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Basic Study Converting of Sound Pressure to Electricity with Arrangement of Sound Speaker using Thermoacoustic Technology

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Abstract: This paper describes the suitability of a loudspeaker to be used as a linear alternator. The present study is intended to clarify experimentally that the ability of loudspeaker to detect a frequency of sound wave by applying the sound into a resonator with the different of length. The result of the experiment will determine the suitable length of resonator that give the best reading. The linear alternator is a linear motor which commonly used as an electrical generator. It is a type of alternating current electrical generator. The function of an alternator is to convert mechanical energy to electrical energy. The linear alternator operate under the principle of electromagnetic induction. Unlike linear alternator, other alternator work in rotary motion while the linear alternator work in linear motion. Electromagnetic induction is a result of an electromotive force across an electrical conductor cause by the dynamic interaction with magnetic field. The data of the experiment was conducted based on the three length of resonator. Based on the experiment, all three resonator give the best reading when the operating frequency of 200 Hz was used. The peak to peak voltage recorded for 100 mm length was 776 mV while the peak to peak voltage recorded for 150 mm length was 824 mV. The last resonator give the reading of 776 mV. For the decibel reading, the 100 mm resonator give the reading of 100.2 dB. The resonator of 150 mm give reading of 98.5 dB and the 200 mm give decibel reading of 99.8 dB. For the experiment with heat engine, the highest peak to peak reading is 40.7 mV and the decibel reading is 110.9 dB.

1. Introduction

Nowadays, we used a lot of energy in our daily routine. There are many source of energy exist in this world. The new method of converting energy source from a waste heat to sound energy is call thermoacoustic technology [1]. This paper will be described energy from a sound wave on the converting by thermoacoustic system. The term thermoacoustic is basically a combination of two words that is thermal and acoustic [2]. The term is used because the processes that occur in



thermoacoustic involve both thermal and sound. The thermal is involve in this because waste heat is used in the process [3]. When the certain temperature different is achieved, the sound will produced. The sound will then harvested to produce electricity. Besides that, the connection between thermodynamics and acoustics are also known as thermoacoustics. The interaction of both thermodynamics and acoustics can be seen as the combinations between thermal gradient and acoustics vibration are used to convert heat supplied at certain temperature gradient into acoustic energy or to generate refrigeration effect using input acoustic power [4]. To be performed complete this phenomenon of acoustic interaction, the thermoacoustic effect must be achieved. The thermoacoustic effects is the phenomenon of non – zero net transport that occurs in an acoustic field. A thermal boundary layer form in the acoustic field as there is a presence of a solid surface. The heat transfer takes place between the oscillating gas parcels and the solid surface in the boundary layer. This will result in a positive transfer of heat from one end of the solid surface to the other, whose direction depends on the device whether it is a heat engine or a refrigerator [3, 5].

Waste heat is produced by machine or processes that use energy. Waste heat can be utilized by another process such as thermoacoustic. Thermouacoutic is a process that converting waste heat into acoustic energy [6]. The acoustic energy is then been converted into electrical energy. The issues is to harvest the acoustic energy that had been converted from the waste heat. The suitability of a loudspeaker to be use as a linear alternator is a concern. The loudspeaker is use to harvest the acoustic energy and converting it into electrical energy. Another issue is the ability of loud speaker to detect high frequency sound wave [7]. The acoustic energy will travel through a resonator before been harvested by the loudspeaker. The suitable length of resonator that give the best performance should be determine [8, 9].

A thermoacoustic engine is said to be a device that converting heat energy into acoustic energy. It utilizes high amplitude sound waves to pump heat from one place to another. This device can be classify as a standing wave device and a travelling wave device [10-12]. The standing wave device it call such in that way because it operate using the effects that arise from the resonance of standing waves. In travelling wave's devices, the direction flow of the heat is opposite to the direction of propagation of wave [13]. The wave propagates from cold to hot end. In contrast of the wave propagation, the heat transfer from the hot to the cold end. The heat is then convert to acoustic energy when the wave propagates from cold to hot end. This occur on travelling wave heat engine [14]. While for the travelling wave heat pump, the propagation of waves in such an opposite way as the travelling wave heat engine. It propagates from the hot end to the cold end. It is the same for the heat, it propagates in the opposite way such as from the cold end to the hot end. The other obvious different between this two type of device is that the part comprise for both device [15, 16].

2. Methodology

The experimental setup was very crucial to determine the availability of the loudspeaker to act as a linear alternator. The experiment start by connecting the function generator to the power amplifier. The power amplifier was then connected to the loudspeaker. The speaker that connected to the power amplifier was called the source speaker. The other speaker is connected to the digital storage oscilloscope was called the sink speaker. Both source and sink loudspeaker was connected to a resonator with the length of 100 mm. In this experiment, the manipulated variable chosen was the operating frequency of the source speaker. The operating frequency of the source speaker being manipulated by changing it value using the function generator. The operating frequency used in this experiment is range from 50 Hz – 300 Hz with the increment of 50 Hz. The data of the experiment was displayed by the digital storage oscilloscope. The parameter that need to collect is the peak to peak voltage and the output frequency of the sink loudspeaker. All the parameter were displayed on the digital storage oscilloscope. The experiment were repeated using different length of resonator which is 150 mm and 200 mm. Figure 1 shows the experimental set up for this research methodology.

2.1 Loud speaker as a linear alternator

Linear alternator is a linear motor. It is commonly used as an electrical generator. It is a type of alternating current electrical generator. The function of an alternator is to convert mechanical energy to electrical energy. The linear alternator operate under the principle of electromagnetic induction. Unlike linear alternator, other alternator work in rotary motion while the linear alternator work in linear motion. Electromagnetic induction is a result of an electromotive force across an electrical conductor cause by the dynamic interaction with magnetic field.

As been describe earlier in the introduction, a loudspeaker is a device that been used to convert electrical energy to sound energy. While a linear alternator is a device that been used to produce electrical energy. An electrodynamic speaker can operate both ways. It can be use to produce sound waves by converting the electrical energy to sound energy. The loudspeaker also can be used to produce electricity. The external acoustic pressure acting on the diaphragm will cause the voice coil to move in the magnetic field where it is suspended inducing a voltage in the coil.

2.2 Experimental strategies

The experiment is to validate the suitability of loudspeaker to act as linear alternator. The loudspeaker was placed at the end of the heat engine using suitable length that were obtained from previous experiment. The heat engine was heated until it reach certain temperature gradient. When the temperature gradient reached, the heat engine produced sound. The loudspeaker will collect the sound. The data collected form the experiment were the peak to peak voltage, output frequency and the decibel reading. The data then analyzed and calculated using the Equation formula (1) until (4)

$$p = p_0 \times 10^{\frac{Lp}{20}} \quad (1)$$

$$p_0 = 0.00002 \quad (2)$$

$$I = I_0 \times 10^{\frac{Lp}{10}} \quad (3)$$

$$I_0 = 10^{-12} \quad (4)$$



Figure 1. (a). Experimental setup for measuring Voltage, Vpp and Output frequency, Hz (b). Experimental setup with Thermoacoustic Heat Engine for measuring frequency, Hz and decibel dB.

3. Results and Discussions

The data collected were presented. All the data collected from the experiment of performance of the linear alternator were presented in form of table and graph. In the experiment, the manipulating variable used was the length of resonator and the input frequency used. The length of the resonator were tested using three different length that are 100 mm, 150 mm, and 200 mm. The operating frequency used were from 50 Hz – 300 Hz with the increment of 50 Hz. The data recorded to test the performance of the linear alternator such as decibel (dB), output frequency (Hz), the peak to peak voltage (V_{pp}) and the maximum voltage (V_{max}).

3.1 Decibel against input frequency with different of resonator length

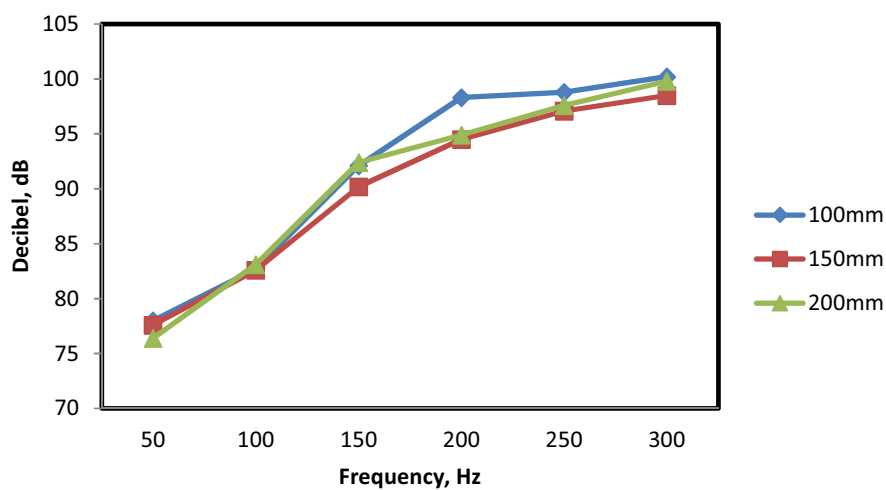


Figure 2. Decibel (dB) against input frequency (Hz) with different resonator length.

Based on the figure 2, the trend of the graph show an increasing pattern of the decibel data collected with increasing of input frequency. When 100 mm resonator was used, the range of decibel recorded was from 78.0 dB to 100.2 dB. Next, when 150 mm resonator was used, the range of decibel recorded was from 77.6 dB to 98.5 dB. Lastly, range of decibel from 76.4 dB to 99.8 dB was recorded when 200 mm length of resonator used. In this study, it can be conclude that the highest decibel recorded was 100.2 dB while the lowest was 76.4 dB. The highest decibel was recorded when the length of resonator used was 100 mm with the operating frequency was 300 Hz. The lowest decibel recorded was when 200 mm resonator used and the operating frequency was 50 Hz. Kang et al. used the operating frequency of 171 Hz to conduct the experiment. In this experiment, the operating frequency used from 50 Hz – 300 Hz so that the input frequency can be vary to get various decibel reading.

3.2 Comparison between the voltage (V_{pp}) against input frequency (Hz)

Based on the figure 3, the comparison of peak to peak voltage data collected between all three resonator with the length of 100 mm, 150 mm and 200 mm were compared. For all the resonator used the range of data of peak to peak voltage collected were from 79.1 mV to 824 mV. Each of the resonator show the same trend of data which the highest peak to peak voltage recorded with the value

is 200 Hz operating frequency. For 200 Hz operating frequency used, the highest data recorded between all three resonators when using the resonator with 150 mm long. Hence, the most effective length of resonator that can be used was 150 mm and the suitable operating frequency was 200 Hz. By review the past study some of researcher used the operating frequency of 194.5 Hz to conduct the experiment. According to the past experimental study, this experiment study used optimum frequency recorded was 200 Hz.

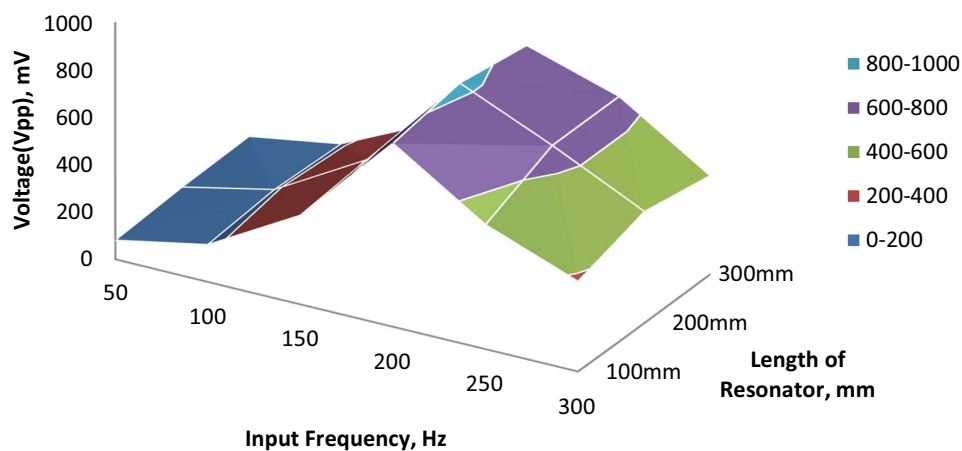


Figure 3. Voltage (Vpp) against Working Frequency (Hz) and Length of Resonator (mm).

4. Conclusions

All in all, this chapter present all the data recorded from the experiment. For the first experiment, three different length of resonator was tested using the commercially available loudspeaker as a linear alternator. For the 100 mm length of resonator, the highest decibel reading recorded was 100.2 dB. The highest peak to peak voltage recorded for the resonator of length 100 mm was 776 mV. For the 150 mm length of resonator, the highest decibel reading recorded was 98.5 when the operating frequency was 300 Hz. The highest peak to peak voltage recorded for the resonator with the length of 150 mm was 824 mV. For the last resonator which 200 mm long, The highest decibel that been recorded was 99.8 dB while the highest peak to peak voltage recorded was 776 mV. When testing with the heat engine, the highest decibel that been recorded was 110.9 dB. For the peak to peak voltage, the highest reading recorded was 40.7 mV when the time taken was 13.00 min. The experiment manage to harvest the voltage of 100 mV while this experiment manage to harvest 40.7 mV.

References

- [1] A R Irfan, M. Z. M. Zarhamdy, S M Sazli, M N Amni, N. A. Shuaib, and A. Azlida 2019 *AIP Conference Proceedings* **2129** 020181
- [2] Z. Yu and A. J. Jaworski, 2010 *Energy Convers. Manag* **51**(2) 350–359
- [3] A R Irfan, M Z M Zarhamdy and N Z Asmuin 2014 *Applied Mechanics and Materials* **663** 317-321
- [4] A. R. Irfan, M. Z. Md Zain, S. M. Sazli, P. M. A. Asraf, N. A. Shuaib, and A. Azlida 2019 *AIP Conference Proceedings* **2129** 020180

- [5] S. Jung and K. I. Matveev, 2010 *J. Mech. Eng. Sci.* **224** (1) 133–141
- [6] H. Agarwal, V.R. Unni, K.T. Akhil, N.T. Ravi, S.Md. Iqbal, R.I. Sujith and B. Pesala, 2016 *Appl. Acoust.* **110** 110–118
- [7] Z. Yu, P. Saechan, and A. J. Jaworski 2011, *Appl. Acoust.* **72** (5) 260–267
- [8] H. Kang, P. Cheng, Z. Yu, and H. Zheng, 2015 *Appl. Energy* **137** 9–17
- [9] A. Rossi, F. Immovilli, C. Bianchini, A. Bellini, and G. Serra 2009 *IEEE Energy Convers* 2436–2440
- [7] Z. Yu, A. J. Jaworski, and S. Backhaus 2012 *Appl. Energy* **99** 135–145
- [9] C. R. Saha, P. H. Riley, J. Paul, Z. Yu, A. J. Jaworski, and C. M. Johnson 2012 *Sensors Actuators, A Phys.* **178** 179–187
- [10] K. Wang, J. Zhang, N. Zhang, D. Sun, K. Luo, J. Zou and L. Qiu, 2016 *Appl. Therm. Eng.* **102** 272–282
- [11] K. Wang, D. Sun, J. Zhang, Y. Xu, J. Zou, K. Wu, L. Qiu and Z. Huang, 2015 *Appl. Energy* **160** 853 - 862
- [12] G. Yu, X. Wang, W. Dai, and E. Luo 2013 *Appl. Energy* **111** 1147–1151
- [13] Z. Wu, L. Zhang, W. Dai, and E. Luo, 2014 *Appl. Energy* **124** 140–147
- [14] Y. Wang, Z. Li, and Q. Li, 2016 *Energy Convers. Manag.* **110** 135–141