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NOISE CONTROL SOLUTION FOR DIESEL GENERATOR – A CASE STUDY

Abstract: *Today's modern cities represent the complex interconnection of many districts. It is not uncommon that some of them are both business and residential, which creates positive and negative mutual influences. Business operations nearby residential buildings can, in many cases, create a noise disturbance that affects the acoustical comforts of the residents. Usual types of noise sources in these situations are HVAC systems and generators that tend to produce an excessive amount of noise. To avoid complaints and lawsuits, business owners often seek advice from professionals in noise management to solve the problem. This paper addresses a case where a backup diesel generator creates noise disturbance affecting the business-residential building, and provides a possible solution to the problem.*

Keywords: noise engineering, noise simulation, Predictor LimA.

INTRODUCTION

Generators, as a backup system nowadays, are integral parts of many businesses. Modern office buildings are equipped with computers, informational networks and server machines that need to be always operational. Companies such as banks rely heavily on these systems, and digital information flow interruption, due to the fact that power grid failure can result in significant business losses and inconvenience to clients. In those cases, diesel backup power generators represent a safe choice to provide short term power and keep the systems operational until the power from the electrical grid is restored.

Diesel generators are essentially internal combustion engines that burn fossil fuel, converting chemical potential energy via the mechanical system to electric energy. A controlled explosion inside the combustion chambers, movement of the pistons and exhaust systems produce a significant amount of noise in the vicinity of the generators.

In modern cities, within business districts, it is very common that office buildings are clustered together. Besides office spaces, these buildings can be also residential and noise created by the operation of the backup systems can significantly affect the resident's quality of living.

To solve the problem of noise being generated by electrical backup systems, noise engineers undertake different solutions and methods. In this process, it is very important to understand the principles of these systems operation, in order to avoid potential damage once a noise control solution is applied. In the particular case of diesel generators, a potential problem is overheating that can occur during hot summer days. In addition, to burn fuel, these engines require oxygen and a sufficient amount of airflow must be provided to the intake and exhaust manifolds [1]. This creates constrictions on the noise control design solution as the generator cannot be

simply enclosed completely inside the noise-insulating box.

This paper is related to the study of the real case scenario, where noise gets emitted by a diesel backup generator. To assess the problem, noise level measurements have been performed and traffic content of the nearby street analyzed. Based on the gathered data, a simulation of the noise propagation has been done using the software package Predictor LimA. Within the simulation, two cases of noise control solution have been analyzed and the results of the analysis presented.

PROBLEM ANALYSIS

Diesel backup generator "Cummins C440 D5" is located in the open area, nearby the technical building of an international bank that operates in Serbia. Across the access street, there are two business-residential buildings that are affected by operating diesel generator noise. Fig. 1 shows the positions of the generator (noise source) as well as the position of the affected buildings (noise receivers). Fig. 1. represents the 3D model of the buildings superimposed on the Google Earth GIS layer.

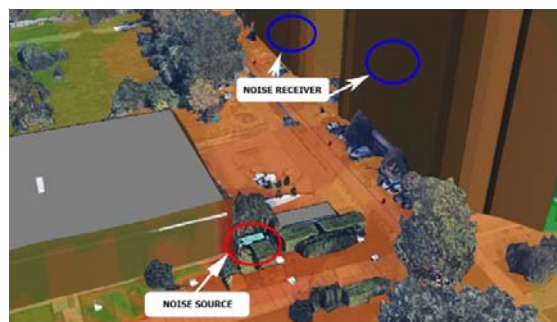


Figure 1. Noise source and receiver positions

A small street near the noise source, that provides access to the parking lot, has a low traffic intensity. By a method of traffic counting, it has been established that around 200 cars pass during the day (08:00 – 18:00),

around 60 cars during the evening (18:00 – 22:00), while during the night (22:00 – 06:00) around 20 cars pass along the street. Observation has been done within one whole day in the middle of the week. These data have been later used in the simulation.

For the purpose of noise level measurements, four measurement locations have been chosen. A-weighted sound pressure level (SPL) and spectrum have been measured when the generator was at full load, as well as when it was turned off (residual noise). The device that has been used is the class 1 sound analyzer Brüel & Kjær Type 2250. During residual noise measurements, attention has been paid that no other sources are present (traffic, communal activities, environmental, etc.). Two measurements have been performed near the noise source at 1 m distance and 1.5 m height, the third measurement at 10 m distance from the source, while the fourth has been taken near the noise receiver at around 18 m from the noise source (see Fig. 2.). The duration of each measurement taken was 3 min.

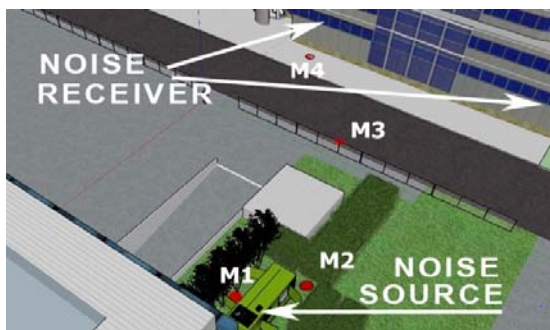


Figure 2. Measurement location at the site

Reduction of the noise can be typically solved by insulation at the noise source, placement of a barrier in the noise pathway, or by increasing insulation at the receiver position partitions (façade and windows). In most cases, where it is possible, the first option is the most effective as it requires the least amount of material and investment, providing the highest noise reduction. In this paper, noise reduction by enclosing the generator has been considered.

For the purpose of reducing the graphical data, only one measurement of the third-octave band spectrum has been shown, at the measurement position M1, in the case when the generator is operational (Fig. 3. - top) as well as when it was turned off (residual noise, Fig. 3. - bottom). By observing the broad spectrum A-weighted SPL, it can be seen that generator at 1 m increases noise from 55.9 dB to 78.3 dB. The reduction of 22.4 dB difference without completely enclosing the generator could be very difficult to reach. However, it may not be necessary to have such high noise reduction, given the fact that the noise exposure is not constant during the entire day and the generator is operational only when the electrical power grid fails to deliver electricity.

The most problematic positions, where noise disturbance is present, are the first several floors of the noise receiver building. At the time of measurement, it was not possible to measure the noise levels at the façade

of those floors, so data had to be extrapolated from a limited number of measurements. Without an extensive amount of gathered data, the best solution to the problem can be achieved by simulation of the noise propagation. According to the latest EU directives and CNOSSOS methodology [2][3], noise in urban areas should be measured at a height of 4 m. For this reason, simulation has been performed at the height of 4 m (first floor), as well as 12 m (4-5 floor).

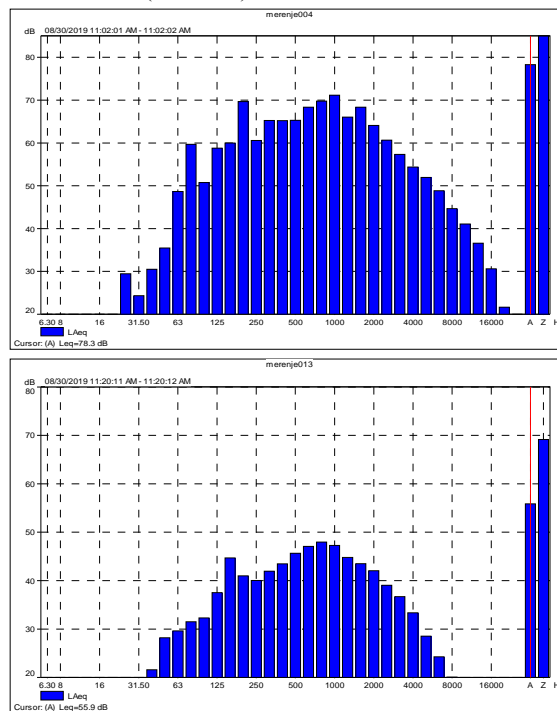


Figure 3. The third-octave spectrum of the A-weighted SPL when a generator is active (top) and turned off (bottom)

SIMULATION METHOD

Analysis of the noise propagation, generated by a backup diesel generator, has been done using the software package Predictor LimA. This package contains different methodologies for noise propagation assessment. Even though the latest CNOSSOS methodology is the most comprehensive, it also requires the most amount of input data. Due to its complexity, it may not be the best suited for noise assessment in smaller environments [3]. For this reason, ISO 9613. 1/2 (1/3 Octave) calculation model has been used [4].

Once the model is chosen, the Geographic Information System (GIS) layer of the simulation area has been chosen. The software supports the integration with Google Earth that must be also installed on a PC. By typing a search parameter for the area of interest (address, name of business building, etc.) an image with GPS coordinates can be loaded into Predictor LimA. Drawing of the object is then performed in the top-view perspective, and for each object, its height can be specified. In the drawing stage, noise sources are also specified. For this simulation, a diesel generator has been modelled as a point source. The acoustical power

of the generator, in third-octave band resolution, is calculated based on the measurement performed at 1 m distance from the sound source [5]. To account for the worst-case scenario, the noise source is set to be active 10 hrs during the day, 4 hrs during the evening, and 8 hrs during the night. In addition, traffic noise from the small street has been denoted as a secondary noise source with 200 cars during the day, 60 cars during the evening and 20 cars during night, all with an average speed of 20 km/h. The last stage of preparation is setting up the calculation grid. For the purpose of this simulation, both horizontal ground grid (following terrain) and vertical grid (modelled buildings) have been defined. After simulating 4 m and 12 m height, the software computes the contours representing the distribution of the noise level in the area. The results are presented in Fig. 4. Circles that appear along the dashed line represent the noise sources generated by traffic.

Simulation of the two different acoustic enclosure solutions

After simulating the noise propagation of the diesel generator, a simulation of two noise control solutions has been added to the simulation. The first solution is denoted as “partial enclosure” and considers the placement of barriers at two sides of the noise source. The idea is that the direct noise pathway, as well as the back reflection from the building closest to the source, should be blocked by highly absorptive barriers composed of acoustic perforated panels. The height of the barrier is set to be 3 m while the acoustical properties

(transmission loss) have been calculated based on the absorption coefficient of the perforated panels [5]. Characteristics of the perforated panels will be discussed in the next section. In essence, this solution represents a trade-off in noise reduction efficiency and the size of the potential investment. The top of the enclosure for an intended practical solution is composed of acoustic louvers which cannot be simulated by the used software. Thus, simulation has been performed without this section by using vertical segments of the barrier only. Simulation results are presented in Fig. 5.

The final step of the simulation is the solution denoted as “total enclosure”. Even though it is not a simple box around the generator, as previously stated that the device needed cooling and airflow, the term “total” means that all four vertical sides of the generator are enclosed by barriers. On the top, vertical angled acoustical louvers are considered, but it was not possible to simulate this segment. This solution requires more acoustic material, but it will also reduce more noise than the partial enclosure. Results of the simulation can be seen in Fig. 6.

By observing Fig. 4-6, it can be seen that placing enclosures reduces the noise levels around the generator, especially near the façade of the building denoted as noise receiver. The effect is most prominent in the case of the total enclosure, where noise is contained around the generator (Fig. 6.). Presented results are related to the simulation at 4 m height. For 12 m height, the situation is even more visible, but results are not presented due to the limitation in paper length.

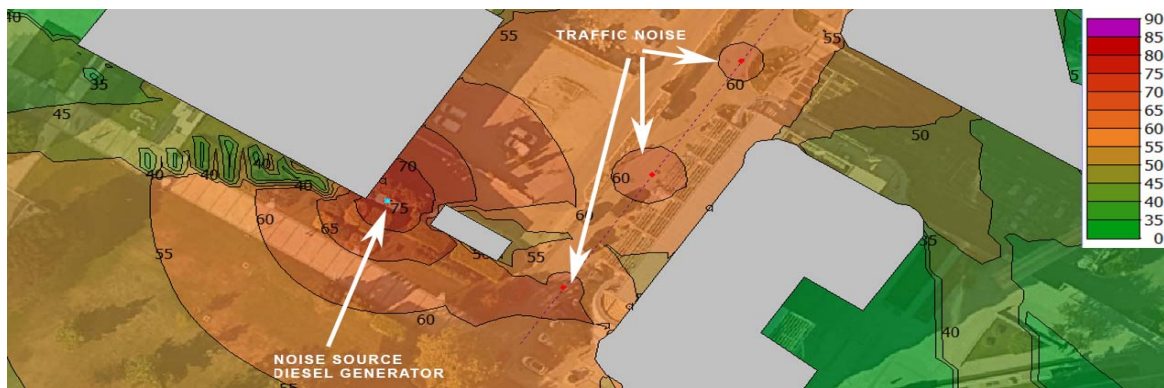


Figure 4. Simulated noise contours of a diesel generator, in the case where there is no enclosure

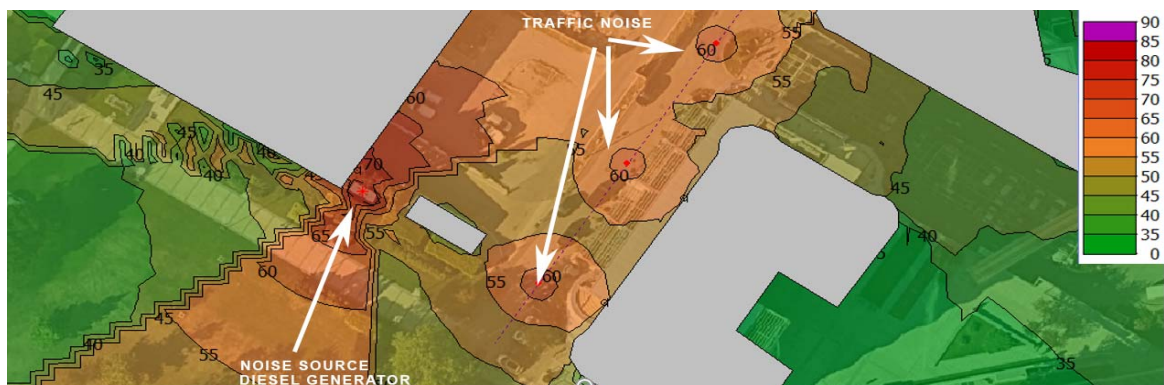


Figure 5. Simulated noise contours of a diesel generator, in the case where the partial enclosure is applied

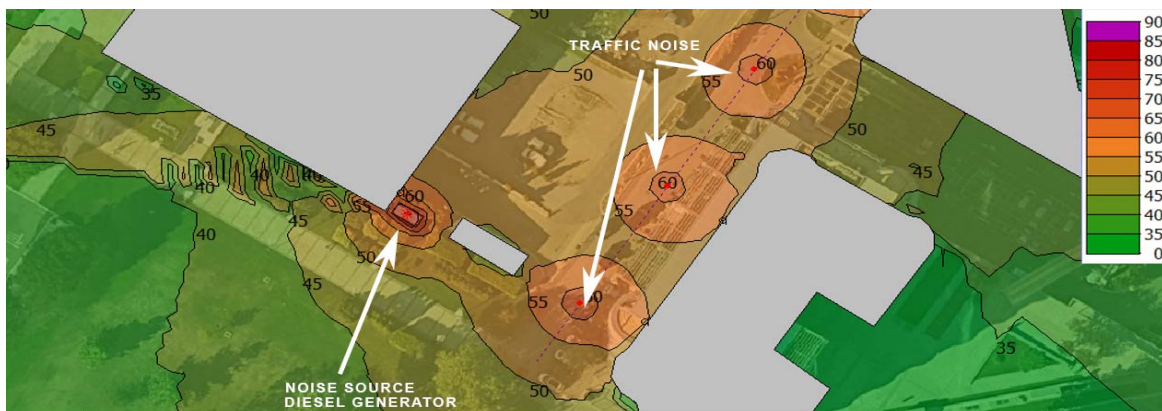


Figure 6. Simulated noise contours of a diesel generator, in the case where the total enclosure is applied

Perforated acoustic panel

Simulation of the absorption coefficient is based on the measured data gathered at the measurement position M1. Using a methodology available in acoustic engineering literature [6] [7], by changing the parameters of the perforated acoustic panel, the absorption curve can be fitted to match measured noise spectra as close as possible (Fig. 7.). By applying noise reduction through absorption in the panel, it can be seen that the perforated panel is the most effective in between 250 Hz and 6.3 kHz (Fig. 8.). This is very close to the measured data at position M1 when the generator is operational. Spectrum components up to the 160 Hz in measured data will be reduced much less, as barrier losses efficiency towards the lower frequencies.

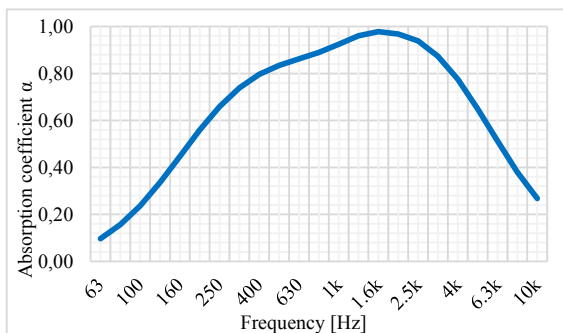


Figure 7. The simulated absorption coefficient of the perforated panel

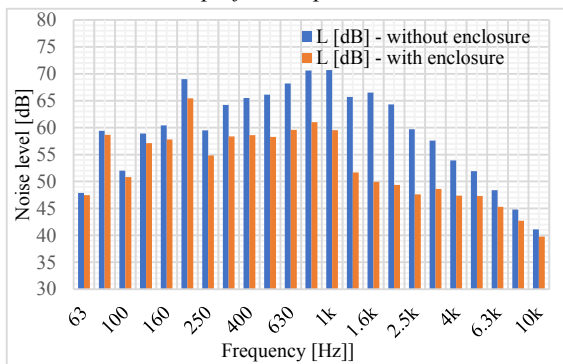


Figure 8. Noise reduction through absorption in panel

The simulated absorption coefficient in Fig. 7 is true only for the sound that reaches the barrier at the normal incidence angle. It is expected that the curve will somewhat deviate with different angles of sound impact. This is far less important in the case of the total enclosure since it is expected that sound shall perform multiple reflections inside the enclosure, whereas the chance of normal incidence shall increase.

DESIGN OF THE NOISE CONTROL SYSTEM

The results obtained using simulation provide valuable inputs for noise engineering to devise an applicable solution. In reality, many challenges cannot be simulated and require some knowledge about machinery operation that is being acoustically treated, field observation as well as consults with engineers in different areas. Some of the problems that occur are simply a matter of constricted space around the observed noise source. This particular case has the following challenges:

- Perforated panels must be structurally strong and resistant to weather conditions.
- The entire enclosure, composed of barriers must be supported by a frame that can withstand the static load.
- Around the generator, there is soft ground.
- Some trees constrict the placement of the barrier.
- Service doors on the generator are 1m wide and it is a requirement that they can be fully opened.
- A generator requires sufficient airflow for cooling.
- Intake and exhaust manifold require airflow to operate.

The solution for the perforated panels is to use a composite structure. To avoid corrosion, the steel frame must be coated with a PVC layer. The front perforated plate should be coated with anticorrosive paint and lined with fiberglass material inside. This will prevent the accumulation of moisture inside the panel. Mineral wool as a base absorber inside the perforated panel should be of a defined density. The density of the mineral wool that corresponds to the simulated absorption coefficient (see Fig. 7.) is 30 kg/m². A cross-section of the considered metal perforated panels is given in Fig. 9.

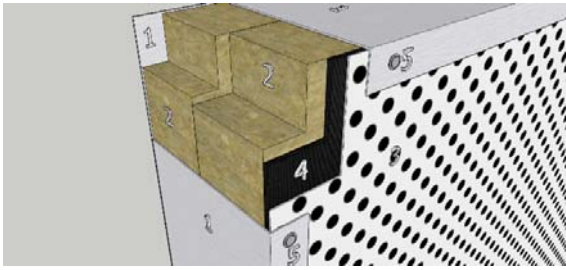


Figure 9. Cross-section of the metal perforated panel

In order to support the enclosure structure, a metal frame has to be built on top of a concrete foundation. Both frame and concrete need to be structurally strong to support the static load of the panels, having in mind that the weight of the 1 m² of the commercially available panel is approximately 10-15 kg.

In the vicinity of the generator, five decorative trees influence the shape of acoustic enclosures. As mentioned previously, two solutions have been considered. Partial enclosure assumes that only two sides are surrounded by barriers. For the installation at the site, this solution would be easier, as trees around the generator do not have to be trimmed. Besides, service doors are available for maintenance and easy access to the technician. Acoustic louvers have been placed on top and angled in a way that reduces the noise being generated towards the upper floors of the receiver building. This is particularly important since the exhaust manifold is placed on the top of the generator, emitting noise upward. By having the two sides without barriers, a partial enclosure solution enables sufficient airflow to the machine. Details are given in Figure 10. The graphical representation is based on realistically available physical space around the diesel generator.

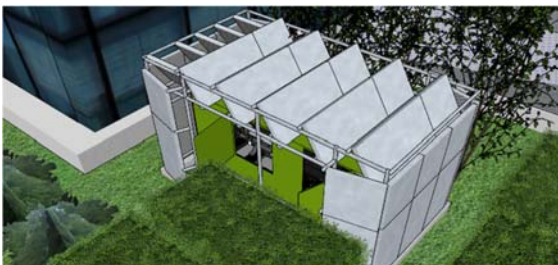


Figure 10. Partial enclosure solution 3D view

Total enclosure solution is more challenging in the terms of practical realization. Metal supporting frame and concrete foundation needs to be structurally stronger, with a greater static load capacity. Some of the trees would also need to be trimmed, to enable fitting of the enclosure. Physical space in between the generator and the side barrier should be larger than 1 m, so maintenance technician can have an access to the service doors. Additionally, a metal perforated panel door must be placed at one side to allow entrance into space in between the generator and enclosure. The larger roof of the enclosure means that roof itself will provide enough airflow for the machine to operate properly. A higher number of acoustic louvers at the top will reduce the noise generated towards the upper floors of the noise

receiver building even more than in the case of the partial enclosure. A graphical representation of the solution is given in Fig. 11.



Figure 11. Total enclosure solution 3D view

RESULTS

Based on the simulation explained in the previous section, at 4 m height on the façade of the receiver building, partial enclosure solution (Fig. 12. orange) would bring significant noise reduction of almost 10 dB per third-octave band, then in the case when no solution is applied (Fig. 12. blue). When comparing total enclosure to the partial enclosure solution, above 400 Hz, noise is reduced, even more, by on average 6 dB (Fig. 12. green).

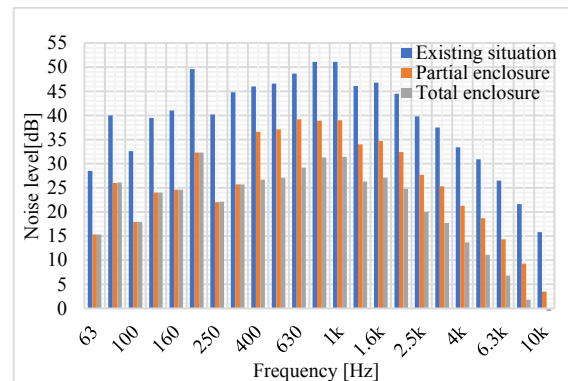


Figure 12. Noise reduction of proposed solutions

If the traffic intensity is higher than in simulation, the noise level emitted by traffic will mask the noise from the generator. In this case, the partial enclosure could be a good trade-off solution. If the opposite situation is present, a total enclosure solution would be preferred.

Using Predictor LimA integration with Google Earth, simulation results can be applied to 3D visualization of noise distribution in the area. This is shown for all of the previously discussed scenarios in Fig. 13. (top – without enclosure, middle – partial enclosure and bottom – total enclosure).



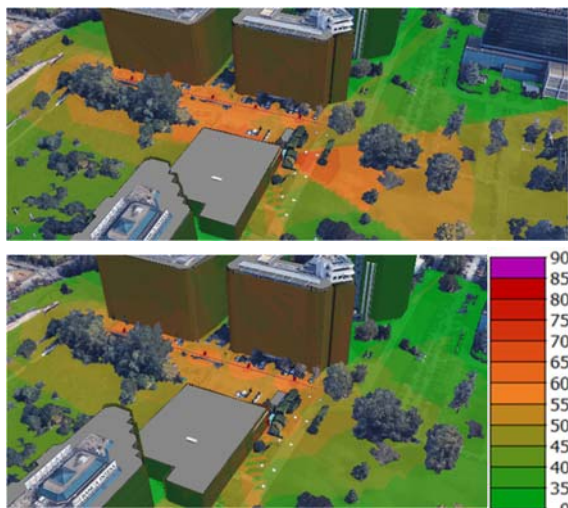


Figure 13. Visualization of the Predictor Lima simulation in Google Earth.

CONCLUSION

The process of designing the applicable noise control solution, from the perspective of noise engineer includes the assessment of the problem through measurement and observation, simulation of the sound behaviour based on the input data, testing, calculation and simulation of a different possible solution, assessment of the applicability of the proposed solution through materials, methods, and consultation with experts in other engineering fields.

This paper discusses a study case of a diesel generator that transmits the noise and disturbs residence in a nearby building. To solve the problem, the measurements have been taken, which served as an input for the simulation of the noise propagation. Two different acoustic enclosure solutions have been analyzed - partial and total enclosures. In addition, the results have been analyzed and the arguments for both solutions presented.

To sum up, it has been shown that a partial solution is easier to implement and requires less investment, while a total enclosure solution is an acoustically better choice in terms of noise reduction.

REŠENJE KONTROLE BUKE DIZEL GENERATORA - STUDIJA SLUČAJA

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Rezime: Današnji moderni gradovi predstavljaju složenu strukturu različitih tipova naselja i gradskih zajednica. Često su neki delovi naselja stambeno-poslovne strukture, što stvara pozitivne i negativne međusobne uticaje. Radne aktivnosti koje se odvijaju u poslovnim objektima, a nalaze se u blizini stambene zgrade, u mnogim slučajevima mogu stvoriti buku koja utiče na akustički komfor stanovnika. Uobičajene vrste izvora buke u ovim situacijama su HVAC sistemi i generatori koji u svojoj okolini stvaraju visoke nivoe buke. Da bi izbegli pritužbe i rešili problem, vlasnici preduzeća često traže pomoć stručnjaka koji se bave kontrolom buke. Ovaj rad predstavlja studiju slučaja, gde pomoćni dizel generator stvara buku koja utiče na poslovno-stambene objekte i predlaže rešenje problema.

Ključne reči: Kontrola buke, simulacija zvuka, Predictor Lima.

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