FOREIGN MATERIAL DETECTION IN AGARWOOD BY USING THERMAL IMAGING TECHNIQUE

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This report is submitted

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STUDENT DECLERATION

" I hereby declare that the work in this thesis is my own except for the summaries and quotations which have been duty acknowledge "

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SUPERVISOR'S DECLARATION

"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of degree of bachelor of mechanical engineering (plant and maintenance)".

Signature :..................................

Name of Supervisor :..................................

Date :..................................

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ABSTRACT

Agarwood is extremely valuable wood in Malaysia. This wood is increasingly becoming an attraction among businessmen and entrepreneurs in Malaysia who want to expand the value of the wood. Agarwood basically have several grades of A, B, C and D. Each grade has its own price where it is judged by the shape, hardness and colour of the wood. Dark wood is more expensive than brown colour wood. Agarwood has several advantages such as fragrance and medicines. During the production of Agarwood, it requires some method for the production of Agarwood, for example drilling and injured the tree. After 6 to 9 months, after forcing the agarwood, a farmer will ensure that the trees will produce Agarwood. The probability of Agarwood occurs when inoculant injection failed to produce Agarwood. This often occurs when not using a genuine injection. A working paper was produced to find a solution for detecting the presence of Agarwood in the tree. Thermal imaging is one of the tools that are used to detect the presence of Agarwood. Thermal imaging is a tool that detects the heat contained in the object. Thermal imaging normally used to detect cracks in buildings, plant and pipeline in the detection for misalignment and imbalance of rotation machine. In this study, thermal imaging was used to detect the production of Agarwood in the tree with the use of thermal energy sources such as hair dryer and vibration of the shaker. This method is measured based on the condition of heat source. For the hair dryer, the condition of observation is based on the position of heat direct where front and beside. For the vibration shaker is vibrothermograhpy method was observe based on wet and dry condition.

ABSTRAK

Kayu gaharu merupakan kayu yang sangat berharga di Malaysia. Kayu ini semakin menjadi tarikan dikalangan pengusaha dan usahawan di Malaysia yang ingin mengembangkan lagi nilai kayu tersebut. Kayu gaharu secara asasnya mempunyai beberapa gred yang terdiri dari A,B, C dan D. Setiap gred mempunyai harga yang tersendiri dimana penilaian melalui bentuk, teras dan warna kayu tersebut. Kayu yang berwarna gelap lebih mahal berbanding kayu yang berwarna coklat cair. Kayu gaharu ini mempunyai beberapa kelebihan seperti bau wangi dan ubat ubatan. Ketika penghasilan kayu gaharu ia memerlukan beberapa cara untuk penghasilan kayu gaharu, sebagai contoh penggerudian dan melukakan pokok tersebut. Selepas 6 ke 9 bulan selepas penghasilan kayu gaharu, Pertani akan memastikan bahawa pokok akan menghasilkan kayu gaharu. Keberangkalian penghasilan kayu gaharu terjadi apabila inkulen atau suntikan yang tidak asli gagal menghasilkan kayu gaharu. Perkara ini sering terjadi apabila penggunaan suntikan yang tidak asli. Satu kertas kerja telah dihasilkan bagi mencari jalan penyelesaian bagi mengesan kehadiran kayu gahru didalam pokok. Pengimejan haba merupakan salah satu alatan yang digunaka bagi mengesan kehadiran kayu gaharu. Pengimejan haba merupakan alatan yang megesan haba yang terdapat didalam objek. Kebiasan Pengimejan haba digunakan bagi mengesan keretakan bangunan, saluran paip di kilang dan pengesanan bagi juling dan ketidakseimbangan mesin putaran. Dalam kajian ini, Pengimejan haba telah digunakan bagi mengesan penghasialan kayu gaharu didalam pokok. Dengan penggunaan sumber tenaga haba seperti pengering rambut dan getaran daripada alatan getaran. Kaedah yang diguna kan berdasarkan alatan yang digunakan bagi memberi haba. Pengering rambut diguna kan pada kayu di kedudukan hadapan dan tepi, manakala getaran adalah vibrothermography dilihat dalam dua keadaan iaitu basah dan kering.

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LIST OF ABBREVIATIONS

VT	Vibrothermography
PT	Pulse Thermography
LT	Lock In Thermography
FFT	Fast Fourier Transform
HVAC	Heating, Ventilation and Air Conditioning
IR	Infrared Radiation
FPA	Focal Array
NDT	Non Destructive Test

CHAPTER 1

INTRODUCTION

1.1 Background

Thermography is a method that uses for certain experiment and testing for the product. Thermal imaging is popular for a plant and maintenance engineer, and also as a method to detect the defect on the plant or piping lines. It used to detect the different temperature based on the parameter is temperature. Most of this thermography parameter is temperature different because the defect can be detected by using the different colour of the imaging. Thermal imaging has become much more popular over the past 10 years because uncooled micro bolometer technology has lowered prices significantly on the infrared (IR) equipment.

Furthermore, the potential for thermography is the limitations of thermal imaging that will help to decide to use perform of thermal imaging or use the electrochemical in diagnostic the condition based maintenance. There a few abilities of thermal imaging that can be used such as scan for heat loss, air leakage, HVAC systems, and roof moisture detection. Thermal imaging technology has created a more efficient and safer method of measurement. The benefits of thermal imaging impact many aspects of your job such as can a lower the cost of detecting the location potential failure, can increase the productivity because thermal imaging to provide fast and accurate measurement and last is reduce the risk of the user distance from the hazard.

Malaysia is one of the countries that produce fragrant wood and the famous name called as "Karas". Agarwood tree or karas can be found in the jungle of Kelantan, Perak, Pahang and Terengganu jungle even though it is a rare species (Noratikah et al, 2015). Agarwood is the valuable wood now day that has a higher price. The agarwood became more popular after the research was finding the resin of agarwood a very useful for health and agawood also can be perfume for room space or office. Makeable of this trade was finding a good quality of agarwood that have higher quality of resin and the black spot on the wood. Some of this farmer was using a foreign material for make sure the agarwood tree became mature or aged. The farmer was finding man who expert for does the job of injecting the insulin (foreign material) in the tree. After a few months or mostly need wait for six months, the resin was curing the tree and became agarwood. The problem is when the tree was injected with insulin, there are few trees a failure to become agarwood and the resin not exists. The farmer only knew when cut down the tree, for make sure there a no waste of tree , a farmer need a some like scanner or x-ray to detect the foreign material in the tree. In this problem, Thermal imaging is the suitable equipment that can use for detecting the foreign material in the agarwood.

Thermal imaging was using a camera that uses a heat as parameter to detect the foreign material. Thermal imaging is the visible radiation pattern that can convert object of visible image. This two-dimensional temperature mapping technique has potential for characterizing products of several operations of agricultural and engineering. Thermal imaging has been successfully adopted for studying plant physiology, irrigation scheduling, and yield forecasting in agricultural field. Likewise maturity evaluation, detection of bruises in fruits and vegetables (Digvir S Jayas, 2005), detection of spoilage in agricultural produces by microbial activities, and detection of foreign materials are the potential post-harvest operations to use thermal imaging. In this experiment, thermal imaging was using for detecting the foreign material in agawood. The agarwood as a basement for experiment, the parameter for this experiment is the density of resin, the density of agarwood, the temperature and the type of wood. This experiment was carrying out in the lab in FKM cubic.

1.2 Problem Statement

Identification on the quality of agarwood is very complicated. The common problem faces by agarwood farmers those use modern inoculation technique in harvesting the resin into verify the conditions of the formed resin itself. In general, process to cut down the tree and perform a visual inspection across the cutting areas. Somewhere, cut down the trees which do not achieved a good quality of agarwood resin are waste for farmers as it stopped. the formation of agarwood resin and lost the planted trees to gain a good resin.

Figure 1.1: Agarwood trees in the forest in Malaysia

On the other hand, thermal imaging technique is an advanced non-destructive inspection technique use in electrical system, condition based monitoring and structure health monitoring. It has potential to locate failures, defect or foreign materials based on the thermal signatures from the temperature images. This study has an objective to utilize the technology for inspection of different wood densities use to stimulate the formation of agarwood resin in the agarwood trees

1.3 Objective

The main objective of this project is to detect the foreign material in agarwood. This project is focus on the inspection of the agarwood itself. Beside, during the completion of this research, the objective need to be achieve are:

i. To determine the existed of high density core in agarwood based on the condition of the wood

ii. To study the ability of thermal imaging technique to detect the foreign material in agarwood.

1.4 Scope of Project

Method that uses in this experiment is thermal imaging for detecting surface of defect or crack object. Thermal imaging is non-destructive test (NDT) method. Thermal imaging is the one of the accurate method of detection for the gas leakage but it can use for other experiment or test. This thermal imaging also known as infrared testing, it can be divided into two categories passive and active infrared. The passive thermography, in its use as a non-destructive thermal investigation in the search of hidden defects or damages in the road or bridge pavement structure, together with information on the degradation mechanism, serves as an early diagnostic tool, which completes the methodologies utilised for the survey of the state of the paving. For the active infrared is the object test is thermally excited, the main scope of the experiment are the thermal imaging use for detecting the foreign material in agarwood. By using the thermal imaging it can detect the foreign material that was produced in agarwood. Based on the parameter, thermal imaging can detect by using thermography or infrared that needs a different temperature of the object. To get a different temperature of object, those need a different type of density of object. For the wood has a different density of resin, resin most likely oil. The result image it can be classifying the foreign base of the colour of image of thermography result. The experiment scopes are using a thermal imaging for detecting the foreign material that have in agarwood.

Figure 1.2: Foreign material in agarwood have a different colour

(Source: https://vietnamagarwood.files.wordpress.com/2014/02/inoculation-of-agarwood-tree.jpg)

CHAPTER 2

LITERATURE REVIEW

This chapter will contain the summarizing of all the literature review gathered from many academic book and journal as resources. This chapter discuss on properties of agarwood and thermography technologies available in non-destructive applications. The infrared thermal imaging is aimed to investigate the formation of agarwood resin in the stem of agarwood tree.

2.1 Agarwood Trees

The forest treasure agarwood or the name aloeswood, eaglewood and also gaharu. Agarwood is most popular tree in Malaysia with a fragrant wood and the unique smell. Agarwood can be finding in all forest in Malaysia such as Kelantan, Johor and Terengganu. In previous review Noratikah et al (2015) was classified the type or agarwood, there are five species that of agarwood that record in Malaysia where A malaccensis, A microcarpa , A hirta, A.rostrata and A beccariana. The entire name a based on science name that depend on type of tree that produce the agarwood and all the species are able to produce a resin or oil that have high quality. Different agarwood have a different quality of oil that produce by agarwood. Usually, agarwood from the low grade have a low quality and cheap compare to high grade of agarwood.

Figure 2.1: Example of foreign material in agarwood

(Source: https://gaharujinkou.wordpress.com/natural-oud-oil-agarwood)

Recent evidence suggests that by the author (Norazah et al, 2013). Agarwood tree can be found in the forest and plantation in Malaysia. Aqualaria malaccensis is one of the names of agarwood in Malaysia, this tree has been found at Sarawak (Tawan, 2004) .This species that is a source of gaharu , that has been noted as being locally frequent in the middle in west Sarawak and fairly common spread to a state. This type of agarwood trees produce seed after 7-9 year, while other species only once produce seed on their life cycle. Agarwood only existed when the tree of agarwood is injury or illness, and has been cure using the antibody to against the illness. For the agarwood tree that lives in plantation was injected with inoculation to form the agarwood.

2.2 Formation of Agarwood

The success of agarwood plantation depends on the stimulation of agarwood production in the trees (Selina et al.2013). Based on the research, agarwood was form when the tree are cut or bleed off the tree and the resin from the tree cure back by using a resin, that the agarwood form and resin that cure the tree is agarwood oil and after several month after the treatment agarwood from on the tree. Illustration of induction methods commonly used in agarwood formation. In natural maturation process, no induction or injury is required but need years to achieve considerable amount of resin synthesis.

Figure 2.2: Method to gain the resin in agarwood trees

(Source:https://www.researchgate.net/figure/303729587_fig2_Fig-42-Application-of-the-fungal-inoculation-technology-on-an-agarwood-producing-tree)

General practice of artificial induction is to drill the stems, roots and large brunches. The drilled pores were kept open to ease access of natural agents into the pores. Addition of sugary syrup or inoculate to these pores attracts insects and facilitates infection. Metal or PVC tubes were installed in those pores to prevent healing the pores and establish prolonged infection. Syringe with inoculate and inducers were also used to assist batch and continuous inoculation and induction. In some region, indigenous people peel off the bark to promote infection to the core tissues and harvest the chips of woods. These are all the way to get a higher quality of agarwood. (Veronica et al, 2015) was studies focused on pre-treatment of the raw material to increase the oil yield. To gain a more extraction oil in agarwood, it need a new skill to absorb or extraction more oil in the tree. pre treamnet is crucial step to obtain the agarwood oil, in previous study there are many way to extraction the agarwood essential oil such as soaking in the water, chemical treatment , microwave and the sonication process (Azah et al, 2008) all the method is use to extract the oil from the agarwood tree. Chemical reaction is addition on some chemical liquid to extract the oil into a surface of agarwood and microwave is using the heat to producing oil such as make a salted fish by using heat from the sun. Previous study by using a soaking process it take a 28 day experiment to produce agarwood oil, this experiment was use a water to immerse the agarwood, and the agarwood was immersed until 28 day in the water. The experiment use a water as an exchanging heat medium in the water to determine the optimize distillation time. Other previous review, the method of extraction became more interesting where use the hydradistillation (HD) extraction to gain and increase agarwood oil production. Previous research by the author

Noratikah et al (2015) the research is to aim the see the different of oil extraction method by standard hydrodistillation and re-design hydrodistillation method. On the research re-design hydrodistillation couple with stirrer was gain high oil yield. Based on the two highlight parameter which is sample size and shaking time as control to get the maximum yield, every method give an advantage for extract the agarwood oil but this method need a chemical reaction to produce high volume of agawood oil. On a previous research says some of the chemical constituents of the gaharu oils were identified by comparison of their mass spectral data with the existing (Azah et al.2008). In general, the agarwood oil is complex mixture of chemical reaction of sesquiterpence, hydrocarbons, sesuiterpence alcohol and also alipaharic hydrocarbon it very difficult to analysis and identified based on apparatus alone gaharu oil have a distinctive smell where the agarwood aroma, also the oil is vary difference colour which is the colour more to greenish brown to dark reddish brown. Agarwood have benefit oil and the oil is very expensive to produce in conventional ways (Tumuli et al, 2005). Based on oil composition of agarwood, research has been done to prove the composition of oil based on the healthy, naturally infected and artificially inoculated agarwood by using same equipment which is GC and GC/MS. By using this equipment the result show the difference oil composition among that treatment have been done to gain agarwood oil with regard to their quality. At the end the oil that has obtained from the in clouted plant was showed almost similar distribution of the component on a healthy plant.

2.3 Grade of agarwood resin

Agarwood resin is most valuable thing in agarwood tree. The objective of agarwood seeker is to gain the resin that was produce by agarwood tree. The resin that has been collect was grade depend on the quality and viscosity of the resin. The grading of agarwood is depend on the content of the oleoresin content (Noratikah et al. 2015). In addition, agarwood from the higher grade and quality have a higher price compare to lower grade of agarwood. (Nor azah et al. 2013) found The agarwood has been grading depend on the density, content, colour, scent and gaharu formation in the wood. Currently the agarwood has been grading by using individual experience and perception by seeing the agarwood. A few of gaharu was been grading base on their name and origin to attract the buyer. The price of agarwood is depending on its grade, the higher the grade, the expensive they are. Author (Azma et al, 2007) found there are many attempt has been done to grading the agarwood. Attempt to classification agarwood by it density of the black colour of grey scale image has been created. in addition, on the year 2016,(Sahrim Alias et al, 2016) author was created a another approach by using a signal based classification system by using electrical nose (E- Nose), which this method has been develop by FRIM and is currently useful. Agarwood has been grading in to four categories which A, B, C and D (Nor Azah. 2013) at table 2.1 and table 22 It using a boxplot method combines with Z-score transformation technique to gain new technique to grading the agarwood.

Table 2.1: Physical appearance of various grade of agarwood

Grade	Characteristic
A	Dark, dense , concentrated, heavy
B	Dark purple, less dense , small hole
C	Dark yellow stripes, dark yellow
D	Whitish yellow

Azah MA et al (2013) explain about physical appearance of agarwood

Based on the determination of statistical analyse in this research, Agarwood has been Grade based on the content into four group. For the result on the research, the agarwood grade has been determined by using Z- Score in actual scale in table 2.2.

Table 2.2: Z-Score standard scale and resin content values (%) after transformation

Z- score grouping	**Resin real value (%)**
A (x < +SD)	> 33.3
B (mean < x < +SD)	22.06 – 27.58
C (-SD < x < mean)	9.84 – 18.43
D (x< -SD)	< 7.14

Azah MA et al (2013) explain about Z-Score standard scale and resin content

Another research about grading the agarwood has been using a GC-MS analyse to determine the chemical composition of the agarwood (Gunawan pasaribu et al., 2013). The result show the hypothesis for the agarwood , where the agarwood quality increase is depend on the resin yield increase, in addition , the aroma dendrite has been found on each of agarwood and it can be as a chemical extinguisher to increase the grade of agarwood

2.4 Thermography

Infrared (IR) thermography is a non-destructive test (NDT) that has been use for inspection method for the scanning or examiner the material, part and system without effect the future condition. Data acquisition of thermography is safe better than X-ray or C-scan. Fundamental of thermal imaging, infrared radiation was discovered by an astronomer Sir William herchel in 1800 from the history, Sir William try to find the colour is responsible for heating, he was measured the temperature of a different colour in sunlight to get the result. From the Sir William experiment, was discovered in the natural temperature have a hottest temperature beyond the red region and not visible to see. Thermal imaging can be x ray where can see the structure of the part without change the solid body and the temperature of the part the solid body. All object with a temperature greater than absolute zero (-273 C) emit infrared radiation (Anamalai, 2005). Absolute zero is where the temperature is measured by unit kelvin and at the lower temperature for example at 0 degree; it is not absolute zero where in kelvin it still have a degree of temperature at 273 K. For the thermal imaging, temperature is important parameter that use for detection, radiation is one element that use in thermal imaging technique where thermal energy only can use with contact of radiation of the object. To proof the statement, (Cengal and Boles, 2008) says Radiation is the energy emitted by matter in the form of electromagnetic waves as a result it changes with the electronic configuration of the atom or molecules.

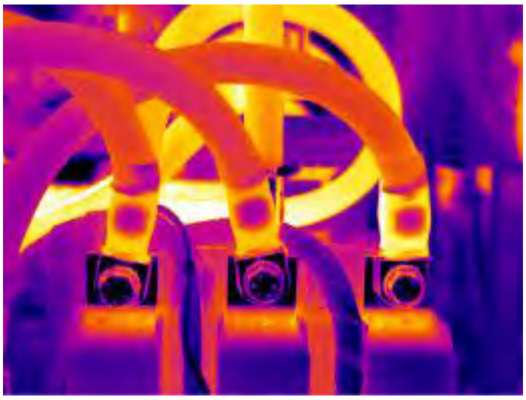


Figure 2.3: Signature of thermal imaging camera

(Source: www.infraredtraining.com.au/infrared-training-courses/ir-training-for-electrical-systems)

In heat transfer studies, energy transfer by radiation is faster that the energy convection and conduction furthermore, radiation is not require any contact to transmit energy to another body. C. Ibarra-Castanedo et al (2014) found Radiation is exactly the real phenomenon of energy of sun reach the earth. An infrared thermal imaging system provides the surface temperature of any object and these data may be used directly or indirectly for many applications. That proves that not only on leakage or for pipeline can use thermography for other thing that can conduction on temperature also can be used for thermal imaging. The band of electromagnetic of infrared radiation is between 0.74 and 100 um (Ibarra-Castanedo et al, 2014). there are many way to measure the thermal variation, one of the excellent method that can be used by using a IR radiometer, normally a focal array (FPA) camera is capable to detect radiation on a mid-on range 3 to 5µm or at long period at range 8 to 14µm of infrared bonds. Figure 2.4 show, the theme respectively of two of the high transmittance atmosphere window calling as MWIR and LWIR.

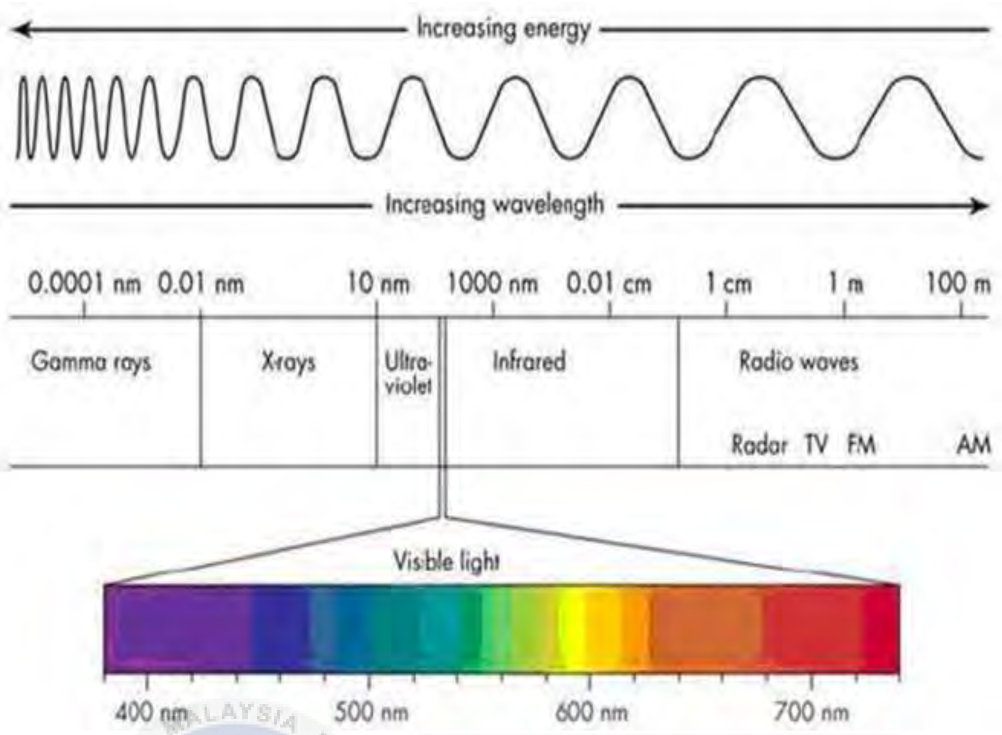


Figure 2.4: The infrared band in the electromagnetic spectrum (Soib Taib et al, 2012)

2.4.1. Type of Thermography

Thermography can be divide in two approaches can be seen on figure 35. First is passive thermography is a natural features that are interested in at lower or higher temperature rather than background temperature. And active thermography is use the external source of energy to produce different contrast between the background. *e.g.* a specimen with the internal flaws.

In addition, the active thermography is usually use for many cases such as inspected parts that have an equilibrium temperature to surrounding. In thermography, there are many option of energy source that can be used to induced for different thermal contrast between a different defective and non-defective part in external (Giorleo G, 2002) if the energy was get direct hit to a surface and then it propagated through the material core. For internal excitation can be achieved by using mechanical oscillations, with a sonic or ultrasonic transducer for two modulated simulation for burst and amplitude. In addition, for external excitation, in can be form with optical devices such photographic flashes or hair dryer as heat source. On a figure 2.5, there are three type of classification for active thermography techniques based on the excitation mode. Lock in thermography and pulse thermography was presented the optical techniques that applied on externally and vibrothermography, which used the ultrasonic waves to excited the internal heat.

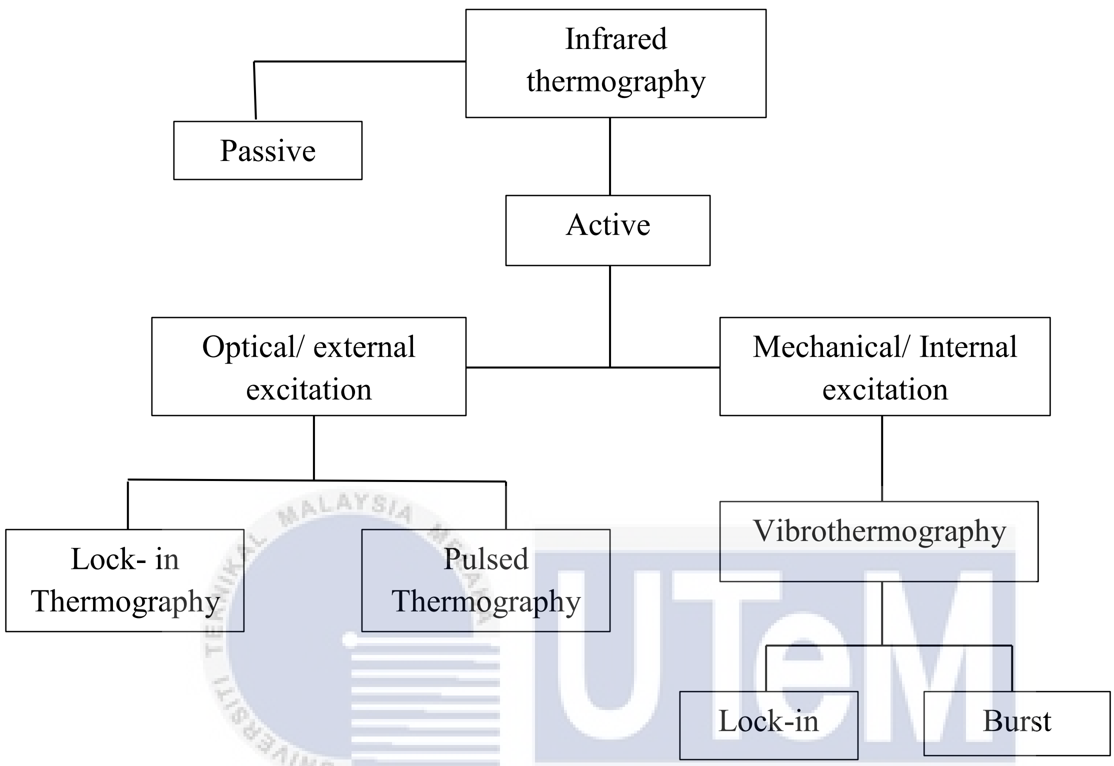


Figure 2.5: Infrared thermography hierarchy

2.4.2 Lock- In thermography

Lock-In thermography (LT) also familiar with as a modulated thermography is a technique that derived from a photothermal radiometry (Giorleo .G,2002). In addition, proves that lock-in thermography and heat flow measurement as new developed pettier sensor have performed during a fatigue crack. Lock-In Thermography is allows a space resolved measurement for a crack (Jurgen Bar, 2016). in case of thermographic specimen was be painted in black for emissivity and the thickness of coating influences the result and therefore qualitative measurement are problematic. The thermal response for the result of image is recorded in a same time using a infrared detector and decomposed by a lock-in amplifier. . The infrared detector is capable to monitoring the whole large image surface (typically in a 320 x 256 or 640 x 512 pixel matrix configuration) and the reason Lock In thermography is use because capable to modified mathematically the amplitude and phase of the response.

In LT, the sinusoidal waves has been use for periodic the waves form, by using a sinusoidal as a input give an advantage for frequency and shape of the response are preserved, the variables of the amplitude and phase delay of the way can be change. Figure 2.7 shows an example of the row output data signal filtering of the temperature at different point. As can be seen, noise is disturbing the result, processing is required to extract the noise and also amplitude or phase information signal.

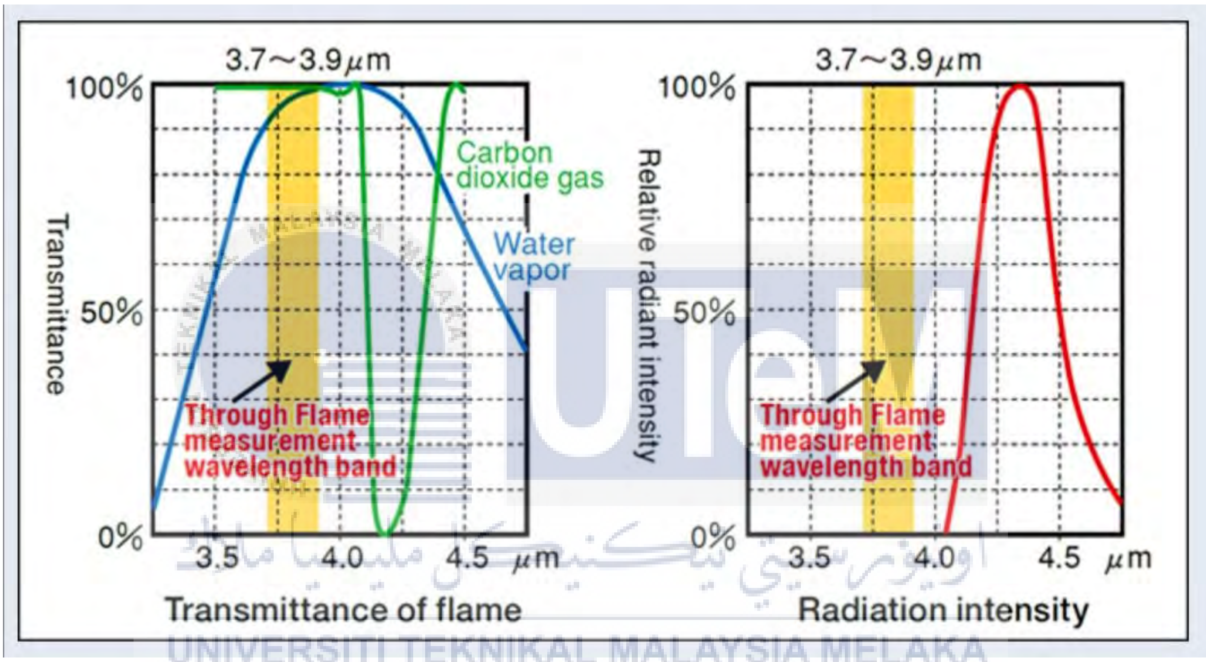


Figure 2.6: Transmittance of flame and radiation intensity

(Source:https://thermal-imaging-camera.irpod.net/produkte/r300bp-tf-en/thermal-imaging-camera-avio-nec-infrec-r300bp-tf/)

On the processing Lock-In thermography data, there are four points that can be used for sinusoidal simulation as show in figure 2.7.There was use to describe the input signal I. is represented on a top. The respond for signal s is drawn at the bottom. The output and input have a same shape when use sinusoids, the variable only can change in amplitude and phase that can be calculated as follow (Busse. 1992).

$$A = \sqrt{(S_1 - S_3)^2 + (S_2 - S_4)^2} \tag{1}$$

$$\phi = \arctan\left(\frac{S_1 - S_3}{S_2 - S_4}\right) \tag{2}$$

The advantage of 4 point method is fast but is only valid for sinusoidal simulation and the result will effect by noise. The noise can ride out by increasing the number of cycle or by averaging the several points.

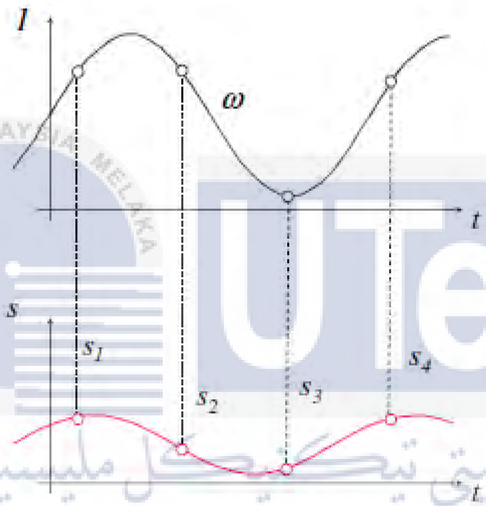


Figure 2.7: Four point methodology for amplitude and phase delay estimation by Lock-In Thermography.

There are many advantage of LT , the LT experiment is slower excitation rather than Pulse Thermography, but A complete experiment of LT was discovering a wide range from low to high frequencies and fitting function can be used for complete the amplitude or phase profile for each point. The energy source that required performing LT is less than the active technique, which is to inspect the part it only interesting a low power source to be used.

2.4.3 Pulsed Thermography

For Pulsed thermography (PT), the specimen surface is direct to a heat pulse using a high power source such as hair dryer, hot water spray or photographic flashes. Combination of several waves' different frequencies and amplitudes can throughout a heat pulse. The direct heat touches a specimen surface, heat energy travel from the surface through to specimen. At the same time, the internal flows will bot effect when surface temperature get a direct heat. Figure 2.9 hows the experimental setup for pulse thermography, the different between LT and PT is, PT is fast and straight forward.

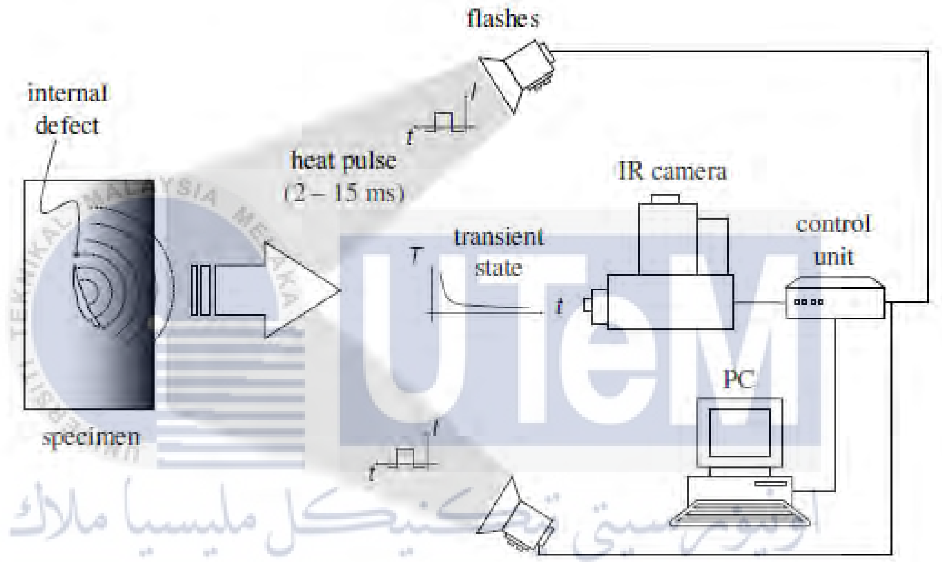


Figure 2.8: The experimental setup for pulse thermography.

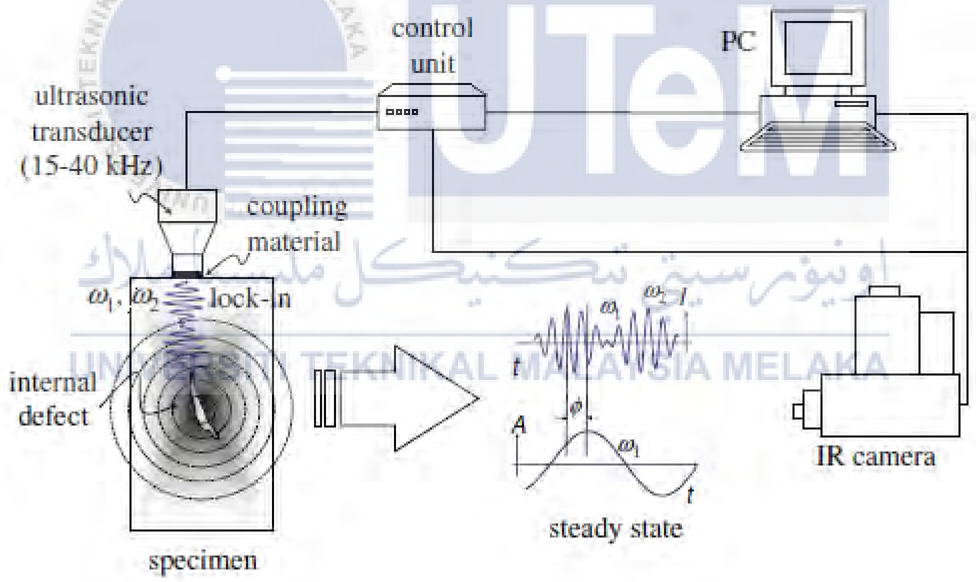
(Source:http://www.visiooimage.com/fr/products_ir_ndt_thermography_tutorial.htm)

Otwin Breitensteina et al (2016) in his research find the processing pulse thermography data is the rare difficult investigated approach because of not ease to deployment. Pulse thermography is a fast inspection if relaying on a thermal simulation pulse, where, with a different duration of time for high thermal conductivity material inspection and to a few second for low material conductivity specimen. The pulse thermography is more complex when compare to Lock In thermography.

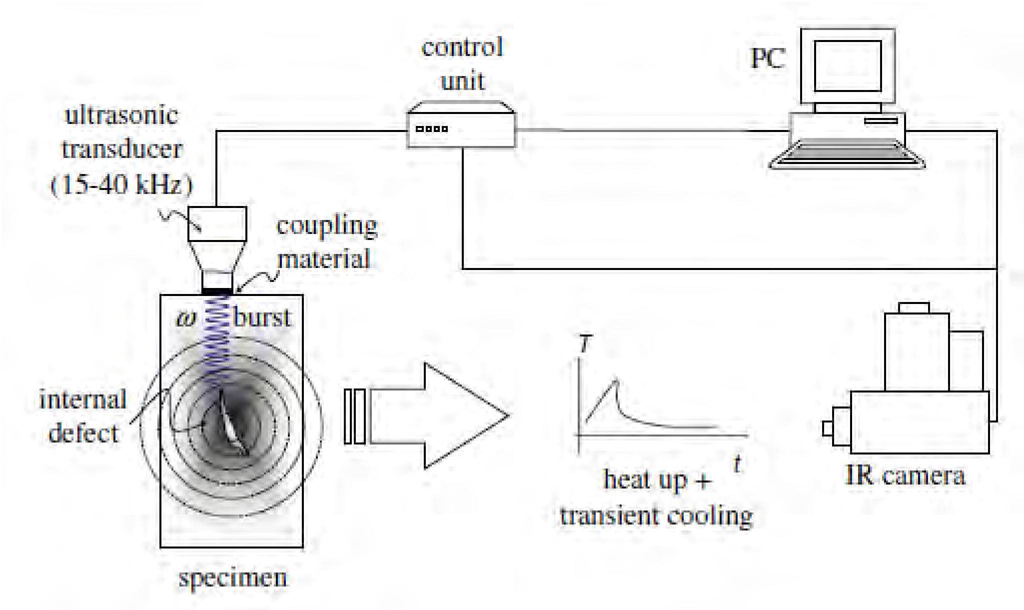
2.4.4 Vibrothermography

A Mendioroz et al (2009) in the research found Vibrothermography (VT) is a ultrasound thermography,vibrothermography is an internal inspection without heating the surface by using an optical method. vibrothermography is a modification from the optical method in Lock In thermography. The heat source for vibrothermography was produce from a friction, when mechanical vibration is induced externally at the specimen with direct hit from mechanical to thermal energy so the heat was occur, such as use the shaker or air vibrator can produce heat on the internal structure. .

Vibrothermography can be perform in two where analogue and optical method (C. Ibarra et al, 2014).The first one lock in vibrothermography where combination with lock-in thermography and the second is burst thermography where induced with a pulse thermography. These two approaches are show in Figure 2.10a and Figure 2.10b



(a)



(b)

Figure 2.9: (a) Configuration for lock in vibrothermography. (b) Configuration of burst vibrothermography

(Source: http://www.visiooimage.com/fr/products_ir_ndt_thermography_tutorial.htm)

2.5 Emissivity of Thermography

Thermal imaging is tool that uses the temperature as a parameter. The temperature of the object was measure by using the infrared camera that can detect the infrared energy that have in the object. To get the perfect result, the emissivity plays important role as parameter that need to consider during experiment. In research paper Petra et al (2016) found the emissivity of material is different according to the type of material. For non-metal material with a rough surface have a higher emissivity with low reflection. The emissivity of material is the most problem when use thermograpic camera to seeking accurate and get reliable result. The material emissivity is depending on the nature, the surface finish and temperature. The emissivity of material is respond on the ratio of the energy radiated by an emission source. For a black body, there have same temperature but different on emission source. In thermal imaging, the black body are absorbed and re-emit all the energy and the emissivity is equal to 1. Table 2.3 show the material with emissivity ratio, all other body is lower than 1. The emissivity table is use for accurate measurement thermography, it good to know the value of emissivity.

Table 2.3: The material with different emissivity

Material	Emissivity
Aluminium	0.03
Brick	0.96
Concrete	0.90
Chalk	0.34
Tin	0.06
Gold	0.02
lead	0.26

Petra et al (2016) explain about the material with different emissivity

2.6 Application of thermal imaging on structure health monitoring.

Lorve, Branko and Pedro (2011) was use thermal imaging and combined with the thermoelastic stress, and pulse heating thermography to analysis the impact damage of composite material including fibre fracture and delamination. Pulse heating of flash thermography is became a standard non-destructive testing method to test the composite structure. Thermal energy currently and significant with theme of heat increase at certain spot, where it can be observe by using thermal camera. from the thermal camera it can be observe the condition of composite damage, to gain the best result for thermal infrared imaging or pulse heating thermography. For detecting the damage material it can be used a long wave IR camera and for an elastic deformation it can be analysis by using a cooled middle wave. The thermal imaging also can use for human body (Author Cotter and Woodworth. 2015). The experiment of the thermal effect of the ultrasonic bone inspiration are try to investigated that are reasonable using the thermal imaging for develop surgical bone, by using a FLIR camera. At the end, the beneficial of the infrared thermal imaging during ultrasonic aspiration is can use to monitoring the temperature rise on the bone also can use for future clinical studies. In other research, Laura and Eugenio (2016) thermal imaging was use for non-human primates, that show the infrared thermal imaging or thermography is very useful on detecting. The experiment was used to find the effect of pleasant touch on skin temperature, heart rate and heart rate variability.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter 3, was being described more about methodology that will use to complete the experiment project. Methodology is about the rule, tools, procedure and technique that will use for finishing the experiment step by step. To accomplish the objective, this method will be implemented to gain the perfect result in the experiment. By using the five stage of methodology which is planning, analysis, design, testing as a guideline to complete the task. To gain the thermography result of detection there are three major steps during work progress which is planning, implementing and analysis result.

The real experiment are used the agarwood tree as the specimen, but for this experiment was using a wood block that has different density as specimen. In this experiment, the specimen was use a mahang wood as an outer wood and balau wood as an inner wood both of the wood have a different density and molecule structure. The wood was search according the density and the specification that has same as agarwood. The wood was cut 26 cm long and 7.5 cm diameter

3.2 Flowchart

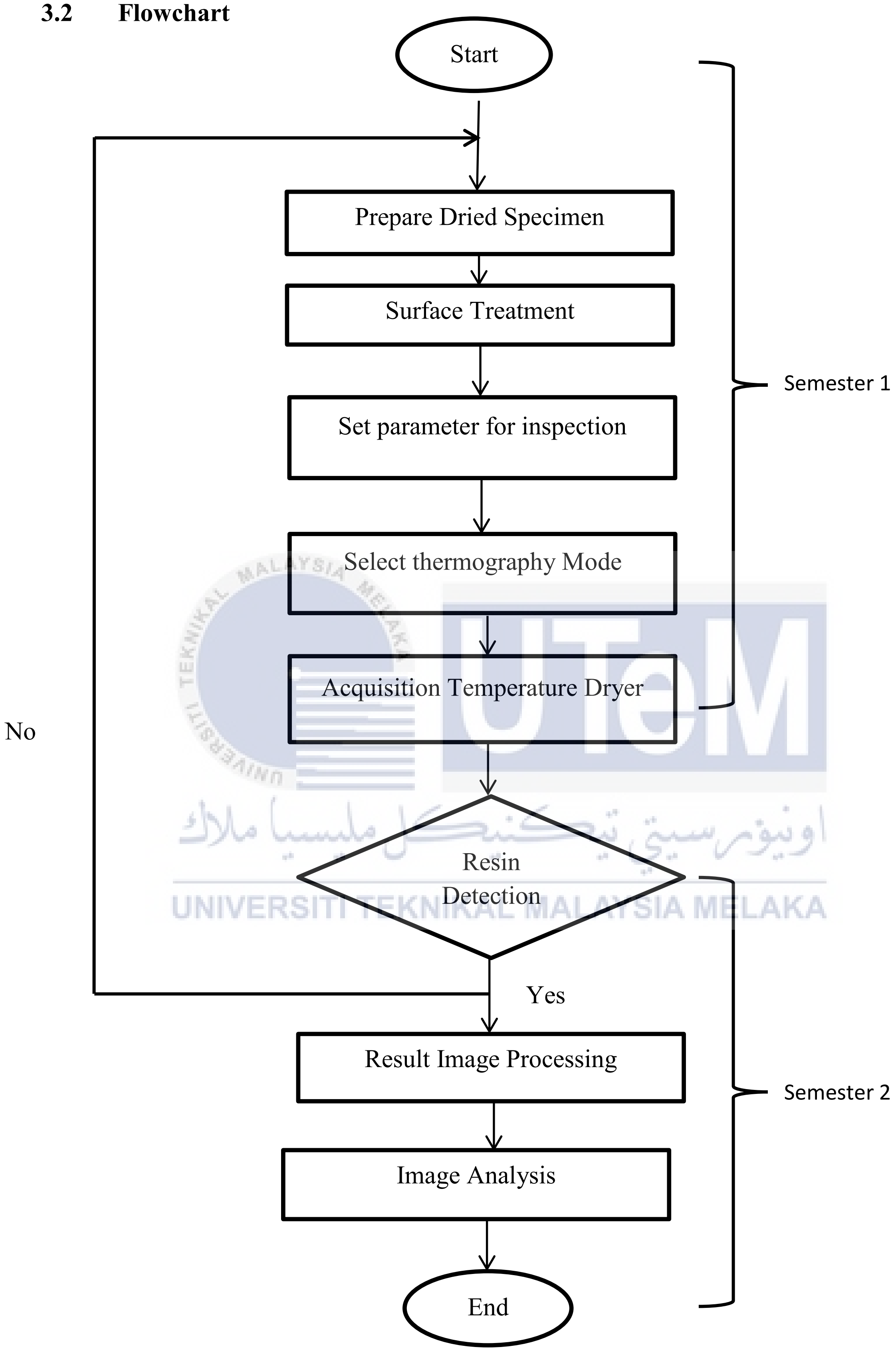


Figure 3.1: Flowchart of Experiment.

3.3 Analytical Study thermal imaging technique And Emissivity

3.3.1 Thermal Imaging technique

Thermal imaging was detecting the abnormal temperature in certain place. The abnormal temperature came from the defect leakage of piping or unbalance machine. In agriculture industry, thermal imaging or thermography was used to detect the pre harvest and mature of the vegetable and fruit. Thermal imaging also used to detect the foreign material in the vegetable to detect any insect or caterpillar.

. In thermal imaging, it was use the thermal camera as one of the tool as an inspection tools. Thermal imaging is infrared technology where use the principle of infrared radiation (IR) to detect the temperature and the radian energy of the specimen. In this experiment, the non-destructive testing (NDT) of the infrared thermography is used to examine the wood block with length of block is 26 cm and diameter of the wood is 7.5 cm by doing a defect inspection on the large structure.

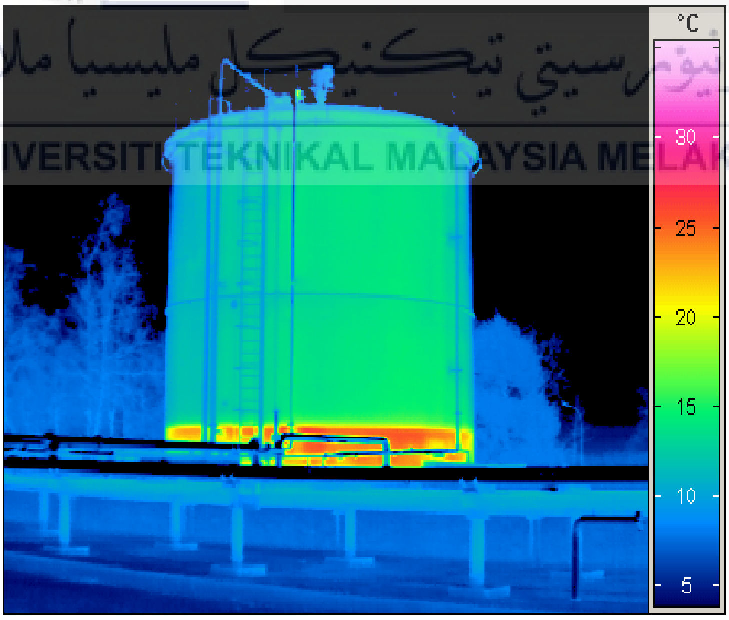


Figure 3.2: Proof that thermal imaging can use for detecting the temperature of tank

(Source:http://www.infratec-infrared.com/thermography/application-area/process-optimisation/chemical-industry.html)

The inspection occurs when the source of the heat is applied to the wood and spread the thermal energy induces into the material. The thermal energy at the defect area will diffuse the heat in different behaviour compare to the original structure and record by using infrared camera. The infrared is the element that detects energy emitted from the wood and converts it to temperature by display the temperature distribution images (Jurgen Bar, 2016). The infrared image is processing by the certain software to measure the heat distribution and determine the defect occurs. The method use in this experiment also called a reflection mode of active thermography which is based on the heat emitted from the source is reflected on the plate to the infrared camera (Giorleo G. and Meola C, 2002). The proper equipment like infrared camera and others tool in laboratory is used in order to investigate the hypothesis stated in this report based on the experiment objectives. Thermography is a granted technique, it easy to detect wide area. The method is non-destructive and can be used in field for agriculture.

3.3.2 Emissivity

Thermal imaging is tool that uses the temperature as a parameter. The temperature of the object was measure by using the infrared camera that can detect the infrared energy that have in the object. To get the perfect result, the emissivity plays important role as parameter that need to consider during experiment. The emissivity of material is different according to the type of material. For non-metal material with a rough surface have a higher emissivity with low reflection, but for metal material with the smooth surface and shiny have a lower emissivity and higher reflection. Wood that use in the experiment has a rough surface and non-metal material. Wood is the material that has a higher emissivity and low reflection, but if the wood have smooth and gleam surface it may have higher reflection and low emissivity. Thermal imaging was scanning the temperature of the object, when it has a higher reflection it may cause the difficulties during to detect the structure.

3.3.3 Foreign Material in a Wood

The objective of this experiment is to detect the foreign material in agarwood. The foreign material in agarwood is the resin and the core of the hardness wood that has been cure in agarwood. Agarwood has become popular because of the smelt of the wood that has been cure by the resin in the wood. The resin is a medicine to cure the illness of tree because of the natural defect and crack. Thermal imaging is use to detect the resin and the harness core that has been produce in the middle of wood.

3.3.4 Thermal Properties of Wood

In thermal properties, the entire object has their own heat thermal. The wood heat thermal is different based on the harness, density and structure of the wood. In the experiment, thermal imaging is use to achieve the objective. Thermal properties is use to find the thermal conductivity and thermal diffusivity of the wood to reach the heat in all body.

The heat source energy that emitted to the body:

$$Q = mc\theta \qquad (3)$$

The specific heat (c) of the wood can be determined by the following term:

$$c = Q / m(\tau 2 - \tau 1) \qquad (4)$$

Where Q is the heat source energy required to change the temperature of body from the temperature t_1 to t_2 and the mass of the body is m. For the experiment, there are two different condition, where wet wood and dry wood. the specific heat of the wood is independent with the density and species, but it varies with the moisture or condition of the wood.

The specific heat of dry wood is:

$$C_\theta = 1.114 + 0.0046\tau \qquad (5)$$

And the specific heat of the wood with moisture or wet wood content is {?}

$$C_\theta = (4.19u + 1.114 + 0.0046r) / (1 + u) \qquad (6)$$

From the thermal conductivity (1) is the thermal energy Q per unit time t which the heat flow through a thickness of the wood with the surface area that get direct heat. From the difference time $(t_2 - t_1)$ under a steady state temperature it can gain:

$$\lambda = Q / At\,(t_2 - t_1) \qquad (7)$$

3.4 Experimental Study

3.4.1 Mode of Thermal Imaging Technique

On this experiment, vibrothermography will be used for achieve the objective. The experiment will be use the external and internal heat source for generate the heat. One of the applications of vibrothermography is detect crack or shape in a wood. A set of different density wood with knows area of hardness has been tested to prove detection capabilities on the developed vibrothermographic experiment. Two different heat sources were present in the experiment (1) hair drayer (2) shaker as use for standard ultrasonic inspection. Equipment vibrothermographic experiment has been used with the FLIR A615 camera with the software of thermal imaging. The experiment has been carried out for different time of excitation and condition of specimen.

Figure 3.3: The wood different outer is a low hardness and inner is high hardness

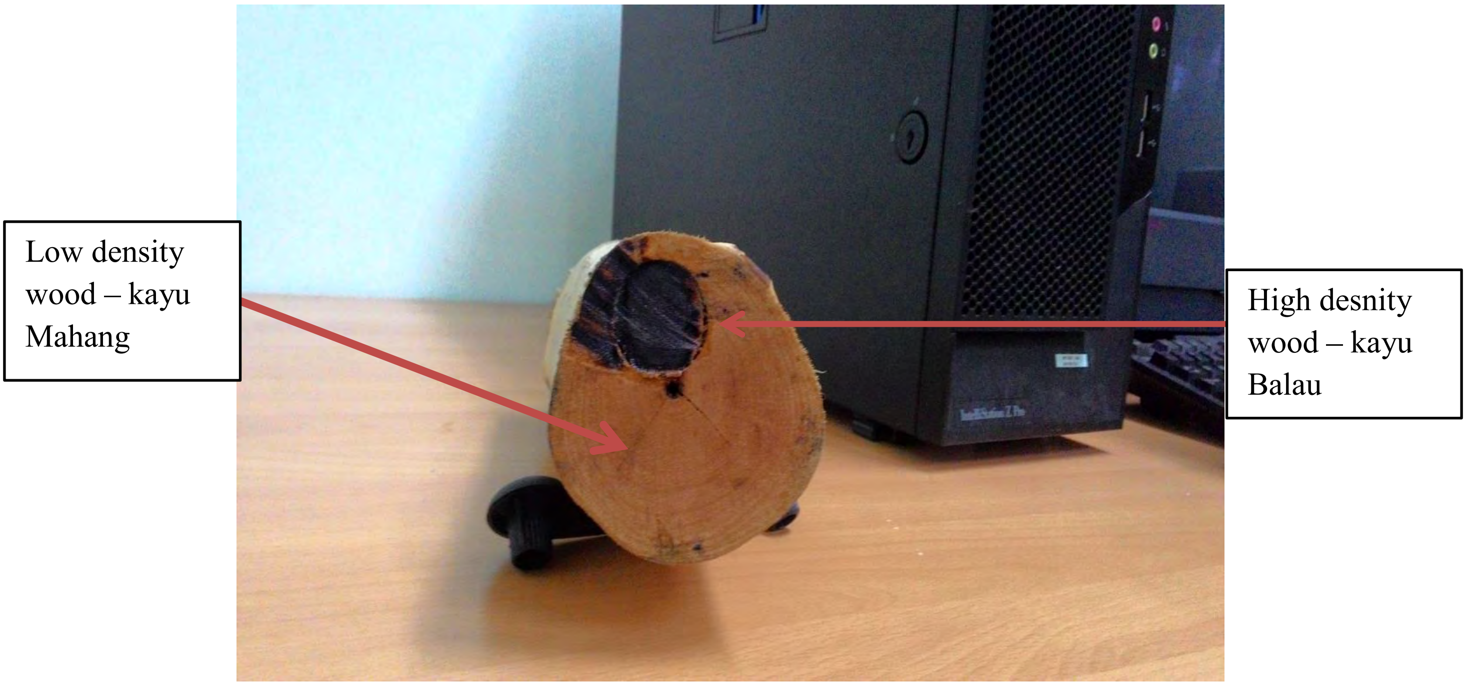


Figure 3.4: Real specimen with high density core

3.4.2 Design of Experiment

3.4.2.1 Apparatus and Equipment

In this experiment, it has five apparatus and equipment should be prepared to do the thermal imaging. Table 3.1 below shows the list of equipment had been used in experiment

Table 3.1 List of Equipment

Apparatus	Specification
1. FLIR Camera (A615) 	- High revolution for detect the radiant heat energy. - A compact and affordable thermal imaging camera where fully controlled by the computer. - A615 produces crisp thermal images of 640 x 480 pixels. - The FLIR a 615 has a high speed infrared windowing option.
2. Hair Dryer (heat source 1) 	- Use as the heat source for second method to transfer heat to a specimen - Use as the source of heat for the experiment - Connect to power supply to produce the hot air.

3. Shaker (heat source 2) 	- Shaker use to test trails to conducted the structural health monitoring and damage detection algorithms validation. - Use to vibrate the specimen to give an direct heat.
4. computer pc 	- Run the software for thermography program - The image that capture from the FLIR Camera was transfer to the computer and analyse the result.

The shaker and hair dryer each of them will provide a pulse of thermal energy for heating a surface of the wood circle. The A615 FLIR camera is positioned on the same side of the wood circle. Power cycle was use to supply the electric to the computer and camera. After the camera treats the heat, it will show on the computer desktop that was installed by software of A615 thermal imaging software. There are two methods on getting the heat where by using the heat source from the shaker and hair dryer.

3.4.2.2 Setup the Apparatus

The experiment will be held on the lab at campus industries, where in the condition monitoring lab. The experiment was setup by using all the equipment according to the finding that use as objective. The experiment setup start with place the specimen at middle, get direct heat from hair dryer and camera focus at specimen that get direct heat from hair dryer. The camera was detected the radiant heat energy and transfer to the computer that use to analyse the thermography image. Figure 3.4 shows, the example setup for the experimental of thermography, the camera was setup in the middle of the table and heated by hair dryer.

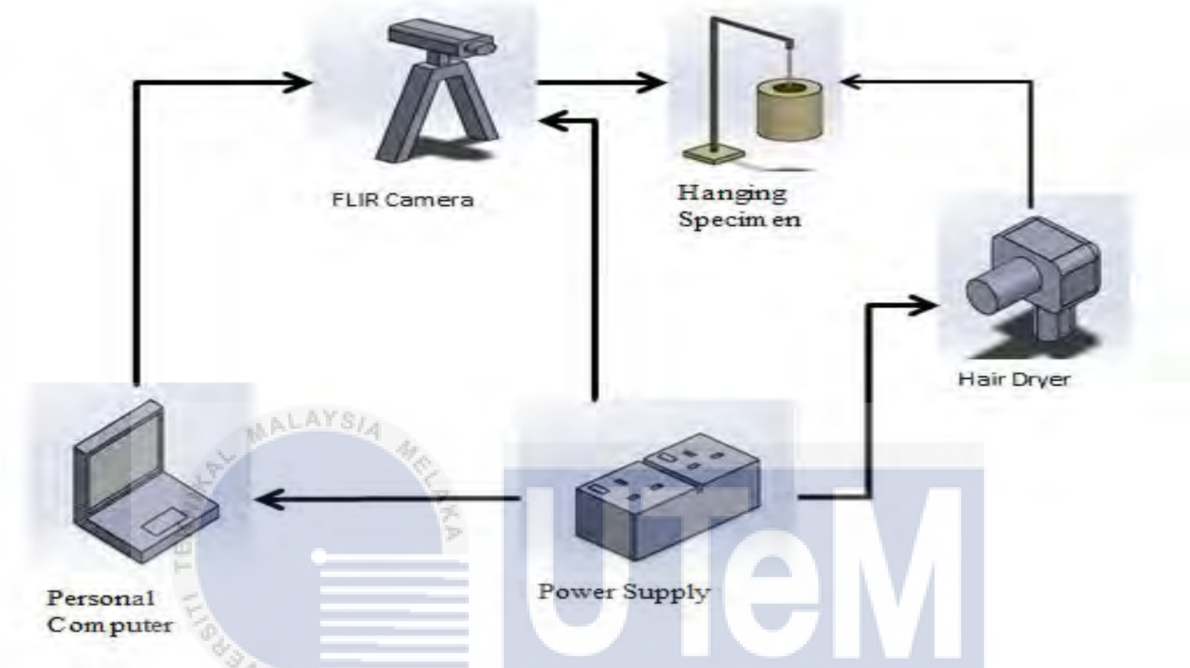


Figure 3.5: The apparatus setting for hair dryer heat source and camera was focus on the wood circle to detect the heat.

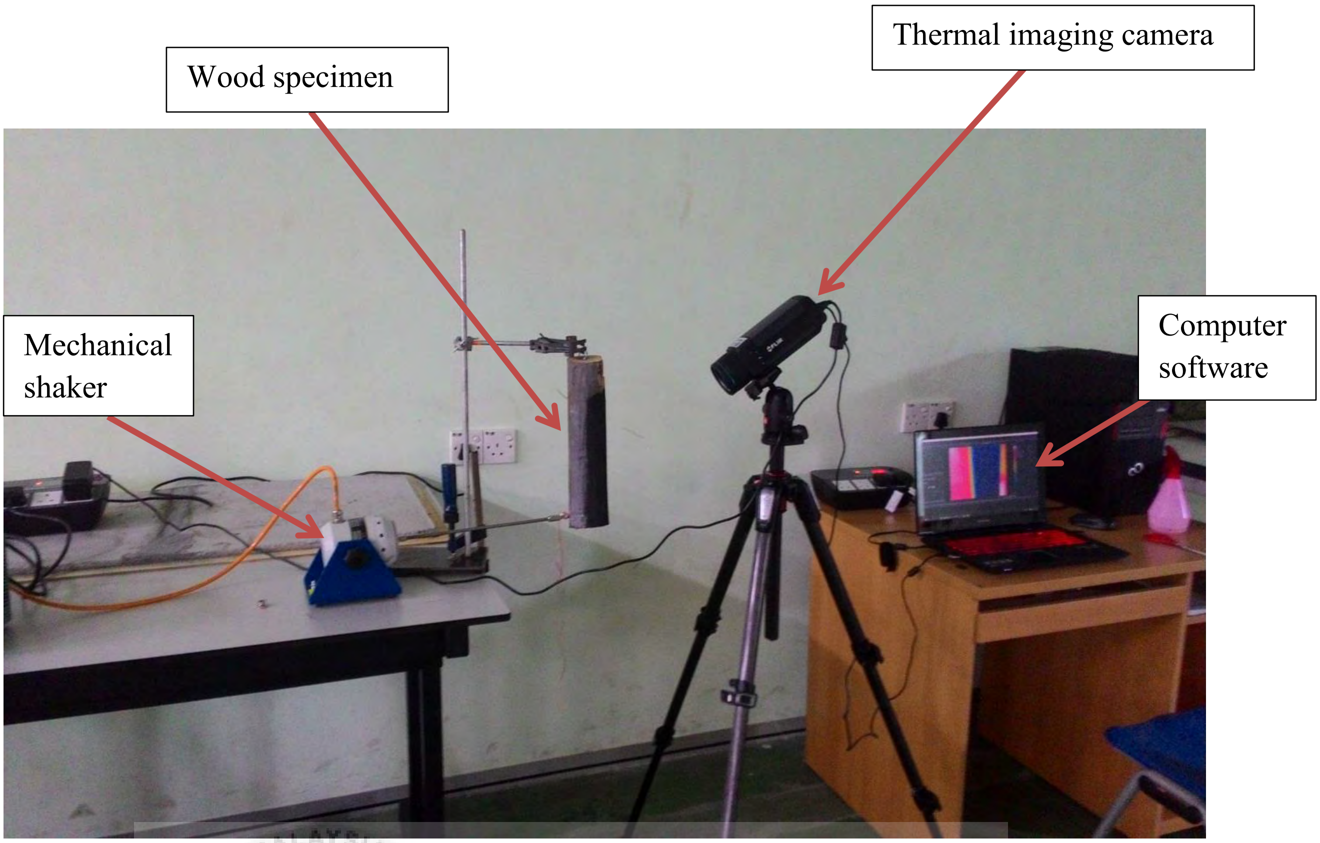


Figure 3.6: The apparatus setup for vibrothermography

3.4.2.3 Schematic Diagram

Figure 3.4 shows the schematic diagram of experimental setup. For this experiment, it uses the wooden block with diameter 7.5 cm and length 26 cm for lower harness word, and higher hardness with diameter 2 cm and 14.5 length cm.

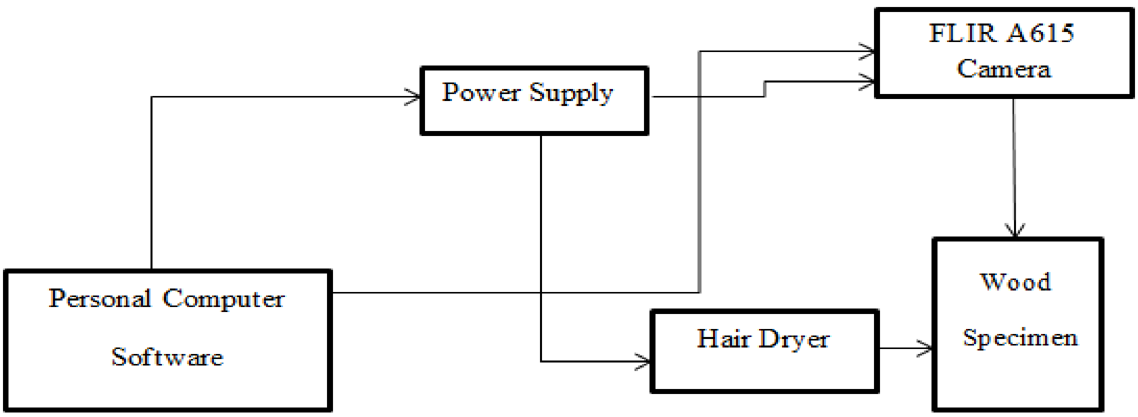


Figure 3.7: The schematic diagram of the thermal imaging technique.

3.5 Signal Analysis

In this experiment, the temperature of hardness area will show the lower temperature compare to the lower hardness where show high temperature based on the structure of the specimen. For the hardness wood had a compact structure than the lower hardness, where can absorb more heat and had a good conducted. So, the heat transfer from the outer surface of block wood is faster than the internal where the hardness was higher. In addition, result image before extracting is blurring and unclears. A normal condition for image, a video was record using A615 FLIR camera and after that abstracted to an image. By using Image J, above problem can be clearly image without any distribution. Image J also can be used for extract the clear picture. Both of the method was use to remove, filtering and extracting noise effect from image result. From this analysis process the threshold process is to gain the cold region, the process of analysis easy to be done. Figure 3.6 show some example excitation by using software Image J.

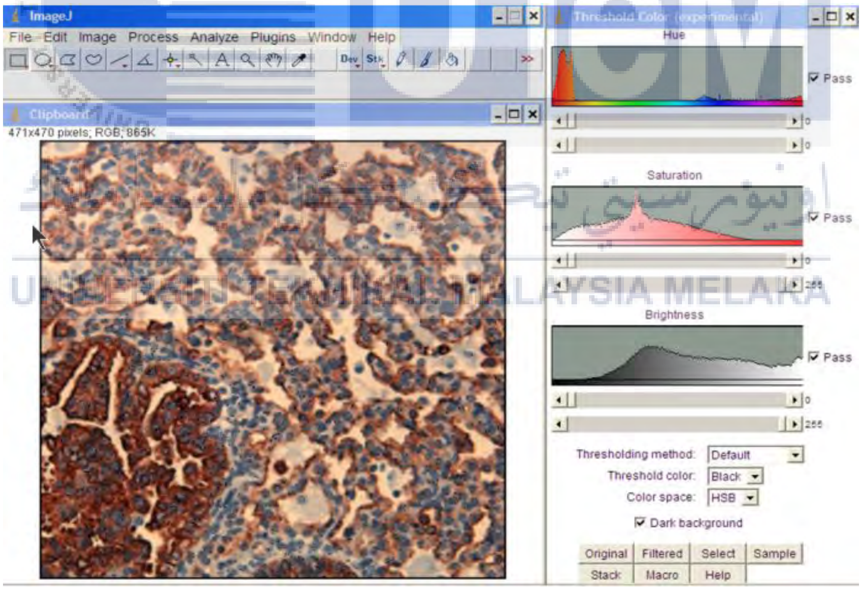


Figure 3.8: Image processing in software Image J

(Source: http://www.openwetware.org/wiki/Sean_Lauber:ImageJ_-_Threshold_Analysis)

3.6 Measured Parameter

For this experiment, there a six of constant parameter that has been set for run the experiment. The parameter is based on the characteristic of the wood and method that has been used to setup up the experiment. The outer wood and inner wood has different characteristic based on the quality of the wood and also density of the wood, but both of the wood have a same characteristic where is good absorb heat. Both of the wood is very suitable as replacement of agarwood for experiment. Then other constant parameter is frequency that was used to get the direct heat during vibrate. Every constant parameter is important for the experiment and future discussion. Below the constant parameter that has been used for this experiment.

The density of outer wood	:	765 kg/m^3
The density of inner wood	:	963.58 kg/m^3
Initial / surrounding temperature	:	24.5 Celsius
Duration of heating time	:	10 minute to 20 minute
Vibration Time	:	2 hours
Vibration frequency	:	850 Hz

3.6.1 Density calculation for the wood

To know the density of the wood, the experiment has been done by following the Archimedes theory where, the principle is about buoyant force where the object weight is equal to water displaced during submerged with constant gravitational g.

$$P = m / v$$

P = Density (kg/m^3)

M = Mass (kg)

V = Volume (m^3)

<u>Mahang Wood (outer wood)</u>

Mass = 0.04793 kg

Volume of water displaced = 65ml

= $6.5x^{-5}\ m^3$

P = m/ v

= 0.04793/ $6.5x^{-5}\ m^3$

= 765 kg/m^3

<u>Balau wood (inner wood)</u>

Mass = 0.07805 kg

Volume of water displaced = 81ml

= $8.1x^{-5}\ m^3$

P = m/ v

= 0.07805/ $8.1x^{-5}\ m^3$

= 963.58 kg/m^3

3.6.2 Impact Test for Wood

The impact test is to see the suitable frequency that can be used to vibrate the wood during to get the direct heat from vibration. The impact test was create from labview program and using the approximately probe to measure the average frequency for a wood.

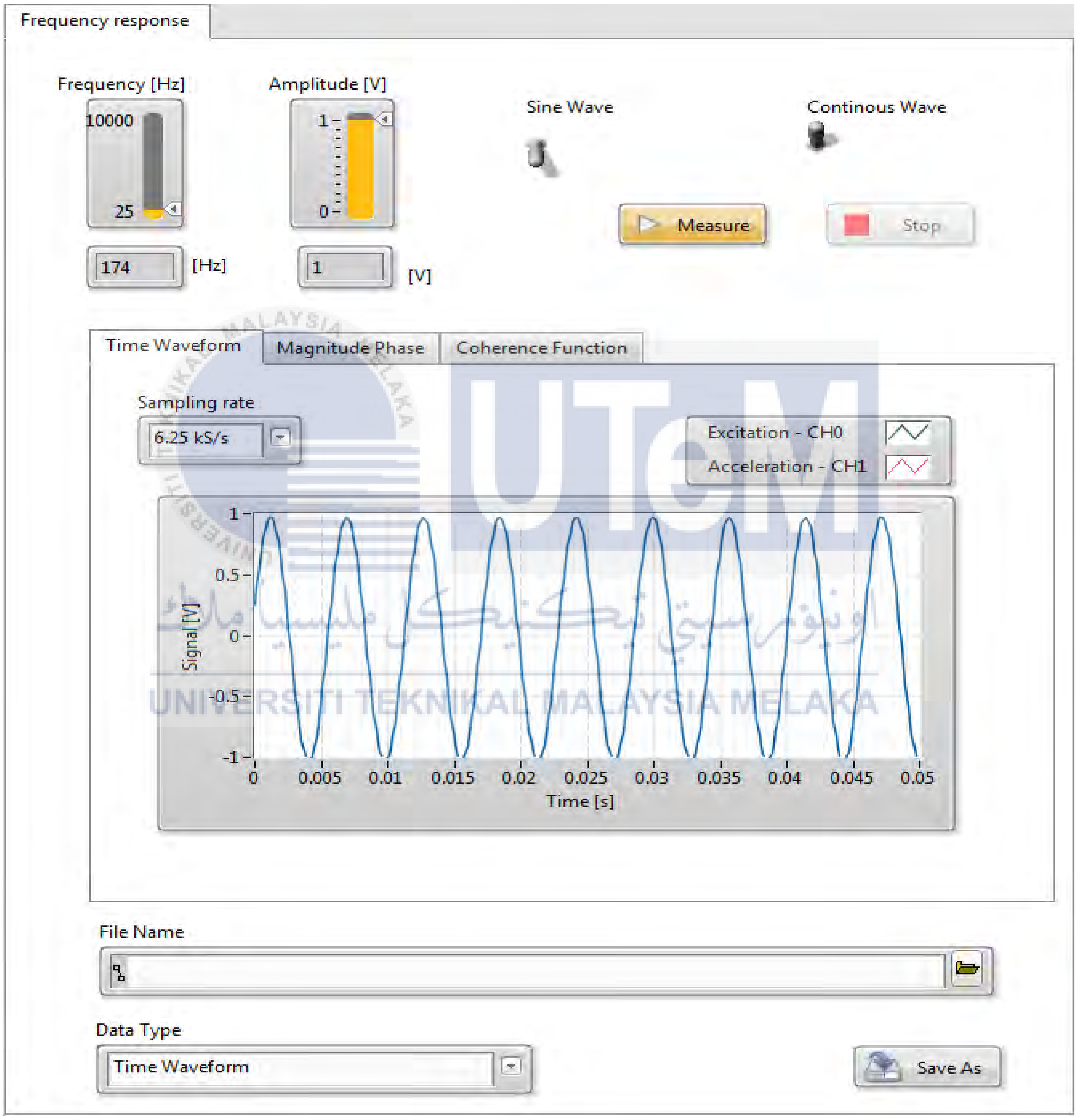


Figure 3.9: The processing of impact test for a wood

CHAPTER 4

RESULT, DISCUSSION AND ANALYSIS

This chapter will describe the analysis and discussion about the foreign material that has been detected in the experiment based on the different of temperature and physical different based on the image and graph. Also describe principal working of FLIR camera to detect the foreign material. This chapter has been divide into two method of direct where based on heat source where hair dryer and vibrothermography (mechanical shaker). Both of the method gives a significant effect to detect the foreign material detection in agarwood.

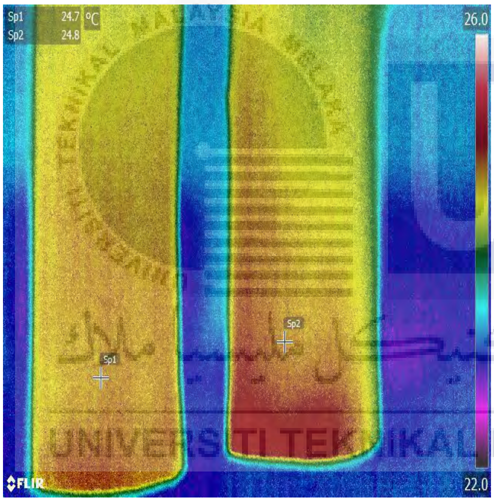
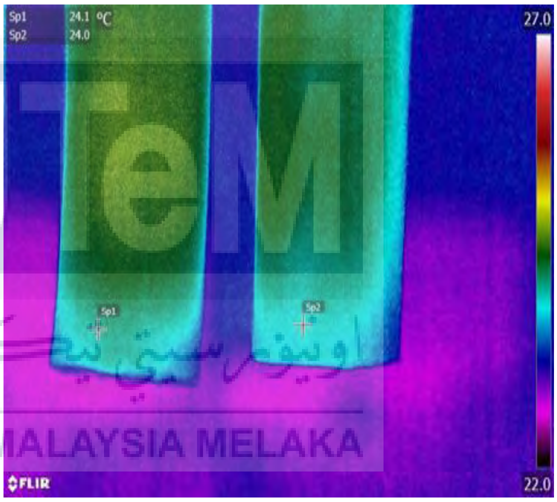
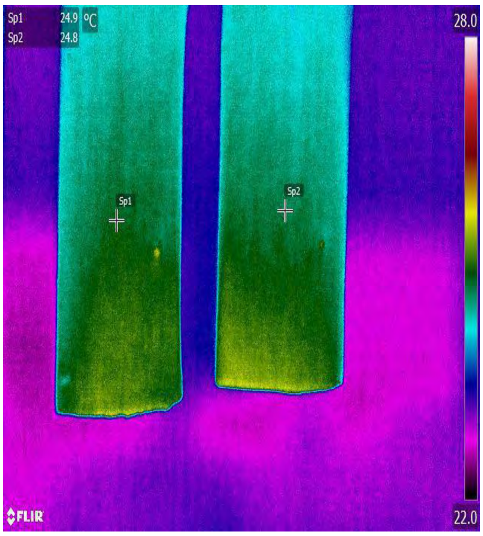
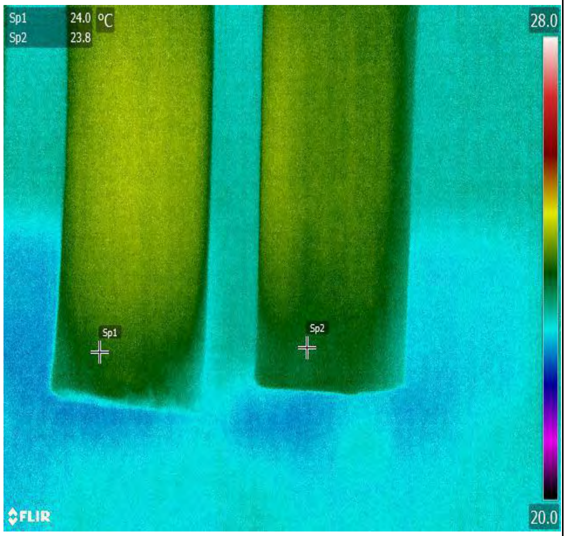
From the result, the temperature of monitoring are having a different when the wood with the core and without core. Thermal images on the monitored area of the wood are recorded based on the heat source and condition of the wood. The images were record after several time for example for hair dryer, the images were recorded after 10 minutes of heating by using hair dryer as heat source and also record the images after 10 minutes during cooling. The temperature image obtained from the rainbow colour scheme with maximum and minimum are not constant based on the specimen temperature, the temperature in range 21° C to 28° C based on the condition of the wood during heating and cooling. Another method was using a vibration shaker to run the vibrothermography experiment. The vibration shaker was connected to the function generator and stringer connected to the specimen. The frequency vibrations are fixed at 850 Hz, and the frequency was gain by using the impact test experiment toward to the wood.

4.1 Result of the Experiment

The result show for two method of heat source where from the hair dryer and shaker that has been used for give a direct heat for specimen. Shaker was vibrating with frequency 850 Hz where the value was get during force impact test toward to the wood. Period time of heating is based on the movement of wave that can be seen on FLIR camera image.

4.1.1 Hair Dryer

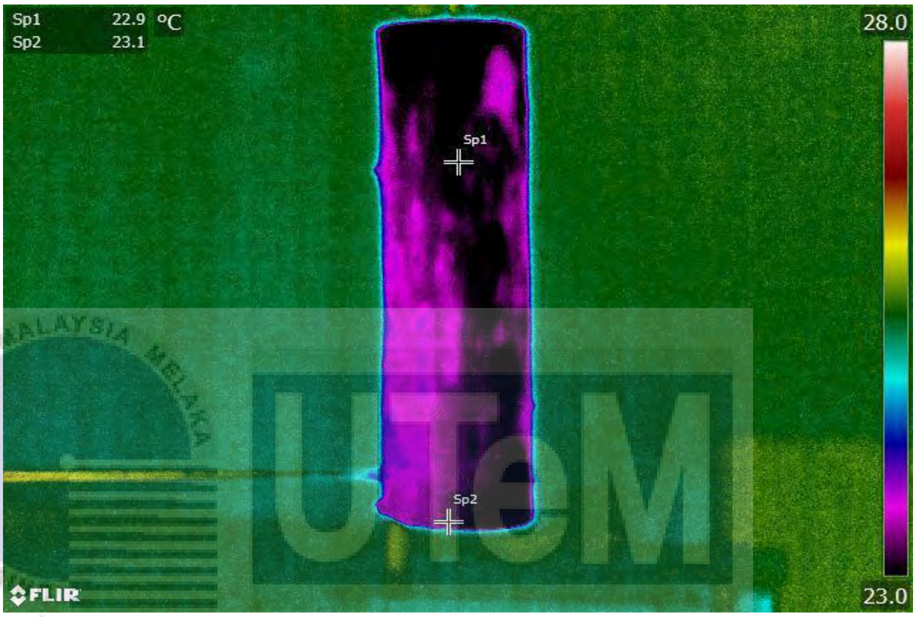
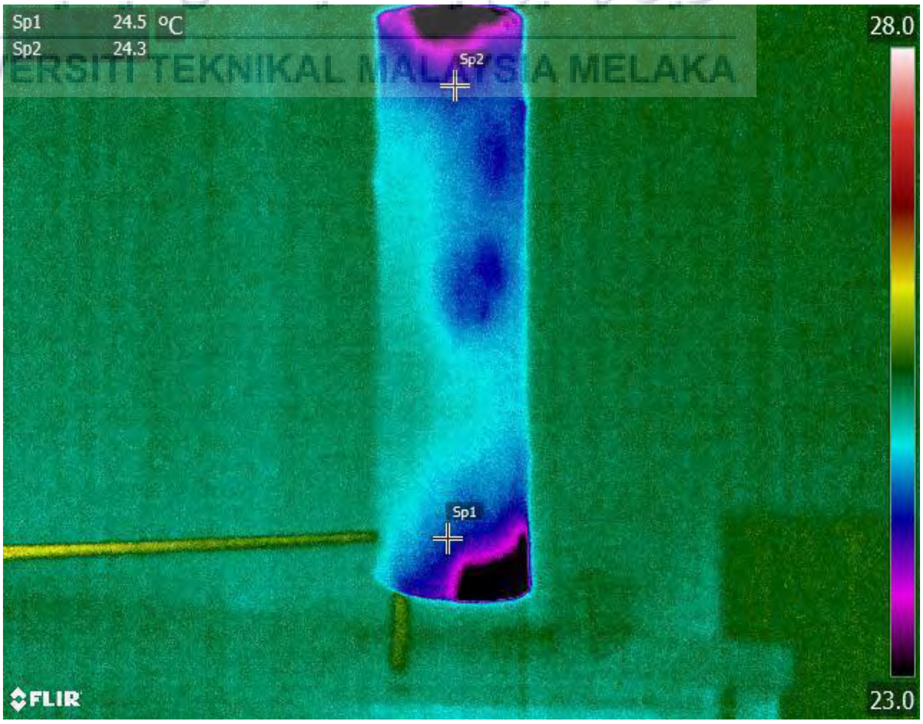
Table 4.1: Result from the FLIR for hair dryer heat source

Position	Image Result	
	Heating	Cooling
Front		
Beside		

4.1.2 Mechanical Shaker (Vibrothermography)

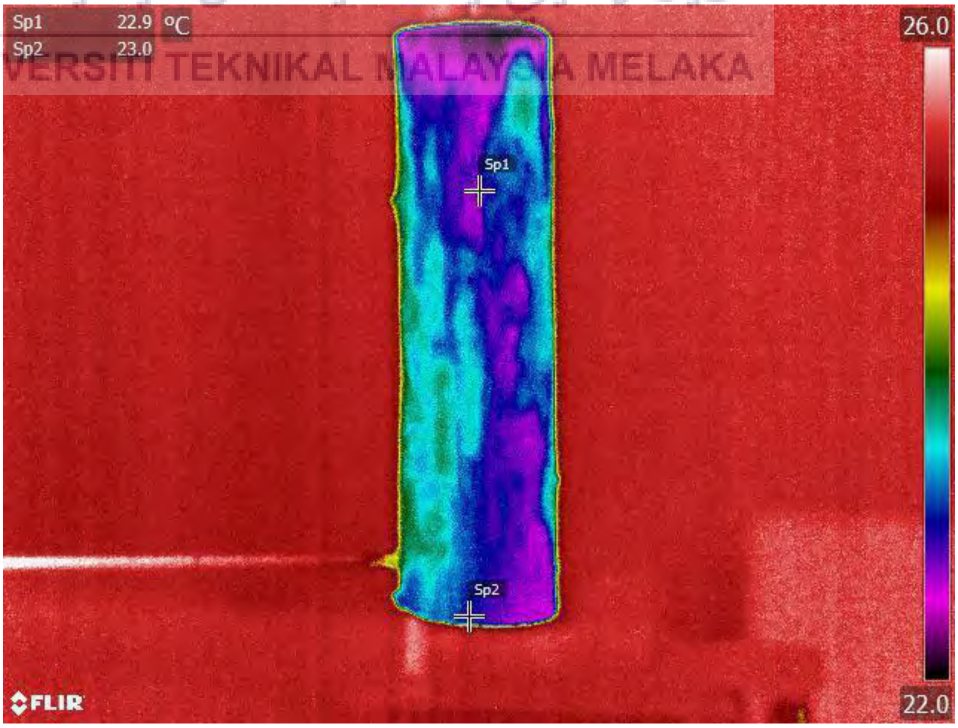
4.1.2.1 Without Core Wood

Table 4.2: The result of vibrothermography for without of core wood (high density wood)

Condition	Result
Wet	
Dry	

4.1.2.2 With Core Wood (High Density Wood)

Table 4.3: The result of vibrothermography with core wood(high density of wood

Condition	Image Result
Wet	
Dry	

4.2 Observation result hair dryer and vibrothermography

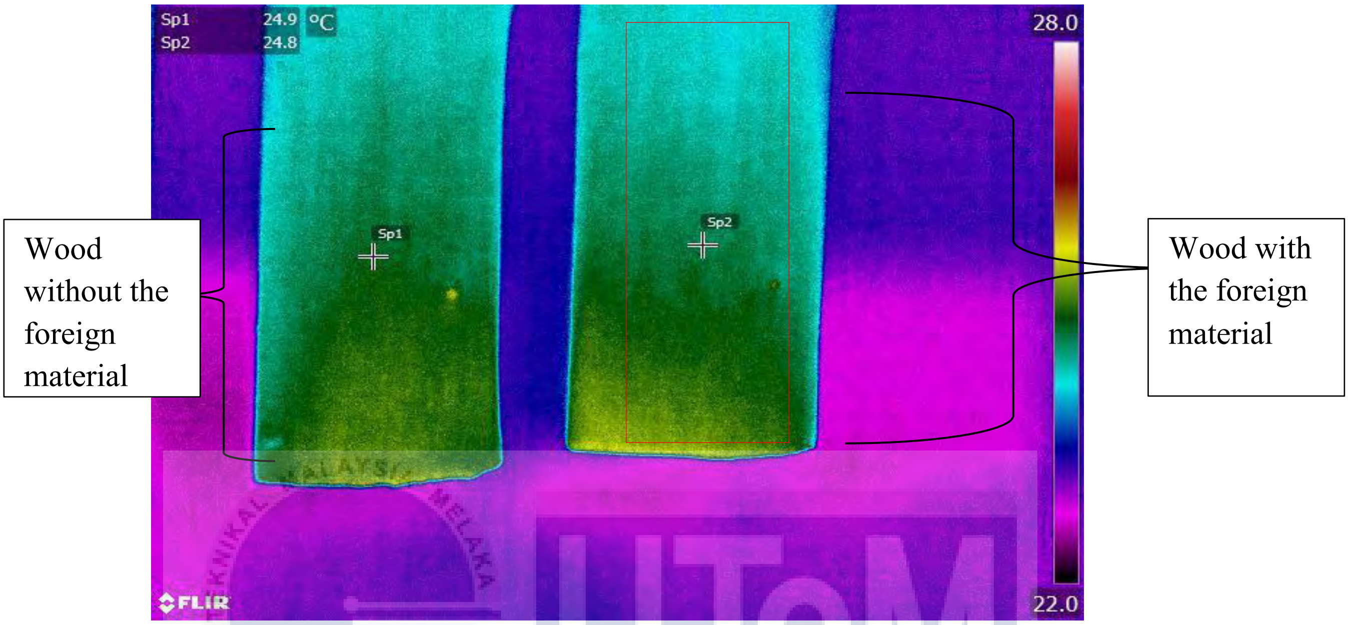
4.2.1 Hair dryer

4.2.1.1 Heating process

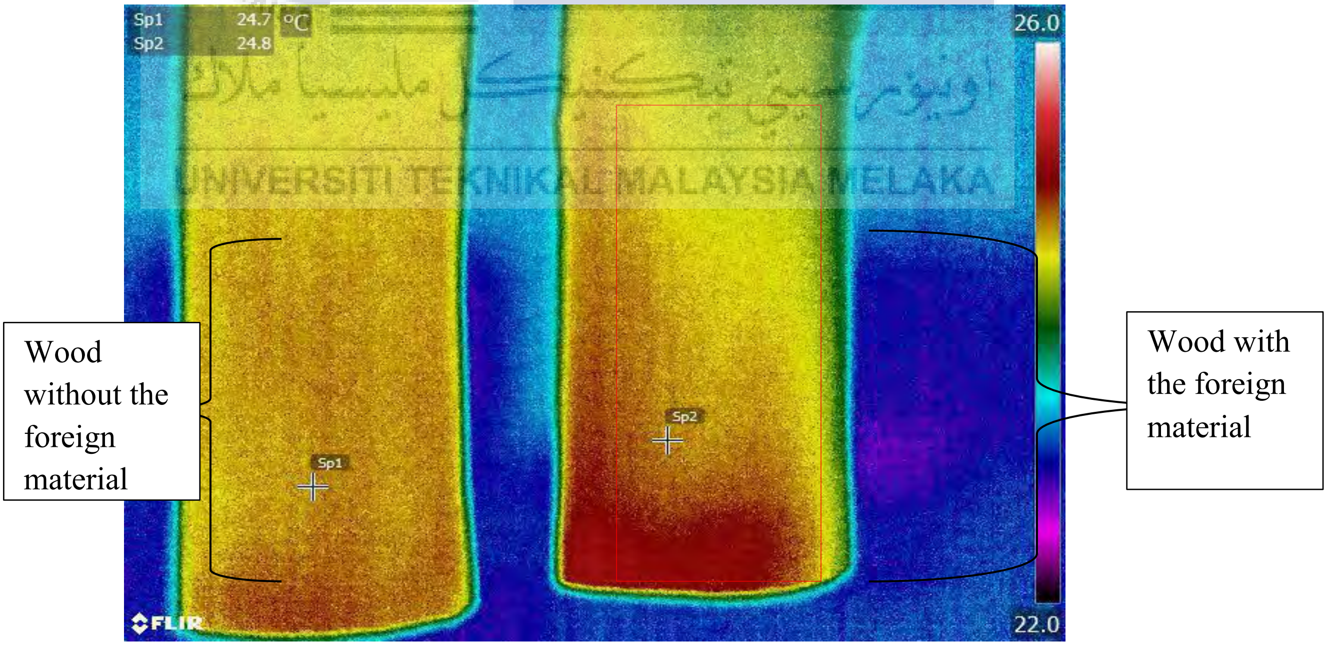
First observation is the relativity of deflection of the heat towards the wood and to detect the different of the heat observed for wood with the core and without the core, it clearly observed the low temperature spot on the visualized in the temperature image along the core detected by camera image. The image on begun to see when the wood or specimen was heated above 10 minutes and wood surface received more thermal energy due to the increase in duration of the thermal imaging.

Temperature different of the wood was monitored from the point Sp1 and Sp2 that point with different location. Sp2 as the lower temperature and Sp1 act as the higher temperature. The heat source were direct in two ways where front and beside of the specimen during experiment. Both of situations are to see which way more suitable to see the different of heat that ambient on the wood structure. In Figure 4.1, the heat from the hair dryer increased the wood temperature from 24° C to 27° C in within 15 minute. The temperature range for maximum and minimum for Figure 4.1(a) 4°C and Figure 4.1(b) 6°C is used fin infrared thermography to provided high sensitivity in thermal wave visualization across the wood monitored area. The dark solid line show the existed of the core detection when the heat source was directly to the specimen. From the images on Figure 4.1, from the Figure 4.1(a) is the result when the wood has been heated in front position, the image showing the different result between the wood with core and without core. The heat cannot go through to the upper and have a hitch at the middle, it different with the without core wood where the heat ambient can go through to the upper surface.

For the Figure 4.1(b), the hair dryer was placed beside of the specimen and camera was detected in front of the specimen. The image observation shows are reflected of the heat ambient where in the middle of the wood with the core, the temperature side of the wood is higher than at the middle, but for the wood without the core have same average temperature. For the prove, at the rectangle box on the figure show the different of impact barrier in the middle of wood which emitted heat does not penetrate in the middle of wood. From the Figure 4.1, that prove the position of heat source are important to detect the foreign material in agarwood, the image of foreign material is more easy to detect when the heat was directly heat at the beside of the specimen because easy to camera to detect the heat wave that reflected when the heat try to absorbed at the core of the wood. From the observation, when the thermal waves try to achieve at the core, the deflection of waves are obviously seen that caught on the thermal imaging camera.



(a) Image temperature for hair dryer heat source in front heating



(b) Image temperature for hair dryer heat source in beside heating

Figure 4.1: Both result of the position of hair dryer heat source during heating the specimen

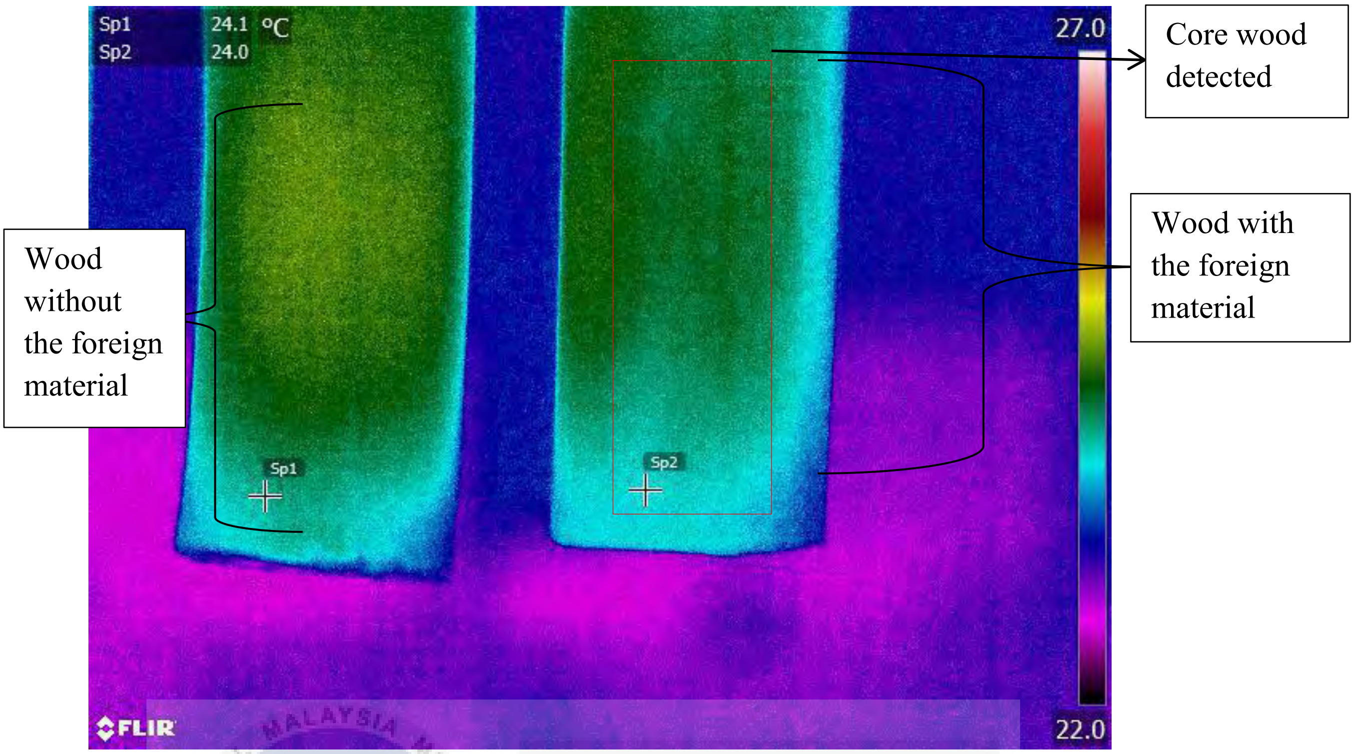
4.2.1.2 Cooling process

After the specimen of the wood had been heated to see the existence of foreign material, then this observation is to see the image of thermal imaging which path faster cooled after being heated. The wood specimen with core and without core was fixed together and observation of the differentiations of the image was recorded. From the image 4.2, Sp1 and Sp2 were located at two different positions where Sp1 located at the specimen without core and Sp2 located at specimen with core. It clearly to observe the different temperature spot is visualized image between the specimens where the cores are more visible when the cooling time was increase from 10 minutes to 15 minutes. The cores are faster to lose the temperature than the outside region.

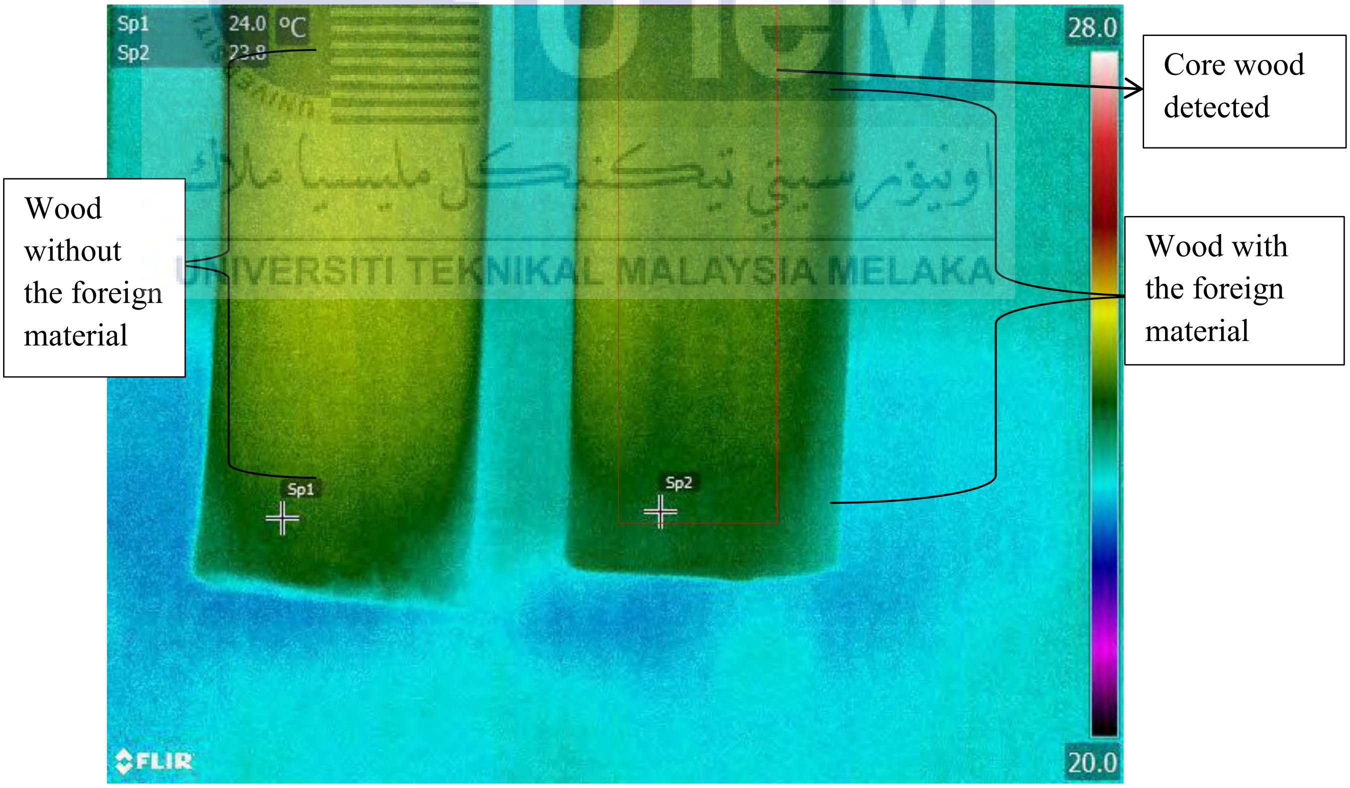
The temperatures decreasing on the wood surface were monitored from two point; Sp1 and Sp2 which located at different location as shown in Figure 4.2. The temperature of the wood during cooling keep increase about 23.3°C to 24°C within 10 minutes. The phenomenon of cooling region is faster than expected due to wood is good conducted material. The rectangle boxes on Figure 4.2 represent the monitored area where the core were located and specimen that without core shows different heat ambient on the image.

The lower the temperature in the optical radiation thermography indicated low temperature in the foreign material in the wood compared with the wood without foreign material, the heat ambient are average located in wood surface. The defect region was obviously can be seen when the temperature keeps decreasing due to time change. Therefore, the rainbow HC colour scheme is selected between 20°C to 28 °C. The 8°C temperature range was used in this thermography to provided medium sensitivity in thermal wave visualization on the wood monitored area.

However, from the observation Figure 4.2, there were little different between front cooling and besides cooling. It is because during cooling process, the core of wood show different temperature compared without core. The image result shows the defect due to different of density of the wood that affecting the material conduction. The result also proves that, material with higher density had good conductor and faster in releases the heat to the upper side.



(a) Image temperature result during front cooling



(b) Image temperature result during beside cooling

Figure 4.2: Both front and besides cooling of the wood to compare the characteristic of image visualization.

4.1.2 Vibrothermography process

Vibrothermography experiment is mechanical vibration that induced externally to the structure direct conversion or direct contact from the mechanical shaker to emitted the thermal energy occurs and the heat is release by frictions precisely at the locations where the core are located. On this method, the mechanical shaker was used to give an internally heat to the wood specimen in two condition where dry condition and wet condition. The frequency of the vibration was fixed at 850 Hz for wet and dry condition. The time taken to gain the best result is fixed to 1 hour per wood. The frequency was gained by doing the impact test to the wood specimen to gain the suitable frequency for the wood structure. From this experiment, the objective is to observe the different temperature between regions in visualization image from thermal camera.

4.1.2.1 Dry condition

Thermal images on the monitored area are recorded after 1 hour of vibrate so seen the thermal radiation from the mechanical shaker as show in Figure 4.3 and 4.4. The temperature images are obtained in two conditions with core and with core wood in the middle of based wood. Both of the wood has been vibrate with fixed frequency at 850 Hz and obtained from the rainbow Hc colour scheme with minimum and maximum threshold for the with core wood is 26°C to 30°C and without core is 27 c to 32 c. the temperature of image threshold are different based on the wood temperature before vibrate. However, the temperature image after 1 hours begun to indicate high temperature on the internal of the wood due to the increase in duration of the thermal internal convection. The temperature are detected increase on the internal of the wood are monitored from two point at location Sp1 and Sp2 as in the Figure 4.3 and Figure 4.4. The location of Sp was put different location to see the ambient different of temperature at two location. The presence of core detection in the middle of the wood become more lightly visible as duration of the vibrate increase. From the figure, the image visualization show an different heat area, for the wood with core has shown different temperature in region a and region b. at the middle of the wood has been seen like a hole ways apparent on the camera detection. But for the without core, sp1 and sp2 shows are different 0.4°C where at the core of the wood the heat was absorb more heat during vibrate. For the wood with core sp1 and sp2 has 0.1°C different at the middle, that show the high density wood is good conductor and easy to release the heat to upper.

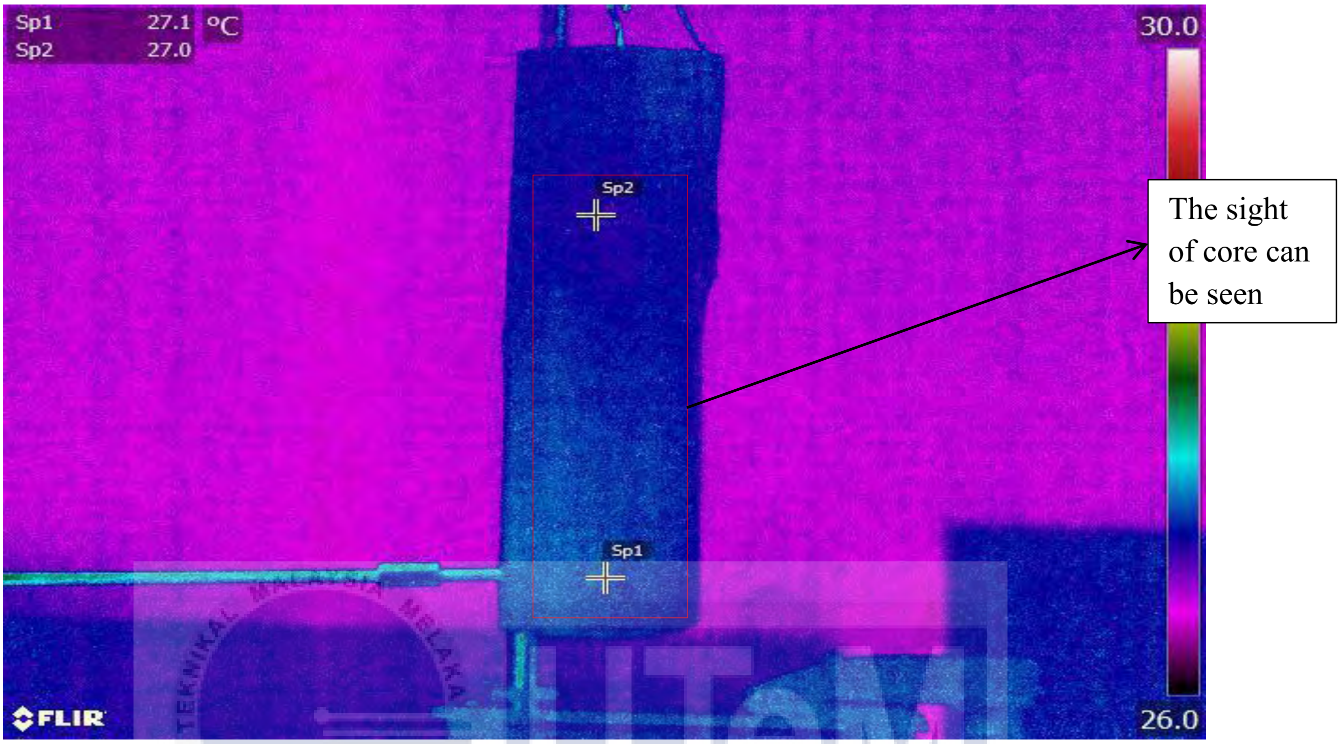


Figure 4.3: The thermal imaging images dry and with core for vibrothermography

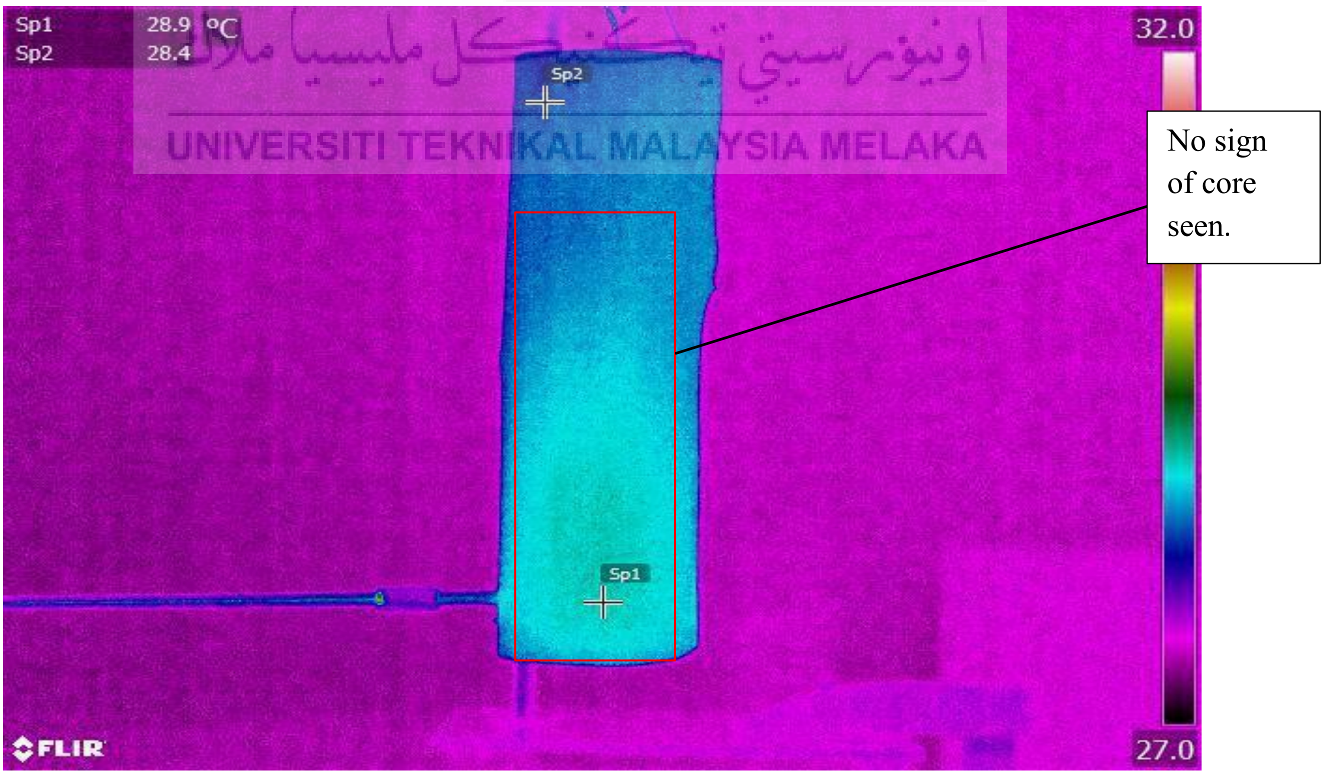


Figure 4.4: The thermal imaging images dry and without core for vibrothermography

4.1.2.2 Wet condition

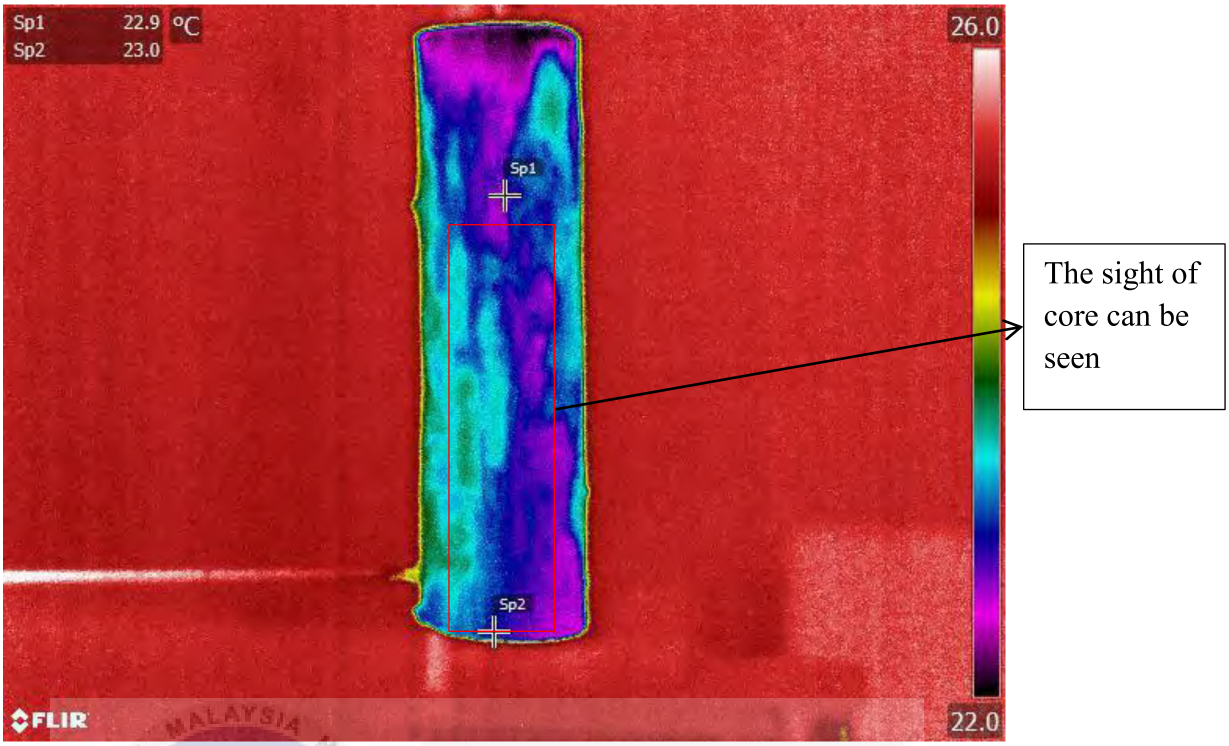
For the wet condition is same ways as the dry condition, but before the specimen wood was vibrate, the wood specimen with and without core was dipped into normal water to get wet, the duration of submerge the wood in range 10 to 15 minutes. After the wood was wet, run the vibration method to the wood for fixed time 2 hours for without and with core wood.

The thermal images are monitored on the wood specimen after two hours to see the increasing of the temperature due to vibration heat transfer. Sp1 and Sp2 were located at two different locations at the middle but at the upper and lower position of the wood. The temperature images are obtain from the same colour scheme but different maximum and minimum range is 5°C different for the sensitivity of camera image.

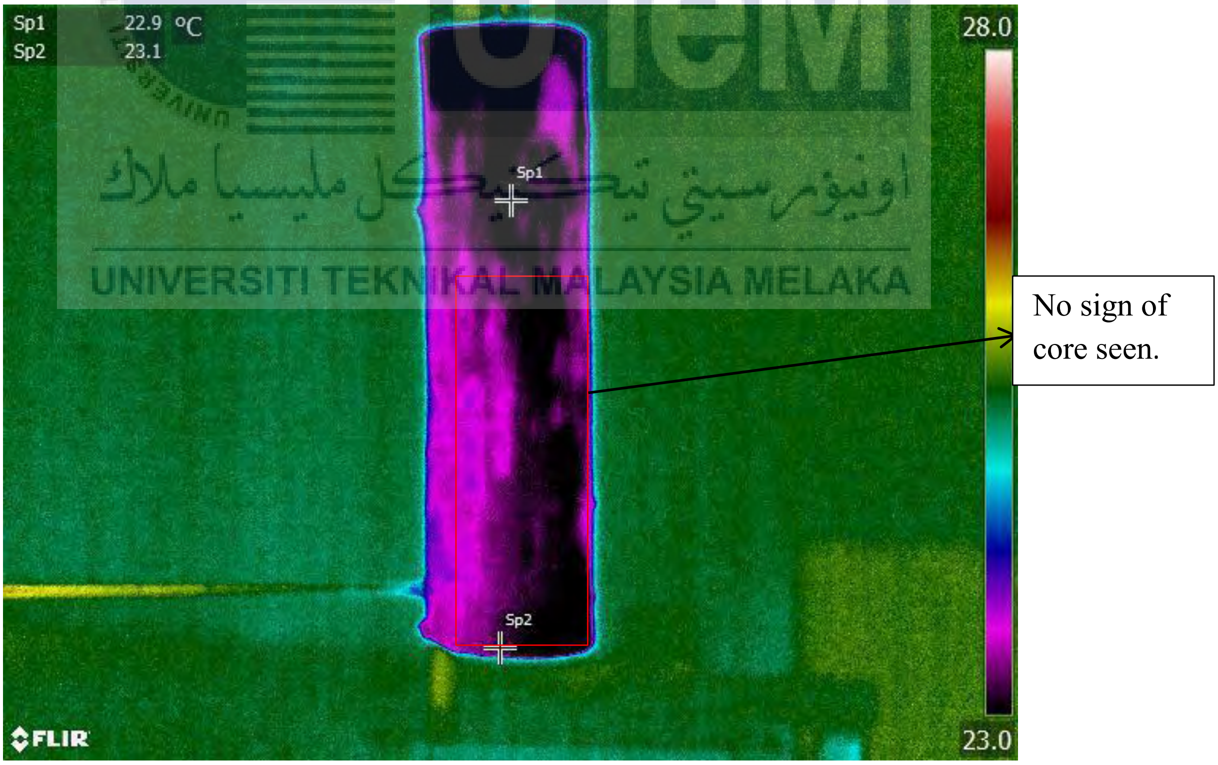
The temperature different between two points for both of the image result is 0.1°C to 0.2°C based on the Sp1 and Sp2 condition that prove the different between core and intact region on the wood. For the wood with core, it showed lower temperature compared to the specimen without core that shows the convection temperature was move spread to the body of the wood but with the core wood the temperature was reflected and show het boarder at the middle of the wood.

Therefore, the rainbow HC colour scheme is selected to be between 23°C to 28°C for the specimen without core and between 22°C to 26°C is with core wood. The 4°C to 5°C temperature range is used in this vibrothermograhpy to provide high sensitivity in the thermal wave visualization across the monitored area.

However, the effect of condition of the wood has made the visualization of background different, this probably due non-uniform temperature between room temperature and wood specimen. Other than that, the uninform colour of images due to paint condition on the surface which cause different ratio of temperature that spread on the body after absorb the heat vibration from the shaker.



(a)



(b)

Figure 4.5: (a) The result of vibrothermography mix in wet condition (b) The result of vibrothermography without core at wet condition

At the same time, the image was likely bluffed because of effect of sound and the different of density the outer wood and inner wood are too small different and prevent us from visualization the different between with core and without core. At the same time, the overheat of temperature also can prevent us from visualize the defect using the infrared thermography due to the condition of temperature which already reached the uniform temperature in the whole structures or the temperature difference in core areas already become too small to be detected. Therefore, the hair dryer need to the left and to the right to prevent from overheated. For the vibrothermography, the temperature increases are small and prevent us to differentiation the visual of the image.

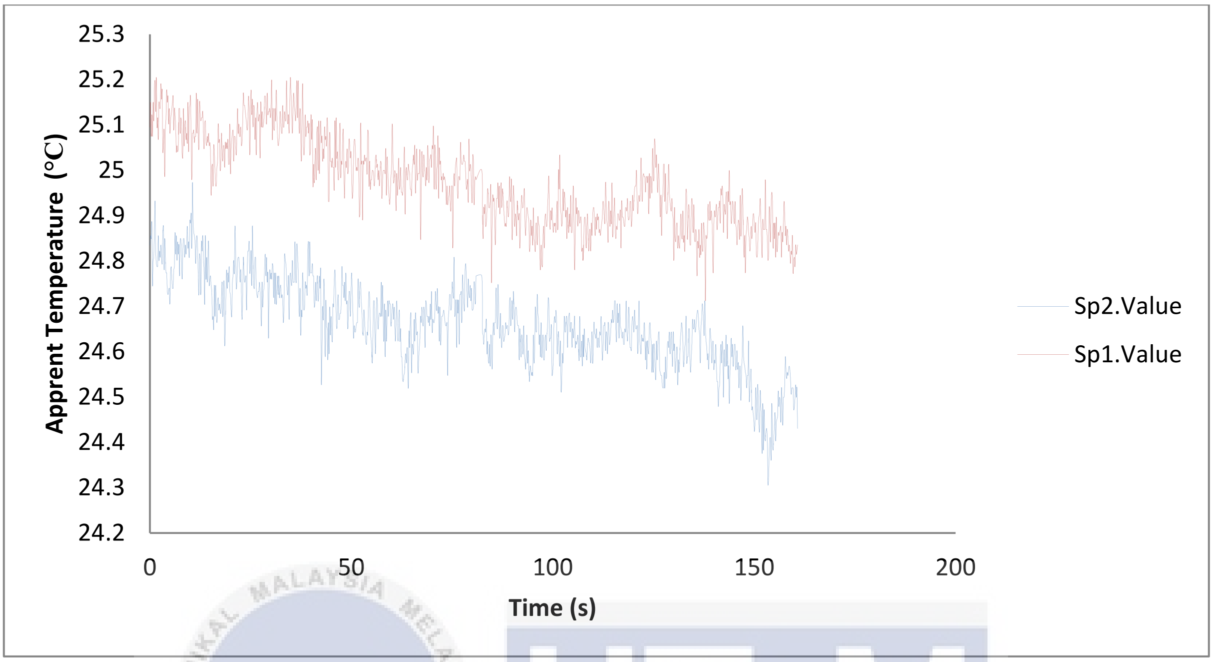
4.3 Analysis of the result

4.3.1 Graph analysis of temperature data

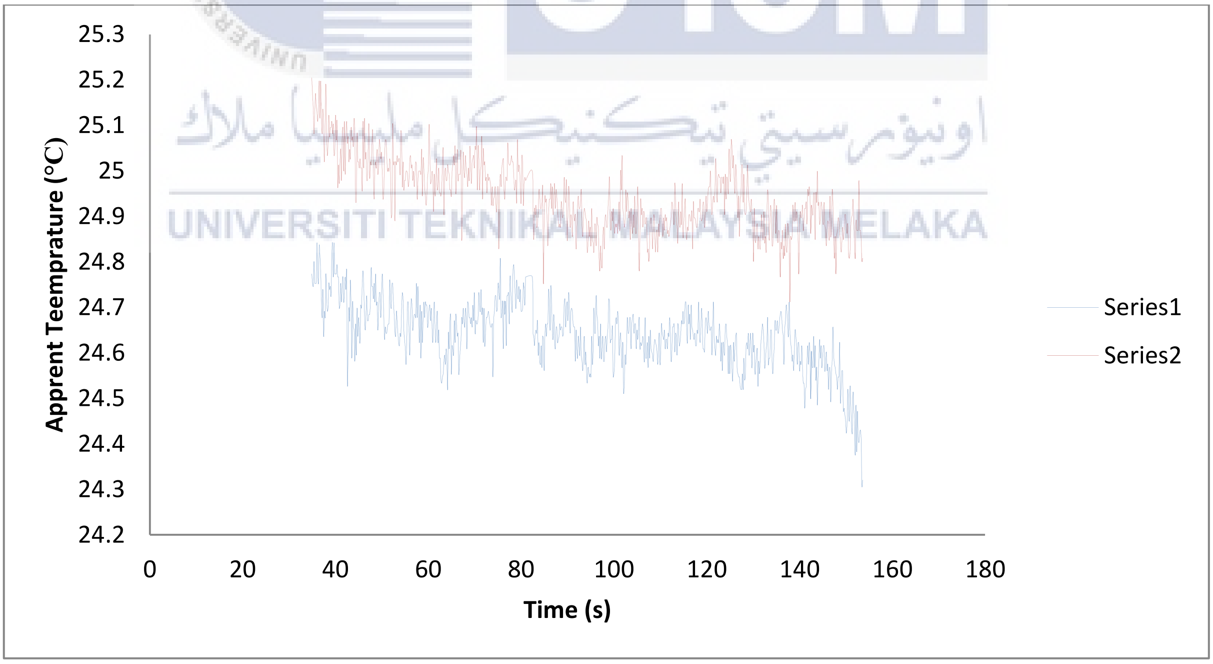
From the experiment, data temperature different has been taken to see the different spot for sp1 and sp2 that located on the specimen. From the graph image, the result can be compare for specimen wood with the core wood and without core.

4.3.1.1 Heat source hair dryer

For analysing the change of temperature between two locations that locate the sp1 and sp2 the data of temperature has be taken and plotted a graph. For the heating process by hair dryer sp1 was located at specimen without core and the position of the sp1 at the middle of the wood, and for sp2 was locate at middle of specimen with core wood. From the Figure 4.6(a), the sp1 value is higher than sp2. At the same location, but the temperature data of sp1 is higher. That show, the high density wood had a good conducting and faster release the heat to the upper. From the graph, it also proves the temperature will be low when the agarwood have the foreign material inside. For the Figure 4.6 (b), the data temperature was taken during the process cooling down. Same as a heating, the sp1 and sp2 was located at two different locations, and sp2 was located at the specimen with the core. The graph shows, the different temperature of sp1 and sp2, sp2 have lower temperature and sp1 have higher temperature. The temperature different 0.2°C was determined between sp1 and sp2. This was happen because the wood with the core had a faster cooling down process then the outside, the structure of material for the high density wood make the process of cooling became faster and prove that the high density wood is good conducted material.



(a)



(b)

Figure 4.6: The graph shows the value of sp1 and sp2 for cooling and heating, (a) the graph during heating for hair dryer heat source. (b) The graph during cooling for hair dryer heat source.

4.3.2 Vibrothermography graph

4.3.2.1 Wet conditions

For Figure 4.7, this graph showed the temperature data of vibrothermography for wet condition.

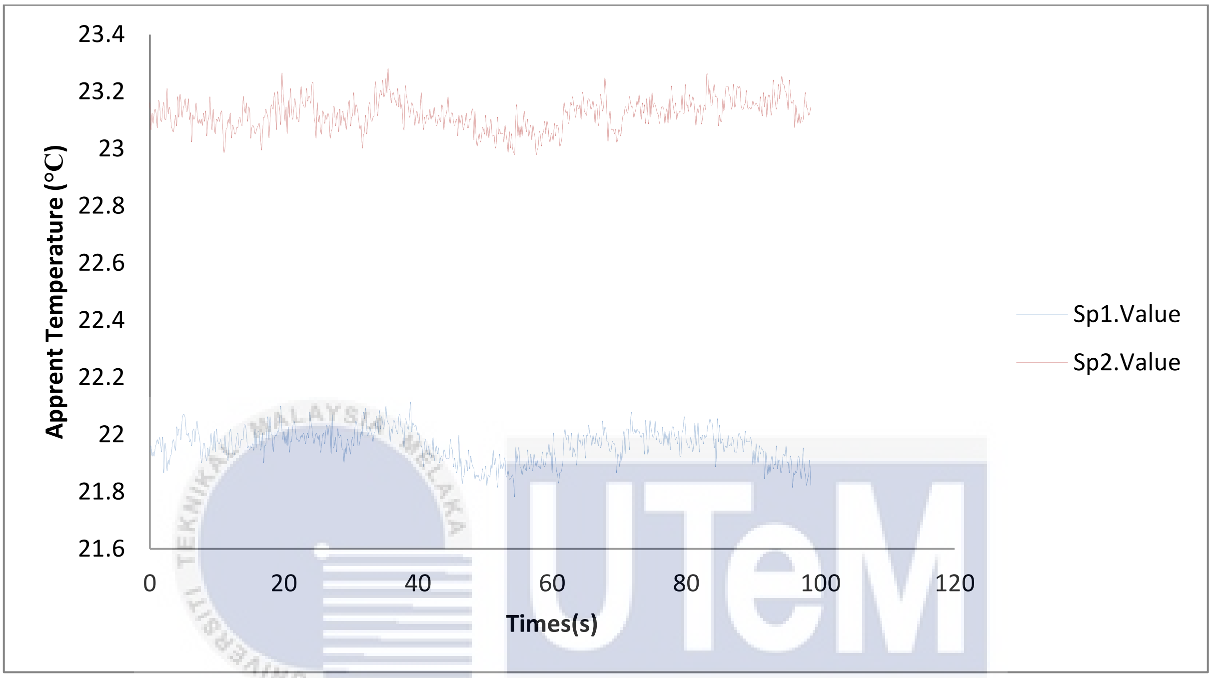


Figure 4.7: The graph data temperature for specimen with core

Graph above shows the different point of heat at two different locations of sp1 and sp2. Sp2 was located at the upper side where at the point wood with no core and sp1 was located at the middle where at the core wood. the temperature different prove that at the wood core, when the heat was absorb during friction, the heat was spread throughout the wood and at the path where had a core, the region is more cooling than other path. The high density wood has a good conductor and fast release the heat to upper after absorb. From the thermal images, the heat board that hitch from the heat enter to the core. The thermal image of wet condition with the core show little different due to the heat range is only 1.2°C. Figure 4.8 showed, the graph temperature data for wet condition with no core, where Sp1 and sp2 at the same location as wood with core. For the result of the data, the heat different between two point is absolutely same only different 0.1°C, that mean when the wood have a core, it will give an different temperature from the both side of cores that proves the existed of foreign material in the wood.

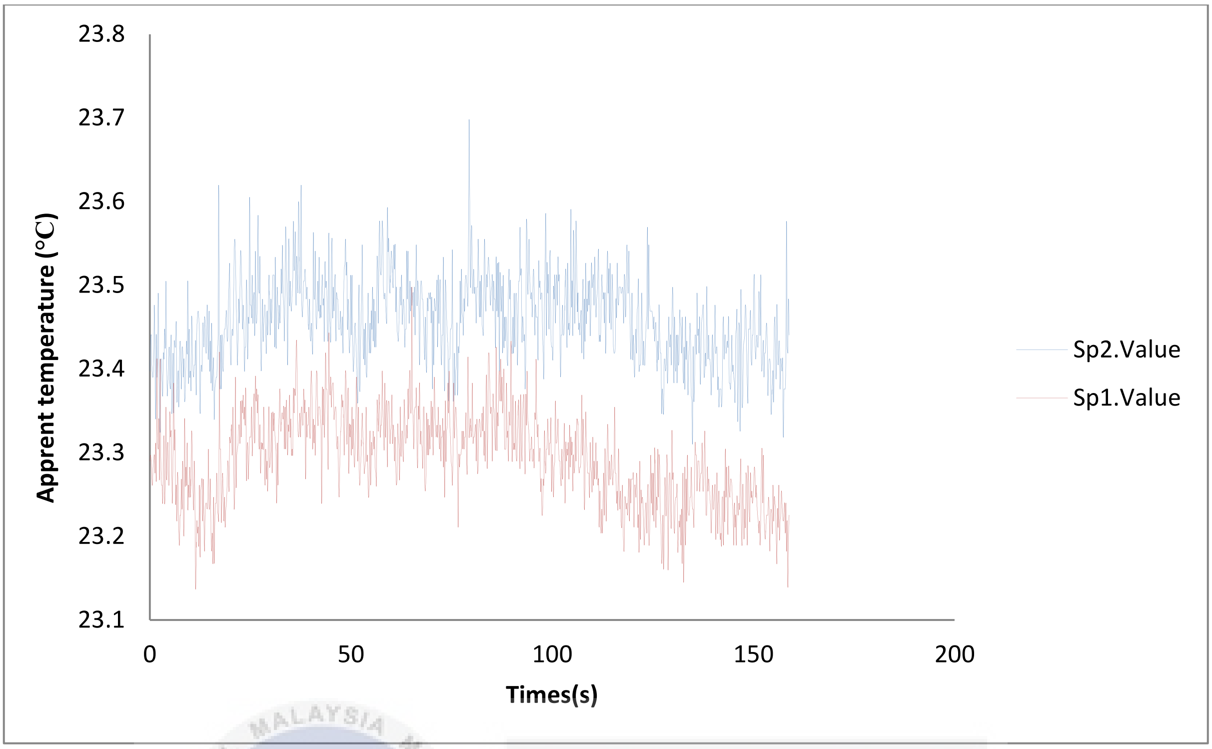


Figure 4.8: The result of temperature data without core for wet condition

4.3.2.2 Dry conditions

The temperature data for dry condition had a higher temperature due to dry condition of the wood same as image on Figure 4.9. Sp1 and sp2 was set at two different locations and had a different data temperature. For the wood with core sp1 and sp2 have a different range of temperature, the range of temperature 1.2 for sp1 and sp2. Sp1 was located at the middle of wood and sp2 was located at the high upper of wood. For comparison, the data dry wood without core on Figure 4.10 was plotted at the same location of sp1 and sp2. For the wood without core show the low range 0.1°C temperature. The wood with the high density wood had a good heat conductor and have a faster release heat better than side of the core. From the observation, when wood accept the heat waves from the friction, the heat was dispersed throughout the wood. For wood that has a core, the absorbed heat is stored longer and release heat in lower wood density. This shows that the timber has a low density absorb heat quickly and keep in quite a long time, compared to wood have a high density

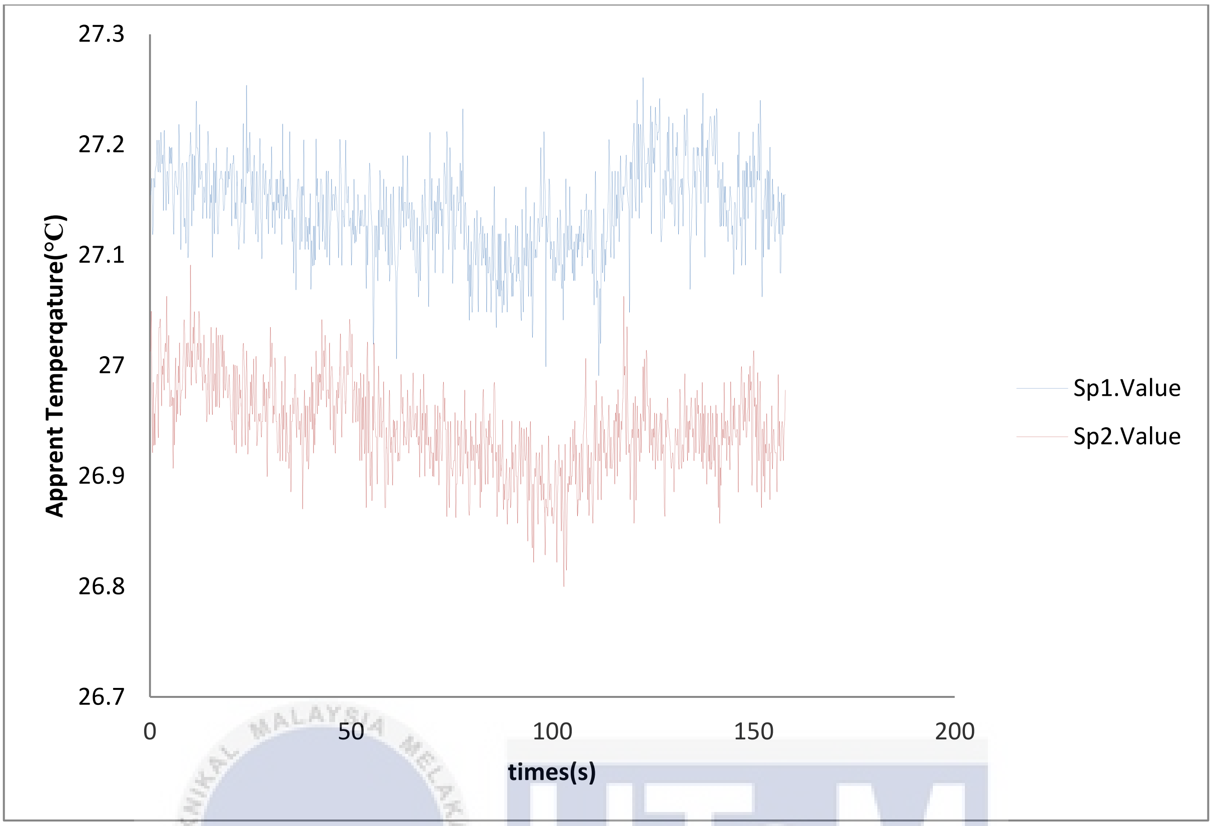
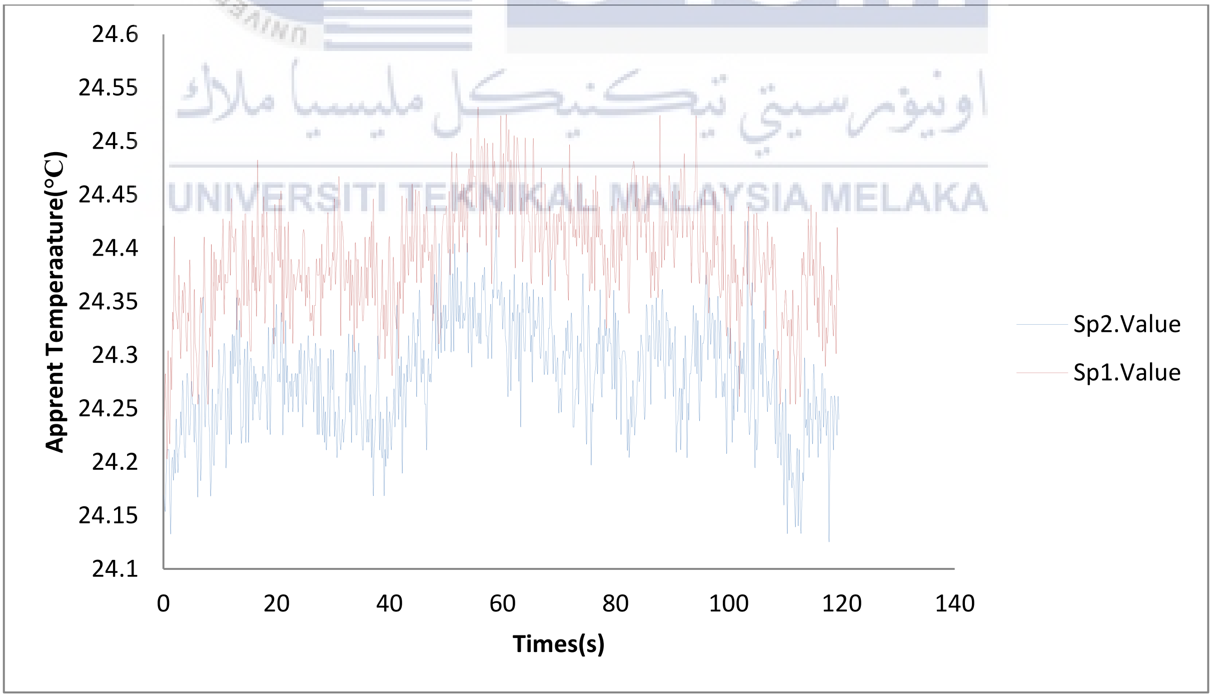


Figure 4.9: The graph temperature data for dry condition with core



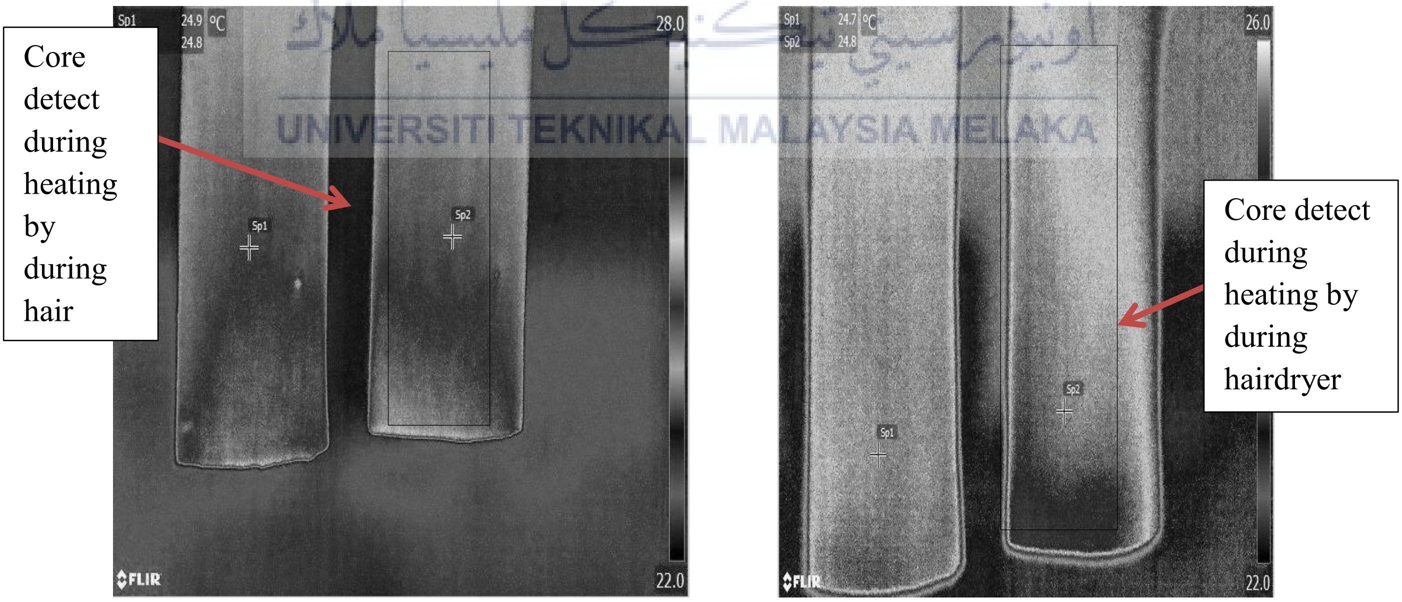
4.10: The graph temperature data for dry condition without core

4.4 Image processing of the temperature images

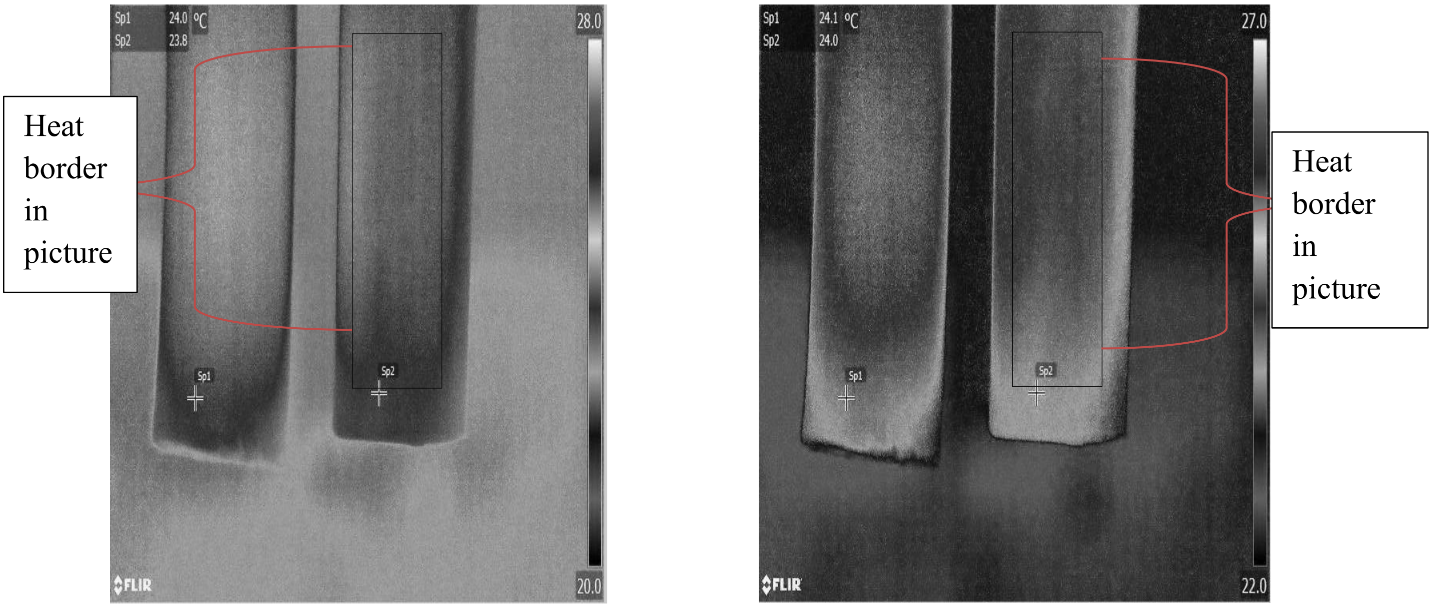
In this process, image processing is an important stage where will analyse and digitized in order to get a desired image. There are many ways or lots of images processing technique that can be used for this section. For the experiment colour thresholding, average image and separate colour compression is used to analyse image. Generally, feature extraction is the process of creating features to be used in the classification. Classification process is the process to make decisions based on test and analysis done on the image.

4.4.1 Image Thresholding

Referring the image below on Figure 4.11 and 4.12, the entire image on both figured is the filtered image that undergoes the RGB grey process. Then, by using the threshold value has been set; the coolest region of the image is detected (in the middle of the wood) as show in Figured 4.11 and Figured 4.12. For the Figured 4.11, the comparison was between mix and unmixed with high density wood. Based on the pictured, the coolest region can be detected based on the different of theme colour. Then the image undergoes the binarization process to be easy in the analysis.



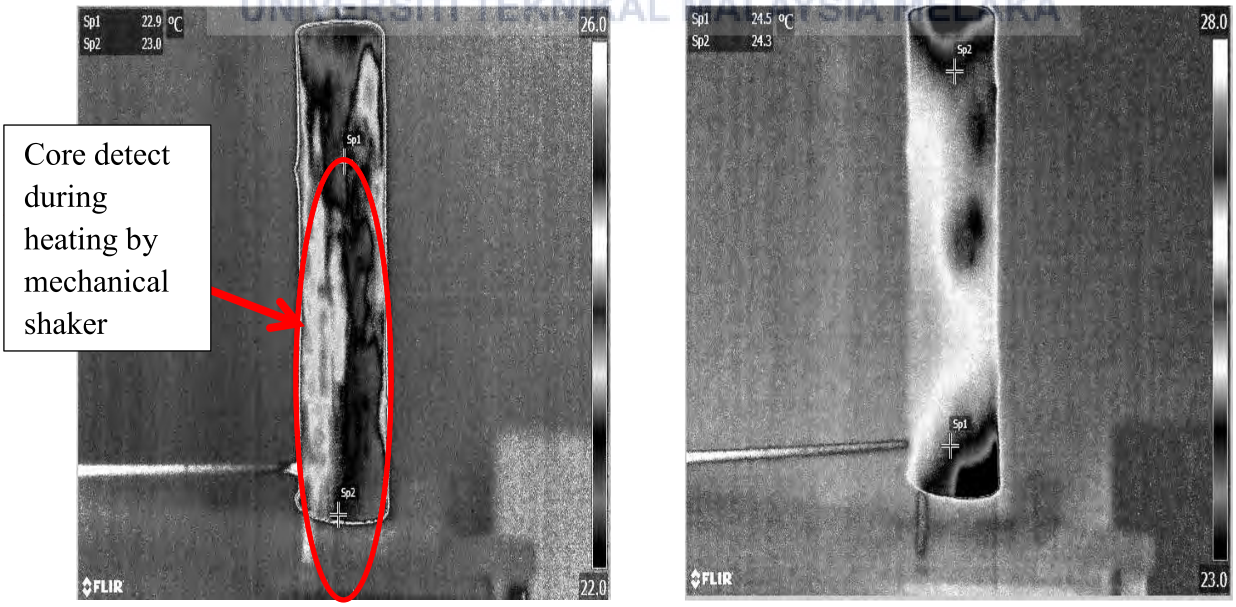
(a) (b)



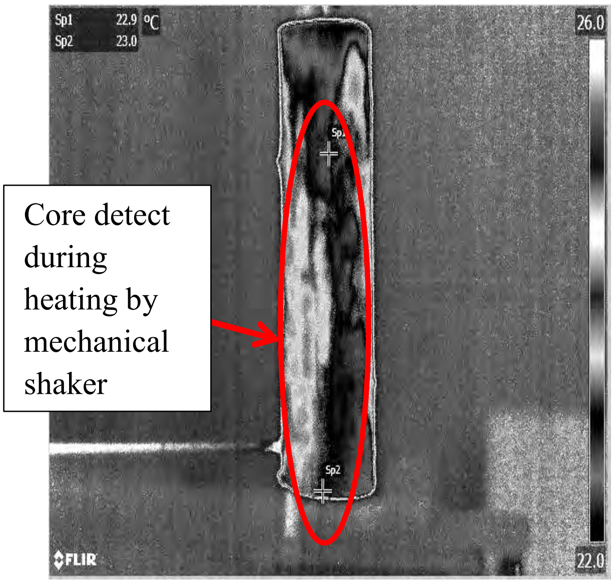
(c) (d)

Figure 4.11: (a) The image after thresholding for hair dryer method front wood cooling, (b) front wood heating, (c) beside wood cooling, (d) beside wood heating

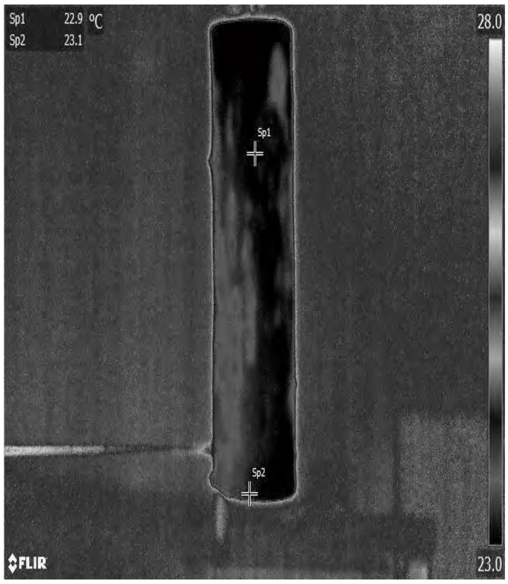
In Figure 4.12 was show the image after thresholding and change in gray colour, in this process, image has remove the noise and blurred image, the heat border are clearly can be seen on a figure due to heat and cooling process.



(a) (b)



(c)



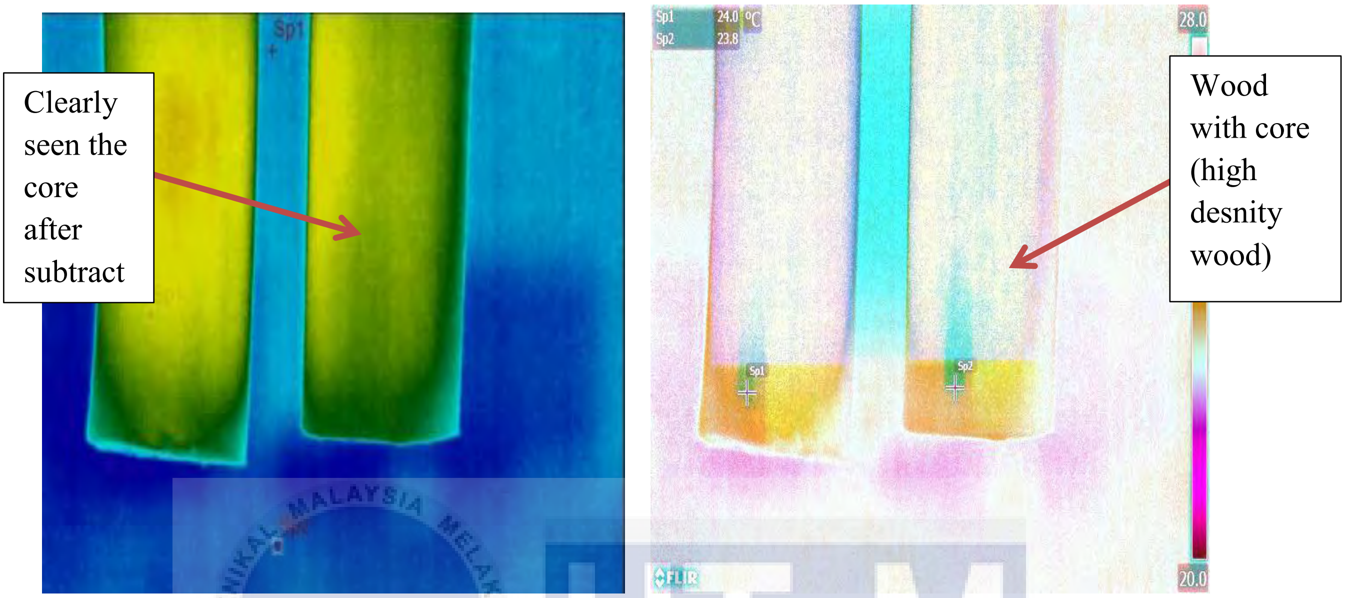
(d)

Figure 4.12: (a) The image after thresholding for vibrotermography method dry wood with core, (b) dry wood without core, (c) wet wood with core, (d) wet wood without core.

In Figure 4.12, the red circle shows the defect on the wood, and that the core has been detect by camera and after threshold the image became clearer. The grey image only shows the black and white colour, but from the circle, that has shown the border of coolest region that has been captured.

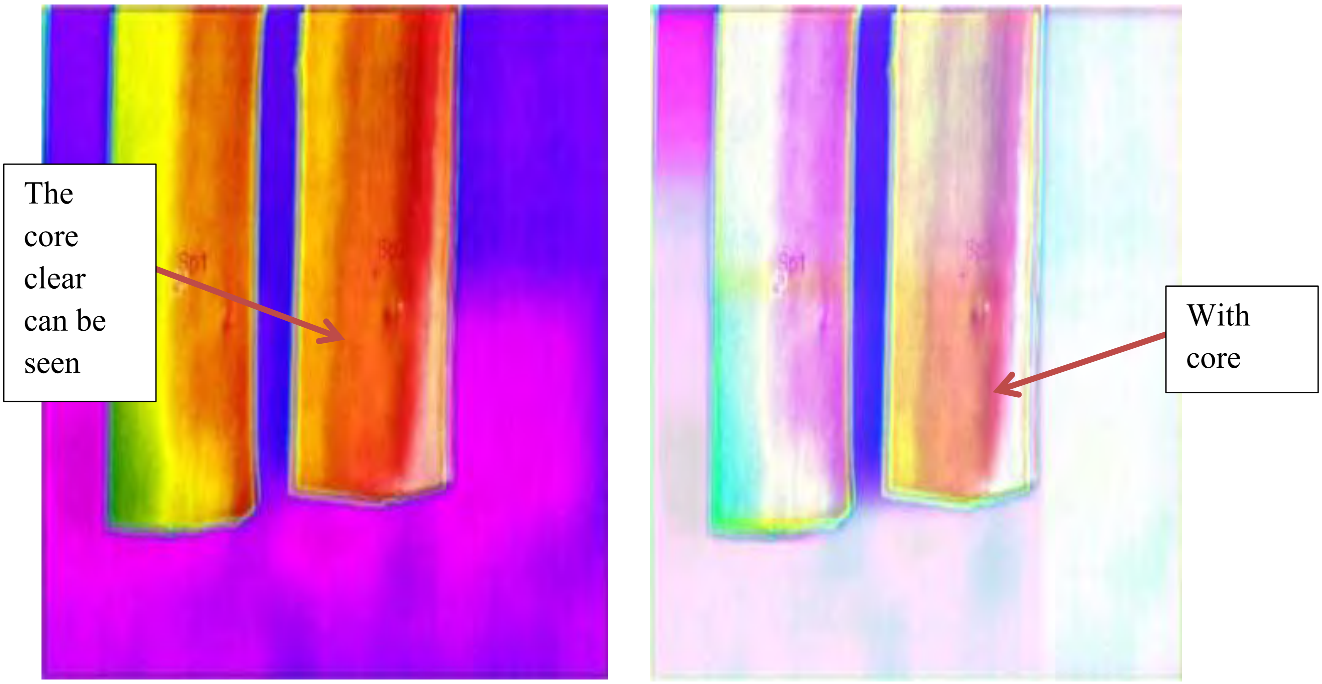
4.4.2 Image average and separate colour

After image tresholding, the visual image was inserting to image j software to subtract the noise and separate the original colour. This analysis was to clear the image and get a clear image for defect on the wood. From the image below, show the image during heating and cooling for hair dryer heat source. Figure 4.13a, show the besides cooling image after average two image, the heat boarder are clearly can be seen after image average. For Figure 4.13b, the image shows result after extract the colour and the core are clearly can be seen. For the Figure 4.14, the image temperature had the average image and separates the colour for heating beside of the wood. After average the image, the core is easy to detect based on the visual different. After separate the original colour, the core is clearly seen based on toner colour. The heat boarder clearly can be seen after separate the colour and average the image.



(a) (b)

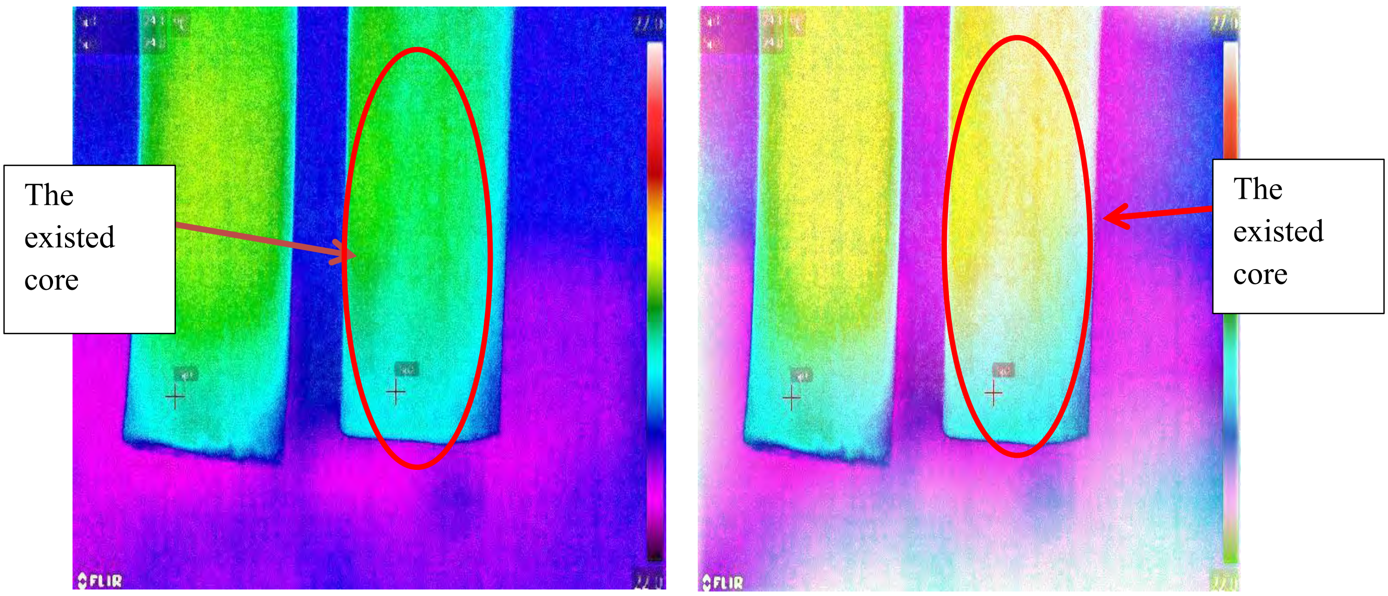
Figure 4.13: Image result for besides cooling after average and separate colour, (a) after average an image result for cooling condition (b) after separate the colour for cooling condition



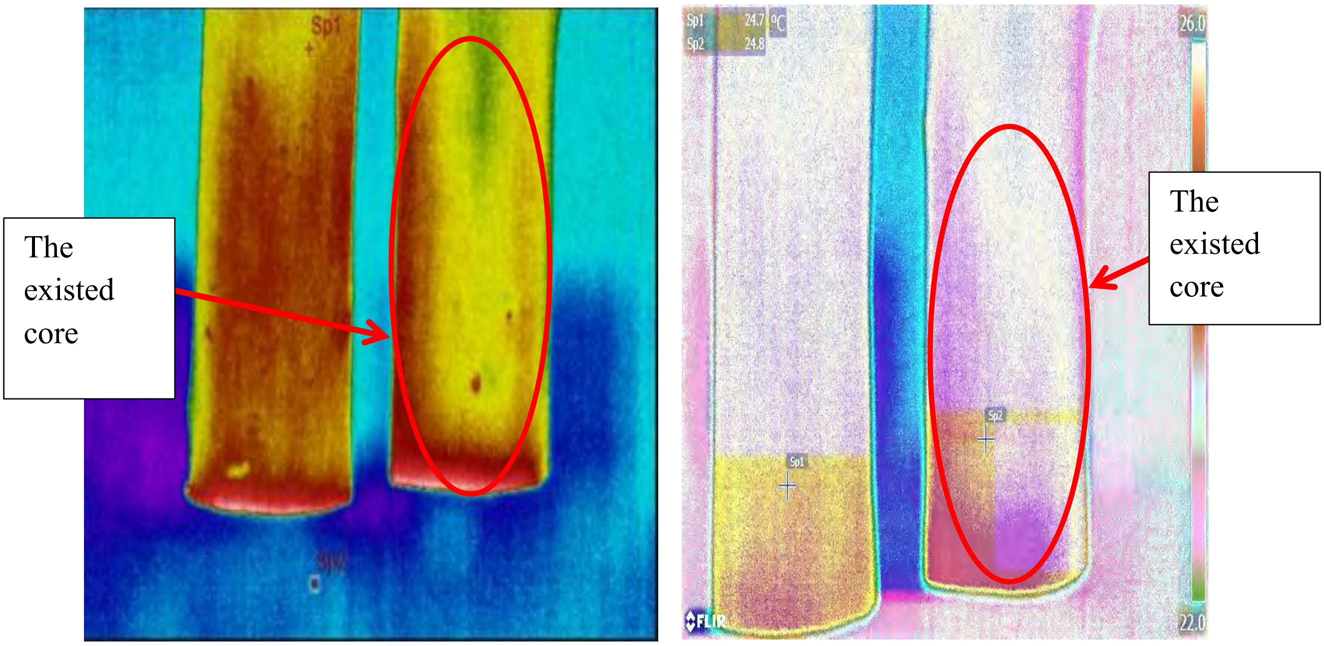
(a) (b)

Figure 4.14: (a) Image result for heating beside for hair dryer, image after average, (b) the image result after separate the original colour

The result of heating and cooling for hair dryer heat source in front position has shown on Figure 4.15. The image result shows after the image had average process the core can be seen and easy to compare the specimen with and without core.



(a) (b)



(c) (d)

Figure 4.15: The figure of the image result after enchantment, (a) Image front heating after subtract noise, (b) image front heating after separate colour, (c) Image front cooling after subtract noise, (d) Image front heating after separate colour

From the Figure 4.16 below show the image after average and separate the colour for vibrothermography experiment. The vibrotherography has two conditions wet and dry, and with two specimens with core and without core. Both of the specimen is one with core and one without core and both condition is wet and drying wood are be used for the comparison. The purpose comparison based on condition is to observe which condition is more suitable for detection for foreign material in agarwood.

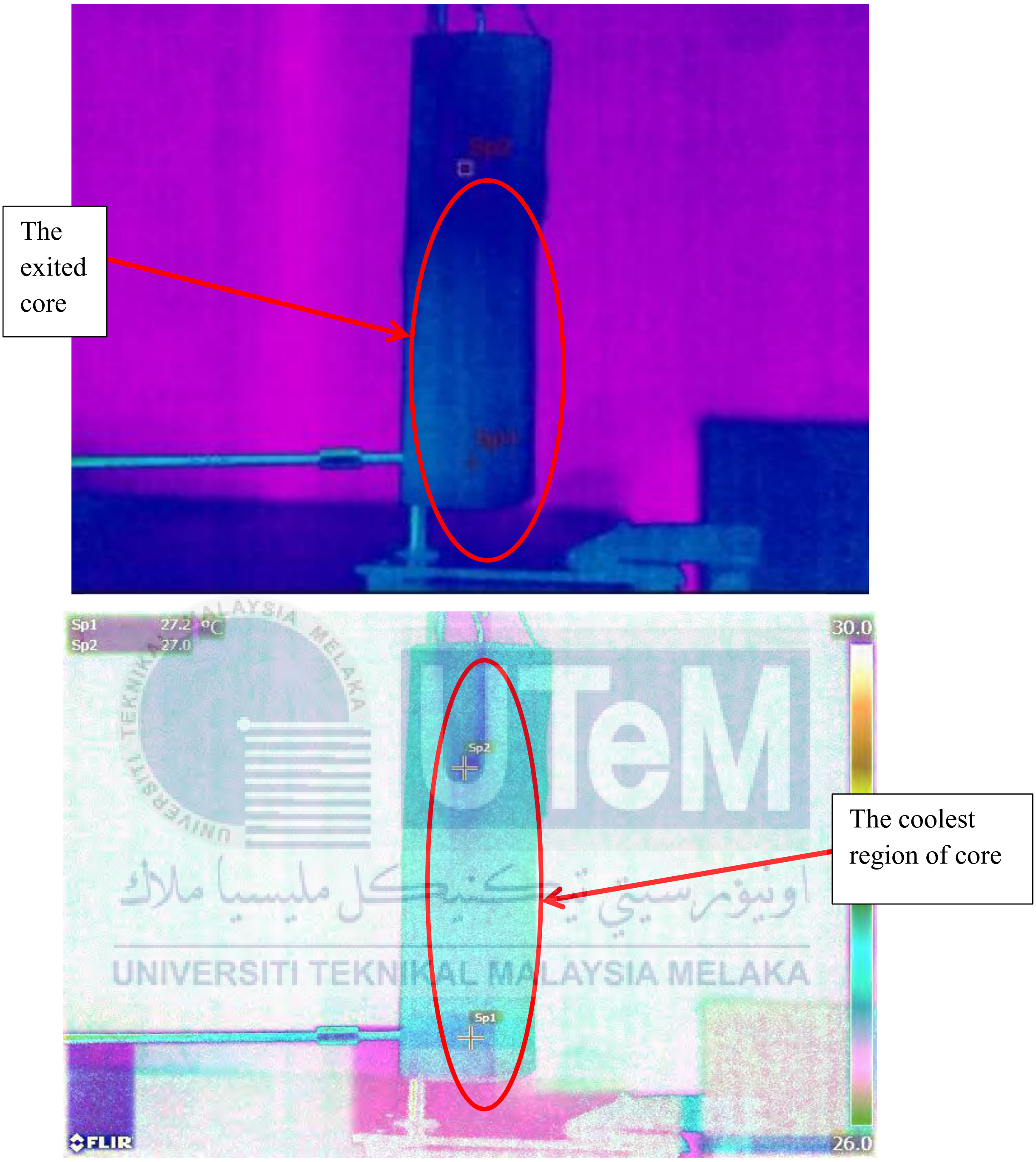


Figure 4.16: Image result of vibrothermography method wet condition with core

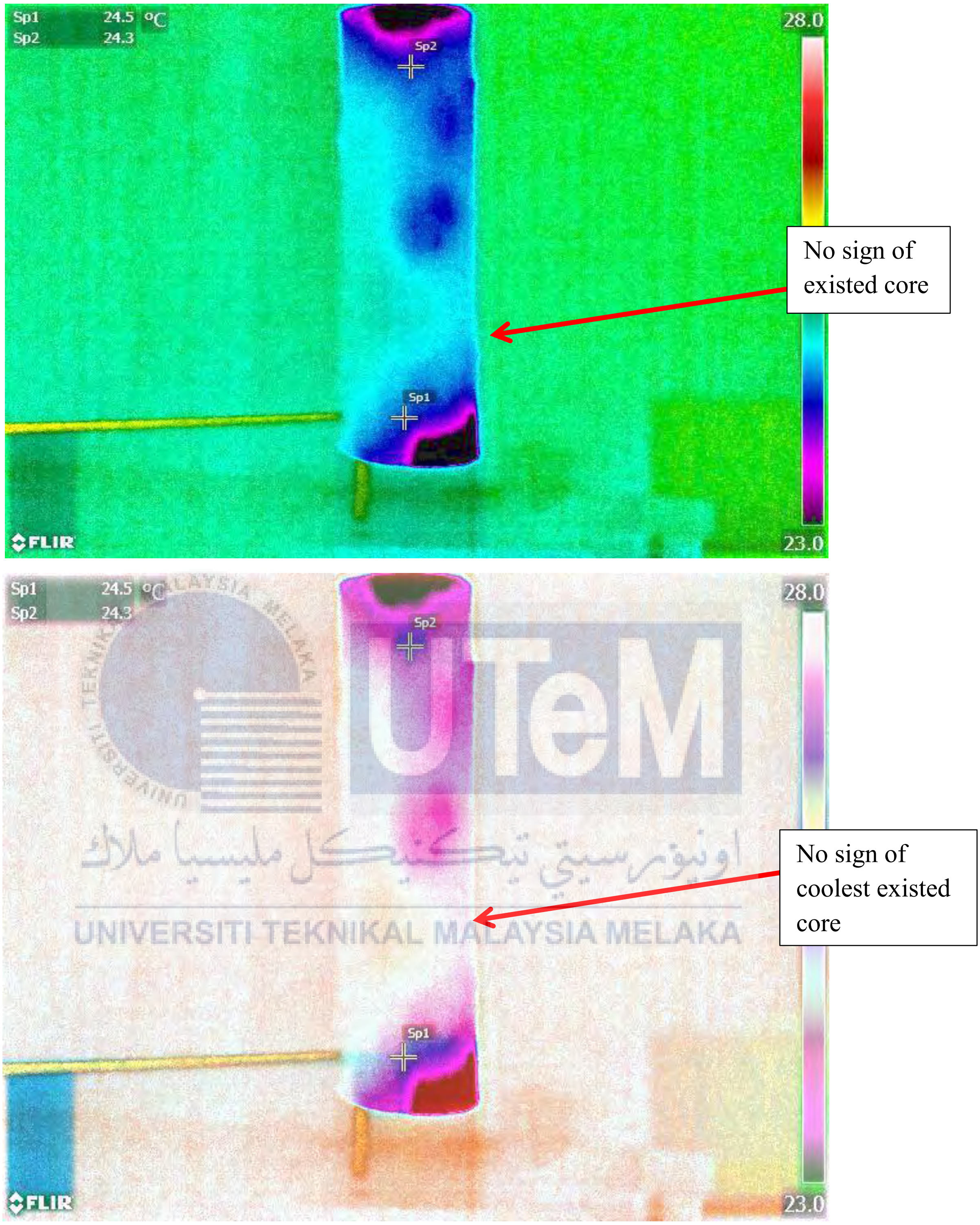


Figure 4.17: The image result of vibrothermography dry condition without core

The result of the image after average and separate the original colour, from the observation on Figure 4.17, there are no sign of existed of foreign material during detection and prove that the specimen that has been tested has no density wood inside

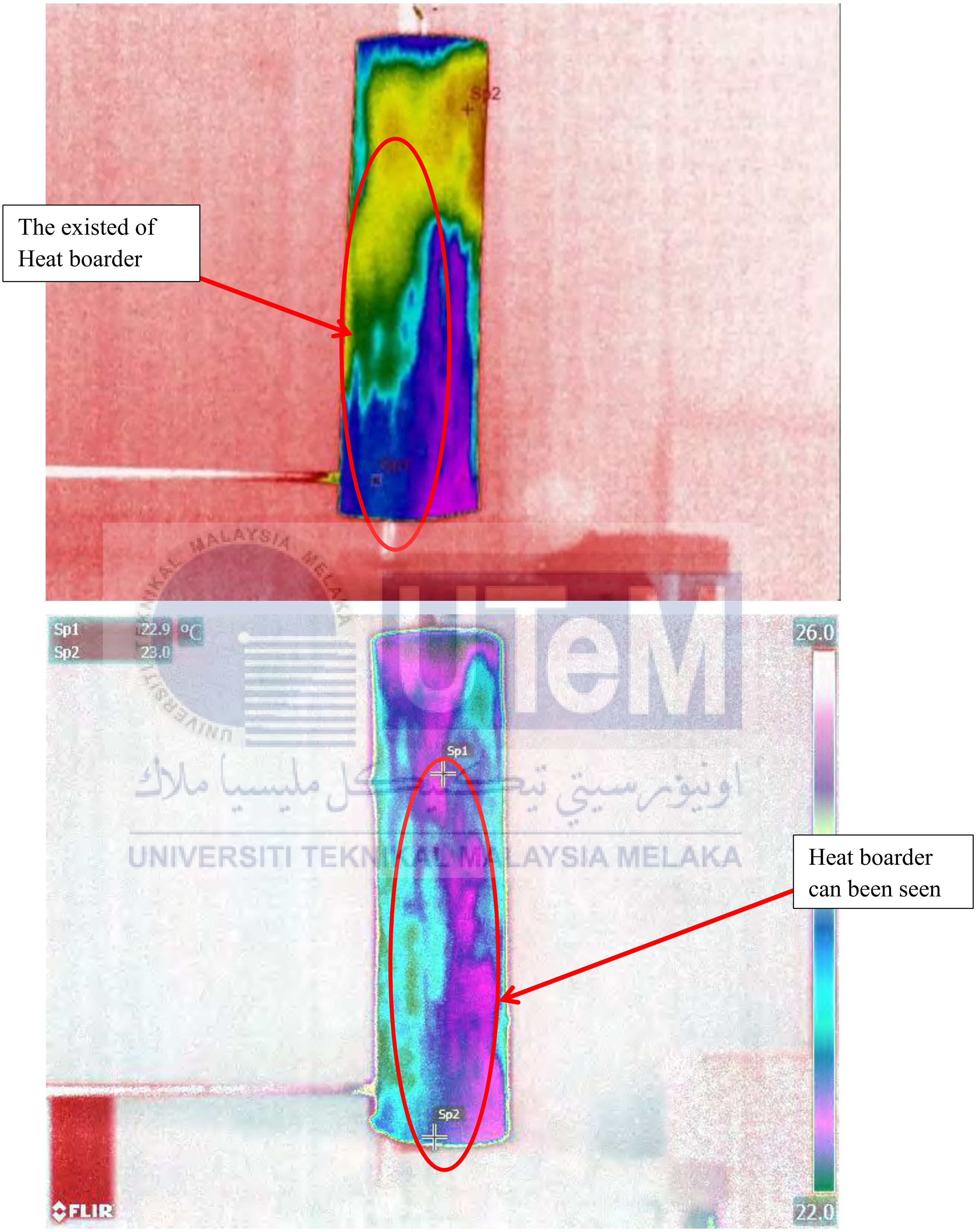


Figure 4.18: The image result for vibrothermography wet condition with core wood

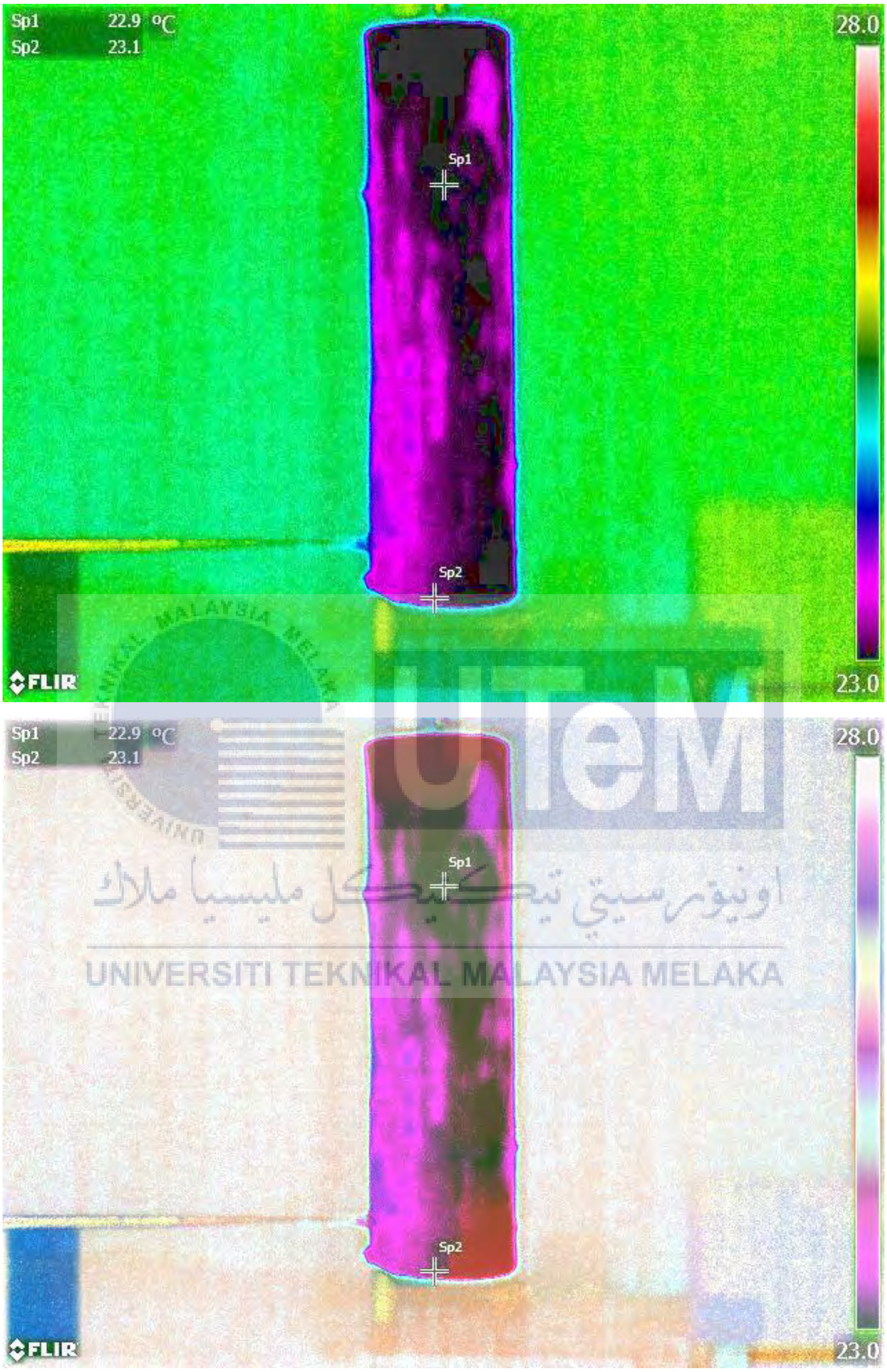


Figure 4.19: The image result for vibrothermography wet condition without core wood

From the result Figure 4.18 and Figure 4.19 show the result for wet condition for vibrothermography. From the image processing, the existed of core are more detail can be seen of heat boarder. From the comparison image for Figure 4.18 and Figure 4.19, the sign of heat boarder can be seen on figure 4.18, for the Figure 4.19, there are no sign of existed heat boarder for core.

4.5 Foreign material detection

From the analysis of graphs and image enchantment, the result of the experiment show the core of the wood or high density of the wood can be detect by using the thermal imaging camera, but the sight of existed of the high density wood is not very clear and need for analysing the image based on the image result and data temperature.

From the analysis of graph has shown when the wood with high density wood at the core, had a lowest temperature then left right side of the wood. On figure 4.6a, sp1 value and sp2 value have average 0.2°C for the different between the spot at the core and without core. The sp2 spot was located at the surface of core wood had sp1 locate at upper wood without core without high density wood. With same average of heat, sp2 location had a lower temperature than sp1. The wood with core or high density wood had a good conductor where absorb the heat and release faster to the upper side. Same goes on the graph Figure 4.6(b) show the wood specimen with core wood same location sp1 and sp2 but at different condition where in cooling mode. The area with core wood had a cooled region than the outer.

For vibrothermography experiment, two different specimen woods one with core and one without core have been used for comparison on temperature data. Based on Figure 4.7 and 4.9 the wood with core had 0.2°C temperature different when sp1 and sp2 at different location, sp1 and sp2 were located. For the Figure 4.8 and Figure 4.10 show the tabulated data temperature for wood specimen without core. The temperature different below 0.1°C at two location. The proved of existed of the foreign material is when the wood had high density wood inside had a higher different temperature than wood specimen without core. During image capture, the wood with core had high temperature than outer wood. The outer wood absorbs the heat from the friction and separated to whole body and high density wood is absorbed and keeps at the core before release to the upper.

The core regions which have a thinner wall due to based wood make the camera easy to detect the heat boarder during absorbed the heat waves from hair dryer and mechanical shaker. The non-uniform thermal wave propagation of heat can be considered of the surface defect of the wood. From the experiment that has been done, from the observation has proven that energy transfer by radiation is faster that the energy convection and conduction furthermore, radiation is not require any contact to transmit energy to another body (C. Ibarra-Castanedo et al, 2014). The heat energy waves that propagation to the wood had a faster absorb to the wood during heating, the outer specimen easily overheats when hair dryer not rotate left and right. The rotation of hair dryer was done for to give an average heat to a surface of specimen. From the rotation, the heat border of core is easily can be observe during rotation.

Thermal imaging has a potential to evaluate the heating pattern in several of heating method. For instance, it is possible to use for real life agarwood tree. Hair dryer can be a heat source for using thermal imaging to detect any foreign material in agarwood, but in condition had a different temperature of surrounding. In thermography, there are many option of energy source that can be used to induced for different thermal contrast between a different defective and non-defective part in external (Giorleo G, 2002) if the energy was get direct hit to a surface and then it propagated through the material core.

Thermal camera and FLIR software were used to map the surface temperature and structure distribution of the agarwood, respectively, in condition wet and drying. Wood specimen structure had core within high density that used in experiment. Before heating process, the initial heat is 24°C for dry specimen and after heating the average temperature increase due to heat waves absorbs.

For vibrothermography, the both condition wet and dry was measured the initial temperature. Normal heat was increase 0.2°C to 0.3°C after vibrate two hours. The heat source for vibrothermography was produce from a friction, when mechanical vibration is induced externally at the specimen with direct hit from mechanical to thermal energy so the heat was occur, such as use the shaker or air vibrator can produce heat on the internal structure The result also same for the wet condition. All the condition may be possible to detect with the help of measured temperature using thermal imaging camera. The image result, video result and heat temperature data has proven the existed of foreign material in specimen and can be used for the real life for detect defect in the agarwood.

From the image analysis, the image was thresholding, average ad sepated the original colour for adjust the image to get clearer without blurring. The image analysis shows, the wood had a foreign material, at the area of defect had a low toner grey colour compare the wood without core. The comparison based on the image result before and after analyse. For the image analysis by using Image J was proved the existed the foreign material in the wood by analysing the image using an average image. The image form different timing was using to analysing and after average them clearly can see the foreign material. Abnormal wood show the core during heating and normal wood shows an average temperature and visualization during heating and cooling process. Abnormal wood show the heat boarder due heat waves propagation, but for normal wood the heat are freely move without any boarder or restriction in the wood. The image after thersholding, separate colour and average give a good proven of existed of foreign material in the wood.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

This chapter represent the conclusion of the foreign material detection in agarwood using thermal imaging technique. Conclusion is made based on the objective that achieve in the investigation.

5.1 Summary

This study is focus on detection of foreign material in agarwood by using thermal imaging technique. This investigation based on the thermal imaging process and material detection in agarwood. In thermal imaging process or thermography was focus on vibrothermography where internal detection of the specimen. For detect the foreign material in agarwood, Vibrothermography is suitable to detect. In this investigation, the percentage of resin in agarwood is unknown material, by using a thermography, the process to determine the resin became easier. Agarwood have a different density of wood when it forms in wood. The structure of formation agarwood is more complex and the density also different.

5.2 Conclusion

Optical and vibrothermography infrared thermography is conducted on the wood specimen with the core and without core. The increase of the temperature due to heat radiation and conduction from the vibration shaker and hair dryer has succeeded in visualizing the high density wood or core in the wood specimen. The existed of the foreign material in the wood can be detected by using thermal imaging camera due to radiation and conduction contact of heat. The existed of foreign material can be seen by comparing the wood with high density wood or core and without core. The heat range using hair dryer must be controlled to avoid overheated and recognize the core became difficult. The image that has been done shows thermal imaging is compatible to detect the foreign material in the wood. The result also indicates a feasibility of image processing for thermal image enhancements in infrared thermography over wood structure. The video and image temperature show the core as what has been expected. That mean the thermal image camera can be used for detect not only for metal surface or leakage also can used for detect foreign material in agarwood. The objective of experiment is achieve where to detect the foreign material in agarwood by using thermal imaging technique, this technique can be used to detect the foreign material in structure of wood. to give an heat source for wood it had a two way external heat source and internal heat source, for natural source sun can be radiation heat source for the thermal imaging inspection. From the experiment, thermal imaging is suitable to use for wood structure but depend on the temperature gain.

5.3 Recommendations

The thermal imaging method has a potential to be used in many was for example for plantation operation of agriculture. However, the opportunities of thermal imaging are still not very famous and need more time to use in agriculture. Intensive research and real time experiment should be conducted for real time applications to increase the productivity and ultimately net profit for a farmer. By using real specimen may help to get good real result and data temperature. Thermal imaging need to be study in detail for future research and the outcome of this kind of research would yield valuable data required for the site specific management and precision farming. With the good technology of thermal imaging it may not be possible to develop universal methodologies for detect the foreign material in agarwood.

REFERENCES

Noratikah Mad yussof (2015), Agarwood Essential Oil: Study On Optimum Parameter And Chemical Compounds Of Hydrodistillation Extraction.,*journal of applied science and agriculture*,10(5):1-5,2015.ISSN 1816-9112

Nor Azah ,S SaidatulHusni, J Mailina, L Sahrim, J Abdul Majid& Z MohdFaridz,.(2013), Classification of Agarwood (Gaharu) by resin content.,*Journal of Tropical Forest Sciene* 25(2): 213 – 219.

Tawan C.S. 2004. Thymelaeaceae. Tree Flora of Sabah & Sarawak. Volume 5. Goverment of Malaysia. Pp. 433-484

Selina Akter*1, Md. Tanvir Islam, Mohd Zulkefeli, Sirajul Islam Khan (2013)., Agarwood Production: A Multidisiplinary Field To Be Explored In.,*international journal of pharmaceutical and life science*.,volume 2 issue 1.,ISSN 2305-0330

Veronica Alexander jok, Nurhaslina Che radzi , Ku Halim Ku Hamid,.(2015), Agarwood Oil Yield As A Reslut of Changes in Morphology Due To Soaking Proces. Social and Behaviour Science 195(2015)2443-2450

Nor Atikah Mat Yussof, Saiful Nizam Tajuddin, Anwarruddin Hisyam, Nor Adila Mohd mar.(2015), Agarwood Essential oil: Study on Optimum Parameter and Chemical Compound of hydrodistillation extraction., *Journal Of Applied Science and Agricultured*., 10(5) : 1-5, Azah, N.M.A., Y.S Chang, J. Malina, A.A.Said, A.J. Majid, S.S Husni, S.H.hasnida N, Y. Yasmin,.(2008)., Comparison of Chemical Profile of Selected Gaharu Oils from Peninsular Malaysia,. *The Malaysia Journal of Analysis Science*, 12(2); 338-340

Tamuli P., Boruah P., Nath S.C. and Leclercq P. (2005). Essential oil of eaglewood tree: a product of pathogenesis. *Journal of Essential Oil Research* 17:601-604

Azma A, Nik Kamariah NI , Tuty Asmawaty AK, Jasni MD, Nor Amizan J & Noorlin MA,(2007)., Agarwood determination system using image Processing technique., *Proceeding of the International Conference an Electrical Engineering and Information*., Pp 427-429.

Sahrim A,. Nor Azah M. A , Mailaina J., Abdul M,. Mohd F. O,. (2016)., Discrimination of Pure and Mixture Agarwood Oils via Electronic Nose coupled with k-NN kfold classifier., *Procedia Chemistry* 20., 63-68.

Gunawan P., Totok K. W ., Gustan p. (2013)., Analysis of Chemical Composition Distinguisher for Agarwood Qualities., *Indonesia Journal of Forestry Research*., Vol 2., No 1..1-7..

Cengal, Y.A & Boles, M.A., 2008, Thermodynamic :An Engineering Approach, 6th Ed.,McGraw Hill,Singapore.

C. Ibarra-Castanedo1, Marc G, Jean-Marc P., Stéphane G., Abdelhakim B. and Xavier P. V. M.,(2014)., Active Infrared Thermography Techniques for The Nondestructive Testing of Materials.,Chapter X., 1-25

Giorleo G. and Meola C.(2002).,Comparison between pulsed and modulated thermography inglass-epoxy laminates, *NDT&E International*,vol 35:.,pp 287–292.

Jurgen Bar.,(2016),. dtermination of dissiated energy in fatigue Crack Propagation Experiment with Lock-In Thermography and heat flow Measurement., *Procedia Structural intergrity* 2,. 2105-2112

Busse G., Wu D. and Karpen W.(1992).,Thermal Wave Imaging with Phase Sensitive Modulated Thermography.,*Journal Applicaton Physics.,*71(8):3962-3965.

Otwin Breitensteina, Felix F.,, Jan B, Florian S, Bernhard M., (2016)., Local solar cell efficiency analysis performed by injectiondependentPL imaging (ELBA) and voltage-dependent lock in thermography (Local I-V)., Energy Procedia 92 (2016) 10 – 15.

A Mendioroz, E Api˜naniz, A Salazar, P Venegas and I S´aez-Oc´ariz., (2009)., Quantitative study of buried heat sources by lock-in vibrothermography: an approach to crack characterization., *Journal Of Physics and Applied Physics*.,vol 42.,pp 1-8.

Petra Honnerová.,Zdeněk .,Veselý.,Milan Honner (2016)., Experimental mathematical model as a generalization of sensitivity analysis of high temperature spectral emissivity measurement method., *Journal Measurement*., Vol 90., pp 475–48

Lovre .K.O, Branko .K, Pedro .N, Zeljko D.,(2011)., Thermal Imaging And Thermoelastic Stress Analysiaof Impact Damage Of Composite Material.,Engineering Failure Analysis., vol 18,.pp 713-719.

J. Cotter, G Woodworth, S.V.Gupta, P.manandhar , T. H. Schwartz,.(2015), Infrared thermal imaging during ultrasonic aspiration of bone.,*Physics Procedia* ., vol 63.,pp 167-176

Laura C. G, Eugenio H (2016)., Data on thermal infrared imaging in laboratory non-human primates: pleasant touch determines an increase in nasal skin temperature without affecting that of the eye lachrymal sites., *Data in Brief*.. vol 9,. pp-536-539