Sensors And Digitization

Lab 2 - Infrared Imaging

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Chapter 1

Introduction

1.1 Background Of Study

During a course module in sensors and digitization, we undertook a laboratory tutorial in infrared imaging. We had lectures on it and that made us ready to perform the necessary tasks given in the laboratory tutorial.This is a report for the findings we made during this course.

Infrared is a form of light that we can not see with our eyes, but that we can sometimes feel on our skin as heat. Infrared radiation is an electromagnetic radiation just as radio waves, ultraviolet radiation, X- rays and gamma rays. All these forms, which collectively make up the electromagnetic spectrum, are similar in that they emit energy in the form of electromagnetic waves traveling at the speed of light. Infrared radiation (IR) is one of the three main ways of transferring heat from one place to the other, convection and conduction being the other two means. All materials, which are above 0 degrees Kelvin (-273 degrees C), emit infrared energy. The infrared energy emitted from the measured object is converted into an electrical signal by the imaging sensor (micro-bolometer) in the camera and displayed on a monitor as a color (artificially colored to represent thermal activity via visible light) or monochrome thermal image.

The major difference between each 'band' in the spectrum is in their wavelength, which correlates to the amount of energy the waves carry. For example, while gamma rays have wavelengths millions of times smaller than those of visible light, radio waves have wavelengths that are billions of times longer than those of visible light.

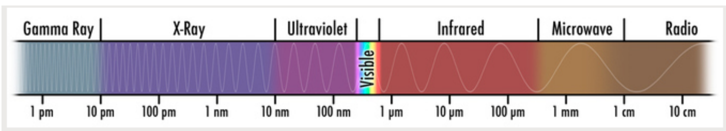


Figure 1.1: The Electromagnetic Spectrum

Light travels through the Universe as a wave, but it is rather different than the ripples we see moving across the surface of a lake. Light waves are made up of electric and magnetic fields. So another name for light is electromagnetic radiation. And the entire spectrum of light is similarly called the electromagnetic spectrum.

One of the basic properties of any wave is its wavelength, which is just the distance between the peaks of one ripple, or wave, and the next. For light, it is the length of one full cycle, or pulse, of the electric and magnetic fields. A related property is the frequency, or the number of waves that pass a fixed point every second. Our eyes detect differences in the wavelength of visible light as differences in color. Essentially, color is your brain's way of converting the different wavelengths of light that your eyes see into something that you can quickly understand. Red light has a longer wavelength than green light, which in turn has a longer wavelength than blue light. The wavelength of infrared light is longer than red light, in some cases many hundreds of times longer. These longer wavelengths carry less energy than red light and do not activate the photo-receptors in our eyes, so we cannot see them.

1.2 Objectives

The goal of this practical work is to study the application of the Infrared Radiation (IR) imaging to temperature measurement and to observe the influence of several parameters on the efficiency of these measurement, While correlating physical properties such as Planck's law and Kirchhoff's Law.

To achieve the tasks asked by our supervisors we undertook these various steps to achieve them successfully. Below are the steps in which we took :

- Firstly, we studied the camera we are to use this laboratory and the Altair software and performed some activities with it to see its functionalities.
- Secondly, we performed some calibrations of the camera as well and also gave comments and critics of the calibration process in which we used.
- Thirdly, we performed estimation of emissivity. We gave the emissivity of each given material used during the application of the Infrared Radiation (IR) laboratory experiments.
- Fourthly, we performed transmission and reflection coefficients on some materials asked.
- Lastly, we performed an active thermography application.

Chapter 2

Hardware And Software Specifications

2.1 Hardware Specifications

Theses where the hardware components in which we used for the laboratory course :

1. PC Component
2. IR Camera- FLIR Cedip SC7000 Series
3. C.A 1875 Tutorial Bench
4. Industrial Parts and Electronic Circuit

2.1.1 PC Component

Our PC component with a monitor, keyboard, mouse with a basic windows operating system which had the software which will be used to perform the tasks installed on it. This will be useful in monitoring and controls of the activities during the practical session.

Figure 2.1: PC Component

2.1.2 IR Camera- FLIR Cedip SC7000 Series

This was the camera used for this laboratory course. It is an infrared camera manufactured by FLIR. The FLIR SC7000 Series is specifically designed for academic and industrial research and science applications. They are flexible camera with high sensitivity, accuracy, spatial resolution, and speed at an affordable cost.

Key Features :

- Multiple Detector Options
- Ultra High Frame Rates With Windowing
- Removable Filter Wheel
- Multiple Video Outputs

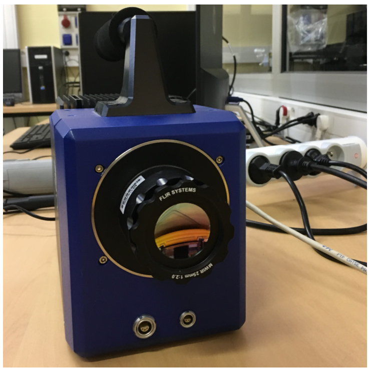


Figure 2.2: IR Camera

Specfications :

- Detector Type : Mercury Cadmium Telluride (MCT)
- Spectral Range : 7.7 - 9.3
- Resolution : 320 x 256
- Detector Pitch : 30
- Well Capacity : 37/12 M electrons
- Sensor Cooling : Internal Sterling
- Readout Modes : Asynchronous Integrate Then Read

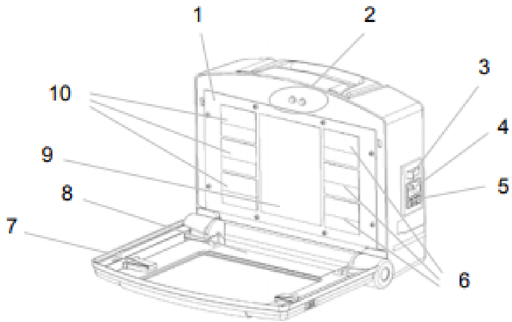
2.2 C.A 1875 Tutorial Bench

The C.A 1875 tutorial bench comprises a hot plate with several targets having different surface conditions and made of different materials, along with test screens that are affixed to the front of the bench using magnets. The purpose of this bench is to allow the student to discover the main possible causes of error when making a measurement using an infrared camera.
The aim of this kit is to highlight the main causes of errors encountered when measuring with a thermographic camera. For example :

- Influence of materials emissivity
- Influence of positioning
- Reflection and transmission

Parts of the Bench :

1. Hot plate
2. LEDs indicating rising or falling temperature
3. On / Off switch
4. Power cord connection
5. Fuse compartment
6. 10: Plates of different materials
7. Cover protecting the bench
8. Test screen attachment plate
9. Black reference plate for the various tests



Specifications :

- Power supply: 230 V 50 / 60 Hz
- Consumption: 400 mA
- Temperature of hot plate: 50 to 55°C (+or-)3°C
- Dimensions: 280 x 225 x 110 mm
- Weight: 1.8 kg
- Fuse : Dimensions: 5 x 20 mm, Rating: 0.5 A fast-blow -250 V.

2.2.1 Industrial Parts And Electronic Circuit

Electronic Circuit: This component is based on a silicon circuit board wi th an Operator Presence Control OPO trigger incorporated heating element. We will use these materials to see how thermal activity interacts with the circuit board and how to determine effects via Infrared Camera software

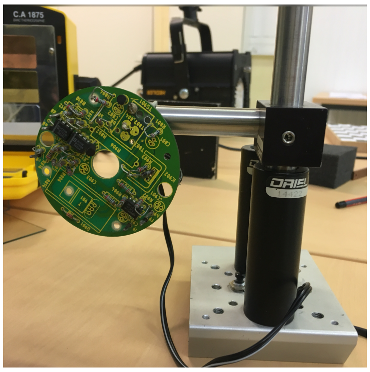


Figure 2.3: Electronic Circuit

Industrial Parts : The following where the industrial parts in which we used in the laboratory course.

Figure 2.4: Flat-bottom holes

Figure 2.5: Pained Picture

2.3 Software Specifications

2.3.1 Altair Software :

This software will be used for our practical work. This software suite offers powerful and sophisticated features for scientists and engineers who want to acquire, display and process infrared images. The Altair suite is composed of several software tools allowing simple and conventional tasks as well as more complex focal plane array management features.

Key Features :

- Exclusively Dedicated to High End Thermography
- Operates with all FLIR HighEnd Cooled infrared cameras
- Unique temperature analysis functions
- Real time storage of images on laptop at full frame rate
- Built in video player for multi sequence films
- Full exportation capabilities
- Filtering management capabilities
- External analog signal acquisitions
- Detector raw data availability
- Customized calibration available

Chapter 3

Study of the camera and Altair Software

In this first part, we'll will study how to detect a defected component on an electronic circuit. To start with, connect on the Ethernet port of the computer then press the camera power button and launch the Altair Software (on the computer). Wait that the camera's temperature is stabilized and obtain the first infrared image.Open live camera, freeze and save it using F9(to freeze) and F12(to export in BMP or JPG format).It is possible to change the color palette as you want. In our case we use the "roygbiv" one.

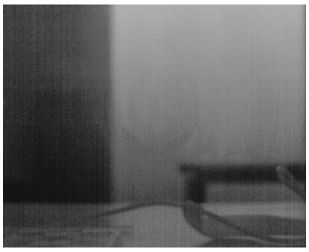


Figure 3.1: First infrared image

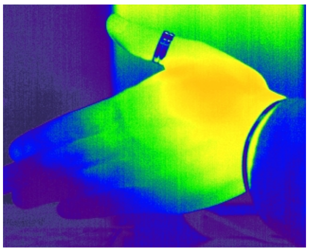


Figure 3.2: Image chosen with palette

Secondly,on the electronic circuit we will determine which component is defected. To do that, install the electronic circuit in front of the camera and press the button. After few seconds, we can observe on the live camera the defected parts of the circuit.

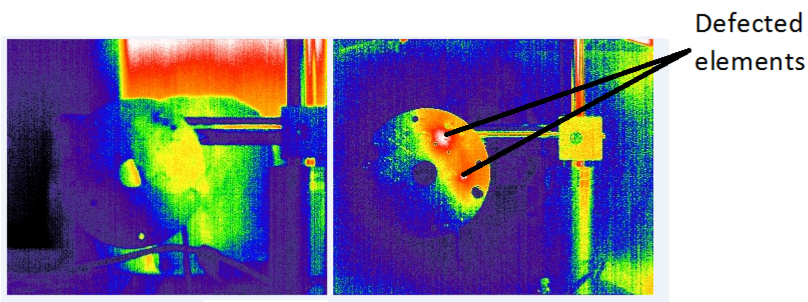


Figure 3.3: Image of the Circuit before and after the detection

The heat radiance of the equipment is "photographed" on the screen and thus an image of the temperature distribution in the installation is obtained.

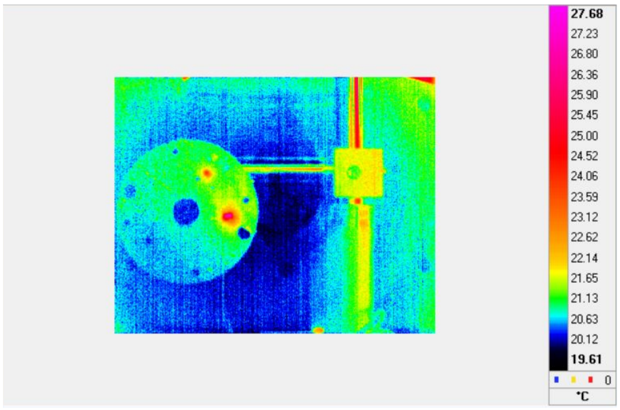


Figure 3.4: Temperature distribution in the circuit

So we can directly observe that in the area of defected components, the temperature is high with a maximum at 27.68 degrees. We can also observe that the mean temperature of the circuit is at 23.65.

By using the spot and the histogram (tools from the software) we can directly detect the positions of the defected components and also the mean, the maximum and the profile temperature (or digital level DL).

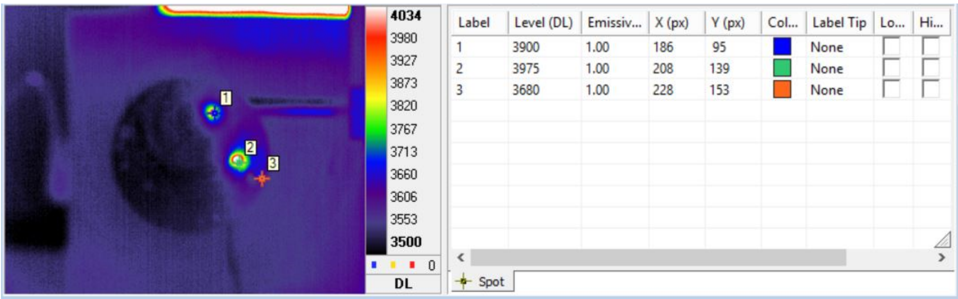


Figure 3.5: Detection of the defected component

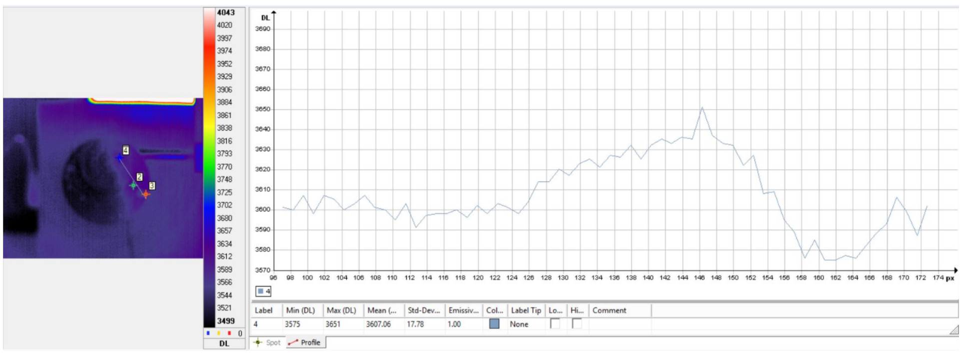


Figure 3.6: Parameters of the defected elements

Chapter 4

Camera Calibration

In this second part, we will realize the temperature calibration of the camera by hot plate. Use the tool from the Altair Software to measure the and record what you need.

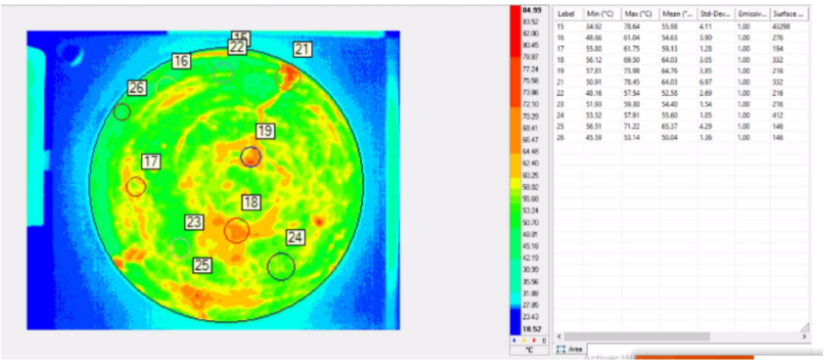


Figure 4.1: Measurement on the hot plate

And then we can compute present onto 2D graphic the relationship between the real temperature and the digital level (DL).

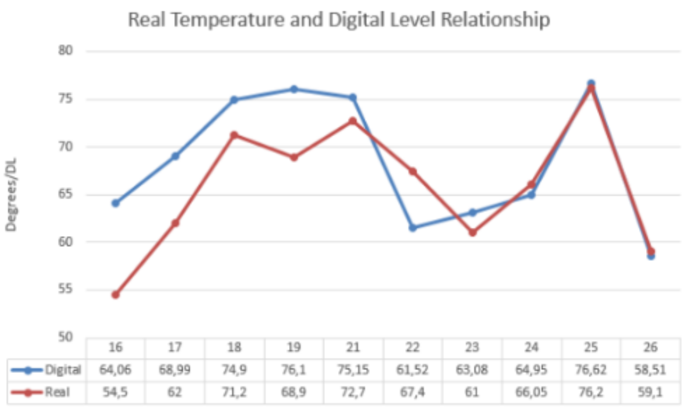


Figure 4.2: Relationship between the real temperature and the digital level onto 2D graphic

The infrared camera consists of a lens to focus the infrared (IR) energy on to a detector, which converts the energy to an electrical signal that can be displayed in units of temperature after being compensated for ambient temperature variation.

So in our case doing the calibration using an infrared camera is better than using the digital thermometer because this configuration facilitates temperature measurement from a distance without contact with the object to be measured.
As such, the infrared thermometer is useful for measuring temperature under circumstances where thermocouples or other probe type sensors cannot be used or do not produce accurate data for a variety of reasons.

Some typical circumstances are where the object to be measured is moving; where the object is surrounded by an EM field, as in induction heating; where the object is contained in a vacuum or other controlled atmosphere; or in applications where a fast response is required.

Chapter 5

Estimation of Emissivity

In this part, we'll determine the emissivity of each material of the C.A 1875 tutorial bench.

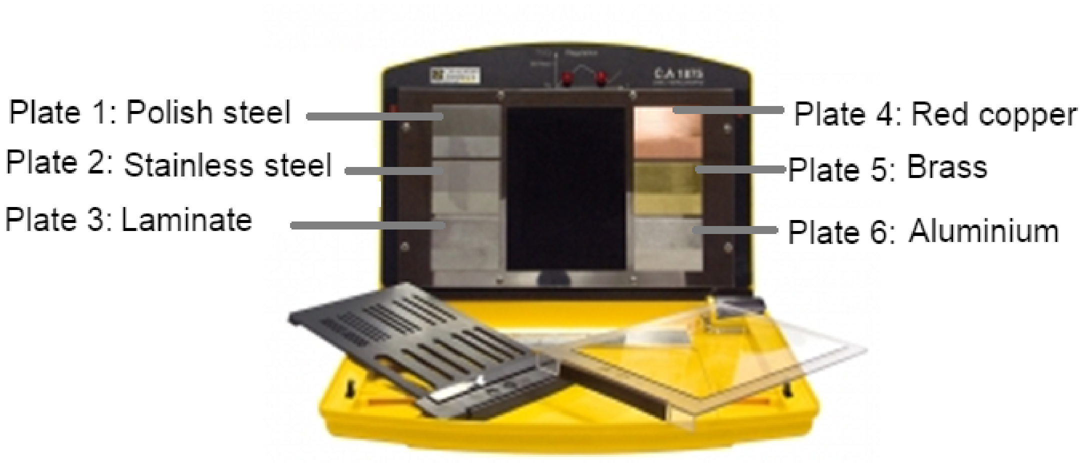
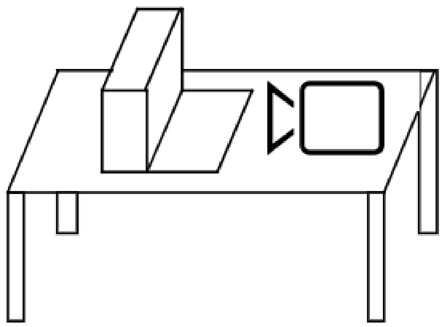


Figure 5.1: Presentation of hot targets

5.1 Installation

The C.A 1875 thermography tutorial bench must be placed on a flat, level surface. The hot plate must be perpendicular to the work top and in front of the camera.



Once the bench is in place, connect it to a mains outlet with an earth and power up using the On/Off button. Wait a few minutes for the plate to warm up before running the first tests.

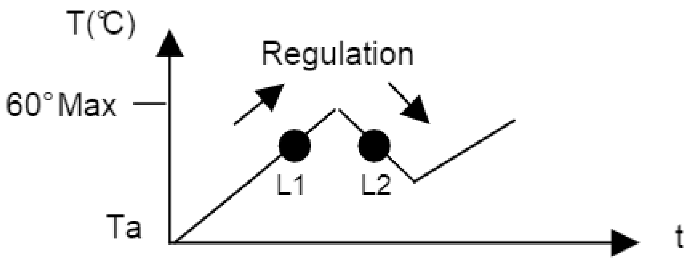


Figure 5.2: Diagram of operation of the LEDs and of the temperature variation of the hot plate

When the bench is started, L1 lights until the plate reaches approximately 55°C. When this temperature is reached, L2 lights and the plate cools to approximately 50°C. Heating resumes, with the lighting of L1, and so on. This cycle continues indefinitely for as long as the bench is in operation.

5.2 Emissivity

The emissivity of a material (often written ε), is the ratio of the energy it radiates to the energy a black body would radiate at the same temperature. It is therefore a measure of the capacity of a body to absorb and re-emit radiant energy. The emissivity is a quantity between 0 and 1. It is shown by the Planck's curve below :

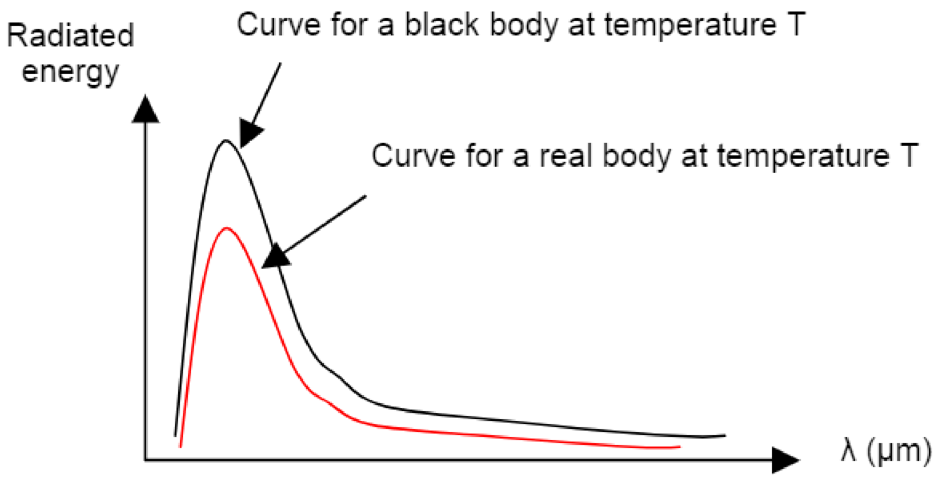


Figure 5.3: Plank's curve

The lower the emissivity, the lower the maximum of the curve.
NB: A black body is a body of which the surface absorbs all radiation received.
A black body is not a real thing, but an idealized object from which the only outgoing radiation is thermal radiation, determined solely by the body's own temperature.

5.3 Estimation of emissivity

In this part, we will measure and calculate the emissivity of each material.

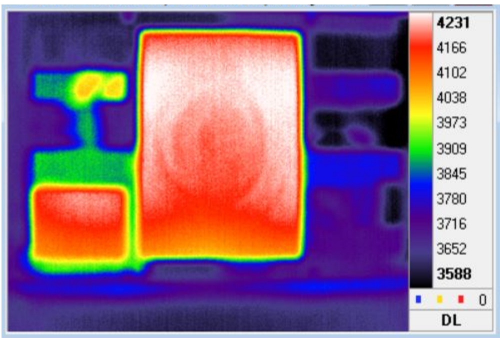


Figure 5.4: The bench before the measurement

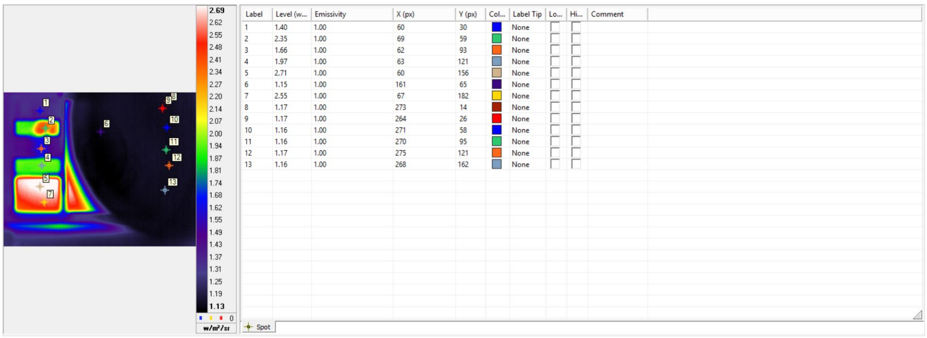


Figure 5.5: Measurement of the radiance

We know that the emissivity of a material is equal to the radiance of that surface divided by the radiance of a black body at the same temperature as that surface. So we get :

- Polish Steel = 0.95
- Red Coper = 0.93
- Brass = 0.953
- Aluminium = 0.54
- Laminate = 0.7
- Stainless = 0.95

The emissivity of a material is the characteristic of that material and of its surface condition. The more capable a body is of absorbing heat, the closer its emissivity is to 1.

Chapter 6

Transmission And Reflection coefficients

With this part we performed an experiment to determine the transmission and reflection coefficient with so materials. We first used a glass plate to determine the transmission coefficient and then we used the same experiment on a black PVC. We later determine the reflection coefficient using a piece of copper.

6.1 Transmission Coefficients

A transmission coefficient describes the amplitude, intensity, or total power of a transmitted wave relative to an incident wave. The Transmission coefficient measures amplitude of transmitted wave versus amplitude of incident wave. The transmission coefficient is defined as ratio of transmitted voltage wave amplitude to incident voltage wave amplitude.

6.1.1 Experiments 1

Our first task for this part was to determine the transmission coefficient of a glass plate. We started by first placing the glass in-front of the bench and took records in which we used to determine the transmission coefficient of it.

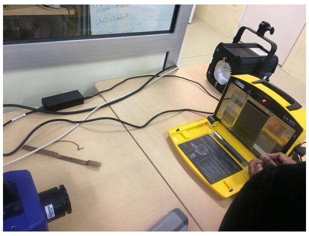


Figure 6.1: Experimental Setup for glass plate

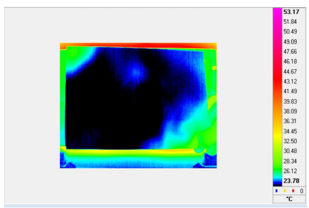


Figure 6.2: Recorded Image

Calculating the transmission coefficient : Having know the incident wave and the transmitted wave we got the transmission coefficient for the glass to be 80.

6.1.2 Experiment 2

The last task for this part was to repeat the same experiment set up we did for to calculate the transmission coefficient of the glass plate we will now use that to determine for a Black PVC material.

Calculating the transmission coefficient : Having know the incident wave and the transmitted wave we got the transmission coefficient for the black pvc to be 60.

Figure 6.3: Experimental Setup for Black PVC

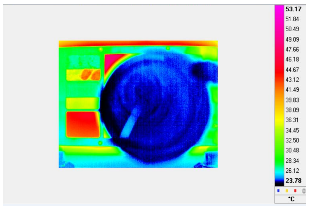


Figure 6.4: Recorded Image

6.2 Reflection Coefficients

The Reflection coefficient measures amplitude of reflected wave versus amplitude of incident wave. The reflection coefficient is defined as ratio of reflected voltage wave amplitude to incident voltage wave amplitude.

6.2.1 Experiments 1

In this part we proposed an experimental set up in which we used to determine the reflection coefficient of a piece of copper.We did this by first place the piece of copper in front of the infrared camera and then recorded the values attained which we then used to determine the reflection coefficient of it.

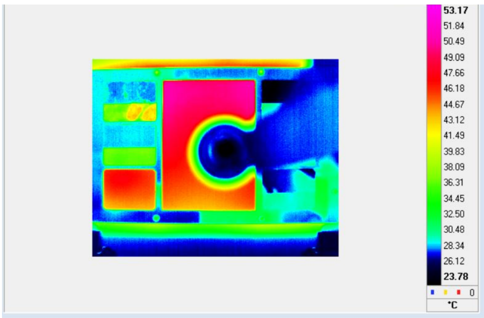


Figure 6.5: Recorded Image of copper.

Calculating the Reflection coefficient : The reflection coefficient of copper in this was experiment as 0.7.

Chapter 7

Active Thermography

Active thermography is an imaging procedure for non-destructive material testing. A heat flow is induced by an energetic excitation of the test object, which can be done in a transmissive or a reflective setup. The resulting heat flow is influenced by interior material layers and defects. These inhomogeneities can be captured on the object surface by high-precision thermographic cameras. The additional application of different evaluation algorithms improves the signal-to-noise-ratio, which allows for detection of smallest defects.

7.1 Experiment 1

In this part we will use the Infrared camera in an application of NDT. we used an halogen as the IR source which we controlled by a sinusoidal voltage generator.

We first put a painted picture in-front of the IR camera and we observed to see if we can see the image afterwards we then applied heat to the picture with the halogen and in which we observed the outcome.

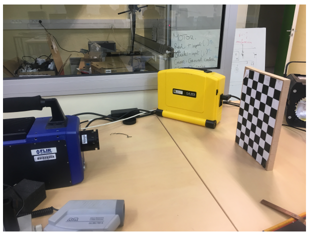


Figure 7.1: Picture in-front of IR camera

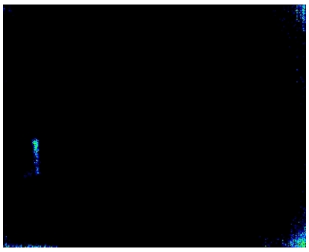


Figure 7.2: Recorded Image

Figure 7.3: Applying heat to the picture

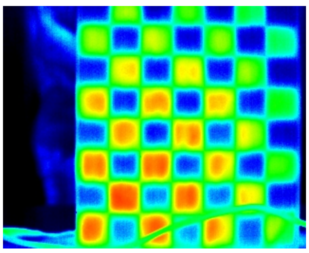


Figure 7.4: After applying the heat

Oberservaton

We can see from figures(5.1,5.2), when we placed the image in front of the IR camera we were not able to see any picture with the IR camera but after applying the heat on the picture we were able to acquire the image since the black squares in the painted picture absorbed the heat from the halogen and as a results made the IR camera able to detect, as shown in figures(5.2,5.3)

7.2 Experiment 2

For the second experiment an industrial plate with flat-bottom holes was used. We first place it in-front of the camera and in which we are to see if we will be able to acquire an image after which we then applied halogen light on it and which we used the Altair software recorder to save 2000 frames .

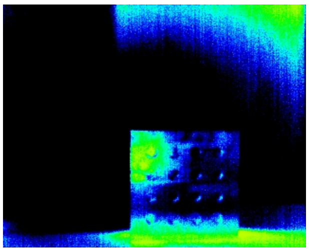


Figure 7.5: Image captured by the IR Camera

Figure 7.6: Applying heat to the material

Observation

For this part, the IR camera was able to determine the holes without first applying the halogen light on it. We then applied the halogen light in which we recorded with the software used. During the recording of the the IR camera was capturing the heat applied on the industrial flat-bottom holes and the image in which we saw later was not showing since the saturation was high.

Applications of Active Thermography

- Detection of layer structures, de-laminations and inserts in plastics, for instance of wind turbines or CFRPs of the automotive and aerospace industry
- Investigation of interior structures, for instance of breakage or impacts on Honeycomb lightweight constructions
- Recognition of deeper material deficiencies, such as blow-holes or ruptured laser welding seams

Chapter 8

Conclusion

In this part we where able to finish all the necessary task asked and we did gained a lot of knowledge in this aspect. We will further on research more on infrared imaging to enable us to be well acquainted in this aspect of technology.

Infrared imaging is being applied in many aspects of life . Be it in health or in daily activities for specific works. Physiological activities, such as fever, in human beings and other warm-blooded animals can also be monitored with thermographic imaging. Firefighters use them to see through smoke, find people and localize hotspots of fires. Law enforcement uses the technology to manage surveillance activities, locate and apprehend suspects, investigate crime scenes and conduct search and rescue operations.

This and many other exmaples tells us how imfrared imaging is very useful as emerged to be a big boost in many developments.

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