MODELLING SEA-CRANE NOISE WITH SEA

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INTRODUCTION

In this paper it will be shown how a statistical energy analysis (SEA) model can be used, together with relatively small scale measurements, to determine the sound power emitted by a large industrial construction. The technique is particularly usefull when full scale measurements are not possible or too demanding.

This investigation was part of a project that aimed to reduce the sound immission around the harbour of Amsterdam.

It was found that a 35 tonnes gantry crane,used for the unloading of ships, was one of the dominant sources of sound (see figure 1). For the purpose of finding the efficiency of possible ways for reducing the sound emission a detailed investigation into the sound production of the crane was set up. Some of the sound sources (e.g. electric engines and cooling fans) could be examined by direct measurement of the noise emission. However, a non-conventional method for determining the sound radiated by the construction had to be used since the crane, which is over 100 m long and 30 m high and consists of several distinct segments, had limited accessibility during operational hours, while taking the crane out of production for an extended period of time would have been too expensive. Moreover, a direct measurement of the sound immission was not possible because of the large number of other sound sources in the vicinity of the crane.

METHOD

It was decided to use a hybrid method. A SEA model was developed to calculate the transmission and radiation of vibrational energy. For this purpose the program AutoSEA (Vibro-Acoustic Sciences Limited) was used. The model was validated using measurements of artificially excited vibration levels.

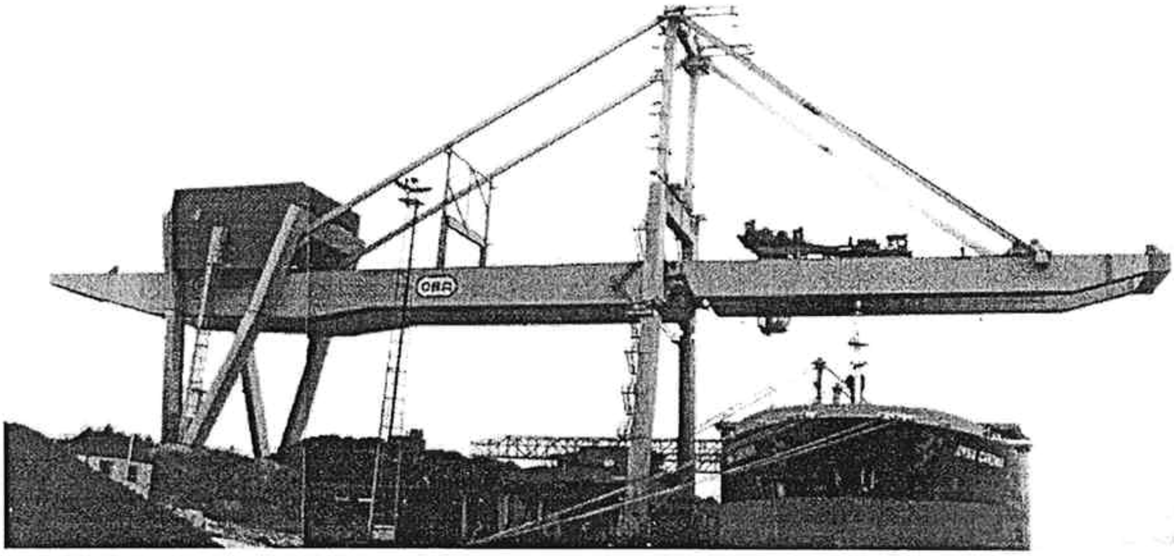

Figure 1: The OBA sea-crane

The excitation power level of the crane in production was determined by comparing in situ measurements of vibration levels with vibration levels in controlled circumstances. As a final check the predicted sound emission was compared with measurements of sound levels close to the crane.

The sea-crane consists of interconnected construction elements, mainly steel plates and stiffening beams. The dimensions of these elements could be found from drawings of the construction plan. It was not necessary to model the complete crane. Instead, only one of the two horizontal carrying beams was modeled. For a correct description of the decay of vibrational energy levels along the length of the crane it proved to be important to model all plates as separate elements.

Vibrations are excited by the rolling of the wheels over the rails when a load is moved from the ship to the shore, or when the empty scoop returns to the ship for another load. The vibrational energy is transmitted in the construction via the connections (modelled by the so-called coupling loss factors) and dissipated (modelled by damping loss factors) or radiated into air.

The damping loss factors need to be determined experimentally since they depend sensitively on how the construction is built. Theoretical and empirical results are only available for simple configurations. The necessary parameters needed for a quantitatively correct SEA model where determined using a vibration exciter and an impulse hammer. Both sources were applied to the rail on one of the carrying beams. Vibration levels were measured using accelerometers on 17 positions distributed over the carrying beam. Damping loss factors within the construction were determined from the decay time of vibration levels in one-third-octave bands. In the SEA model all the elements were given the same spectrum of damping loss factors.

To validate the SEA model the vibration exciter was again applied to the rail, while measuring the power coupled into the rail. Vibration levels were simultaneously measured and recorded on tape for later evaluation.

Background levels were measured with the vibration exciter switched off. It was found that for low frequencies the background level, coming from maintenance activities being caried out at the time of the measurements, was higher than the levels that could artificially be excited. Low frequency noise is however not radiated efficiently by the construction elements. Therefore, it was concluded that checking the model in this frequency range would not be essential for the overall result. A power source, using the measured input power, was incorporated into the SEA model and vibration levels were calculated. Figure 2 shows a comparison of measured vibration levels, background levels, and the result of the model calculation for one of the side plates. The comparison is equally good for the other measurement positions.

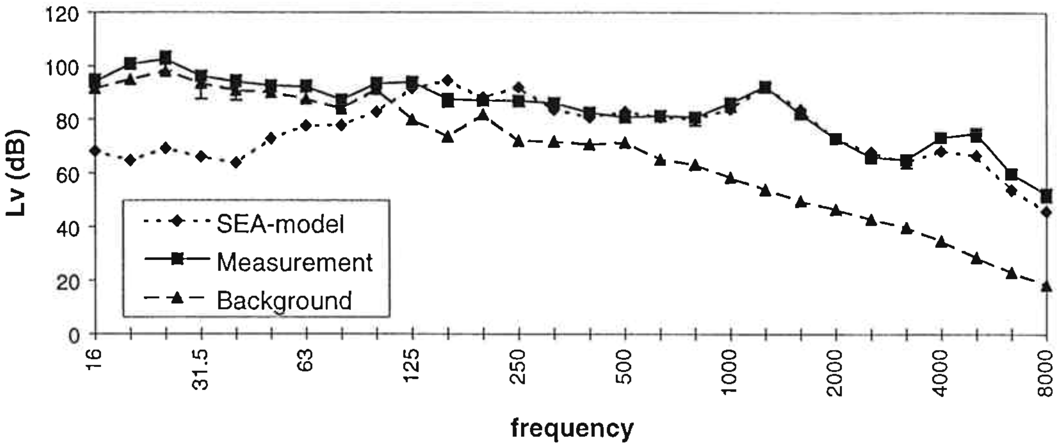

Figure 2: Comparison of vibration levels

Subsequently, the power coupled into the construction during operation had to be determined. For this purpose measurements were made of vibration levels close to the rail. The measured maximum levels during operation were compared with vibration levels found for the same positions when the vibration exciter had been used. The level difference was used as a correction on the input power spectrum in the SEA model. With this information the model could be used to calculate the sound energy radiated by the construction during operation. As a final check the predicted pressure level, as found from the emission measurements from the engines and cooling fans together with the calculated structural noise, was compared to a measurement in the vicinity of the crane. The comparison can be found in figure 3.

The total sound power emitted by the crane during movement of the scoop is calculated to be 117 dB(A). The construction noise contributes approximately 115 dB(A). As can be seen from figure 3 the construction noise is dominant in the mid-frequency range.

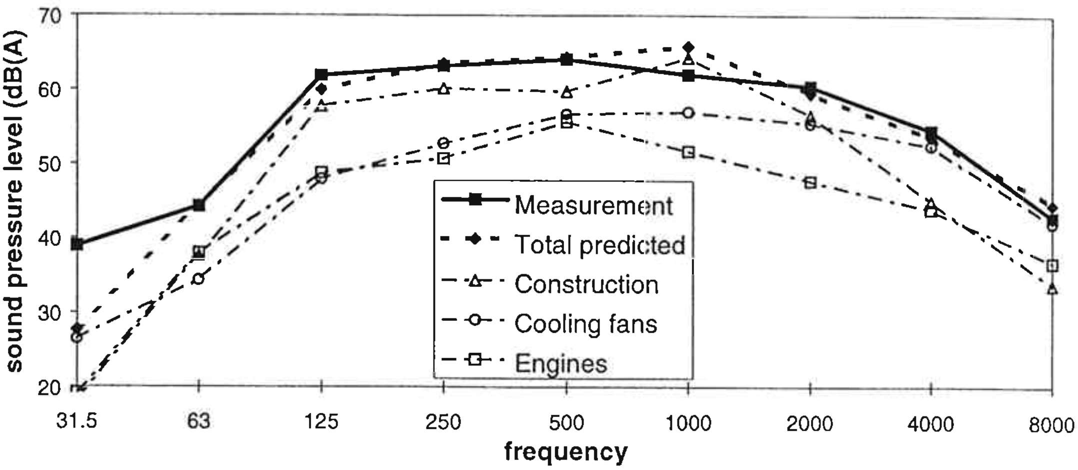

Figure 3: Sound pressure levels in the vicinity of the crane

DISCUSSION

As has been shown, SEA models can be used in industrial noise problems to facilitate the determination of sound power levels emitted by large vibrating constructions. Although it is still necessary to perform a limited number of measurements to determine input parameters and to validate the model, a significant reduction of the experimental effort needed to determine the total radiated sound can be obtained. This is especially true for constructions that consist of many elements which are not identical, or which are not identically excited. This reduction is most welcome, if not necessary, when the construction under study can not easily be accessed and can not be taken out of operation for an extended period of time.

In the case of the sea-crane studied here, it was found that the construction contributed a dominant portion of the total emitted noise. In an existing crane as this one it is difficult to take measures for reducing constructional noise. From a preliminary analysis it was found that a 5–10 dB reduction of constructional noise levels might be expected from smoothing the rail and wheel surfaces. Better reductions can be expected from acoustical decoupling of the rail from the construction, and from reduction of the radiation efficiency of the construction elements. However, the latter options would require major revisions to the crane and where therefore believed not to be realistic.

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Modelling Sea-crane noise with SEA

In this paper it is shown that SEA models can be used in industrial noise problems to facilitate the determination of sound power levels emitted by large vibrating constructions. A large gantry crane in the harbour of Amsterdam is studied. Although it is still necessary to perform a limited number of measurements to determine input parameters and to validate the model, the necessary experimental effort is significantly reduced. This reduction is most welcome when the construction under study can not easily be accessed and can not be taken out of operation for an extended period of time.

Industrial noise problems, noise emission, numerical modelling, statistical energy analysis, structural vibration