Palestine Polytechnic University

College of Engineering & Technology

Mechanical Engineering Department

Mechatronics Engineering

Graduation Project

Designing and Building of Thermal Fatigue Testing Machine for Stone

Project Team

Mou'th Shawer Yehya Hassounh

Project Supervisor

Dr. Maher Al-Jabari

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Abstract

This report summarizes the experimental, design, and modeling work that was performed in this project for developing a thermal fatigue test for stone.

This project helps the Palestinian stone industry by providing a tool for stone quality testing which would assist in import, export activities.

thermal fatigue test make by provision the circumstance which lead the stone become a failure, the thermal fatigue test is divided into heating and cooling process. Each process is need to analysis and model to obtaining the relationship between the temperature and time. After constructing the full thermal machine, the obtained temperature-time curves provided for the full cycle, were compared with the measured actual curves.

PIC microcontroller is used to control the whole system with a logic control, the actuator transfer the specimen between two process several times by insert number of cycles, insert the time which needed to heating and cooling process and the required temperature each of these configuration specified in start of operation by human machine interface.

The final product is a mechatronics system for heating and cooling processes. In future works, this product can be developed to become more intelligent, by adding other tasks to it. These additional tasks could be observing the crack by other tools such as image processing (IM) tools or other observations.

Dedication

To our parents who gave us their support and sustained encouragement. To our supervisor Dr.Maher Al-jabari, whose guidance and support made this work possible.

To Palestine Polytechnic University, especially to our college and department. To the whole team in mechanical engineering department. To our friends in college of engineering and technology.

We dedicate this humble work

Project team

Acknowledgement

Here as we finished our project we stop for a moment to thank every body who has helped us to complete this work.

First we want to thank our supervisor Dr. Maher Al-jaberi who gave us a lot of time and experience in order to complete the project, and gave us the opportunity to start scientific life and methodology in the real life.

Special thanks to Eng. Aref Hebrbawi, Al-Rayyan metalwork shop and Al-Motasem garage for their unlimited support.

Special thanks related to PPU stuff in mechanical engineering department, who gave us valuable notes on our project and used to encourage us to complete the project in successfully.

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5.1 Introduction

The way of proofing the theoretical results is using the practical experiments. This chapter shows the results of experiments that needed to verify the results in chapter three and to verify the suitability of this project to attain the aims of this project.

These experiments concentrating on the temperature only; there are no experiments for the kinematics; because of the importance of the temperature of the stone in heating or cooling room, not for moving the system or the time needed to move the stone specimen from a room to another.

The temperature of the oven and the time of heating are set. So it must be sure that the system can reach to the specific temperature and the heating time set is enough to increase the temperature of the stone specimen to the specific temperature.

The door temperature and the outer surface of the oven will be measured to be sure that the oven is good or bad isolated. Comparison between old oven design and the new development will be concluded.

This chapter presents the work of the experiments, the sensors were used and the results of each experiment.

5.2 Experiments Work

The required components of all experiments are also the temperature sensors. First one is a mercurial thermometer, it ranges from 0 C° to 300 C°, the resolution of this sensor is 2 C°, the error in measuring is about 3 to 4 C°. The second sensor is infrared thermometer. This sensor is for measuring the temperature of the surfaces, the resolution of this sensor is 0.1 C°, and the error in measurement is small.

The procedure of this experiment is simple. The position of the temperature sensors must be pointed, a hole in the cover of the oven is enough to set the thermometer to measure the temperature of the heating room. As before, the infrared thermometer used to measure the temperature of the surfaces; so in these experiments this sensor is used to measure the surface of the stone specimen, and the outer and indoor surfaces of the oven.

After setting the sensors in their positions, the reading of each sensor could be taken every half minute. The period of the experiment is not fixed, some of experiments just for moments, and others extend to about 25 minutes.

5.3 Experiments and Results

5.3.1 Heating and Cooling in The Same Room

In this experiment, the temperature of the oven start from the surrounding temperature; that is mean the power of the heat coil is turned on, then the temperature will increase. The time of heating is 10 minutes, then the power is turned off to measure the cooling in the oven without the fans. The sensors which used in this experiment is the thermometer. The results are shown in figure 5.1.

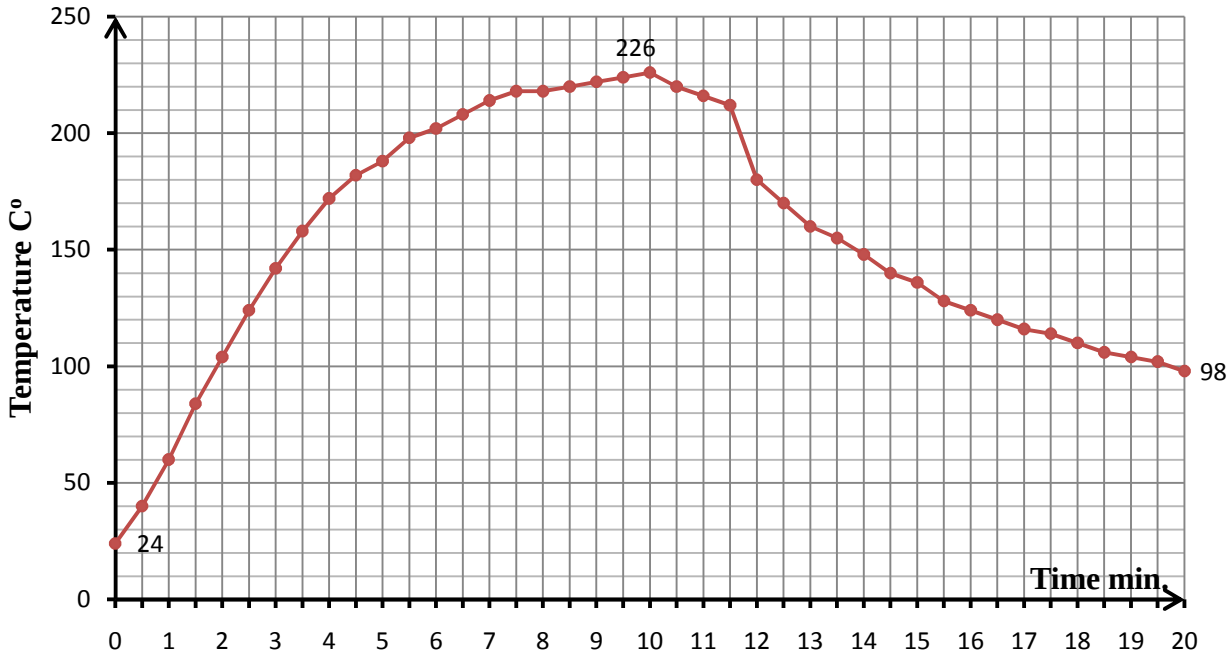

Figure (5.1): Heating and cooling in the same room

The results of this experiment are:

- The cooling operation need time more than the heating operation. In heating operation the temperature change from 24 C° to 226 C° in 10 minutes, but in cooling operation the temperature change from 226 C° to 98 C° in the same time.
- The relation between the temperature and the time is not linear.

The conclusions of this results are:

- If the cooling operation happen in the oven it must set the time of cooling operation more than the twice of the time of heating operation.
- The choosing for one room for heating and cooling is not suitable, because the time that needed in cooling the oven then heating it is too long and increase the energy that consumed.

5.3.2 Comparison Between The Heating Room and The Stone Specimen

Comparison between the heating of the room and the heating of the stone specimen is to show the difference between them and to estimate the time of heating that is needed to heat the stone specimen to the specific temperature. This comparison is shown in figure 5.2.

The sensor used in this experiment is a thermometer to measure the oven temperature and infrared thermometer to measure the surface of the stone specimen.

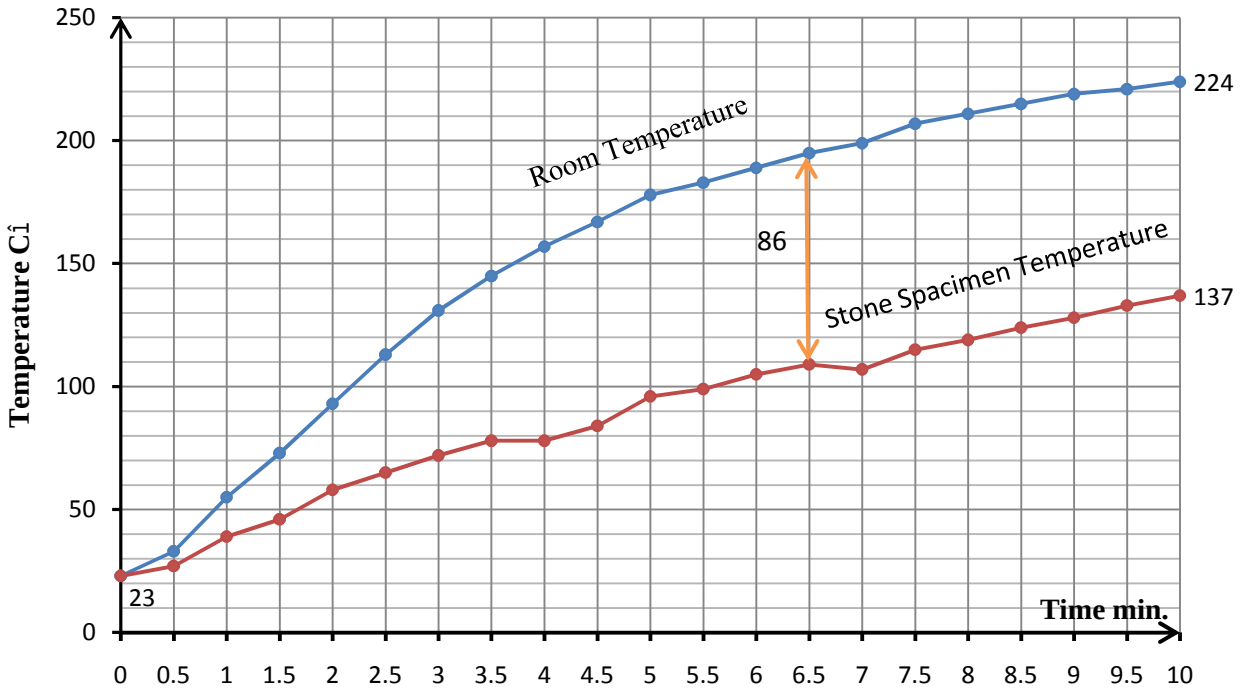

Figure (5.2): Comparison between room temperature and stone spacemen temperature

The results of this experiment are:

- The time that is needed to increase the temperature of the stone specimen to the specific temperate is more than the time needed in increasing the room temperature. As it shown in figure 5.2, in 10 minutes the temperature of the oven reach to 224 C°, but the temperature of the stone specimen reach to 137 C°. although the twice start from the same temperature.
- After the 4th minute the difference between the room temperature and stone specimen temperature is around 86 C°.

The conclusion of this results are:

- In the program of this machine addition of a constant value to the temperature that set by the employee must included, and this value is 40 C°.

- The chosen temperature 40 C° because there are a limitation on the controller. This limitation is the maximum temperature is 170 C°, that is mean the maximum temperature the employee can set is 130 C°.
- The chosen value can change to other and the time of heating can increase or decrease as this value decrease or increase respectively.

5.3.3 The Heating and Cooling Cycle of Stone Specimen

In this experiment the heating operation done in the oven and the cooling operation done in the cooling room using two fans. The heating start from surrounding temperature. The results of this experiment are shown in figure 5.3.

The used sensor used in this experiment is infrared thermometer. This experiment simulate the actual operations that done in this machine.

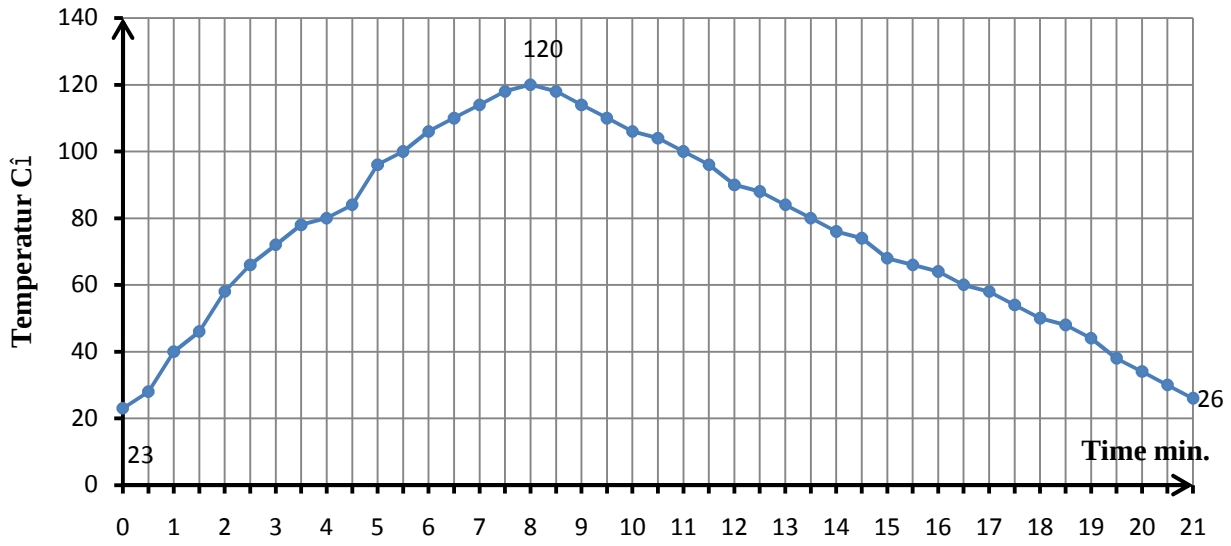

Figure (5.3): Heating and cooling cycle of the stone specimen

The results of this experiment are:

- The time in heating operation is less than the cooling operation. The heating operation takes 8 minutes and the cooling operation takes 13 minutes.
- Using linear regression method the slope of the heating operation is 6.171 C°/min. and the equation of this operation is $y = 6.171x + 23.22$.
- Using linear regression method the slope of the cooling operation is -3.573 C°/min. and the equation of this operation is $y = -3.573x + 181.2$.

The conclusion of this results are:

- The time of cooling operation must not equal to the time of heating operation in the program of this machine.
- The time of cooling operation must be the double of the time of the heating operation.

From the previous diagram have the value of α_1 ,α_2, α_3 as follow :

α_1 =0.6

α_2=0.035

α_3=0.002

When compare these results with the value in chapter three notes that the value is logical, because the theoretical value don't consider some loss of heating .

5.3.4 Comparison Between The Developed Oven and The Old Oven

The indoor surfaces of the old oven was made from steel. The indoor surfaces of the developed oven is made from stainless steel.

In this experiment there is a comparison between old experiment for the old oven and the new experiment for the developed oven. The sensor which used in this experiment is thermometer. The comparison shown in figure 5.4.

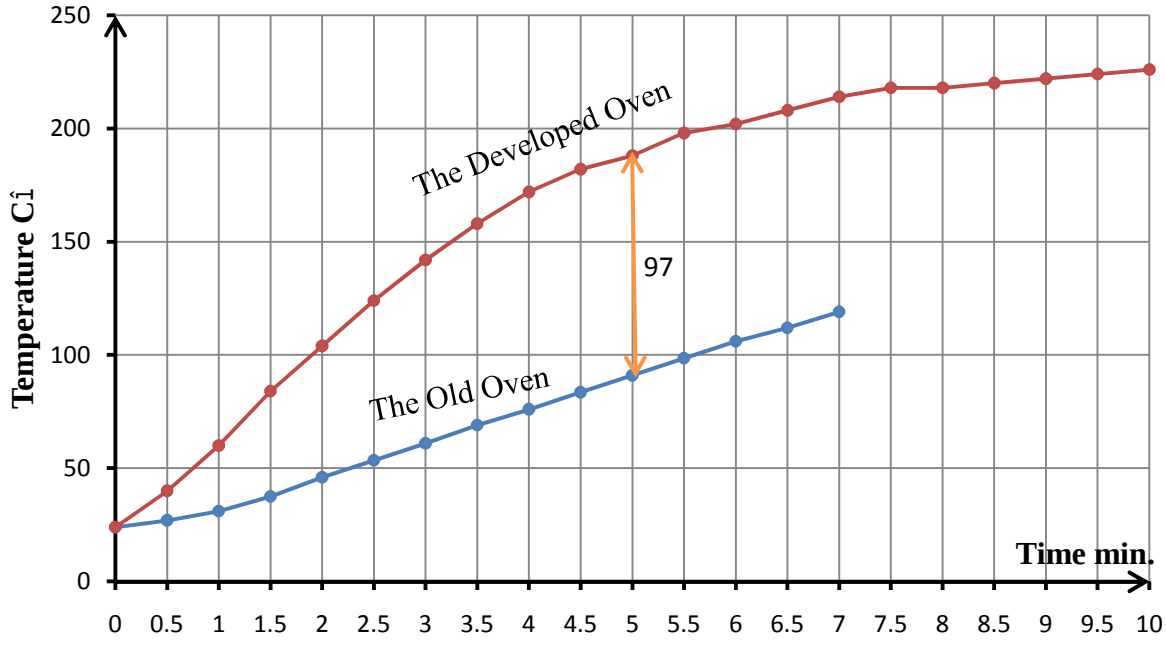

Figure (5.4): Comparison between the old oven and the developed oven.

The results of this comparison are:

- The heating operation in the old oven is slower than the heating operation in the developed oven.
- After 4th minute the deference in temperature between the old oven and the developed oven is about 97 C°.

The conclusion of this results is the developed oven is better than the old oven.

5.3.5 Thermocouple Experiment

The objective of this experiment is to find the relationship between the temperature that was measured and the output voltage from thermocouple.

The sensor that used in this experiment was a thermometer. The thermometer and the thermocouple were putted in the water and took reading at different temperature. The results of this experiment are shown in figure 5.5.

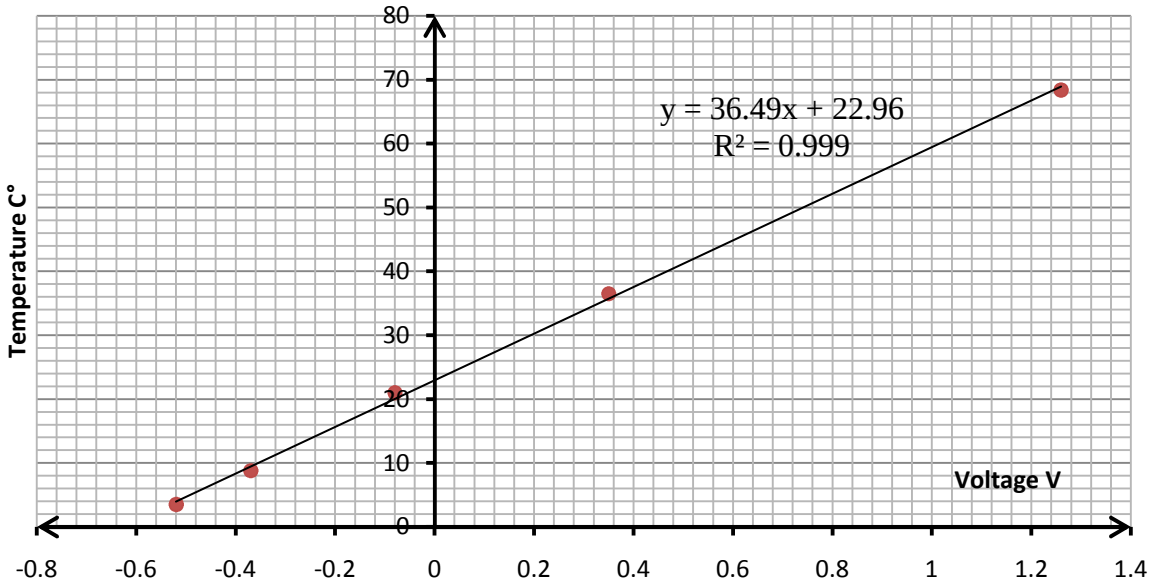

Figure (5.5): The relation between the temperature and the voltage produced by thermocouple

The results of this experiment are:

- The relation between the temperature and the output voltage from thermocouple is linear.
- Using linear regression method the equation of the linear line is $T = 36.49V + 22.96$. T is the temperature, V is the voltage.
- When the output voltage is zero the temperature is 23 C°. And when the temperature is zero the output voltage is -0.63 volt.
- The slope of this equation is 36.49 C°/V.

The conclusion of this results are:

- This equation could be used in the program of this machine.
- The maximum temperature allowed to be reached is when the output voltage is 4 volts, depending on the configuration of the controller. So this temperature is 170 C°.
- The minimum temperature of this machine is when the voltage is zero, depending on the configuration of the controller.

5.3.6 The Time of Heating The Specimen in Constant Temperature

In this experiment the specimen inter the oven when the temperature of the oven is more than the specific temperature.

The temperature of the oven is 165 C°. The temperature of the stone specimen is 23 C°. After 3:30 minutes the temperature of the specimen reach 100 C°. And after 4:30 the temperature of the specimen reach 120 C° and the room temperature reach 155 C°; because the power of the heat coil was turned off.

The conclusion of this experiment is the recommended time for heating is 4:30 minutes.

5.3.7 The Temperature of The Outer Surfaces of The Oven

After 5 minutes of heating the temperature of the best isolated surface is 25 C°, but in contact point between the cover of the oven and the body reaches to 40 C°.

After 15 minutes, the temperature of the best isolated surface is 35 C°, but in contact point between the cover of the oven and the body reaches 100 C°.

The conclusion of this experiment are:

- The isolation in the oven is suitable and affective.
- The contact points between the cover of the oven and the body need more isolation.

Chapter six

Concluding Remark, obstacles and Recommendations .

6.1 Concluding Remarks

6.2 Obstacles

6.3 Recommendations

In this chapter ,the main concluding remarks of building thermal machine test ,and implementation control and monitoring system are previewed together .

6.1 Concluding Remarks

The following are the main concluding remarks:

- The implementation of the project has finished successfully , the thermal test machine is able to work as an embedded system such that the microcontroller controls the oven temperature through the feedback signal coming from temperature sensor with a very good range of motion and durability.
- After studying the literature review of the tests of the stone for stone certification in the most important characteristic, each test from these tests must be subjected on the stone before distributed and uses.
- The most important test is thermal test ,in all labs in the world to make thermal test on all industries such as plastics industry ,the ISO labs contain oven to make thermal test .
- But the thermal test in our lab make by open loop system ,therefore was develop this operation to become closed loop system .
- However the operation of the system is not perfect , it has encounter some problem due to some error in the operating program of the PIC microcontroller and the high sensitivity of the values of the sensor due to any disturbance .
- More effort are still needed to complete the goals of the test machine in order to achieve better and more accurate results ,more testing and tuning are to be made to improve its performance specially on the operating program written to the microcontroller and its temperature sensor calibration.
- The experimental result of the heating and cooling operation gave perfect result with theoretical result ,when make matching between the results .

6.2 Obstacles

As any first time project many problems and obstacles were encountered ,technical ,economical and uncontrolled barriers made it very hard but not impossible mission to finish the project goal.

- A great obstacle stood up against the team when there was need to develop the design from one room into tow room for many reasons was discover in start of project .
- The maximum length of the actuator limitation was problem to assemble the cooling and heating room ,because the two room becomes very close .
- When making the experimental result , the big obstacle its fixing the thermometer inside the oven for measure and read the temperature at the same time of the stone and the oven.
- A major problem that opposed the project progress is there aren't any financial support and administrations attention.
- Some parts from the control unit in this project take big delay which cause a delay in the time table three week .
- In addition to the obstacles found in the electrical implementation ,where the sensor gives voltage values very small reach mill volte , and the noise is very large for the voltage sensor , the voltage from the sensor not reach exact into PIC microcontroller ,therefore was make amplifying circuit to amplify and filtering the voltage, this solution has been applied only in the last few weeks of the project schedule time .
- One of the most important problems that faced in the project is the programming of the PIC microcontroller since the project team didn’t have any experiences in programming and handling of such a tool ,the project team was promised to get training from the university at the beginning of the semester but this training was postponed until the last week in the semester which made it very difficult to work with since of the lack of time and the huge amount of data that must be understood in inadequate period of time .
- Beside the team project had no programmer tools ,they are available only in one lab in the university and not free to use by students , the lab teacher is the one responsible for this action ,gratefully he helped in this process ,but one lab for graduation project with

one assistance and many graduation project of many field with all of their problems made it hard to find him free for writing our code to PIC for better and faster testing and tuning.

6.3 Recommendations

For better future efforts in the field of testing machine ,the following recommendation and tips are made as we passed this experience.

- Developing this project by adding checking crack part by using high technology ultrasonic sensor or image processing to make scanning of the surface of the stone.
- Pursue a strategy of step by step in design any part because for the system simplifying and reducing the error.
- In the cooling room the fan doesn't give the complete cooling of the stone, therefore it's possible to make the entire cooling system such as r refrigerator.
- The most important recommendation is that the university must prepare a large lab for graduation project to help students to work in ,since the graduation lab that is running now is not sufficient to all student ,and other labs are not always opened to students to work in ,as a result you might lose your day, if the lab teacher is out of his work or in vacation.
- Provision the financial support and administrations attention for encourage the student on developing the projects .
- The university must strengthen its relation with scientific institution and colleges outside Hebron, it should market the students graduation projects , be proud of them and let others know about ,an annual journal includes such thoughts and information would be great idea that could help and improve the university picture and reputation and might give its student more opportunities to compare with other universities and improve their experience .
- The university must work up on turning the concepts of the graduation project into commercial applicable plans and projects.

References

1. Union of stone and marble industry (UM).
2. Ministry of National Economy.
3. Heat Transfer, Ninth edition, J.P.Holman.
4. Technical and Educational Vocation Training Center (TVET).
5. Tensile behavior in natural building stone, A. Meda, Civil Engineering Department, Universitg di Brescia, Brescia, Italy, October 2003.
6. www.worldstonex.com
7. www.Wikipedia.com
8. www.scincedirect.com
9. http://www.ndt-ed.org