Mitigation of the ventilation noises at the electric locomotive BR-182

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Introduction

Electric locomotives carry a multiplicity of ventilation systems. The noise of ventilation systems is dominant at standstill in the station. The possibilities of sound power reduction at the inlet and outlet of a cooling tower for the water/oil circuits are presented in this paper. The modelling of the coupled thermodynamic, fluid dynamic and acoustic system is briefly inspected. Modifications of the components with respect to the technical requirements are shown together with measurements of the original and modified cooling tower as well as the effect of silencers. In collaboration with different manufacturers, suppliers and research establishments, these investigations are part of the Joint Research Project "Silent Trains and Tracks" supported by the Federal Ministry of Education and Research (BMBF), Germany.

Thermodynamic, flow and acoustic coupling

The ventilation system has to produce a given cooling power under given boundary conditions (pressure, temperature and maximum rise in temperature). An appropriate mass flow is needed to carry off this amount of heat (cooling performance) under the conditions mentioned. The mass flow is linked to the volume flow by density and thus by pressure and temperature. The resulting volume flow is to be generated by one or more fans against the total pressure loss of the ventilation system. The total pressure loss is given by the pressure loss of the individual components of the duct system, such as inlet-grills, cooler and outlet.

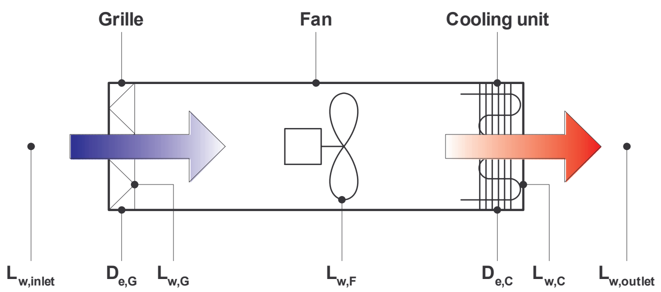

Figure 1: Arrangement of the components with sound power L_w and attenuation D_e assignments.

The pressure loss of the components depends on the local flow rate linked to the system mass flow. For an optimal efficiency the operating point of the fan, given by pressure loss and volume flow, should correspond to the necessary mass flow of the ventilation system. This flow mechanical optimization leads to a reduction of fan noise. Mass flow, temperature, pressure as well as geometrical dimensions of the individual components determine the local flow rate. With these parameters sound power level and attenuation of the components can be predicted by [1-4]. Figure 1 shows the schematic arrangement of a ventilation system. Attenuation rates and sound power levels are assigned in direction of flow to the individual components. According to [1] the sound power of a component is evaluated toward the ventilation openings with the appropriate attenuation of the components lying in this direction. A partial sound power is determined for each component with respect to each opening. These partial sound power levels combine to the total sound power of the ventilation inlet or outlet.

Prediction and realization

The ventilation system of the oil/water cooling tower is modelled as described above. In this system the main acoustic source is represented by the fan. In order to obtain a maximum noise reduction, different component arrangements were modelled. For example, if the fan is installed downstream of the cooler, the fan noise increases. Then, a larger flow rate must be provided due to the rise in temperature. However, the installation of two fans proves favourable as both fans must deliver only half of the volume flow. Constructional restrictions permit only a modification of the ventilation system within the given installation space. A sufficient noise reduction could be achieved only by installation of additional silencers. Additional components in the ventilation system, however, lead to an increase of the total pressure loss. For maintenance of the given mass flow the fan power must be increased. Thus, effective noise reduction can be achieved only by optimal adjustment of the fan unit to the system. This leads to the following measures for noise reduction at the oil/water cooling tower: Installation of inlet and outlet silencers, damping of the fan housing by absorbers, optimal adjustment of the fan operating point to the boundary conditions and the ventilation system. Additionally, an absorbing roof system was attached at the inlet.

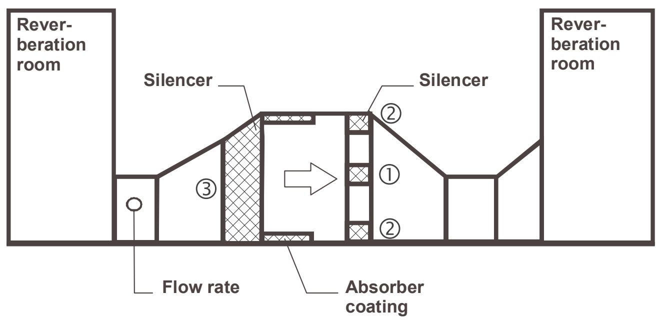

Figure 2: Modified cooling tower built into the silencer test facility: 1, 2 = outlet silencers, 3 = inlet silencer.

Results

The oil/water cooling tower, with its fan as acoustic source, was built into the large test duct of the IBP [5,6] as presented in Figure 2. The generated flow rate was measured at the inlet side of the test duct. The determination of the sound power at the inlet and outlet took place in the connected sending and receiving reverberation rooms according to [7]. The measurements were carried out supplying a constant three-phase current with a frequency of 60 Hz to the fan. Figure 3 shows the octave spectra of the sound-power levels of the original and modified cooling tower (without roof system) determined at the outlet. The effect of the silencers on sound power and flow rate was examined for the modified cooling tower in more detail. As shown in Figure 2, the silencers were removed step by step: First the central splitter at the outlet, then the side splitters at the outlet and finally the inlet silencer. In Figure 4 the measured changes of the A-weighted levels related to the original cooling tower are presented. The dependence on the determined flow rate is shown in Figure 5.

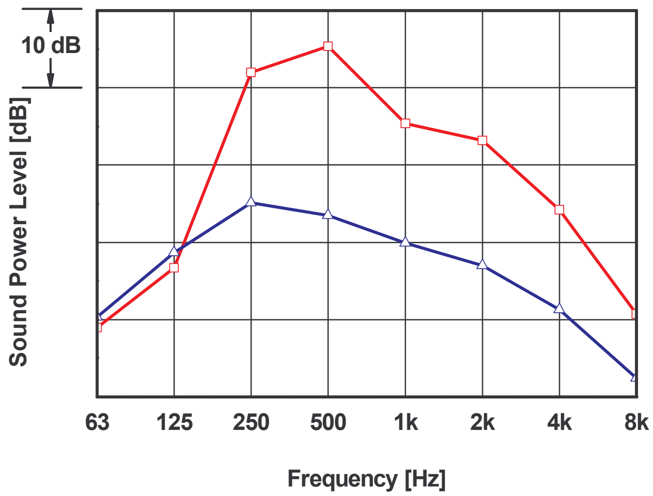

Figure 3: A-weighted octave sound-power level at the outlet, □ original cooling tower, △ with modifications.

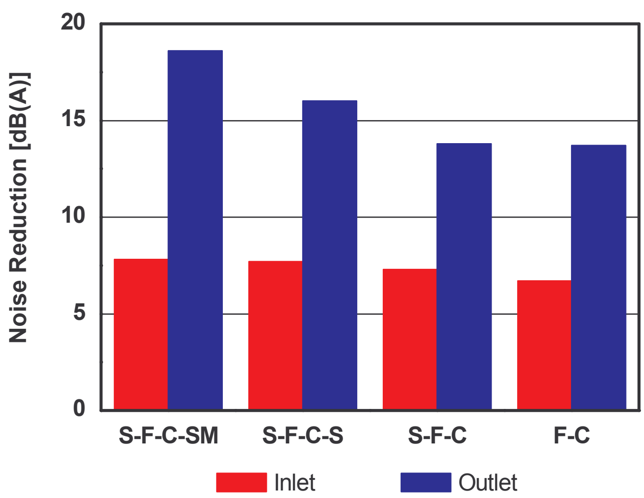

Figure 4: Noise reduction relating to the sound-power levels of the original cooling tower. Component arrangement in flow direction: F = fan, C = cooler, S = side splitters, SM = central and side splitters.

Summary

The system-oriented task of ventilation noises reduction could be represented by a computation model, which takes thermodynamic boundary conditions with requirements on the flow and the acoustics into account. This model supplies important trends and indications for the design of noise control measures. The presented example of the oil/water cooling tower showed, how a substantial noise reduction can be achieved with such a modelling. The cooperation of different manufacturers, suppliers and research establishments allowed the interdisciplinary approach for the modelling and the investigations.

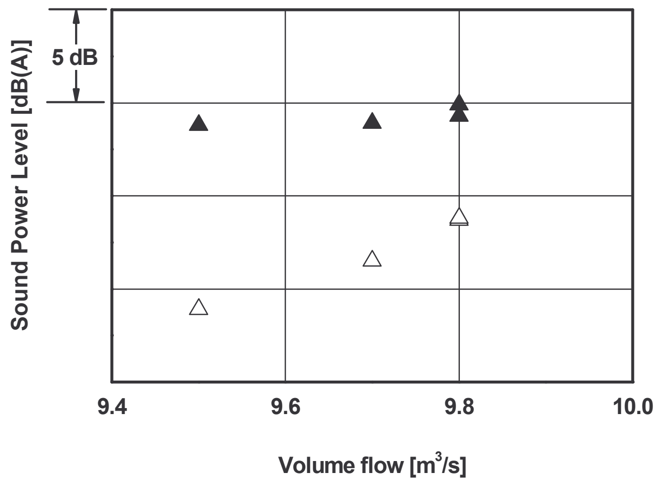

Figure 5: A-weighted sound power: ▲ inlet, △ outlet; component arrangement from left to right: S-F-C-SM, S-F-C-S, S-F-C, F-C.

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