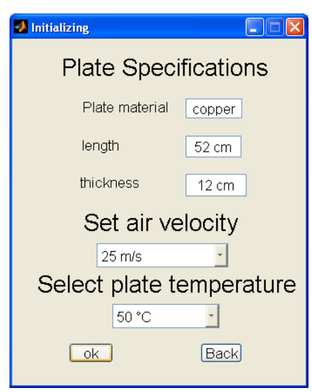


Fig 10. GUI for initializing.

4.4 Data Recording

After the prompt from the experimenter, the software records data, sent by the hardware arrangement. The software has collaboration with '**Microsoft Excel**'. So the software records each data set to a new (**.xls**) file. This arrangement facilitates the experimenter to compare the data with the previous experiments. (Fig. 11) shows the GUI for data recording. The data table shows each data along with their units. The user also has the option to remove wrong or unwanted data, from the table. In an experiment, several data are needed to record simultaneously. So there runs a risk of missing some data. To prevent this problem, hand shake [6] with parallel port is used to ensure that, the system records each necessary data. And if somehow a single data is missing the software will notify the experimenter regarding the missing data. The calculation would not start until the experimenter confirms the system to proceed and the system would apprise the experimenter to perform the experiment from the beginning.

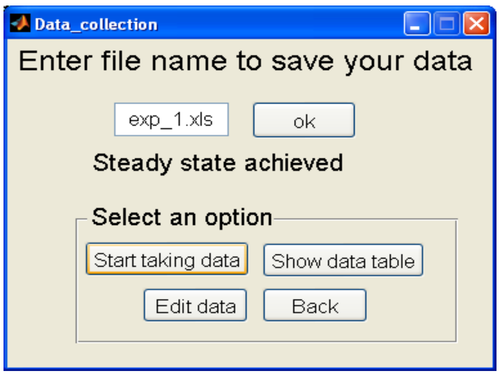


Fig 11. GUI for data collection

4.5 Calculations and Graphs

The final step of an experiment is calculation. Well programmed software enhances the scope of performing numerous complex calculations within a very short time. (Fig. 12) shows the GUI for calculations and graphs. For the calculation purpose, air property table is needed. And the property table has been attached with the software by using MATLAB database [7]. However, the software has facility to view the results (Fig 13), graphs (Fig 14) and also to generate report of the experiment.

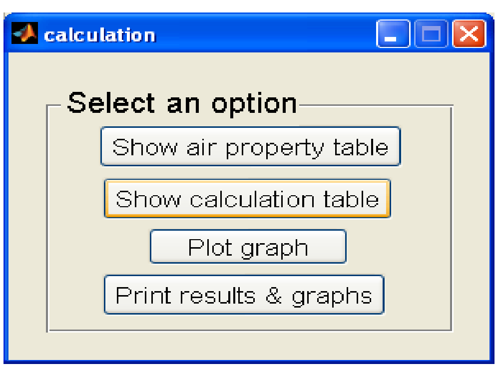
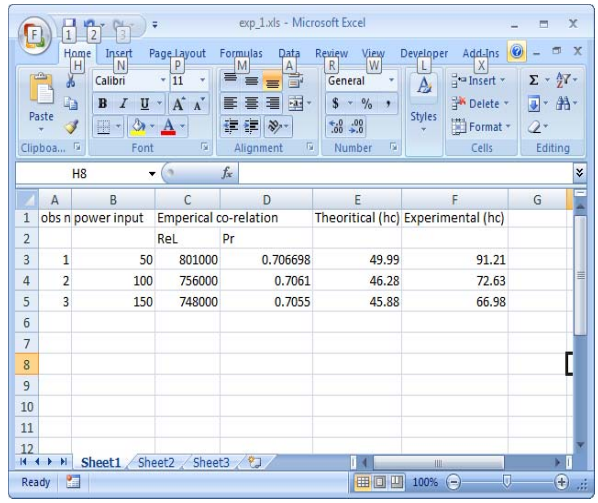


Fig 12. GUI for calculation



	A	B	C	D	E	F
1	obs n	power input	Emperical co-relation		Theoritical (hc)	Experimental (hc)
2			ReL	Pr		
3	1	50	801000	0.706698	49.99	91.21
4	2	100	756000	0.7061	46.28	72.63
5	3	150	748000	0.7055	45.88	66.98

Fig 13. Calculation table

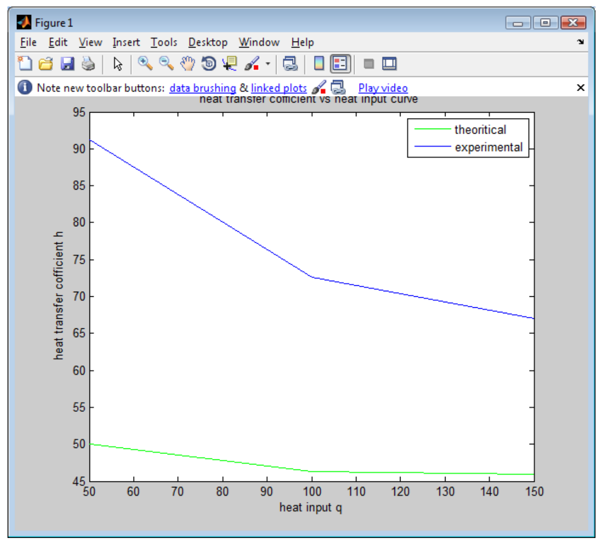


Fig 14. Heat transfer coff. vs. heat input curve

5. FURTHER DEVELOPMENT

Further development of this work would facilitate the experimenter, to perform the experiment at different plate angles. Stepper motors can be connected with the flat plate, for the inclination of the plate at different angles [8]. Software can also be developed which would facilitate the experimenter, to choose the range of the plate angles at which the experiment would be carried out. And the results of heat transfer coefficient, for different plate angles would help the experimenter to find out the plate angle for which heat transfer coefficient would be maximum / minimum. And this would make the experimental setup, as an universal setup [9].

6. CONCLUSION

MATLAB is a user-friendly and a powerful tool that can carry out various engineering applications and calculations within a very short period of time. So

MATLAB has been chosen in this work, to develop the software for automation purpose. GUI is used to make the software more user-friendly. This paper shows the gateway to atomize any testing setup. The objective of this study and present work is entirely to give the students and as well as researchers the idea of the MATLAB automation tool [10] and how to automate a testing facility for the ease of experiment. **The forced convection over a flat plate** experimental setup has been taken as a model for the work. However, any testing facility can be atomized, by following these general steps [11], as described in this paper. The **auto-calibration** process as described in this paper can be used to calibrate any type of sensors. A highly atomized testing setup widens the scope of achieving error free result [12] and performing a test within a very short time. That's why a highly atomized setup can commercially be used for testing purposes.

7. ACKNOWLEDGEMENT

This work was supported in part by R&D department of E-Solutions BD.

8. REFERENCES

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