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Analysis of Noise Reduction in Micro Gas Turbine

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ABSTRACT

The technology of Micro Gas Turbines (MGT) can be found since 1970, when the automotive industry viewed the potentiality of using MGT to replace the reciprocating piston engines. The noise produced by MGT is influenced by the speed of the turbine, as the flow rate of the LPG is increased, the speed of the turbine is also increased. This study carried out to analyze the noise produced by Micro Gas Turbines (MGT) and to reduce noise produce by Micro Gas Turbine (MGT). The sound absorbent selected for the study was able to sustain until 700˚C temperature and sound damping for maximum sound proofing effect and minimum noise destruction. The experiment was carried out by using a developed Micro Gas Turbine. This studies also using a mass flow rate meter to measure the equivalence ratio and sound produced from Micro Gas Turbine MGT was analyzed experimentally with the increment of 5 L/m of LPG using integrated sound meter. This research focused on analyzes the noise produced by MGT. Liquefied Petroleum Gas (LPG) was used as the fuel of MGT. Noise produces by MGT is analyzing experimentally with the increment of 5 L/m of Liquefied Petroleum Gas and mass flow rate of 10 L/m, 15 L/m and 20 L/m. Selection of Multilayer Polyester/Fiberglass Composite as the sound absorbent to reduce the noise of MGT and LPG was used as the fuel of Micro Gas Turbine. Result shown that, the sound pressure level, sound intensity and sound power level had low graph pattern after implementation of the sound absorbent compared to before implementation of sound absorbent. As conclusion, MGT with sound absorbent produce lower noise compared to MGT without sound absorbent. Sound absorbent reduced the noise produced by MGT. This study was successfully implemented. Lastly, the concept of this study may conclude for the industry to reduce noise produced outright secure the community and world from the noise pollution..

Key words : Micro Gas Turbine, Liquefied Petroleum, Gas Sound Absorbent, Noise.

1. INTRODUCTION

Micro Gas Turbines is a type of combustion turbine that produces both heat and electricity on a relatively small scaled with power outputs of 25 kW to 500 kW. MGT evolved from automotive and truck turbochargers, auxiliary power unit airplanes, and small jet engines. It is fuel by Liquefied Petroleum Gas (LPG). Micro Gas Turbines (MGT) consists of three main components which are compressor, combustion chamber and turbine. MGT produce high level of noise while running. The high level of noise produce by Micro Gas Turbines is influenced by the speed of turbine due to high combustion in the chamber [1]

These studies were to analyze the noise produced by Micro Gas Turbines (MGT) and to reduce noise produce by Micro Gas Tur-bine (MGT). This study considered LPG is used as the fuel of Micro Gas Turbine, Multilayer Polyester/Fiberglass Composite as the sound absorbent to reduce the noise of MGT, Noise produces by MGT is analyzing experimentally with the increment of 5 L/m of Liquefied Petroleum Gas and Noise produces by MGT is analyzing on the mass flow rate of 10 L/m, 15 L/m and 20 L/m. The measurement were carried out in order to perform an evalua-tion of the noise produce by the MGT, thus, from the evaluation a further extensive on improvement will continuously improve.

Micro gas turbine is basically a compact and scale down form of a larger turbine with power outputs of 25 kW to 500 kW [2]. It is a rotating engine that extracts energy from a flow of combustion gases that result the ignition of compressed air and a fuel. The fuel can be either a gas or liquid but most commonly natural gas. Micro gas turbine (MGT) consists of three main components which are compressor, combustion chamber and turbine. These three main components are connecting and needs each other. Compressor is connected to a turbine by a rotating shaft. The shaft transmits the power necessary to drive the compressor and delivers the balance to a power utilizing load, such as an electrical generator. The turbine is similar in concept and in many features to the steam turbines, except that it is designed to extract power from a flowing hot gas rather than from water vapor. It is important to recognize at the outset that the term "gas turbine" has a dual usage. It designates both the entire engine and the device that drives the compressor and the load. It should be clear from the context which meaning is intended. The equivalent term combustion turbine is also used occasionally, with the same ambiguity.

2. NOISE OF MICRO GAS TURBINE

Noise can be defined as unwanted sound. Loss of hearing is only one of the effects of continuous exposure to excessive noise levels. Noise can interfere with sleep and speech, and cause discomfort and other non-auditory effects. High level noise and vibration lead to structural failures as well as reduction in life span. Noise also leads to the noise pollution. Noise pollution is not only an annoyance; it is an environmental health hazard [3]. The First Schedule listed that permissible limit of noise level and duration of exposure permitted per day in hour or minute. Any person who contravenes any provision of these Regulations shall be guilty of an offence and shall, on conviction, be liable to a fine not exceeding one thousand ringgit (Factories And Machinery (Noise Exposure) Regulations, 1989).

Micro Gas Turbine produces noise while running. The noise produced by MGT is influenced by the speed of the turbine. As the flow rate of the LPG is increased, the speed of the turbine is also increased.

A measurement on noise level has been carried out in order to determine the noise level produced by the MGT. A sound level device is used to measure the noise level for this experiment. The data result regarding the noise level. It can be seen that the noise level produced by the MGT is increase proportionally to the speed of the MGT. The sources of the noise are occurs due to the in-creasing of the air velocity that relative to the compressor, turbine and the exhaust. The highest measurement of the noise is 134 dB at the speed of 65000 rpm and while the lowest measurement of the noise is indicated at the lowest speed of the MGT of 30000 rpm with 126 dB. This behavior occurs due to the flows of energetic air thus creating interaction of pressure fields and turbulence for rotating the compressor, turbine and the vanes. These significant sources of the noise are occurs due to the in-creasing of the air velocity that relative to the compressor, turbine and the exhaust. This behavior occurs due to the flows of energetic air thus creating interaction of pressure fields and turbulence for rotating the compressor, turbine and the vanes.

Reduction of noise occurs when there is an interferer along the path of the sound travel. Noises produce from the velocity of the high pressure turbine and low speed pressure turbine. This be-havior occurs due to the flows of energetic air thus creating interaction of pressure fields and turbulence for rotating the compressor, turbine and the vanes [1]. There are two methods to reduce noise, which are cover up the sound source or wrapping the sound source. The study shows that, during the test, it was observed that the temperature outlet of combustion chamber reached approximately 1000˚C. This is beyond the turbocharger's bearing and blades ability to withstand such high degree of temperature. After 30 minutes of operation, the redness effects begin to appear on the turbocharger casing [1]. Thus, this study needs to consider high temperature while operating the MGT. The selected sound absorbent need withstand high temperature and has high absorp-tion of noise. The procedure for this methodology can be summarized as shown in Figure 1.

3. EXPERIMENTAL SET- UP

This test was carried out at the automotive laboratory in UTHM with room temperature air of 32 degree Celsius and pressure was considered as atmosphere pressure above sea level, which is 101.3KPa. The experiment was carried out with the developed Micro Gas Turbine. The schematic diagram and the real images of microgas turbine are shown in Figure 2 and Figure 3, respectively.

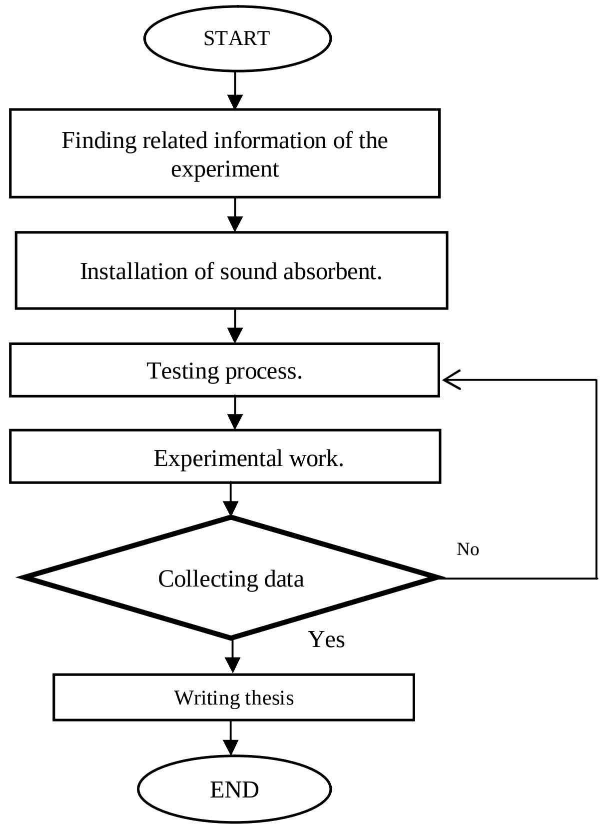


Figure 1: Work Flow Chart of the Study

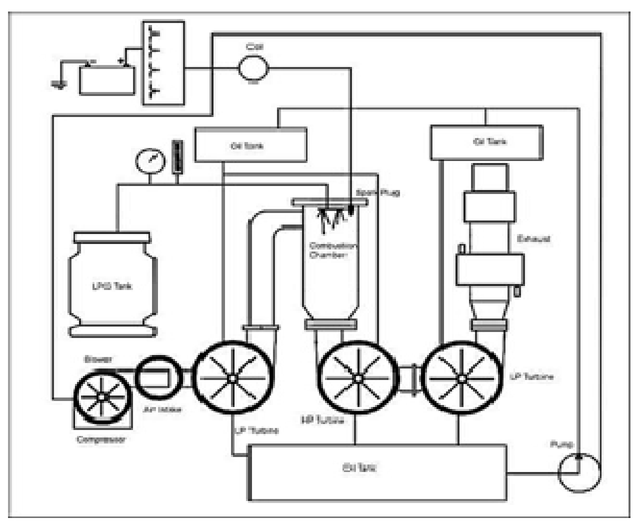


Figure 2: Schematic Diagram of Micro Gas Turbines

Figure 4 shows the Integrating Sound Level Meter was used to measure the level of noise produce by MGT. The noise was measured in the unit of Decibel (dB).. Table 1 shows that specification of compressor and turbine. Figure 5, Figure 6 and Figure 7 show the compressor together the front and back of real images of compressor and micro gas turbine. In this research, Nissan 45V3 Turbocharger was used as compressor for combustion chamber. The turbocharger used the exhaust gas consumes compress air to drive a turbine to combustion chamber. This spins an air compressor that pushes extra air (and oxygen) into the cylinders, allowing them to burn more fuel each second. Turbocharger had produced more power and better performance.

Sound absorbent used for this experiment was Multilayer Polyester/Fiberglass Composite due to the ability of the temperature estimated until 700˚C and had high octave-band center frequency (Hz) absorption coefficients materials. As shown in Figure 7 sound absorbent used in this experiment.

Figure 8 shows that how the data was collected. The Integrating Sound Level Meter that used to measure the level of noise produced by MGT was placed at 3 ft or 1 m from the MGT based on the manual user book and guideline of the Factories and Machinery (Noise Exposure) Regulations 1989 Department of Safety and Health DOSH [4,5]. Figure 9 shows MGT without sound absorbent for collecting data. Figure 10 shows installation sound absorbent and Figure 11 shows sound absorbent was installed at MGT for collecting data.

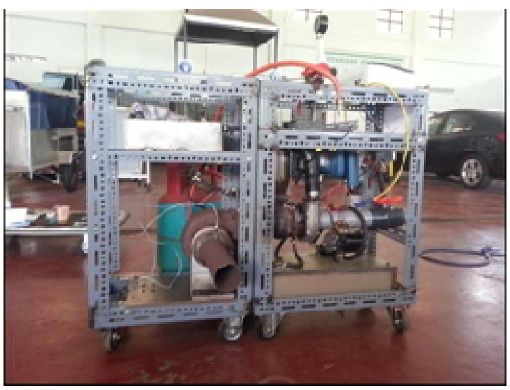


Figure 3: Developed Micro Gas Turbines

Figure 4: Integrating Sound Level Meter

Figure 5: Front View of Turbine

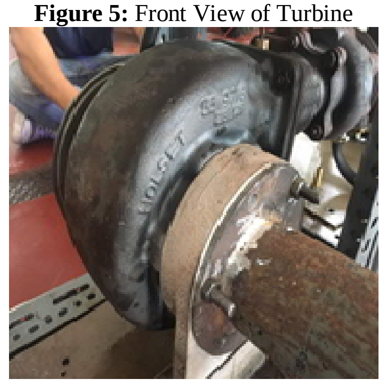


Figure 6: Back View of Turbines

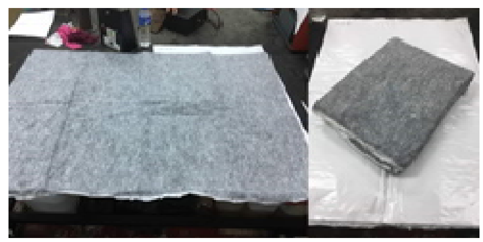


Figure 7: Sound Absorbent

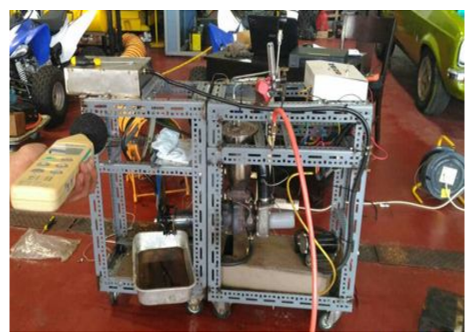


Figure 8: Data Collection

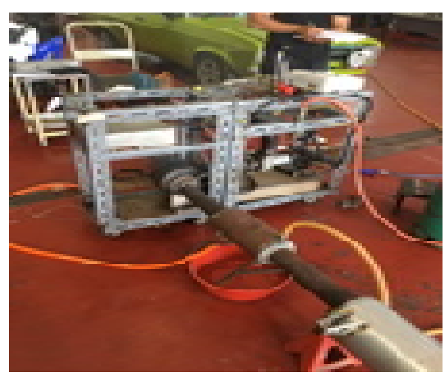


Figure 9: MGT without sound absorbent

Figure 10: Installation sound absorbent at MGT

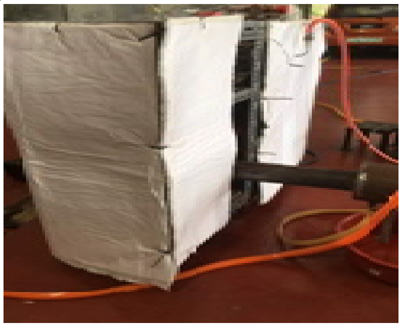


Figure 11: MGT with sound absorbent

Table 1: Specification of compressor and turbine

Turbocharger Model	Compressor				Turbine		
	Inducer Wheel Diameter (mm)	Exducer Wheel Diameter (mm)	Trim	A/R	Wheel Diameter (mm)	Trim	A/R
Nissan 45V3	49.2	71	48	0.6	53.9	76	0.86

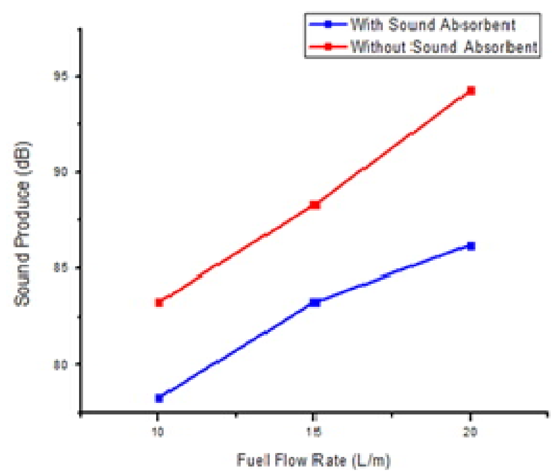
4. RESULT AND DISCUSSION

A fully developed Micro Gas Turbine MGT was used to implement this study. A noise test was carried out to measure the noise level produced by the MGT. MGT is a type of machine that produced noise while running. When sound is transmitted through air, it is usually described in terms of changes in pressure that alternate above and below atmospheric pressure. These pressure changes were produced when a vibrating object causes alternating regions of high pressure (compression) and low pressure (rarefaction) that propagate from the sound source. In this study, noise test was carried out in two different situations. One was MGT with absorbent and another situation was MGT without absorbent. The type of absorbent used in this study was Multilayer Polyester/ Fibreglass Composite. Absorbent was used as sound proof to reduce the noise of the MGT. Two parameters involve in this study are sound pressure level and sound power level.

Table 2: Data Collected

Fuel Flow Rate (L/m)	Sound Produce (dB)	
	With Sound Absorbent	Without Sound Absorbent
10	78.3	83.3
15	83.3	88.3
20	86.2	94.3

Table 2 and Figure 12 show sound test process and flow rate of the MGT affect the noise produced by MGT as the speed turbine in MGT increased when the flow rate was increased. Sound level meter was used to measure the noise produced by the MGT. The test carried out in two different situations. One while the one without absorbent installed at the MGT and the other one with absorbent installed at the MGT. Based on the data above, the MGT produced noise around 78.3 dB while running at flow rate of 10 L/m with absorbent installed at the MGT. MGT produced noise around 88.3 L/m without absorbent installed at flow rate of 10 L/m. MGT produced noise around 83.3 dB while running at flow rate of 15 L/m with absorbent installed at the MGT. MGT produced noise around 88.3 L/m without absorbent installed at flow rate of 15 L/m. MGT produced noise around 86.2 dB while running at flow rate of 20 L/m with absorbent installed at the MGT. MGT produced noise around 94.3 L/m without absorbent installed at flow rate of 20 L/m. Based on the data above, the graph line of without sound absorbent significantly ascending compared to graph line with sound absorbent ascending moderately. Noise produced by MGT increase as the flow rate was increased [6,7,8].



[1] Gerard Hawkins, (2014). Studies And Research Regarding Sound Reduction Materials with The Purpose of Reducing Sound Pollution.

Fuel flow rate

4.2 Sound Pressure Level

Sound Pressure was calculated to define the Instantaneous Sound Pressures measured over a specified period of time Based on the calculated data in Table 3, the sound pressure increased when the flow rate was increased. The data distribution for with sound absorbent ascending moderately compared to graph line for without sound absorbent ascending extremely as shown in Figure 13. At flow rate of 10 L/m, MGT produced 166.40 x 103 Pa of pressure as the absorbent was installed at the MGT. 309.80 x 103 Pa produced at the same flow rate but without absorbent installed to the MGT. At flow rate of 15 L/m, MGT produced 295.80 x 103 Pa of pressure as the absorbent was installed at the MGT. 526.00 x 103 Pa produced at the same flow rate but without absorbent installed to the MGT. At flow rate of 10 L/m, MGT produced 408.40 x 103 Pa of pressure as the absorbent was installed at the MGT. 138.36 x 104 Pa produced at the same flow rate but without absorbent installed to the MGT.

4.3 Sound Intensity Level

Sound intensity calculated to define the average acoustic energy per unit time passing through a unit area that was normal to the direction of propagation for a spherical or free-progressive sound wave. Based on the distribution data in Table 4, the Figure 14 for without sound absorbent proportionally ascending compared graph line for with sound absorbent moderately ascending. The sound intensity increased when the flow rate increased. At flow rate of 10 L/m, MGT produced 6.76 x 10-5 W/m2 of pressure as the absorbent was installed at the MGT. 6.76 x 10-4 W/m2 produced at the same flow rate but without absorbent installed to the MGT. At flow rate of 15 L/m, MGT produced 2.14 x 10-4 W/m2 of pressure as the absorbent was installed at the MGT. 2.69 x 10-4 W/m2 produced at the same flow rate but without absorbent installed to the MGT. At flow rate of 10 L/m, MGT produced 4.17 x 10-4 W/m2 of pressure as the absorbent was installed at the MGT. 4.79 x 10-3 W/m2 produced at the same flow rate but without absorbent installed to the MGT.

Table 3: Sound Pressure Level.

Fuel Flow Rate (L/m)	Sound Pressure level SPL (Pa)	
	With Sound Absorbent	Without Sound Absorbent
10	166.40×10^{3}	309.80×10^{3}
15	295.80×10^{3}	526.00×10^{3}
20	408.40×10^{3}	138.36×10^{4}

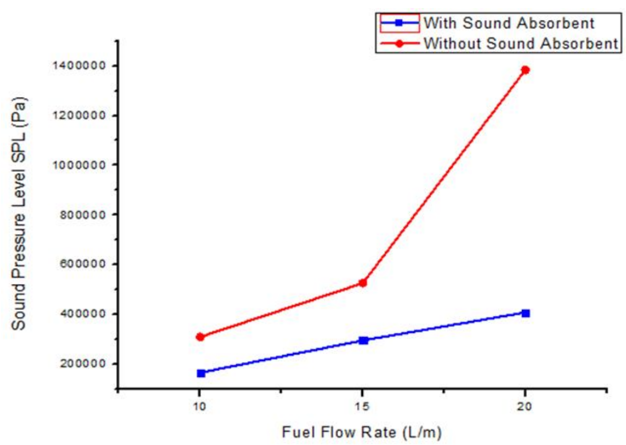


Figure 13: Relation between Sound Pressure Level and Fuel Flow Rate

4.4 Sound Power Level

Sound power was calculated to define the average sound intensity produced in free-field conditions at a distance r from a point source as shown in Table 5 and Figure 15. The sound power level increased when the flow rate was increased. At flow rate of 10 l/m, mgt produced 57.40 x 103 w of pressure as the absorbent was installed at the mgt. 5739.94 x 103 w produced at the same flow rate but without absorbent installed to the mgt. At flow rate of 15 l/m, mgt produced 1857.89 x 103 w of pressure as the absorbent was installed at the mgt. 91512.18 x 103 w produced at the same flow rate but without absorbent installed to the mgt. At flow rate of 10 l/m, mgt produced 2184.40 x 103 w of pressure as the absorbent was installed at the mgt. 287.18 x 106 w produced at the same flow rate but without absorbent installed to the mgt as shown in Figure 1.

Table 4: Sound Intensity Level.

Fuel Flow Rate (L/m)	Sound Intensity Level IL (W/m^2)	
	With Sound Absorbent	Without Sound Absorbent
10	6.76×10^{-5}	6.76×10^{-4}
15	2.14×10^{-4}	2.69×10^{-3}
20	4.17×10^{-4}	4.79×10^{-3}

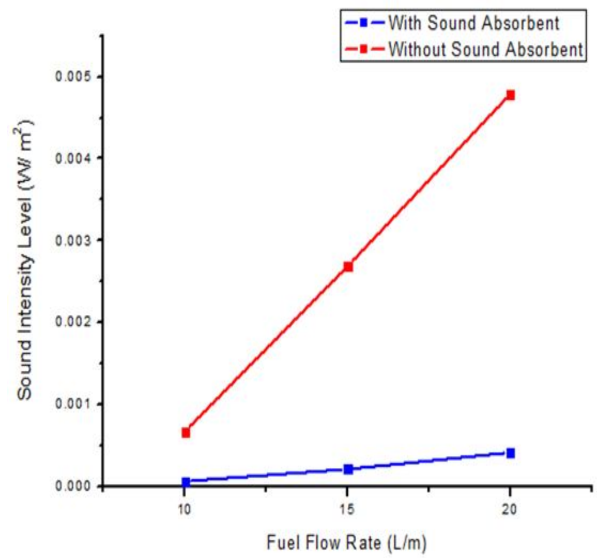


Figure 14 : Relation between Sound Intensity and Fuel Flow Rate.

Table 5: Sound Power Level

Fuel Flow Rate (L/m)	Sound Power Level (Watt)	
	With Sound Absorbent	Without Sound Absorbent
10	57.40×10^{3}	5739.94×10^{3}
15	1857.89×10^{3}	91512.18×10^{3}
20	2184.40×10^{3}	287.18×10^{6}

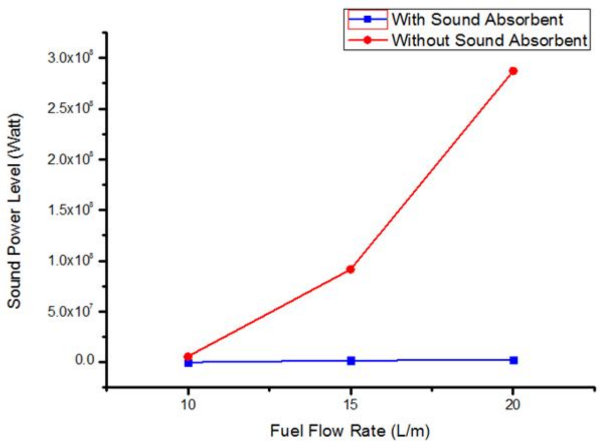


Figure 15: Relation between Sound Power and Fuel Flow rate.

5. CONCLUSION

Data of the noise produced by Micro Gas Turbine were collected during noise test process. Sound level meter was used to measure the noise produced by the MGT. The test carried out in two different situations. One while the absorbent installed at the MGT and the other one without absorbent installed at the MGT. Based on the data, the noise produced by MGT increase as the flow rate was increased. Flow rate of the MGT affect the noise produced by MGT as the speed of MGT increased when the flow rate was increased. Sound Pressure Level and Sound Power Level were calculated. Based on the calculation performed, Sound Pressure Level and Sound Power Level increased as the flow rate of the MGT were increased. The used of Multilayer Polyes-ter/Fiberglass Composite absorbent reduced the noise produced by the MGT engaging the Permissible Exposure Limit regulation (Factories And Machinery (Noise Exposure) Regulations, 1989). As conclusion, MGT with sound absorbent produce lower noise compared to MGT without sound absorbent. Sound absorbent reduced the noise produced by MGT. This study was suc-cessfully implemented.

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