Reduction in Noise Pollution of a Gas Power Plant under Construction Using Synthesis of Copper and Nickel Alloy Foam in a Simulated Setting

Sarmadi, Majid
Department of Environment West Tehran Branch, Islamic Azad University, I.R. IRAN

Nassiri, Parvin*+
Department of Occupational Health, School of Public Health, Tehran University of Medical Sciences, I.R. IRAN

Razavian, Fatemeh
Department of Environment, West Tehran Branch, Islamic Azad University, I.R. IRAN

Khoshmanesh, Behnoush
Department of Environment, Parand Branch, Islamic Azad University, I.R. IRAN

ABSTRACT: *Noise pollution is one of the challenges of installing equipment and developing industries. The control of noise generated by small power plants is a necessity for its use development. Designing the synthesis of copper and nickel alloy foam and using this foam to reduce noise pollution in the exhaust is an effective method to control and reduce noise pollution in power plants. This study aimed to synthesize copper and nickel alloy foam and compare the effect of results of Sound pressure level(SPL)changes in software ANSYS for three ductless, ideal wall, and multilayer wall modes at different frequencies. In this regard, the adjunct duct is modeled in 3D by the software ANSYS, and the output sound intensity of the duct in the acoustic setting is analyzed in several different modes. The results show that three different modes in the exhaust output indicate that the multilayer wall at most frequencies reduces the sound pressure level relative to ductless or ideal wall modes.*

KEYWORDS: *Noise pollution; Copper and nickel alloy foam; Gas power plant.*

INTRODUCTION

The problem of noise pollution is not specific to developing countries but is one of the main problems in developed countries. Today, undesired noise and noise pollution accidents have become more and more prevalent because discussions such as a more suitable environment and a better lifestyle were addressed [1]. One of the sources of noise pollution is industries. In developing countries, continuous electricity generation can play a vital role in industrial and social development; in this sector, power plants as the main centers of electricity generation

* *To whom correspondence should be addressed.*
+ *E-mail: nassiri@sina.tums.ac.ir*
1021-9986/2022/7/2400-2405 6/$/5.06

in addition to the activity, cause many environmental problems, including high noise. Power plant equipment includes the exhaust and booster pumps, fans, and compressors as the most important sources of sound production, which in some cases exceed the recommended permissible sound levels [2]. Therefore, researchers were interested in finding materials with lower weight and lower cost that can absorb sound waves at high frequencies [3]. Various materials such as soft polymer foams, mineral fibers glass wool are converted to heat via the friction of sound waves with the fibers and the air inside them, thus finally absorbing sound transmission. The harmful effects of these materials on health are evident. One of the solutions provided is using metal foams. These foams have sound absorption properties and are a good option to control noise pollution, especially in industrial settings. The important factors affecting the sound absorption coefficient in metal foam include porosity, pore size, pore opening, thickness, air flow resistance, pore morphology, pore opening or closing, angle of the impact of sound waves, and airflow resistance [4 and 5]. In recent years, much attention was paid to metal foams. This is due to their very low density, high strength, specific rigidity, and their unique functional properties [6]. Far-field noise measurements show that the most permeable metal foam reduces noise (up to 10 dB) [7]. in order to quantitatively evaluate the advantages, in terms of noise emissions, of the application of modern electric power an acoustic pollution prediction model was developed. [8] Various studies were conducted in this regard, including a study by *Woods* (2009) at NASA Research Center on reducing aircraft engine noise pollution using open-cell metal foam. The researchers installed a metal foam around the aircraft engine. The metal foam was made of stainless steel and silver metal like a compact honeycomb. Finally, regarding the study results, using the foam as a jet engine box [9]. A study conducted by *Erdeniz et al.* (2017) showed that porous metal materials with open-cell structures due to metal structures with improved functional properties and, in particular, high resistance to mechanical and chemical materials had logical effects on sound absorption to free cell morphology [10]. In a study by *Zhai et al.* (2018), sound adsorption performance on super alloy nickel metal foam with 92% porosity and cell size of 300 to 900 μm achieved a sound absorption coefficient of 0.9 at a frequency between 1 kHz to 6 kHz [11]. A study by Pei-sheng (2018) using nickel foam showed that 7.5 mm thick foam sample formed by the 5-layer foam panel (thickness: 1.5 mm; porosity: 96%; mean diameter: 0.65 mm) can produce an excellent sound absorption effect at 4000 Hz with an absorption coefficient of about 0.8 [12]. The metal foams are divided into two open and closed cells. The closed-cell foams are a set of pores that do not cross each other but in open-cell foams pores cross each other, so they have an effective surface area (an accurate measurement of surface area and porosity) [13]. In recent years, many studies were conducted on the production of metal foam using various metals. For example, aluminum, copper, and steel foams, super titanium alloys and nickel-titanium, and copper-nickel alloys are among the metals which were the focus of much research [14]. The metal foams have pores within their structure known as porosity and are classified according to their size, shape, and type [15]. it is necessary to conduct pre-design studies of power plants to model noise pollution. Therefore, this study is designed to reduce the noise pollution of a 25 MW gas power plant near a residential area and a power plant simulator using copper and nickel alloy foam using ANSYS software. it is necessary to conduct pre-design studies of power plants to model noise pollution. Shaped categories due to their porosity according to their geometry [16]. When enclosing, separating, chambering, and using sound storage can be used when sound reduction of more than 10 dB is considered. The metallic foam method can be used in sound storage resistant to both 600 ° C exhaust heat and moisture [17].

Despite studies conducted on the effect of metal foam and its types on sound absorption due to its lack of use to reduce noise pollution in power plants in the country, few studies were conducted on the effect of these types on industrial environments, especially thermal power plants. On the other hand, in order to reduce the cost of building a power plant and also to reduce noise pollution, it is necessary to conduct pre-design studies to build a power plant to model noise pollution. Therefore, this study was predicted by ANSYS software to reduce the noise pollution of a 25 MW gas power plant near a residential area and a conference hall using copper and nickel alloy foam.

EXPERIMENTAL SECTION

This study is an experimental theory that was conducted aimed to reduce noise pollution in a gas power plant

Fig. 1: Increase of porosity level by electrolysis method.

Fig. 2: Increase the strength and thickness of the metal foam.

Fig. 3: Preparation steps of the metal foam 3 cm in diameter.

under construction using copper and nickel alloy foam in a simulated setting. For this purpose, copper, and nickel alloy foam was first synthesized by the following method. In the first stage, grid or polymer polyurethane foams with a continuous network with a pore diameter of 500 microns are dipped in an alkaline solution to remove any impurities, then oxidize (etch) the polymer surface with acid and put in a chamber under vacuum. In the next stage, we layered the polymer foam. For this purpose, the desired metals (nickel and copper wires) through the electrical arc evaporated in the electric furnace (vapor phase under vacuum or metal vapor deposition (Physical Vapor Deposition (PVD)), and placed on the primary polymer or polyurethane structure to cover the polymer surface. Thus, a thin film of copper and nickel alloy was formed (physical vacuum coating). Then, due to fragility, the chemical method increased its thickness and strength (Fig.1). The electrolysis method was used to increase the porosity surface. Thereafter, in the electric furnace, the primary foam was removed, and finally, an all-metal structure with a thickness of 0.4 cm was obtained (Fig. 2).

After the copper and nickel alloy foam was made, the absorption coefficient of the sound of metal foam was measured by the impedance tube manufactured by a Danish manufacturer (B&K Co. Model 4206) in the stationary wave tube based on ISO10534-2 standard. Since the impedance tube probe had two diameters of 3 and 10 cm and its cross-sectional area was spherical, we prepared the tubes at the same diameter as the tube inlet (Fig. 3). To measure the sound absorption coefficient at high frequencies, an impedance tube with a diameter of 3 cm was used. For this reason, another sample with a diameter of 3 cm was prepared. For this purpose, we first prepared diamond steel wedges with a lathe. Then, we put it on a wooden surface, and by tapping, we could make a 3 cm diameter metal foam. Then, we put it in the impedance tube. Then, the acoustic properties of metal foam were measured in terms of sound absorption in the impedance tube.

The sound pressure level due to installing a metal foam duct of a 25 MW power plant was investigated using the software ANSYS R3 2019. In this software, the pressure level of the adjoining duct sound was prepared. The geometry

Table 1: The changes in the metal foam absorption coefficient according to the frequency

F (Hz)	63	125	250	500	1000	2000	4000	8000
α	0	0.01	0.03	0.05	0.08	0.11	0.24	0.4

Table 2: The absorption coefficient of open cell double layer copper and nickel alloy foam.

F (Hz)	Aasorprion coefficient
1250α	0.31
1600	0.31
2000	0.35
2500	0.44
3150	0.51
4000	0.59

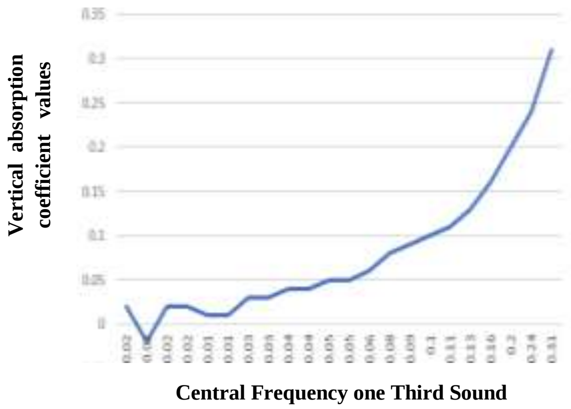

Fig. 4: Vertical sound absorption coefficient in stationary wave tube.

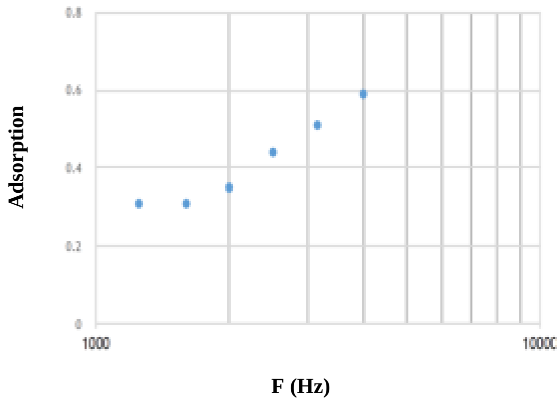

Fig 5: The absorption coefficient of open-cell double-layer copper and nickel alloy foam

of modeling and the model element method are specified, and then, the properties of the elements used in the acoustic analysis are expressed. Following the analysis setting and boundary conditions of the problem, the following results were obtained.

RESULTS AND DISCUSSION

The results of this study are presented in two parts

The results of the synthesis and measurement of the absorption coefficient of the metal foam

After synthesizing single-layer copper and nickel alloy foam thickness (0.4cm), the samples were sent to the laboratory to measure the sound absorption coefficient, the results of which are as follows. The results showed that the central frequency one-third at 6300 Hz sound vertical absorption coefficient was the highest i.e., 0.31, and at the frequency of 63 Hz, it was the lowest i.e., -0.02 (Fig. 4).

The above results indicated that the metal foam at a low frequency had no good absorption coefficient and at frequency 8000 Hz had an absorption coefficient of 0.4 (Table 1).

According to the above results, at the next stage, after increasing the thickness of the metal foam, the adsorption coefficient was again measured. The results at this stage showed that at the frequency of 4000 Hz absorption coefficient increased from 0.21 to 0.59 (in single layer mode) and thus increased by increasing thickness, the absorption coefficient of copper and nickel alloy foam increased (Table 2 and Fig. 5).

The results of the simulation of noise pollution reduction using the software ANSYS

At this stage, the results of spl changes by software ANSYS for three modes of without duct, ideal wall, and multilayer wall at different frequencies were compared (Fig. 6).

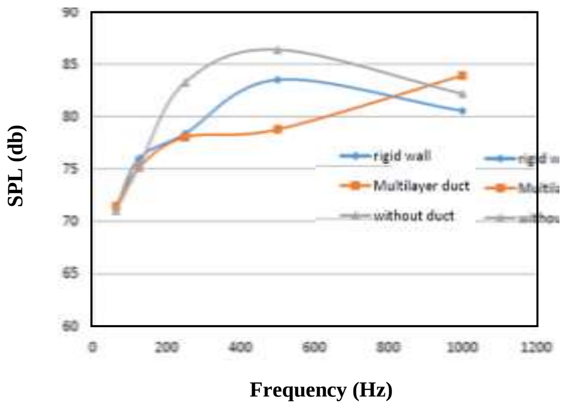

Fig 6: Comparison of SPL frequency changes (0-1000 Hz) in three different models.

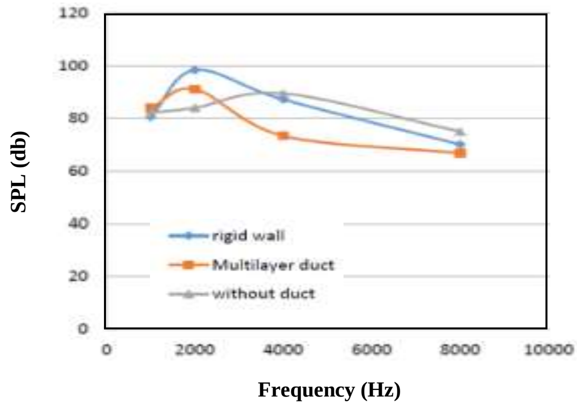

Fig. 7: Comparison of SPL frequency changes (1000-8000 Hz) in three different models.

Figs. 6 and 7 show that the multilayer wall at most frequencies reduces the sound pressure level relative to the ductless mode.

CONCLUSIONS

To reduce noise pollution, we used nickel and copper alloy metal foam with a thickness of 4 mm. Regarding the results, the sound absorption coefficient was not appropriate. In the next stage, another sample was prepared, a double layer of copper foam and open-cell nickel with a thickness of 8mm the results showed that the new sample had a good absorption coefficient. A study by *Zhai* aimed to determine the acoustic absorption coefficient of a nickel alloy in a 50 mm sample, the acoustic metal adsorption performance of nickel alloy was 0.9 [11] which showed a significant difference from the results of two-layer copper and nickel alloy, with a thickness of 80 mm. In another study, *P. et al.* for determining the acoustic absorption coefficient of nickel using a sample using five-layer foam plate thickening (thickness: 1.5 mm; porosity: 96%; mean pore diameter: 0.65 mm) made foam with a thickness of 7.5 mm. The results of the sound absorption coefficient of this metal at frequencies above 4000 Hz was about 0.8 which was closer to the results of double-layer copper and nickel alloy foam [12]. *Hakamada et al.* (2006) reported that no clear relationship was found between pore size reduction and sound absorption coefficient [18], whereas a significant difference was found in the metal foam of the open-cell copper-nickel alloy. *Dziechiowski* (2011) designed a chamber using a steel sheet covered with a metal foam inner layer. This technique is used for noise damping to control noise pollution in the power plant [19].

Software ANSYS was used to predict the noise pollution of a power plant under construction. Therefore, it was predicted that at high frequency and 0.8 cm thickness, copper and nickel alloy foam reduced the sound intensity level appropriately.

In another study by *Navasada et al.* (2013), metal foam with a diameter of 500 microns revealed the best capacity of sound absorption coefficient [20], which corresponded to the diameter of the selected pores of copper and nickel alloy.

According to the study results, the multilayer wall (0.8 cm thick copper and nickel alloy foam) at most frequencies reduces the sound intensity compared to the ductless mode. This foam is much more durable than rock wool and is more resistant to heat stress, and causes lower environmental pollution, copper and nickel alloy foam can be a very good replacement for rock wool on the wall or silencer of a power plant chimney.

Acknowledgments

We appreciate the managers of Tarasht Power Plant who collaborate with us while providing the necessary support to conduct this study.

Received : Jun. 11, 2021 ; Accepted : Oct. 25, 2021

REFERENCES

[1] Saeki T., Fujii T., Yamaguchi S., Harima S., Effects of Acoustical Noise on Annoyance, Performance and Fatigue During Mental Memory Task, *Applied Acoustics*, **65(9)**:913-21. (2004).

[2] Kisku G., Bhargava S., Assessment of Noise Level of a Medium Scale Thermal Power Plant, *Indian Journal of Occupational and Environmental Medicine*, **10(3)**: 133 (2006).

[3] Byakova A., Gnyloskurenko S., Bezimyanniy Y., Nakamura T., Closed-Cell Aluminum Foam of Improved Sound Absorption Ability, *Manufacture and properties. Metals*, **4(3)**: 445- 454 (2014).

[4] Guan D., Wu J.H., Wu J., Li J., Zhao W., Acoustic Performance of Aluminum Foams with Semispan Cells, *Applied Acoustics*, **87**:103-108 (2015).

[5] Manufacture B.J., Characterization and Application of Cellular Metals and Metal Foams, *Progress in Materials Science*, **46(6)**: 559-632 (2001).

[6] Cs. Kadar P.K., Lendvai J., Rajkovits Zs., Energy-Absorbing Properties of Metal Foams, *Journal of Alloys and Compounds*, **378(1-2)**: 145-150 (2004).

[7] Alejandro Rubio Carpio, Francesco Avallone, Daniele Ragni, Mirjam Snellen, Sybrand van der Zwaag., Mechanisms of Broadband Noise Generation on Metal Foam Edges, *Physics of Fpams*, **30**:105110 (2019).

[8] Salucci F., Riboldi C.E.D., Trainelli L., Rolando A., Marian L., "A Noise Estimation Procedure for Electric and Hybrid-Electric Aircraft", *AIAA SciTech 2021 Forum*, January 2021, p. 1-9 (2021).

[9] Woods T., "Metallic Foam Reduces Airplane Noise", NASA's Glenn Research Center;(2009)

[10] Erdeniz D., Schaedler T.A., Dunand D.C., Deposition-Based Synthesis of Nickel-Based Superalloy Microlattices, *Scripta Materialia*, **138**: 28-31 (2017).

[11] Zhai W., Yu X., Song X., Ang L.YL., Cui F., Lee H.P., Li T., Microstructure-Based Experimental and Numerical Investigations on the Sound Absorption Property of Open-Cell Metallic Foams Manufactured by a Template Replication Technique, *Materials & Design*, **137**: 108-116 (2018).

[12] Liu P.-s., Xu X.-b., Cheng W., Chen J.-h., Sound Absorption of Several Various Nickel Foam Multilayer Structures at Aural Frequencies Sensitive for Human Ears, *Transactions of Nonferrous Metals Society of China*, **28(7)**: 1334-1341 (2018).

[13] Boomsma K., Poulikakos D., Zwick F., Metal Foams as Compact High Performance Heat Exchangers, *Mechanics of Materials*, **35(12)**:1161-1176 (2003).

[14] Alhusseny A.N.M., Nasser A.G., Al-Zurf N.M., "High-Porosity Metal Foams: Potentials, Applications, and Formulations", IntechOpen. (2018).

[15] Sing K.S., Reporting Physisorption Data for Gas/Solid Systems with Special Reference to the Determination of Surface Area and Porosity, *Pure and Applied Chemistry*, **57(4)**: 603-619 (1985).

[16] Rouquerol J., Rouquerol F., Llewellyn P., Maurin G., Sing K.S., "Adsorption by Powders and Porous Solids: Principles, Methodology and Applications", Academic Press (2013).

[17] Golmohammadi R., Noise & Vibration Engineering, 4 ed (Persian), Hamadan: Daneshjo(2010).

[18] Hakamada M., Kuromura T., Chen Y., Kusuda H., Mabuchi M., Sound Absorption Characteristics of Porous Aluminum Fabricated by Spacer Method, *Journal of Applied Physics*, **100(11):** 114908. (2006).

[19] Dziechciowski Z., Selection of Plate Components of Operator's Cabin Walls in Aspect of Thermal Insulation and Transmission Loss, *Archives of Acoustics*, **36(1)**: 109-119 (2011).

[20] Navacerrada M., Fernández P., Díaz C., Pedrero A., Thermal and Acoustic Properties of Aluminium Foams Manufactured by the Infiltration Process, *Applied Acoustics*, **74(4)**: 496-501 (2013).