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EFFICIENT DESIGN OF INDUSTRIAL FAN AND COMBUSTION SILENCERS BY FINITE ELEMENT TOOLS AND IN-DUCT SOURCE CHARACTERISATION

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ABSTRACT

This paper presents three case studies of designing and manufacturing a silencer for an existing exhaust duct or project. In all three cases, acoustic finite element method (FEM) was utilized successfully as the main acoustic design tool. First case is an exhaust air duct silencer for a thermal insulation factory. The noise from exhaust air channel of water treatment plant fans presented strong noise emission at two blade pass frequencies, causing disturbance in the nearby neighborhood. Reactive channel silencer was designed to attenuate the noise at the problematic frequencies. Second case concerns design of a simpler but more effective silencer for emergency diesel generator (EDG). Third case is an exhaust gas duct silencer for a gas turbine power plant. Distinctive features of the case were very large silencer dimensions and needed tolerance for exceptionally high exhaust gas temperature. The three presented case studies had their own unique features and challenges, and design basis for each case were different from each other. Acoustic design addressing the challenges was successful in all three cases. In one of the cases the solution is already implemented at the plant, with a result satisfying the customer and fulfilling all design targets.

Keywords: *FEM, Silencer, Source Characterization, Industry*

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1. INTRODUCTION

This article presents three case studies of designing and manufacturing a fan or combustion silencer for an existing industrial plant. The work is related to a two-year Business Finland -funded development project by JTK Power. The goal of the project together with AINS Group was to ensure the long-term profitability and sustainability of JTK Power silencer business and to develop new silencer technology for both the present customer base and new potential clients, including process industry.

JTK Power is a medium-sized engineering company specialized in manufacturing silencers, air raid shelter equipment, valve seat inserts, welded project structures & solutions and associated products and offering mechanical and acoustic advisory services. The main product of JTK Power is duct silencers, used most often in process- and power plant industries. Fluid inside the duct is usually exhaust gas, combustion air or process waste air.

The main acoustic tool utilized for silencer design was ANSYS finite element software, used especially for predicting the noise reduction on low and mid frequencies. Performance of a new silencer is verified at JTK Power manufacturer premises by 6-channel transfer matrix method [1]. Simultaneously, the pressure loss coefficient of the silencer is measured using a frequency-controlled blower and manometer test system.

2. SILENCER SOLUTIONS

Several new, innovative duct silencer solutions were developed during the project. The paper presents three different cases, each with their own unique characteristics. Design methodology presented in [2] was utilized in the design work. Modelling the geometry and calculating the silencer transmission loss were performed in ANSYS/Spaceclaim environment.

The design methodology for each silencer unit took advantage of the accumulated experience and tacit knowledge of the authors. The three factors governing the solution development, also forming the balance of "inconsistent triad" of industrial silencer design, or practically the "pick any two" problem [3], are 1. acoustical performance 2. size i.e. cost 3. flow back pressure and loss. Simplified version of the development process includes a careful requirement specification definition phase, research of relevant silencers models developed earlier, concept drafting by utilizing for example handbooks relevant to the subject, and quick calculations of principle solutions (first on paper and/or in Excel for example).

After a promising candidate for a suitable end product has been developed, the design is transferred into 3D environment, where a relatively simple geometry of the possible solution is built, and the transmission loss is calculated on the relevant frequency range. If the acoustic performance is good enough for further development, layout of the silencer is iterated and possibly a more sophisticated version of the geometry is built until a satisfactory or "as good as it can be" result is obtained. Minor changes to the geometry can still occur from workshop manufacturing-related factors, but these are typically taken into account already in an earlier development phase.

2.1 Drainage Fan Silencer

Saint-Gobain Finland Oy/Isover insulation material factory had received complaints about environmental noise from a nearby neighborhood residents. The design staff of the factory suspected the origin of the noise to be the exhaust duct of the water processing suction fans. Sound measurements from the neighborhood, from the surface of the exhaust duct and from inside the duct confirmed this to be the case: The measured frequency spectra of the exhaust duct matched well with the noise measurements performed in the neighborhood, revealing two distinct blade pass frequencies, on approximately 210 Hz and 270 Hz (Figure 1).

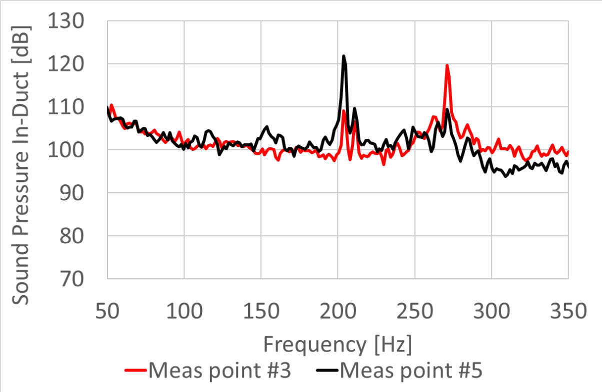

Figure 1. Result of in-duct sound pressure measurement. Suction fan blade-pass frequencies of 210 Hz and 270 Hz can be clearly distinguished.

There were a total of four suction fans at the water processing building. The exhaust ducts of the fans were combined into one common, larger rectangular duct, and finally lead to a chimney on the roof of the building. The exhaust air inside the ducts was humid air, with temperature of approximately 40° C. The ducts were sized of approximately 800x1200 millimeters.

As the fluid inside the ducts was humid air, use of typical absorptive mineral wool materials was prohibited. For the same reason, internal structures of the silencer must allow possible accumulated water to drain out from for example resonator chambers.

Solution was to dimension a quarter-wave resonator-based silencer for all four suction fan exhaust ducts, with noise attenuation maximums tuned to approximately 210 Hz and 270 Hz frequencies (Figure 2). Silencer internal structure was designed to fulfill the practical requirements mentioned above, and to be effective in noise attenuation terms and easy to manufacture.

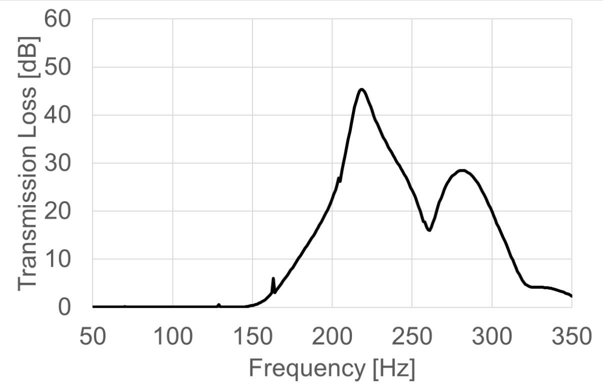

Figure 2. Calculated transmission loss of drainage fan exhaust duct silencer.

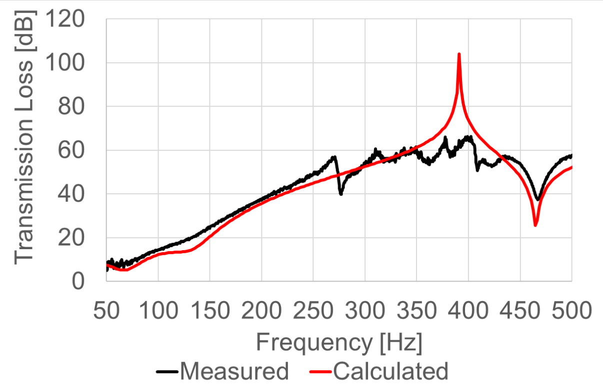

Figure 3. Comparison between measured and calculated transmission loss of the standard EDG silencer. Clearly evident in the figure is the highest measurable and practical TL 60 dB of such construction.

According to calculation, noise attenuation performance is satisfactory, with over 20 dB attenuation on design frequencies. Noise attenuation is designed to allow some tolerance in fan rotation speed and consequent change in blade pass frequency. Till this date, the silencers have not yet been installed or manufactured, meaning that the acoustical performance of the silencers has not yet been verified.

2.2 Emergency Diesel Generator Silencer

An emergency diesel generator (EDG) supplier under the same group of companies as JTK Power currently uses an exhaust silencer purchased outside of the group in their standard product delivery. One goal in the development project was to develop a more economical and higher performance exhaust silencer to be used as the standard exhaust silencer for the EDG supplier.

The internal structure, as well as acoustic and flow related performance of the currently used silencer were determined by company standard measurements. Current silencer was then modelled in ANSYS and calculated transmission loss was compared to the measured transmission loss (Figure 3).

Based on visual inspection and dimensional measurements, the internal structures of the currently used silencer were deemed as relatively complex in proportion to silence size and required noise attenuation. The silencer achieved modest noise attenuation performance on 80…100 Hz frequency region, regarded as an important area of spectrum on smaller EDG exhaust noise.

Based on the measurements and overall performance evaluation of the currently used silencer, a new model with similar outer dimensions and simpler inner structures, but with approximately 10 dB better performance on the crucial frequency band was designed. On higher frequencies, noise attenuation performance was equal to the currently used silencer. Mostly due to the simplified design, the new model achieved superior cost-effectiveness.

2.3 Gas Turbine Plant Silencer

During a plant expansion project for a Danish 40 MWe-size combined heat and power gas turbine plant a separate exhaust ducting, bypassing the exhaust boiler and with its own separate chimney, was built. The gas turbine plant customer needed an exhaust silencer for the by-pass duct that would attenuate the exhaust noise by 35 dB. The size of the rectangular exhaust ducting was very large, with cross-section area of approximately 3x4 meters. Exhaust gas temperature was exceptionally high as well, reaching up to 590° C.

The designed silencer was 11 meters long, with maximum width and height of 4x4,5 meters. The very large size of the silencer caused challenges both in structural design and logistics, as the contract included transport of the silencer all the way up to customers' plant premises. Thorough strength analysis concerning the freighting and lifting of the silencer unit was performed during the development.

Figure 4. R&D-personnel of JTK Power standing alongside the finished silencer unit.

The acoustic and flow-related performance of this type of very large silencer units is not as well known, in comparison to silencers smaller in scale, supplied to customers for many years. Subject is familiar from literature [3], and learnings can be applied in design. Due to the very large size of the silencer, measurement of performance is challenging, as existing equipment and methods cannot be applied.

The silencer is currently installed in the gas turbine plant bypass ducting, and plant has been run normally. Plant exhaust noise emission measurements were performed after a few months of running. The exhaust noise emission was within the contractual limits, indicating that the silencer is working as designed.

3. SUMMARY

This paper presented three different cooperative silencer product development cases, of which some are manufactured and already in use at customers' plants. All three silencer development cases were deemed as successful projects, leading to products for new customers on new business areas for JTK Power.

The finite element software ANSYS used in silencer acoustic performance design proved to a user-friendly tool, and is an important part of low frequency noise attenuation design particularly in demanding projects. When combined with other standard design tools used in the industry, efficient simulation process and a very good correlation to real-life measured performance is achieved with ANSYS.

4. ACKNOWLEDGMENTS

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