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PAAT

Journal homepage: http://penerbit.uthm.edu.my/ojs/index.php/paat
e-ISSN: 2821-292

Progress in Aerospace and Aviation Technology

Measurement of CO, CO_2, Particulate Matter (PM_{10}), Cockpit and Ambient Temperature, Humidity and Noise Level at UTHM Hangar

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DOI: https://doi.org/10.30880/paat.2022.02.02.006
Received 28 August 2022; Accepted 27 December 2022; Available online 31 December 2022

Abstract: This study is focussed on works that are done at the hangar and its effect on human health. The absence of proper air quality or noise level study at the current UTHM hangar has inspired to conduct this study. The objective of this study is to measure the emission rate of carbon monoxide (CO), carbon dioxide (CO_2), particulate matter (PM_{10}), and measure the cockpit temperature, ambient temperature, humidity, and noise level of PT6A-20 engine to obtain the data at the Universiti Tun Hussein Onn Malaysia (UTHM) Hangar. There are presence of 2 engines which are Lycoming O-360 and turboprop PT6A-20 at the hangar. Lycoming O-360 uses avgas and turboprop PT6A-20 uses jetA1 fuel type which will produce higher rate of emission and that is the reason of PT6A-20 engine being chosen. So this study aims to highlight a comprehensive data of CO, CO_2, particulate matter (PM_{10}), cockpit and ambient temperature, humidity and noise level regarding the turboprop PT6A-20 engine at hangar of UTHM to aid future researchers and ensure the air quality and safety rules of the hangar. The air quality standards are used as guideline are the Malaysia Ambient Air Quality Standard and Indoor Air Quality Standard based on the Department of Occupational Safety and Health (DOSH). Also, Occupational Safety and Health (Noise Exposure) Regulations 2019 is used as the standard for noise level. Q-Trak Plus IAQ Monitor model 8554 is used to measure the emission rate of CO,CO_2, level of humidity and cockpit temperature. Dust Trak Aerosol Monitor is used to measure the emission rate of PM_{10}, Pico Data Logger is used to measure the ambient temperature and finally 1352H integrating sound level meter was used to measure the noise level of PT6A-20 engine. Based on the results produced, only carbon monoxide and carbon dioxide are below than the safety limit. The othe 5 parameters which are PM_{10}, cockpit and ambient temperature, humidity and noise level are above the allowable limit according to DOSH.

Keywords: Temperature, humidty, particulate matter(PM_{10}), noise level, turboprop PT6A-20 engine

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1. Introduction

Since the significant expansion in commercial turbojet traffic in the 1970s, there has been a surge in concern about the aircraft and airport air pollution emissions. Air contaminants such as nitrous oxide (NO_x), hydrocarbon, and fine particulate matter (PM), carbon monoxide, and carbon dioxide were produced by aeroplane emissions, which can lead to serious environmental problems such as, acid rain, and climate change, greenhouse effect as well as possible dangers to public, animal health and the environment. Aircraft, unlike most transportation streams, travel long distances at various altitudes, releasing pollutants that have the ability to affect cleanliness of air nearly everywhere which could concern our global ecosystems. Apart from that, aircraft engines do produce extreme level of noise. In recent years, there has been concern about the effects of airport and aircraft-related pollutants on ambient air quality, both inside and outside airport limits[1]. Because of the expected growth in demand for air travel, aviation and its impact on the environment is becoming a hot topic. As a result, CO_2 emissions from air travel were likely to rise dramatically. According to Ribeiro, CO_2 emissions predictions for commercial aviation in 2050 will range from two (best case scenario) to five (worst case scenario) times current levels[2]. Furthermore, according to the International Civil Aviation Organization (ICAO), air pollution around airports has become a serious concern for local and regional habitats, in addition to greenhouse gases. An aeroplane produces various contaminants throughout the landing and take-off (LTO) cycle, which have an impact on local air quality and human health[3].

On the other hand, Airports were not only among the worst polluters of ambient air in the United States, but they also have a wealth of data on everyday operations, including the length of time spent taxiing to and from the gate before and after take-off and landing for each aircraft. This enables a precise estimate of the total amount of daily runway congestion at airports [4]. Furthermore, even after accounting for usual scheduling patterns, everyday runway congestion at airports shows a significant amount of residual fluctuation. Network delays propagating from large airport hub delays thousands of miles distant cause much of the variation in runway congestion. So, airports offer a particularly appealing setting for estimating the current link between air pollution and health[5].

Particulate Matter (PM) was classified into size categories based on the aerodynamic diameter of the particles, with Ultrafine Particles (UFPs) measuring less than 100 nanometers. Several investigations have found that high concentrations of extremely tiny particles dominate or even characterize aircraft emissions. This was shown in a recent study conducted at Heathrow London in comparison to traffic backdrop [6]. When compared to larger particles of more than 35 nm recorded at nearby freeways, some report particles in the 5-40 nm range, while others claim particle diameters of 20 nm[7]. Small particles were emitted in huge quantities and tend to form complex agglomerates in the ambient air, which can be identified using bigger particle size modes[8].The type of fuel and combustion procedures have an impact on the nanostructure of carbon particles. The smallest particle sizes are related with low thrust settings. The aircraft particles are also classified as primarily organic carbon at low thrust and EC at higher thrust settings[9].As a result, the data revealed that hydrocarbons are emitted mostly during ground idle engine circumstances, but PM emissions were more emitted during greater power thrusts, such as take-off and landing[10].

Carbon monoxide is easily taken from the lungs into the bloodstream, where it forms a tight but slowly reversible carboxyhemoglobin (COHb) complex with haemoglobin (Hb). COHb in the blood reduces the capacity and strength of blood to carry oxygen, and lowering oxygen availability to body tissues and resulting in tissue hypoxia. Reduced oxygen supply due to increased COHb levels, which was compounded by reduced perfusion caused by hypoxic cardiac failure, may affect cellular oxidative metabolism. Because hypoxia and reduced blood flow allow CO to bind to cytochrome oxidase, which limits aerobic adenosine triphosphate production, which can cause health complications [11].CO's health effects vary depending on the concentration and time range of exposure. At low doses, consequences range from mild cardiovascular and neurobehavioral effects to unconsciousness and death following protracted exposures or abrupt exposures to high CO concentrations[12].

Numerous noise sources, both on the ground and in the air, define the aviation environment. Since the Wright Brothers' first powered aircraft were introduced, exposure of pilots to noise has been a hazard and has been increasingly common. Power plants, transmission systems, jet exhausts, propellers, rotors, hydraulic and electrical actuators, cabin pressurisation and conditioning systems, cockpit advising and alarm systems, communications equipment everything do produce noise[13].

Fuel refinement was projected to progress in the future and become a significant contributor to emission reductions. In the required range of experiments needed to define occupational exposure limits, a newer synthetic jet fuel called as Fischer-Tropsch Synthetic Paraffinic Kerosene under development to replace JP-8 in the future was examined for toxicity which comes under Occupational Exposure Limit (OELs) [14]. The highest dose of 2000 mg/m^3 (6 hours per day, 5 days a week for 90 days) caused multifocal inflammatory cell infiltrations in rat lungs, but no Geno toxicity or acute inhalation effects were observed, and the sensory irritation assay revealed that the refined synthetic fuel was less irritating than JP-8 [10]. However, evidence of cancer risk is typically assessed in two-year inhalation trials in rats[10].

Most importantly workers at airport were exposed to the high level of noise and also to these gases by inhalation, absorption, and ingestion, resulting in occupational illness[1]. This can cause both short and long term problems to the people. So it is always important to know and understand what we deal with so that we can keep those emissions under control according to the safety limits and handle the exposure of high level noise. This will ensure a good health for people around us and save the environment for a better future.

2. Methodology

This study is carried out at the hangar located at Universiti Tun Hussein Onn Malaysia. This experiment has 3 main stages called Stage I, Stage II and Stage III as shown in Fig. 1. Each stage has different procedures and methods to be adhered. Fig. 2 shows before the commencement of experiment, engine inspection is carried out and free from all the foreign object debris (FOD). Additionally, all the measuring equipment was tested and set accordingly for the experiment. The engine that is included in this study is turboprop PT6A-20 as shown in Fig. 3. The turboprop PT6A-20 engine uses jetA1 fuel type. These engine emits various types of air pollutants which could cause health complications to the humans. Apart from that, it also causes environmental pollution such as sound pollution. In this experiment, the rate of emission of carbon monoxide, carbon monoxide, $PM_{10,}$ together with the humidity and temperature of surrounding and the exhaust gas and finally the noise produced by the engine are determined. A Q-Trak Plus IAQ model 8554 is used to measure the emission rate of carbon dioxide, carbon monoxide, humidity and temperature. Meanwhile, Dust Trak Aerosol Monitor is used to measure the $PM_{10,}$ Pico Data Logger TC-08 is used to measure the temperature of exhaust gas and 1353H integrating sound level meter is used to measure the noise level of the engine. All the devices are connected to the computer with the software data analysis respectively to get results of the experiment as shown in Fig. 3.

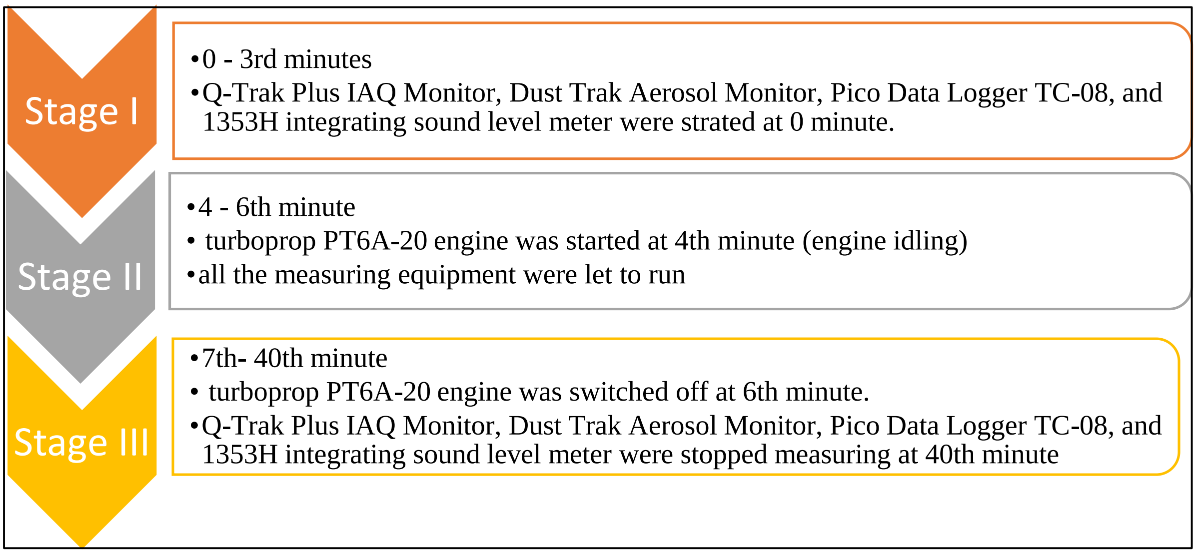


Fig. 1 - Main stages of the experiment

Fig. 2 - Engine inspection and fuel level checking

Fig. 3 - Turboprop PT6A-20 engine

After the Stage III completed, the readings of each equipment are measured using the respective data analysis software. The results are compared to the gudelines in Table 1, Table 2 and Table 3. Justifications were made by the comparison made with the guidelines.

2.1 Experiment Parameter Standards

There are a total of 7 main parameters which are carbon monoxide, carbon dioxide, particulate matter (PM_{10}), ambient temperature, cockpit temperature, humidty and noise level of PT6A-20 engine. So these parameters are referred to the several standards and guidelines. Carbon dioxide, carbon monoxide, humidity, ambient temperature, and cockpit temperature are referred to the Indoor Air Quality Standard according to the Department of Occupational Safety and Health as shown in Table 1. Particulate matter (PM_{10}) is reffered to Malaysian Ambient Air Quality Standard as shown in Table 2. Finally, the noise level was referred to Occupational Safety and Health (Noise Exposure) Regulations 2019 as shown in Table 3.

Table 1 - Indoor air quality standard[15]

Indoor Air Quality Standard according to Department of Occupational Safety and Health	
Parameter	**Acceptable range**
Air temperature	23 - 26 °C
Humidity	40 - 70 %
Carbon monoxide	10 ppm
Carbon dioxide	1000 ppm

Table 2 - Malaysian ambient air quality standard[16]

Malaysia Ambient Air Quality Standard		
Parameter	**Averaging time**	**Standard**
Particulate matter (PM_{10})	1 year	40 μg/m^3
	24 hour	100 μg/m^3

Table 3 - Occupational safety and health (noise exposure) regulations 2019[17]

Noise Exposure Limit based on DOSH	
Employer must make sure that employees are were not exposed	• Daily noise exposure limit exceeding 85 dB or daily personal noise dose exceeding hundred percent. • The maximum sound pressure level exceeding 115 dB at any time. • The peak sound level exceeding 140 dB.

2.2 Experiment Equipment

There are several measuring equipment to identify the level of each air contaminant, temperature and also noise level. Each air measuring equipment is specifically used to measure different type of air contaminants. So equipment are selected based on the focus of this study. There are a total of 4 equipment for the 7 parameters decided in this study. Each model has different range of specification the selected equipment of this study are shown in Table 4.

Table 4 - Equipment and Specifications

Equipment	Specification for parameters
 **Q-Trak Plus IAQ Monitor model 8554**	1. Carbon monoxide • Range: 0 to 500ppm • Accuracy: ± 3% of reading 2. Carbon dioxide • Range: 0 to 5000ppm • Accuracy: ± 3% of reading + 50ppm 3. Humidity • Range: 5 to 95% RH • Accuracy: ±3% RH 4. Temperature • Range: 0 to 50 °C • Accuracy: 0.6 °C [18]
 **Dust Trak Aerosol Monitor model 8520**	1. Particulate matter • Range: 0.001 to 100 mg/m^3 • Accuracy: ± 0.001 mg/m^3 [19]
 **Pico Data Logger TC-08**	1. Temperature • Range: -270 to +1820 °C • Accuracy: 0.025 °C [20]
 **1353H integrating sound level meter**	1. Noise level • Range: 31.5 Hz - 8KHz • Accuracy: ± 1.5 dB [21]

3. Results

In this chapter, the obtained results from the experiment done at the hangar of Universiti Tun Hussein Onn Malaysia are analysed, elaborated, explained and shown clearly in the form of graphs. The measurement of carbon monoxide, carbon dioxide, particulate matter (PM_{10}), humidity, cockpit temperature, ambient temperature and finally the measurement of noise pollution produced by the turboprop PT6A-20 engine are carried out. The experiment is conducted for 5 days and the average results are taken into consideration.

3.1 Measurement of Carbon Monoxide

The amount of carbon monoxide produced from the emission of PT6A-20 engine is studied at the hangar where located in UTHM main campus. As we can see in Fig. 4, the trend line started to climb in the 4th minute and had the highest amount of emission at the 6th minute which is 7.06 ppm. It is the range of minute when the engine was on or idling condition where there engine was let to run without any motion. There is sudden surge in the graph when the engine is switched on because the emission from the engine has higher concentration of carbon monoxide. There is a minor fluctuation in the graph before the 10th minute and it could be due to the emission from the vehicles traveling near to the hangar. Then the trend line decreases until the 16th minute and maintains between 1 to 2 ppm until the end of experiment, where the engine is let to cool down. The acceptable limit for carbon monoxide based on the Department of Occupational Safety and Health is 10 ppm.

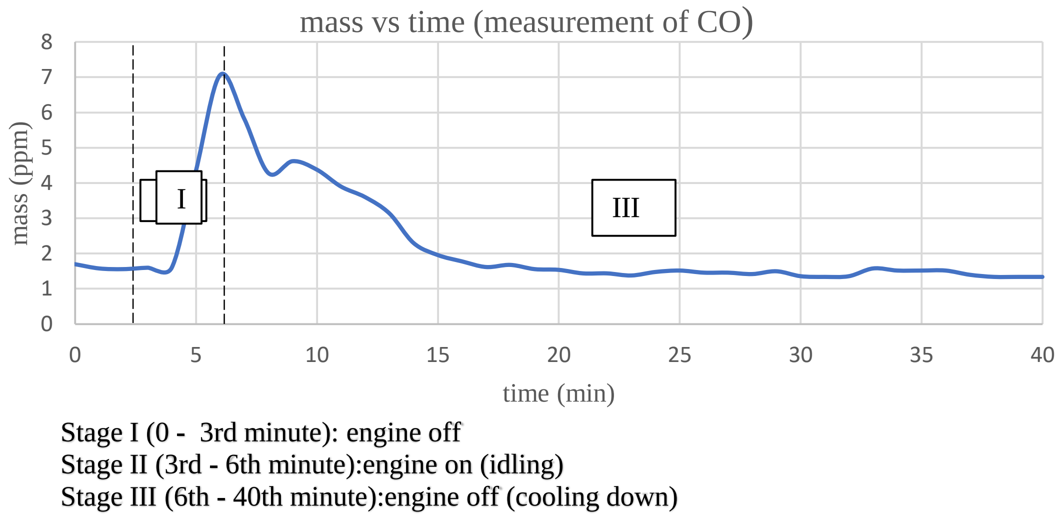


Fig. 4 - Graph of carbon monoxide against time

3.2 Measurement of Carbon Dioxide

The amount of carbon dioxide produced from the emission of PT6A-20 engine is studied at the hangar where located in UTHM main campus. As we can see in Fig. 5, the trend line started to climb in the graph is maintaining close to 700 ppm in the stage I. In the stage 2, the graph started to climb and reached the maximum point at the 5th minute which is 864.6 ppm, while the engine is in idling condition. There is sudden surge in the graph when the engine is switched on because the emission from the engine has higher concentration of carbon dioxide. Then the trend line decreases until the 15th minute and maintains in the range of 600 to 700 ppm until the end of experiment, where the engine cool down. The acceptable limit for carbon dioxide based on the Department of Occupational Safety and Health is 1000 ppm.

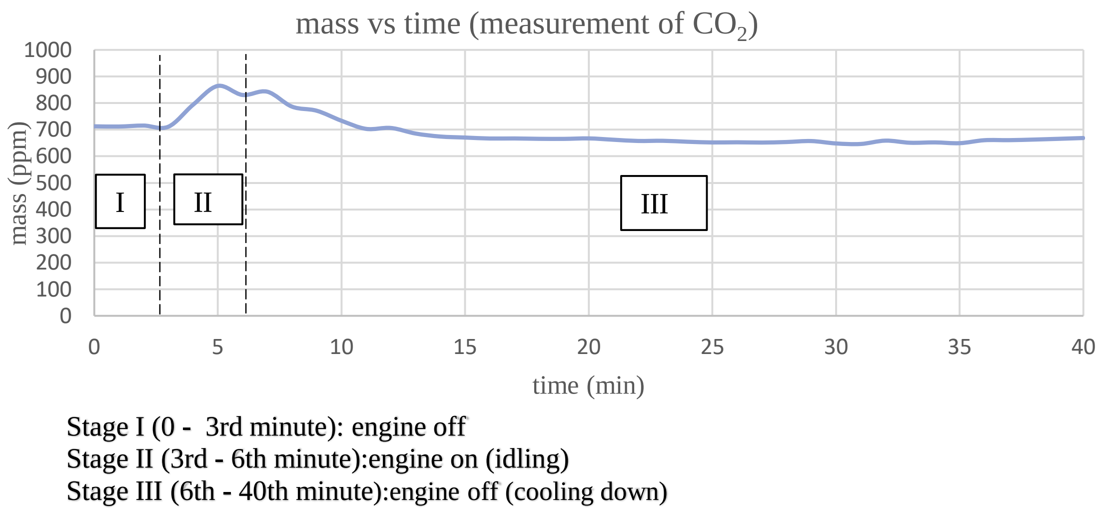
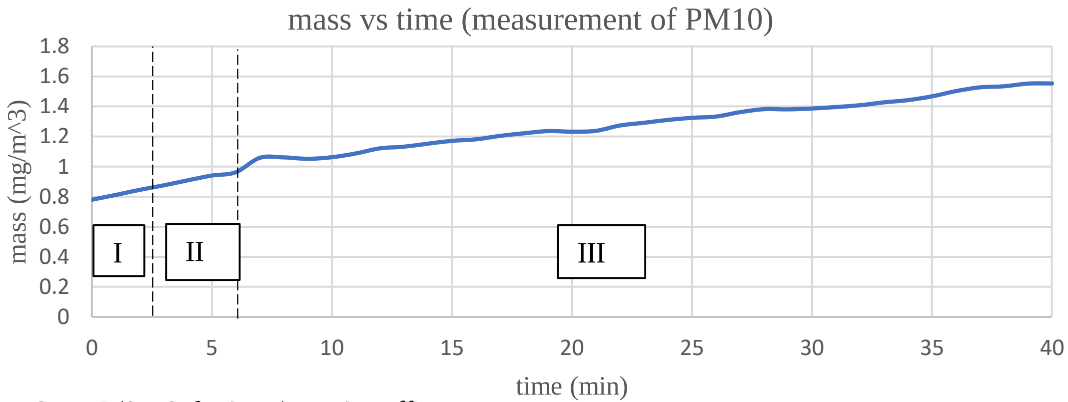


Fig. 5 - Graph of carbon dioxide against time

3.3 Measurement of Particulate Matter (PM_{10})

The amount of particulate matter, PM_{10} produced from the emission of PT6A-20 engine is studied at the hangar where located in UTHM main campus. As we can see in Fig. 6, the graph increases linearly from the starting until the end of the experiment. The graph reaches the maximum point of 1.5533 mg/m^3 which is equivalent to 1553.3 µg/m^3, at the 40th minute of the experiment, which is in stage III. The concentration of the particulate matter, PM_{10} increases even after the engine is let to cool down in the stage III, so this shows the PM_{10} that is produced when the engine is in idling condition affects the surrounding for a long period of time. The acceptable limit particulate matter, PM_{10} based on the Malaysian Ambient Air Quality Standard is 100 µg/m^3 for averaging time of 24 hours.

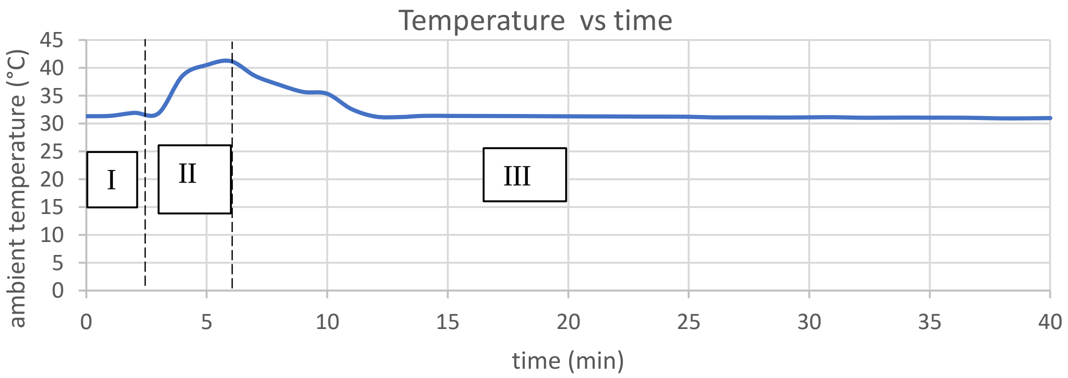


Stage I (0 - 3rd minute): engine off
Stage II (3rd - 6th minute):engine on (idling)
Stage III (6th - 40th minute):engine off (cooling down)

Fig. 6 - Graph of particulate matter (PM_{10}) against time

3.4 Measurement of Ambient Temperature

The effect on the ambient temperature due to the emission produced by the PT6A-20 engine is studied at the hangar where located in UTHM main campus. As we can see from Fig. 7, during the stage I where the engine is in off condition, the ambient temperature is maintained approximately at 31 °C. During the stage II where the engine is set in the idling condition, the ambient temperature rose and hit the maximum point of 41.2236 °C at the 6th minute. This shows that the emission released by the engine increased the surrounding temperature. In the stage III, the temperature started to drop and maintained at approximately 31 °C from the 14th minute of the experiment. The acceptable range of temperature according to the Department of Occupational Safety and Health is 23-26 °C.



Stage I (0 - 3rd minute): engine off
Stage II (3rd - 6th minute):engine on (idling)
Stage III (6th - 40th minute):engine off (cooling down)

Fig. 7 - Graph of ambient temperature against time

3.5 Measurement of Cockpit Temperature

The effect on the cockpit temperature due to the emission produced by the PT6A-20 engine is studied at the hangar where located in UTHM main campus. As we can see from Fig. 8, during the stage I where the engine is in off condition, the cockpit temperature is maintained approximately at 30 °C. During the stage II where the engine is set in the idling condition, the cockpit temperature rose and hit the maximum point of 34.38 °C at the 6th minute. This shows that the emission released by the engine increased the cockpit temperature. In the stage III, the temperature started to drop and maintained in the range of 30-32 °C from the 9th minute of the experiment. The acceptable range of temperature according to the Department of Occupational Safety and Health is 23-26 °C.

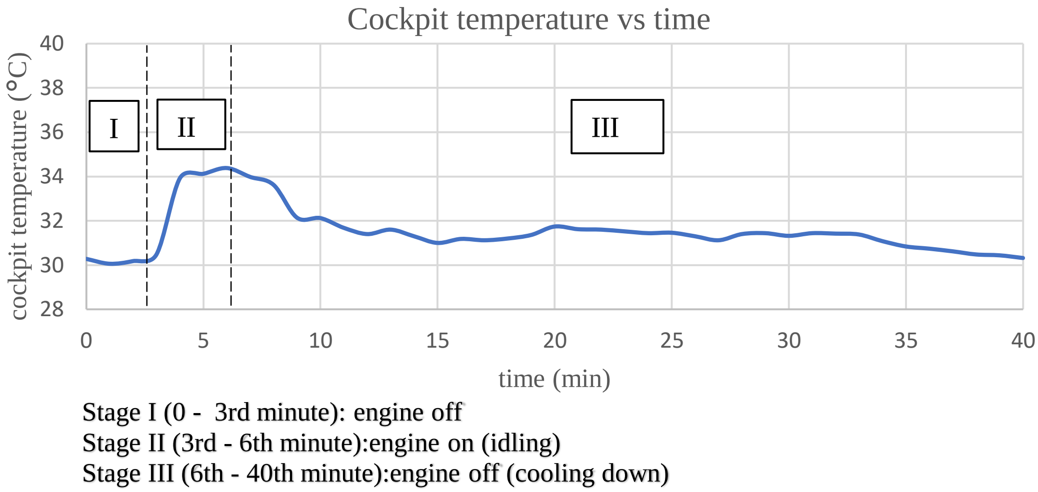
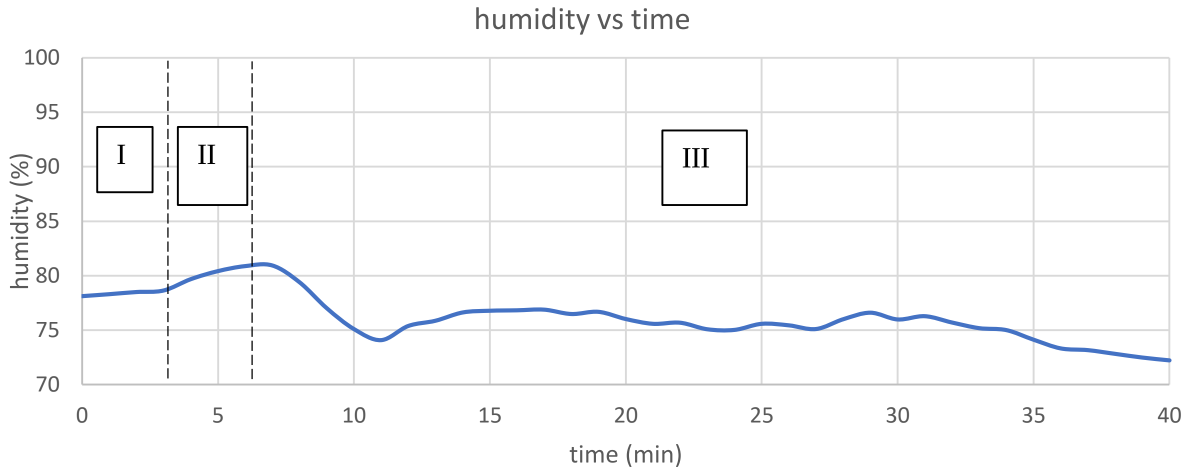


Fig. 8 - Graph of cockpit temperature against time

3.6 Measurement of Humidity

The effect on the humidity due to the emission produced by the PT6A-20 engine is studied at the hangar where located in UTHM main campus. As we can see from Fig. 9, during the stage I where the engine is in off condition, the humidity is less than 80%. During the stage II where the engine is set in the idling condition, the level of humidity rose and hit the maximum point of 80.94% at the 7th minute. This shows that the emission released by the engine increased the humidity of the surrounding. In the stage III, the temperature started to drop and maintained in the range of 72-76 % from the 15th minute of the experiment. The acceptable range of relative humidity according to the Department of Occupational Safety and Health is 40 - 70 %.

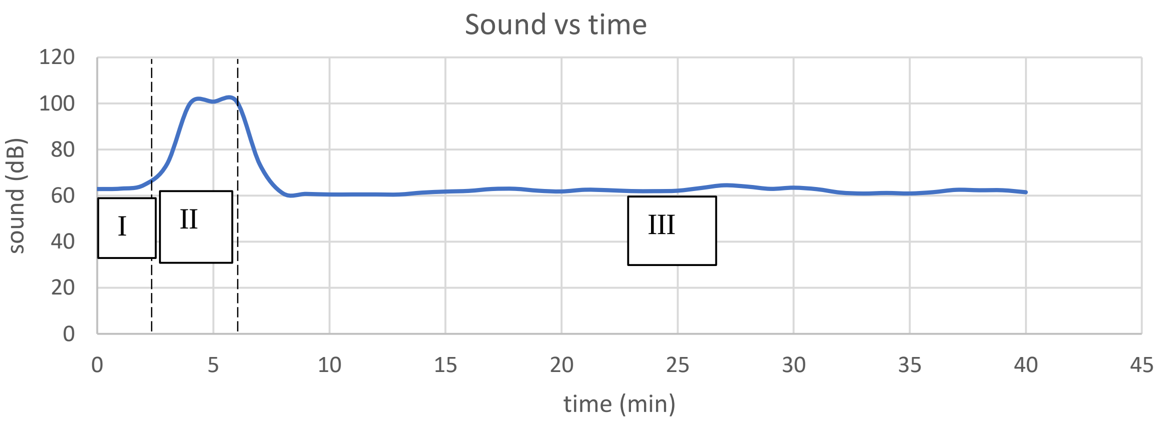


Stage I (0 - 3rd minute): engine off
Stage II (3rd - 6th minute):engine on (idling)
Stage III (6th - 40th minute):engine off (cooling down)

Fig. 9 - Graph of humidity against time

3.7 Measurement of Noise Level

The noise produced by the PT6A-20 engine is studied at the UTHM hangar. As we can see from Fig. 10, during the stage I where the engine was in off condition, the noise level was in the range of 60 - 65 dB. During the stage II where the engine was set in the idling condition, the level of noise rose and hit the maximum point of 100.78 dB at the 6th minute. This shows that the noise produced by the engine is extremely high to the surrounding. In the stage III, the noise level started to drop and maintained in the range of 60-61 dB from the 8th minute up to the end of the experiment. The acceptable range of daily noise exposure level according to Occupational Safety and Health (Noise Exposure) Regulations 2019 is below 85 dB and below 115 dB at any time.



Stage I (0 - 3rd minute): engine off
Stage II (3rd - 6th minute):engine on (idling)
Stage III (6th - 40th minute):engine off (cooling down)

Fig. 10 - Graph of noise level against time

4. Conclusion

Based on the results from experiment conducted at the UTHM hangar, we can see that how the operation of the turboprop PT6A-20 engine affects the 7 parameters of the experiment which are carbon monoxide, carbon dioxide, particulate matter (PM_{10}), ambient temperature, cockpit temperature, humidity and also the sound level. Based on the results, the highest amount of carbon monoxide that is produced during the idling of the engine is 7.06 ppm. Since it is lower than the guideline provided by the Indoor Air Quality Standard according to the Department of Occupational Safety and Health which is 10 ppm, the emission of carbon monoxide is still under safe limit. Moreover, the highest amount of carbon dioxide that was recorded during experiment was 864.6 ppm. It is also proven to be lower than the guideline of 1000ppm according to Indoor Air Quality Standard of the Department of Occupational Safety and Health. So the emission of carbon dioxide from the engine is still under the safety limit. However the concentration of PM_{10} is extremely higher than the allowable limit of Malaysian Ambient Air Quality Standard which is 100 $\mu g/m^3$. Both cockpit and ambient temperature are also more than the acceptable range drawn by the Department of Occupational Safety and Health which is between 23 - 26 °C. Humidity is more than the limit of 40-70% as well and finally the noise level does shoot up more than the safety limit in the stage II where the engine was in the idling condition.

Acknowledgement

The authors would like to thank the Industrial Hygiene Research Group (IH), Department of Aeronautical Engineering and Department of Mechanical Engineering, Faculty of Mechanical and Manufacturing Engineering of Universiti Tun Hussein Onn Malaysia (UTHM) for supporting throughout this research work.

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