SIMULATION OF NOISE POLLUTION REDUCTION IN A POWER PLANT UNDER CONSTRUCTION USING ANSYS FLUENT SOFTWARE

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Abstract

Noise pollution is one of the challenges of equipment installation and industry development. Controlling the noise produced by small power plants is a necessity for its development. Acoustic design of silencer and gas outlet duct using absorbent material and determination of chimney height are one of the effective methods to control and reduce noise pollution in power plants industries. The purpose of this research is to reduce the noise pollution of Hitachi 25MW gas power plant. This study evaluates the effect of adjoint duct height and adsorbent layer (from rock wool, stainless steel and metal foam) on the spread sound intensity in the surrounding environment. In this regard, the adjoint duct has been modeled as three-dimensional in the ANSYS software environment and the sound intensity exited from the duct has been analyzed in several different states in the acoustic environment.

According to the results, if the exhaust height increases to four meters and the insulation layer is placed with 10 cm thickness with lattice steel plates, fireproof cloth and rock wool and the silencer develops about 2 meters along the primary silence, we will reduce noise pollution by at least 15 dB.

Keywords; Metal foam, noise pollution, Ansys Fluent Software, gas exhaust power plant.

Introduction

The problem of undesirable and accidents due to making noise pollution has been considered more than ever because of expressing some discussions such as more suitable environment and more desirable lifestyle. Therefore, researchers have been interested in finding low-cost and low-weight materials that can absorb noise waves with high and low-frequencies (1). Various materials such as soft polymer foams, mineral fibers such as glass wool converted noise to heat through the friction of noise waves with the fibers and the air inside them, so, ultimately, they absorb sound waves. But nowadays, the harmful effects of these materials on the health are not hidden for Everybody. The use of metal foam is one of the solutions provided in this area. These foams have sound absorption properties and are a good option to control noise pollution, especially in industrial environments. Important factors affecting the absorption coefficient of the metal foam are: porosity, cavity size, cavity opening, thickness, airflow resistance, cavity morphology, the cavity was open or closed, the angle of sound waves collision and airflow resistance (2).

Despite studies on the effect of metal foam and its varieties on sound absorption due to its non-use in reducing noise pollution in power plants in the country, little research has been conducted on the effects of these types on industrial environments, and in particular thermal power plants. Therefore, the aim of the present study was to synthesize multilayer metal foam with nano-surface topography and investigate its results in reducing noise pollution of a new gas-fired power plant.

Power plants are the main centers of electricity production. In developing countries, continuous electricity production can play a vital role in industrial and social development. These centers have environmental problems during operating, including too much noise. The use of metal foams is one of the solutions provided in this area. These foams have sound absorption properties and are a good option for controlling noise especially in industrial environments (3). The simplest method to make foam is to produce the foam directly through gas bubbles in the molten metal. In this method large pieces can be produced at a relatively low cost. Therefore, considering the noise pollution state in industrial environments, especially in power plants, it seems that the use of sound insulation and absorbent products and evaluation of their effects have special importance.

The use of metal foam can play an important role in the power plant industries to reduce noise pollution. On the other hand, the use of multilayer metal foam in reducing noise pollution will be evaluated due to the high resistance of the metal foam to humidity and heat, good rigidity in low weight, recyclability, vibration attenuation due to noise and necessary energy absorption, and we can evaluate the effect of multilayer metal foam on reducing noise pollution in a gas power plant unit under constructing by making multilayer metal foam and piloting it (4).

disorders, temporary or permanent changes in hearing threshold and tinnitus are other effects of sound (5). To prevent these effects, it is necessary to control noise and reduce the level of noise exposed by people. This parameter needs to be fully identified and evaluated voice. It is necessary to evaluate and measure parameters such as noise frequency, time and the level of sound energy in order to evaluate the sound in the environment(6).

Woods conducted a study in 2009 at the Nasa Research Center on the reduction of noise pollution of aircraft engine using open cell metal foam. The low weight and anti-combustion of this absorbent was the reason for using this metal foam. This study has specially paid attention to the precise properties of the foam such as its pores size and compressibility. The researchers installed metal foam around the aircraft engine to conduct the study. The metal foam was made of stainless steel and had been made of silver metal like a compact bee's nest, weight reduction of metal foam due to its dimensions was very important in this study. Therefore, it was suggested that this foam is used as an aircraft engine box based on conducted searches (7).

Navacerrad. et all. in 2013, conducted their studies on aluminum foam with cavity size 500, 1000 and 2000 microns. Aluminum foam with diameter 500 microns showed the best noise absorption capacity (8).

Tupou. in 2013, conducted a study on the design of packages and methods of noise pollution reduction in thermal power plants in New York. Silencer and various insulations, including mineral insulations were used to reduce sound (9).

Edenize. et all. in 2017, showed that porous metal materials with open cell structure had logical effects on sound absorption to the free cells' morphology due to new biological metabolism and metal structures with improved functional properties and mainly high resistance to mechanical and chemical materials (10).

Zhai. et all. in 2018, obtained the acoustic absorption function in Nickel superalloys metal foam with porosity 92% and cell size 300-900 μm and sound absorption coefficient of 0.9 at frequency between 1 and 6 kHz (11).

Tao Yang. et all. in 2018, used production methods from solid state to produce metal foams with high-melting temperature, in this method, closed cell foams are produced with acceptable dispersion and cavity size. Another production method from solid is the use of space maker materials. In this method, the space maker materials such as Naf, Nacl, and so on are mixed and pressed with metallic powder and the space maker is removed from the system after sintering (metallic materials forming method) (12).

Lenko Stanev. in 2017, found that open cell aluminum foam is used for damping and sound absorption, and its surface morphology increases acoustic absorption (13).

Pei-sheng. in 2018, showed that a 7.5 mm thick foam sample which has been formed by a 5-layer foam panel (thickness: 1.5 mm; porosity: 96%; average diameter: 0.65 mm) can produce an excellent sound absorption at 4000 Hz with about an absorption coefficient of 0.8 (14).

Bahreini. in 2014, conducted a study about evaluation of the effect of aluminum alloy foam cavities on sound absorption coefficient. The aluminum alloy foams were with similar porosity but in three different cavity sizes: less than 106, 106-250, 200-1000 micron, the results showed that the size of suitable cavity in the studied range with the highest sound absorption was in the range of 250 to 500 microns (15).

Aliabadi .et all. in 2013 , showed in their research that the implementation of acoustic cabin is one of the most efficient practical interventions for sound exposure control in power plants (16).

Aminzadeh. et all. in 2012, conducted a study on the reduction of the output steam vent noise of thermal power plant at Sarcheshmeh Copper Complex. In this study, a silencer with a diameter 1.5 m and length 3 m was used to reduce noise pollution so they could reduce 30 dB of noise pollution (17).

Material and Method:

This study is an empirical theory research that is being conducted in the Thermal Power Plant which has not yet been fully utilized. Most of sources with high noise level will be conducted in the exhaust section of the gas turbine at 3 x 5 m as the following figure. Then the noise reduction was made by metal foam and data analysis was performed using Ansys software.

Fundamental of research:

In this exhaust, the manufacturer has installed a 16-sheet silencer in the shape of a rectangular cube and has reduced noise pollution from 103 dB up to 93 dB

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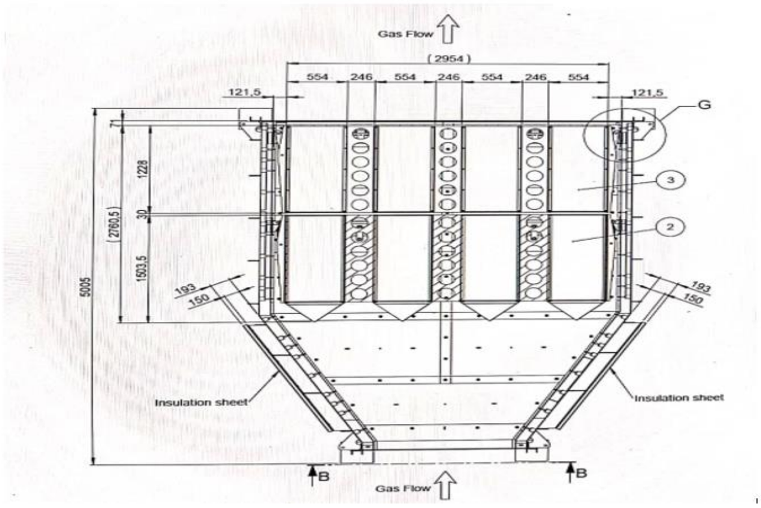

Fig .1. View of the stack silencer

measurements were conducted in the following conditions by XL2 sound analyzer (serial number: A2A-13858-E0 9) and the sound calibrator device (model: Nor1253 serial number:31975).
Environmental conditions: Temperature: 28 to 32 °C humidity: 10 to 13%
location: Kermanshah, Islamabad West
method: In all of the points P1 to P16 the sound level meter was placed 1.5 to 2 meters from the different parts of the turbine body, and in all points P1 to P16 the sound meter was placed 1.5 meters from the ground (Measurement standard ISO 3746). In Figure 2 shows the different power plant locations and sampling points.

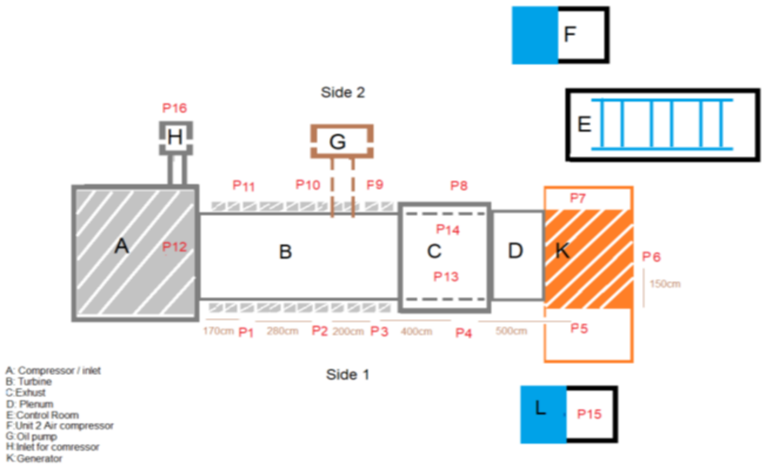

Fig.2 shows the locating the different parts of the power plant

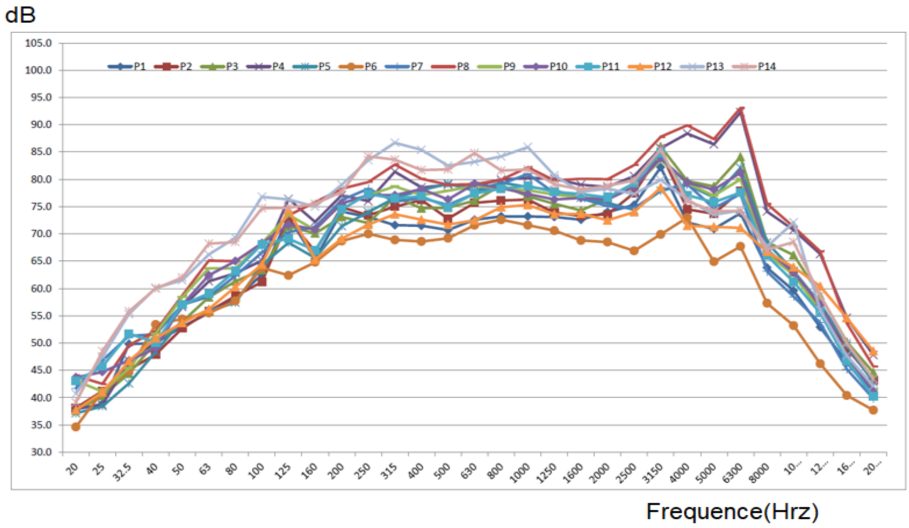

Fig.3. Measurement results at all locations around the gas turbine power plant

According to the conducted measurements of the same power plant (Fig. 3), the highest noise level pollution is in the turbine and exhaust, so obtaining the optimum height of exhaust, installation of a new silencer, absorbent layer thickness and its material were again conducted by ANSYS software.

Total view of Islamabad West gas power plant and Tarasht thermal power plant has been shown in Fig.4 and 5 in terms of similarity.

Fig.4. Overview of similar power plant (Kermanshah)

Fig. 5. Overview of power plant (Tehran)

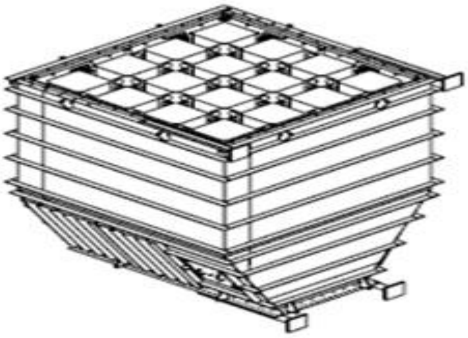

Fig. 6. View of the existing silencer

Fig. 7. View of the existing stack

the aerial view of the silencers at the Gas thermal power plant are connected by lattice steel sheets, in the shape of a rectangular cube and also a view of the exhaust with steel sheet has been shown. (Fig. 6 and 7).

Results and discussion:
A three-dimensional model was made to evaluate the sound intensity passing through the adjoint duct using finite element theory in ANSYS software. Then the modeling geometry (Fig. 8) and the modeling element were then determined and the results obtained from this analysis were presented.

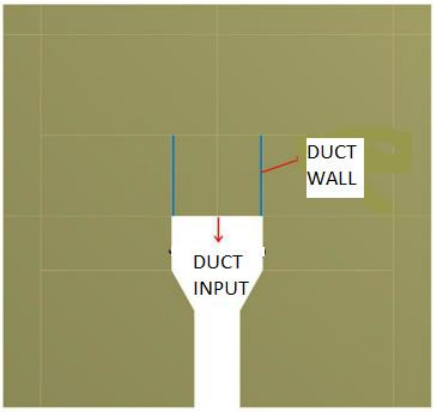

Fig. 8. Modeling geometry in ANSYS application environment

The size of the elements is very important in acoustic analysis. The size of the elements is dependent on the wavelength. During meshing an acoustic environment, it is better to be the size of the elements less than one sixth the wavelengths along propagation wave.

$$L=\frac{y}{6}=\frac{c}{6f}$$

In this regard, the L parameter is the element size along the wave propagation. As a result, the size of the element changes by changing wave frequency . The model must be properly designed to create a suitable and regular mesh. Fig. 9 shows a schematic of created meshing.

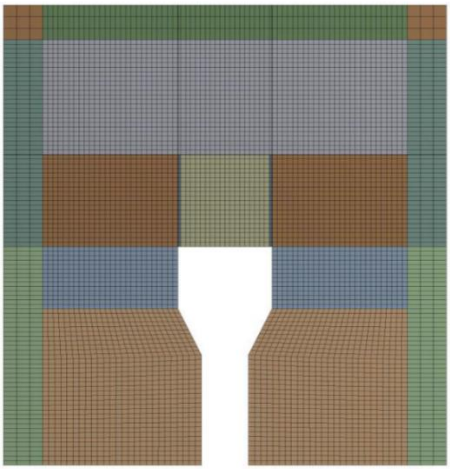

Fig. 9. Schematic of the template in the ANSYS application

Table 1: Sound Pressure Level values at different frequencies

Frequency (HZ)	63	125	250	500	1000	2000	4000	8000	Total
Spl (dB)	72	75	82	84	85	84	87	75	93

material model was selected for each duct layers and its surrounding environment.

Ductless model:

First, the distribution of output sound intensity was evaluated from the silencer without the presence of a duct. Model geometry in this stage includes air, boundary conditions, and excitation wave. Fig. 10 shows the pressure distribution at the frequency of 250 and 1000 Hz without duct, also the sound intensity due to sound wave at this frequency is shown in Fig. 11.

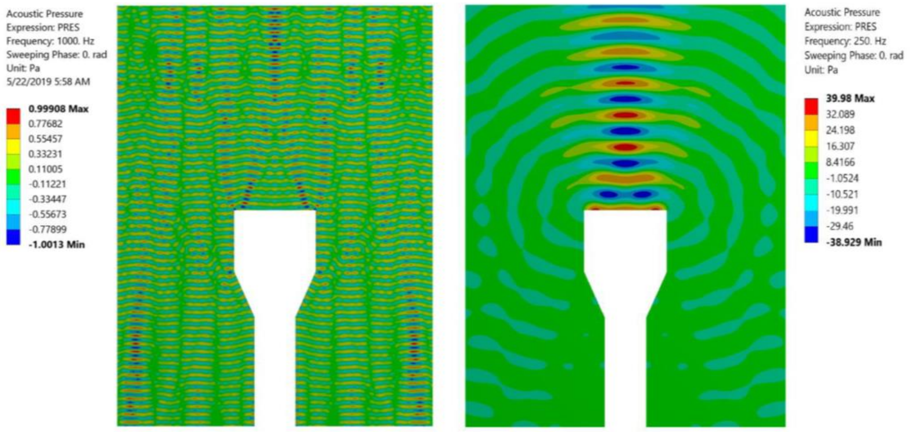

Fig.10. Distribution sound pressure level in the environment without ducts at frequencies of 250 Hz and 1000 Hz

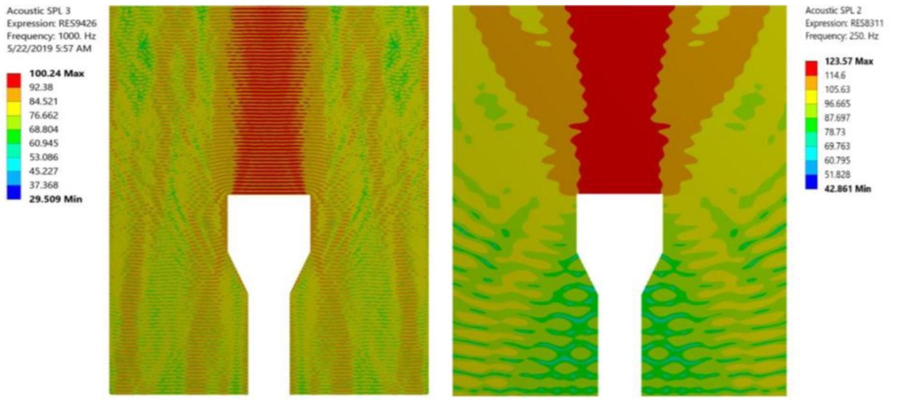

Fig. 11. Distribution of SPL in environment without ducts at frequencies of 250 and 1000 Hz

Ideal rigid wall:

In the second stage, the simulation was conducted in the presence of an ideal wall. In this state, a rigid wall has been considered instead of an adjoint duct wall, and distribution of the sound intensity around the wall was calculated for different frequencies. Fig. 12 shows the pressure distribution at the frequency of 250 and 1000 Hz, with the duct and Fig. 13 shows the sound intensity due to the sound wave in this frequency

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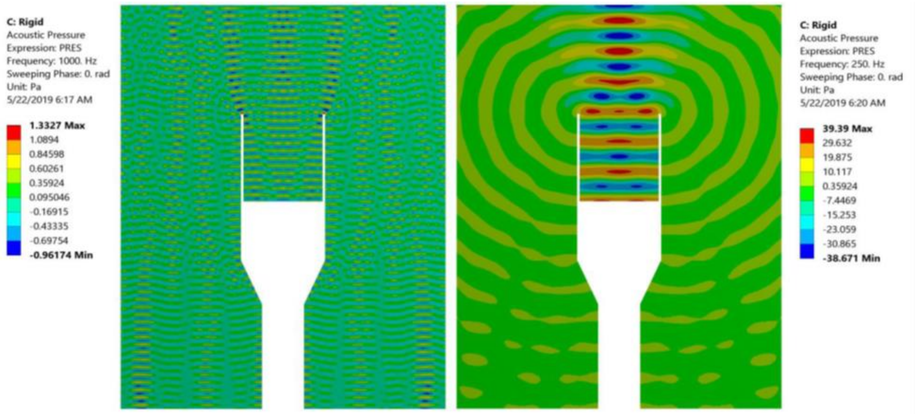

Fig.12. Pressure distribution in the environment with ideal wall assumption at frequencies of 250 Hz and 1000 Hz

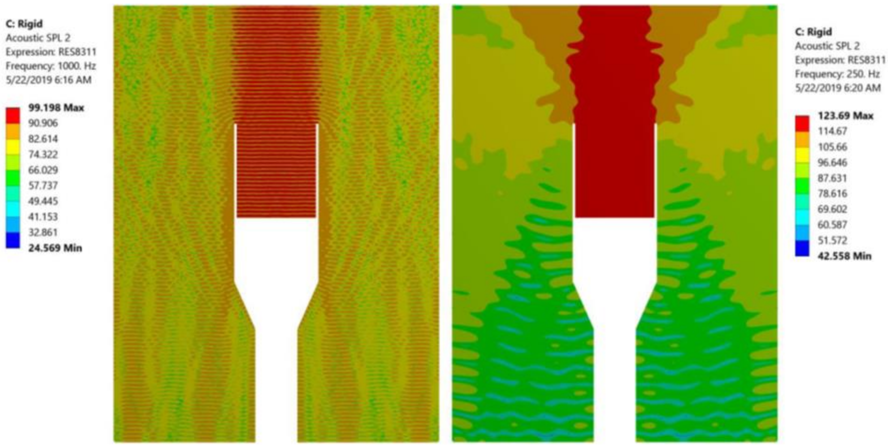

Fig. 13. Distribution of SPL the ideal assumed wall environment at the frequency of 250 Hz and 1000 Hz

Height effect study:

To reach the optimum conditions, three different heights were considered for the duct and the SPL (Sound Pressure Level) obtained was compared (Fig. 14).

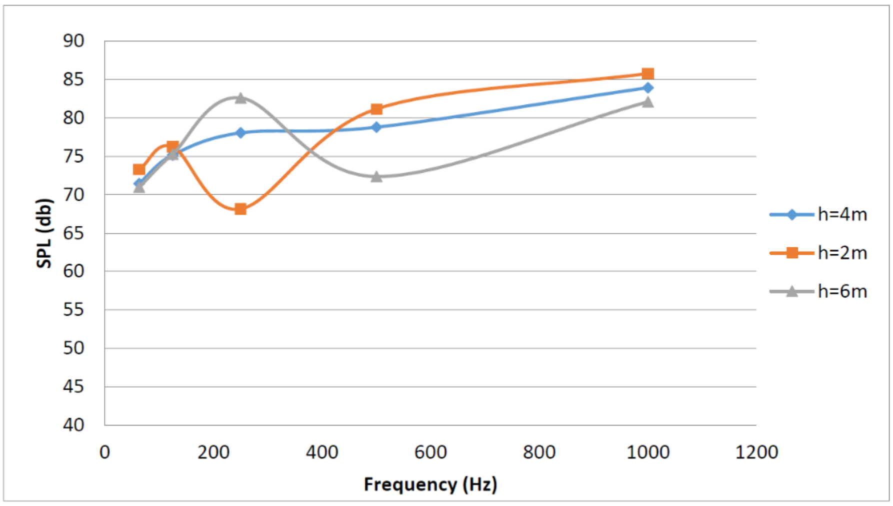

Fig. 14. Comparison of SPL frequency variations for three different duct heights at a point 1 m from the duct surface and 1.5 m from the ground

Using ANSYS software, the optimum height was about 6 meters and we had about 10 decibels of noise reduction. However, considering the structural weight gain and finished price, we considered the best height of 4 meters.

Multilayer wall:

The duct wall was designed as multilayer to improve the output noise absorption from silencer and reduction of the sound intensity around the power plant. The inner layer of the wall is a steel plate. Then a layer of rock wool was placed into the wall. The outer layer of the wall is also a thin steel sheet. Then the Sound Pressure Leve (Fig. 15 to17) due the excitation wave was provided in the presence of the multilayer wall at different frequencies. As can be seen at higher frequencies the sound pressure level at ground level is higher than at lower frequencies.

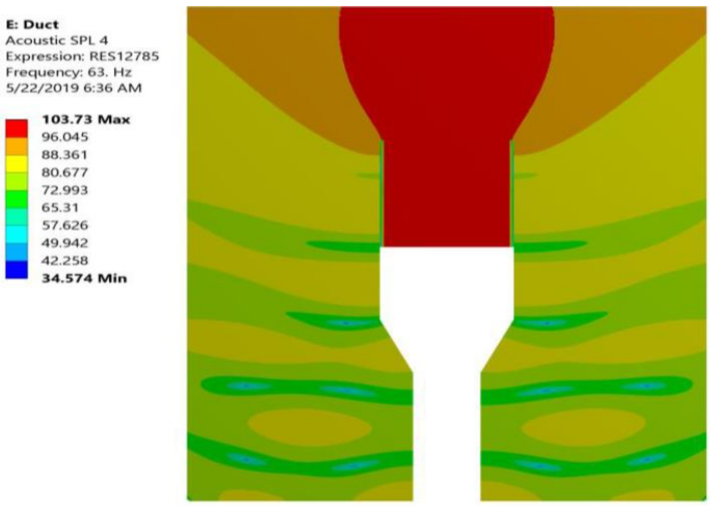

Fig. 15. Distribution of SPL in frequency with multilayer wall in frequency 63 HZ

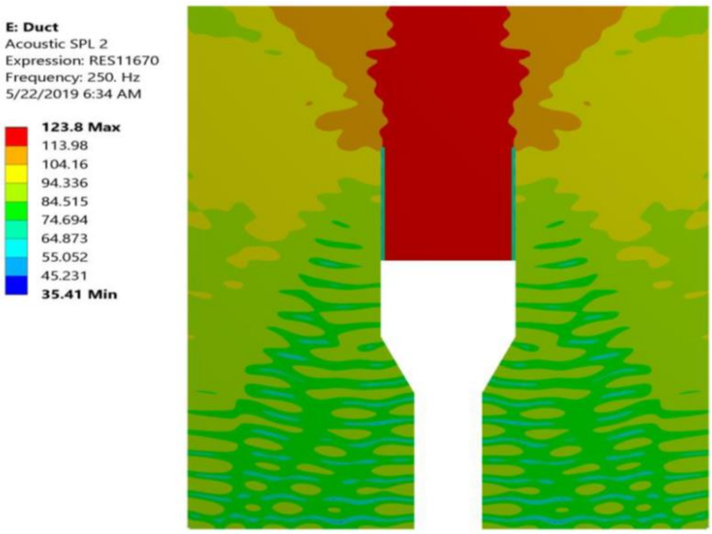

Fig. 16. Distribution of SPL in a multilayer wall environment at a frequency of 250 Hz

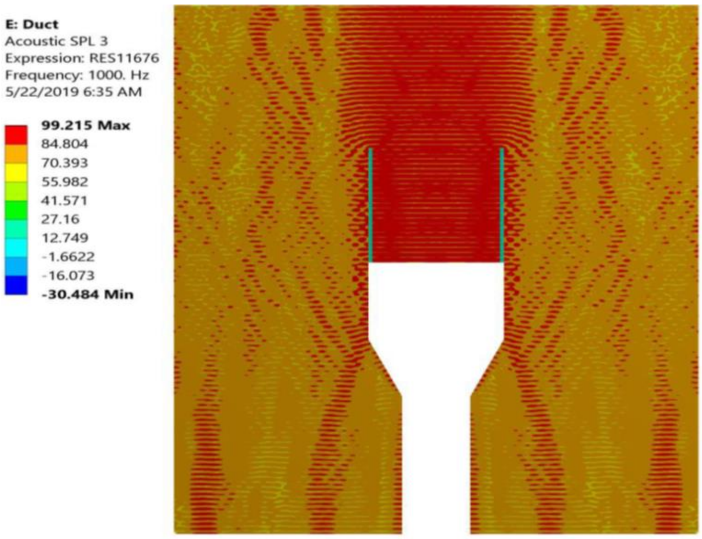

Fig. 17. Distribution of SPL in a multilayer wall environment at frequency 1000 HZ

Evaluation of the effect of aluminum metal foam on the insulation wall:

At First we attempted to measure the sound absorption coefficient at different frequencies. The result of the sound absorption coefficient test on aluminum foam samples is as following table.

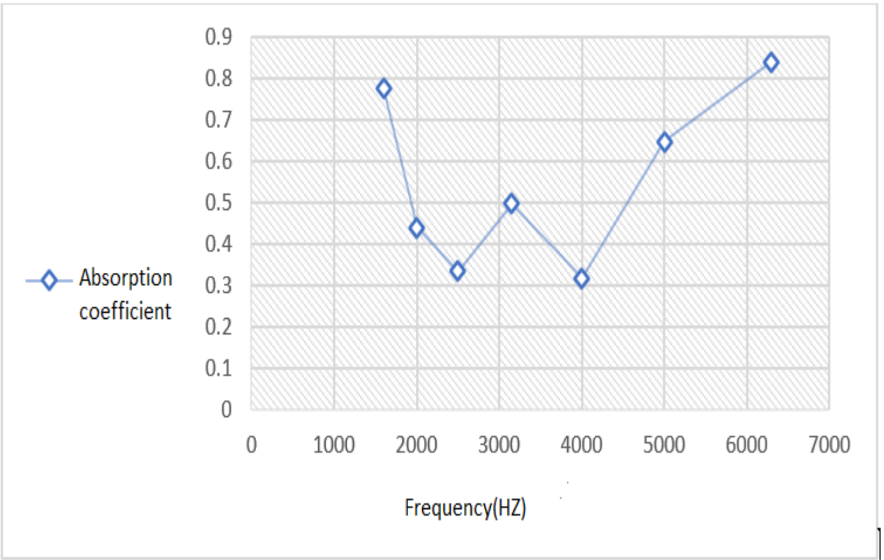

Fig. 18. Diagram of absorption coefficient of aluminum foam

As can be seen from the absorption coefficient at different frequencies, absorption coefficient was observed 0.77 at the low frequency of 1600 and 0.84 at the high frequency of 6300 .As shown in Figure 18, the absorption coefficient of low and high frequency aluminum foam provides acceptable numbers.

Conclusion:

In this study, a multilayer duct was designed to reduce the output sound intensity from the silencer. The properties of the materials were determined from valid references and articles. First, sound propagation simulation was conducted considering the primary material and dimensions and the level of sound intensity reduction was determined at a certain distance from the exhaust. Then the material applied in different layers of absorbent and reflective of noise, the layers thickness and exhaust height were parametrically evaluated in different states and the optimal conditions were determined based on the results. The input conditions of the gas to the adjoint duct were determined using power plant documents. According to the results, a multilayer wall can reduce the output sound intensity of the silencer.

This wall consists of steel, rock wool, fireproof cloth and lattice steel layers, respectively. If the exhaust height increases four meters and the insulation layer with 10 cm thickness and lattice steel plates of inner plates and fireproof cloth and rock wool stands with a 1 absorption coefficient, and 2 meters silencer develops along the primary silencer, we will have at least 10 dB reduction of noise pollution, and if we replace the closed cell aluminum foam with 1.5 cm thickness and 80% porosity of rock wool we will have at least 8 dB reduction of noise pollution that considering the aluminum foam is much more resistant from rock wool and have more stability to heat stress and less environmental pollution can be a strength replacement for rock wool.

Suggestions:

According to the research, it is recommended that the researchers evaluate more on the metal material, size, type of cavities and metal foam surface topography because the aluminum metal foam has good absorption coefficient at low frequencies and if it integrates with rock wool which has good absorption coefficient at high frequencies, can be very effective in reducing the noise of gas power plants and industries with dominant low frequencies.

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