TRANSMISSION OF NOISE FROM THE MACHINE ROOM

Prof. Dr. Lubomír Janovský
Czech Technical University of Prague
Czech Republic

Abstract:

This paper deals in general with the aspects of the sound isolation of sources belonging inherently to traction elevators. It also presents a case study concerning the sound transmission from the machine room to adjacent parts of a residential building and suggests provisions that may be taken to diminish the sound transmission.

1.INTRODUCTION

As specified in most national standards the structure of important buildings, particularly hospitals, hotels, residental and administrative buildings etc., must guarantee absorption of vibrations and sound insulation of sources, located inside the buildings.

There are several sources of vibration and noise associated with the operation of elevators. They may be classified according to their location: (a) sources located in the machine room, (b) sources located in the hoistway. This paper will focus on sources located in the machine room, namely the elevator machine and the controller.

2.ELEVATOR MACHINE AS A SOURCE OF VIBRATION

The machine is mounted on a steel frame (bedplate) and is usually supported by heavy concrete beams with extensive properties as vibration dampers. Rubber pads or silentblocks are inserted between the bedplate and the supporting beams. They have the characteristic of a rubber spring.

Calculation of the resonance frequency

Let us adopt a simplified model, considering the machine with its bedplate a single-mass vibration source on resilient mounting (i.e. spring cushioned), supported by heavy concrete structure. The resonance frequency of that system is influenced by the following parameters:

(a) stiffness of the resilient mounting (N/m),
(b) mass of the sound and vibration source (kg).

The stiffness of the resilient mounting is given by the formula:

$$s = i \text{ x } s_1$$

where i is the number of inserts (rubber pads) and s_1 is stiffness of one insert (N/m).

The mass of the vibration source m_s dynamically affecting its surroundings may be expressed generally as:

$$m_s = m_m + m_b$$

where m_m is mass of the machine with the bedplate (kg) and m_b is mass of supporting beams (kg).

The resonance frequency f_r of a system oscillating continuously in the vertical direction (undamped vibration) is given by the formula:

$$f_r = \frac{1}{2\pi} \times \sqrt{\frac{s}{m_s}} \quad (1/s)$$

The value of f_r must not lie between the frequencies f_1 and f_2, given by the following formulae, as otherwise resonance would take place with resultant high magnitudes of amplitude:

$$f_1 = \frac{1}{\sqrt{2}} \times \frac{n}{60} \quad (1/s)$$

$$f_2 = \sqrt{2} \times \frac{n}{60} \quad (1/s)$$

where n is revolutions per minute of the drive motor.

Furthermore, the resonance frequency must be less than the frequency of the line current (of the mains), i.e. in Europe

$$f_r < 50 \quad (1/s)$$

As a result of the conditions stated above two possibilities exist for the design of the supporting structure of elevator machine:

(a) The machine is supported in a manner resulting in low resonance frequency of the system in compliance with the following conditions:

$$f_r < \frac{1}{\sqrt{2}} \times \frac{n}{60}$$

$$f_r < 50 \quad (1/s)$$

(b) The machine is supported in a manner resulting in higher resonance frequency of the system, satisfying the following conditions:

$$\sqrt{2} \times \frac{n}{60} < f_r < 50 \quad (1/s)$$

When projecting and calculating the bedplate and supporting structure of the elevator machine the maximum permissible load upon rubber pads or silentblocks must be taken into consideration and these inserts should be positioned under the machine or supporting beams in such a way that an equal distribution of load on each insert is achieved.

Sound transmission

The sound pressure level in the machine room is usually not of prime significance as persons do stay there permanently. The sound pressure level in rooms where people live or work is of much greater importance. In fact, the sound pressure level in these rooms has become the decisive criterion and its maximum allowable value has been specified in national standards concerning the acoustics in buildings in respect to the protection of health from the effects of noise and vibrations.

The sound level in rooms adjacent to the machine room is influenced by the following factors:

(a) Noise level of the machine and controller
This factor is given both by the design and construction of the equipment and by the quality of assembling, adjustment and maintenance.

(b) Transmission of noise from the machine room
Transmission is accomplished by vibrations; direct transmission by the air is negligible. The following factors effect the transmission:

Method of the mounting of the machine and controller
Design of the building structure
Quality of building workmanship.

Case study

Many problems concerning the transmission of sound generated in the machine room have occurred in blocks of flats in large housing areas in some European countries. This phenomenon concerns especially rooms on the highest floor at the shortest distance from the machine room. Measurements confirmed that excessive noise in the rooms was caused by vibrations transmitted from the machine room by the building structure. For example, in the Czech Republic the maximum permissible pressure level in residential buildings (bedrooms and living rooms) is 40 dB(A) during the day (between 6 a.m. and 10 p.m.) and 30 dB(A) at night (between 10 p.m. and 6 a.m.).

Measurements were taken in a number of buidings and revealed the unsatisfactory sound insulation of machine rooms as the noise generated by elevator machines and controllers was transmitted to the nearest rooms in such a way that the permissible sound pressure level was seldom maintained.

In Fig. 1 a graph is shown depicting the variation of the sound level with time in a living room in a residential building. The room was located on the highest floor at a short distance from the machine room and measurements were taken at night. The recording in the graph concerns six elevator trips, alternatively in upward and downward direction. The elevator was a small capacity passenger one (rated load 500 kg), driven by a two-speed a.c. motor. As seen in the graph, the sound level was quite acceptable during the periods of constant speed, while it exceeded the allowable value of 30 dB(A) during the acceleration period, at the beginning of the recuperation period after the low-speed winding had been set in operation and particularly when mechanical braking took place. A detailed graph of two first cycles (trips) is shown in Fig. 2. The results of measurement revealed unsatisfactory parameters of the machine in terms of sound generation as well as poor anti-vibration properties of the building structure.

Corrections of results of measuremets

One factor which must be taken into consideration as it may influence the accuracy of measurements is the level of background noise. In practice, the sound level being measured must be at least 3 dB higher than the background noise, otherwise it would be impossible to take a precise measurement. To get a correct result a correction must be made if the difference between the two measurements (with the source on and turned off) is less than 10 dB. No correction is necessary if the difference is greater than 10 dB.

Fig. 1

Fig. 2

The chart in Fig. 3 serves the purpose of correction discussed above. The difference between the total sound level L and the background noise level L_b gives the value of ΔL, which is subtracted from the total level L. For example: If the total noise level be 70 dB and the background noise level 63 dB, the difference would be 7 dB. Entering the bottom of the chart with this value and going up to the curve and from the point of intersection horizontally to the vertical coordinate axis we get correction of $\Delta L = 1$ dB. This value must be subtracted from the total sound level L, i.e. the actual noise level generated by the examined source of sound is 69 dB.

If the total sound level is to be determined in a machine room where two or more elevator machines and controllers are located and operate at the same time, superposition of the sound levels of individual machines must be carried out, as shown in Fig. 4. In the case of two machines being located in the machine room the sound pressure levels are measured for both machines separately and the difference (L_2 - L_1) is found. Then we enter the bottom of the chart with the value of this difference, go up to intersect the curve in the graph and then horizontally to the vertical coordinate axis. The value of ΔL read off on this axis is added to the higher sound pressure level (i.e. $L_2 + \Delta L$) and the total sound level is obtained. If there are more than two machines, for example three, the procedure is repeated using the sound level obtained for the first two machines and the sound level of the third one.

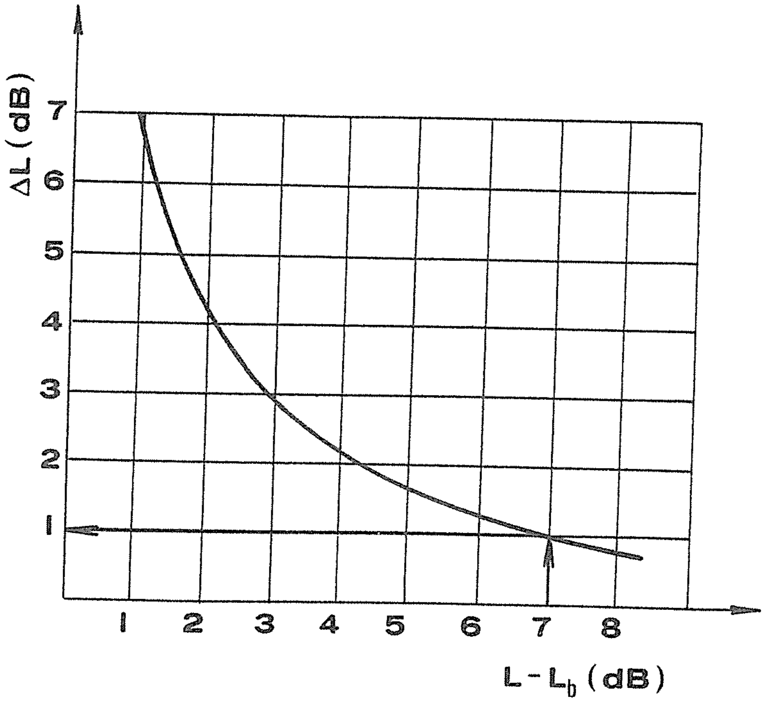

Fig. 3

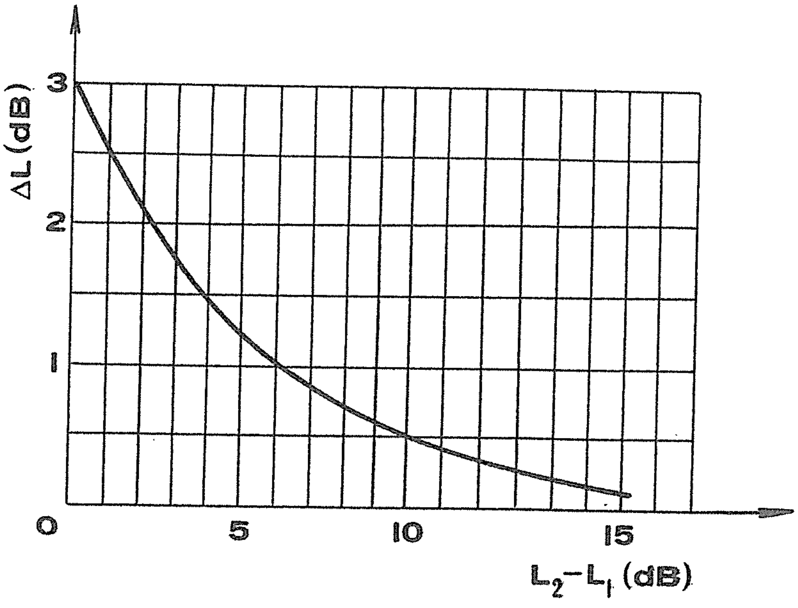

Fig. 4

The noise generated by the elevator machine may be diminished by the application of a reasonably silent electromotor with well balanced rotor, plain bearings (bushings) etc., dynamically balanced coupling with the brake drum and a well designed braking system. Frequent adjustment of the brake is relevant.

Having reduced the noise generated in the machine room further provisions should be taken. It is extremely difficult, if not impossible, to improve the anti-vibration properties of the building structure. However, a satisfactory method of mounting the elevator machine may be applied resulting in a remarkable decrease of the transmission of vibrations to the building structure. The method, represented by a "floating floor", is shown in Fig. 5.

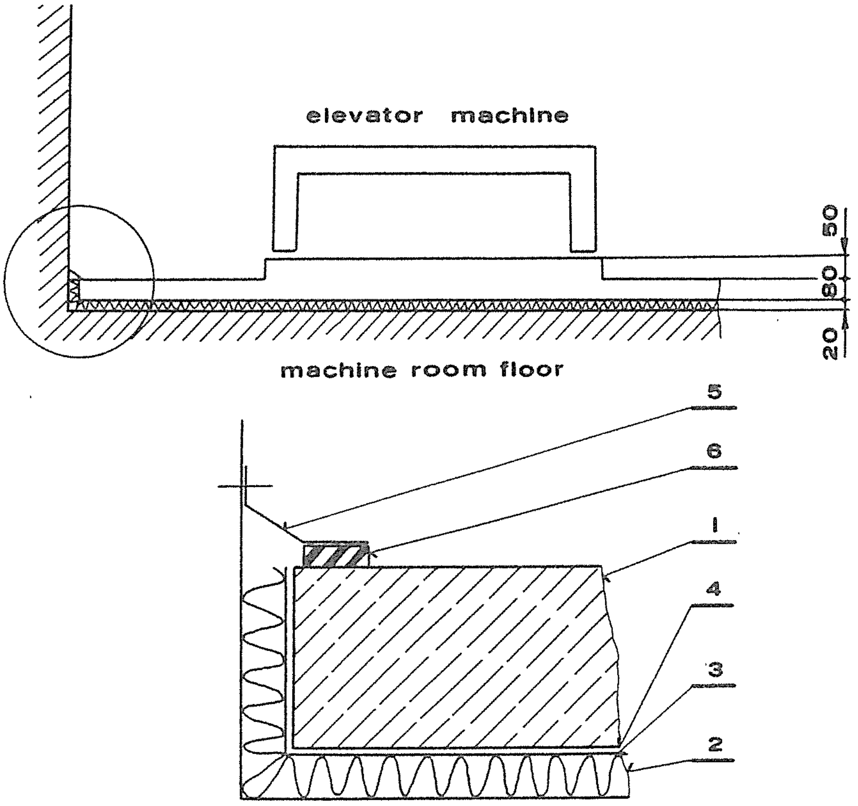

Fig. 5

A "floating floor" *1*, formed by a slab of reinforced concrete, the thickness of which is 80 mm, covers the total floor area of the machine room. Under the machine bedplate the thickness of the slab is increased by another 50 mm. Another slab *2* of synthetic fibre or fibreglass of the thickness of 20 to 30 mm is located under the concrete slab *1*. At the walls it is extended upwards to the height of about 150 mm. The compressibility of this slab is 30% to 40% under the pressure of 2,000 N/m^2. Two layers of asphalt cardboard *3* and a polyethylene foil *4* are inserted between *1* and *2*. The dilatation joint between *1* and the walls is covered with a metal cover strip *5* laid upon a rubber band *6*.

3. CONTROLLER AS A SOURCE OF VIBRATION

The simplest solution seems to be to mount the controller on an insulated baseplate like the "floating floor", described in Sec. 2. If this solution cannot be accepted, rubber springs of honeycomb shape, vulcanized to upper and bottom protective steel plates, may be inserted between the controller and the wall or the floor respectively. This arrangement is illustrated in Fig. 6.

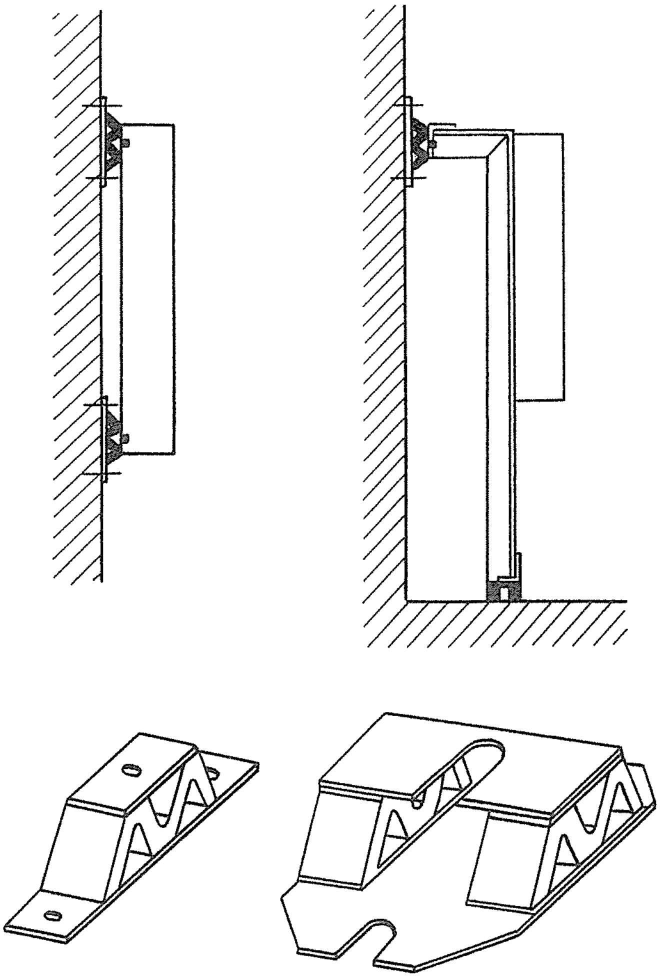

Fig. 6

4. CONCLUSION

Transmission of vibrations and sound from the machine room to the building structure is influenced by several factors and reasonable provisions may be taken to diminish this transmission.

(a) The machine and controller should be well designed from the aspect of the generation of vibrations, i.e. the sound pressure level of the machine and controller should be inherently low. Frequent inspection and adjustment are desirable.

(b) The method of mounting the machine and controller is of great importance. Silentblocks or rubber pads should decrease the vibrations to a minimum.

(c) The building structure should guarantee absorption of vibrations and sound insulation of sources located inside the building.

(d) Additional provisions may be taken to achieve better sound insulation, like the application of the "floating floor" in the machine room.

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BIOGRAPHY:

Lubomír Janovský has been Professor at the Czech Technical University, Faculty of Mechanical Engineering, Prague, Czech republic. He is also an elevator and escalator consultant currently cooperating with foreign elevator manufacturers. He has been a foreign correspondent for *ELEVATOR WORLD* since 1978, a ViceChairman of the Executive Board of *IAEE* and a member of the International Board of *ELEVATORI*. He gained his Ing. (Masters level) in Mechanical Engineering and his CSc. (doctorate) in Vertical Transportation, both from the Czech Technical University in Prague. He has written numerous books and papers on vertical transportation and materials handling, including *ELEVATOR MECHANICAL DESIGN*, published by Ellis Horwood Ltd. in 1987 (1st edition) and 1993 (2nd edition).