Vibroacoustic analysis of an incubator
Simulations and experiments

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Background

Peak levels in incubators to which a premature infant is exposed to can reach extreme values of up to 117 dB(A)(Thomas 1989) or 130-140 dB(SPL)(Bess et al. 1979). Also under normal conditions the noise level in incubators is usually much higher than the 45 dB recommended by AAP (1997). Usually, the idle level is about 57 dB. It rises to a peak level of 82-117 dB(A) while handling or opening the box.
Due to the heavy acoustic load 2-10% of premature babies suffer from hearing impairment or hearing loss (normal population: 0.1%, Wroblewska-Seniuk et al. 2017). Nearly 50% of preterm babies suffer from deficits in language acquisition at the age of three (Foster-Cohen et al. 2007; Ribeiro et al. 2011).

Research questions and claims

The main energy component of noise levels measured in incubators have been found at about 100-200 Hz (Bertsch et al. 2019, similar results can be seen already in Seleny 1969). It can be assumed that especially the vibroacoustic coupling between the incubator's cavity and structural components lead to resonances and excessive sound pressure levels. To support this hypothesis and to understand the complex acoustic mechanisms, both measurements on an incubator and numerical simulations were performed. Comparison between the measurements and simulations show promising results.

Introduction

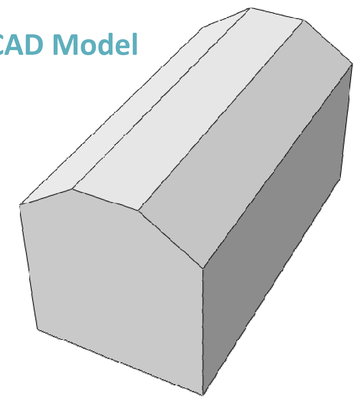
A Dräger Isolette C2000 incubator has been used for investigative purposes. Its cavity is enclosed by planar structural components (Lid, floor, caps). The parallel surfaces inside the incubator favor cavity resonances with standing wave patterns. Those standing waves lead to excessive sound pressure levels when excited, so high pressure levels are expected to be close to the infants' ears. Acoustical excitations can be structure borne (closing/opening doors, putting objects on the surface, moving it etc.) or air born (staff conversations, devices, alarms, ventilation system etc.).

Not only the sound level inside the incubator is expected to be higher than outside (especially with structure borne sounds), but also the acoustic properties of the sound inside the incubator are expected to change drastically according to the resonance properties there.

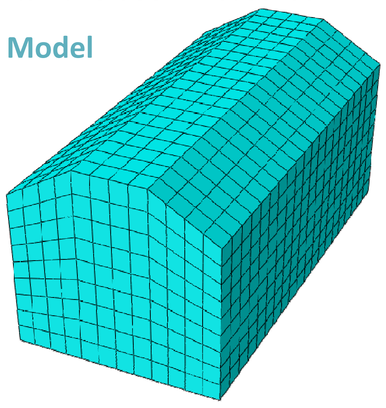
Method

Besides a comparative measurement of the incubator's acoustic properties from the perspective of an preterm infant (Esper K4 measuring microphone at the ear of a simulator manikin, 37 cm below the incubator ceiling) and the perspective of a caregiver (Esper K4 measuring microphone 37 cm above the incubator ceiling from the outside as well as a Neumann KU-100 artificial head microphone 37 cm laterally from the incubator wall) the geometry of the incubators cavity and its structural components have been measured.

CAD Model

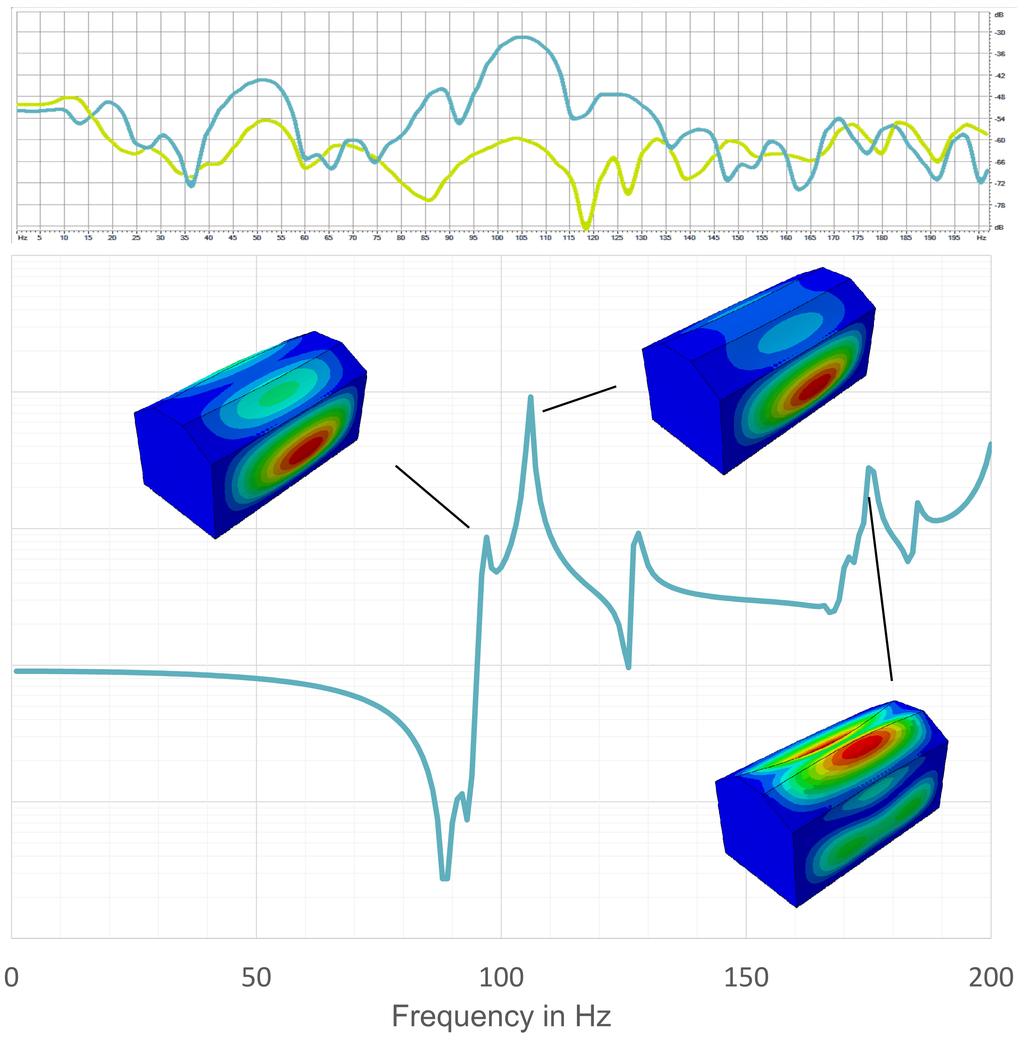


FE Model



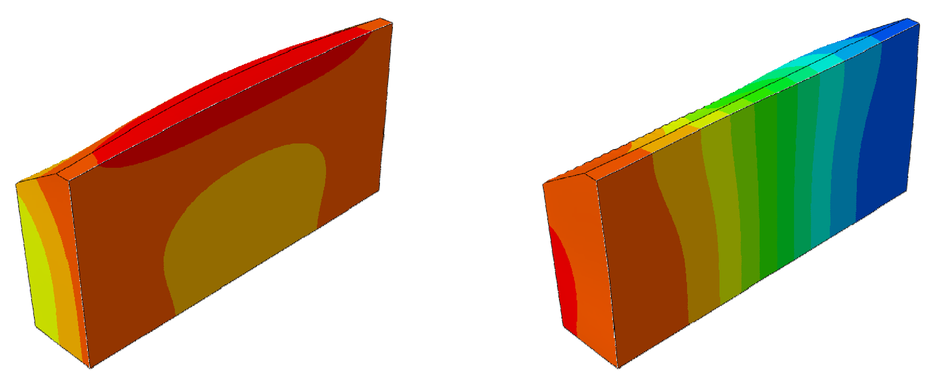
The collected data enabled us to model the acoustic behavior inside the incubator with the help of the finite element tool Abaqus. This software was also used for simulations and post-processing when calculating the full coupling between cavity and structure. The simulations thus obtained show typical vibration patterns at various frequencies.

Results



top: —— measured frequency response of the incubator between 0 and 200 Hz,
—— spectrum of the excitation pulse at 0-200 Hz.
In the vibrational mode of the main resonance (approx. 100 Hz), a gain of 28 dB is shown
bottom: —— calculated frequency response and vibrational modes via numerical simulation.

The comparison of the acoustic measurements with the numerical simulations showed a very good agreement with resonances from measurements and the frequencies of coupled vibrational modes.



The acoustic cavity modes show high levels at 97 Hz and 127 Hz.
Coupled modes show high levels close to the infants head position.
When excited these modes create high sound pressure resonances.

Conclusion

The acoustic behavior of a Dräger Isolette C2000 incubator was successfully modeled based on acoustic and geometric measurements using Finite Element Method.
In accordance with the acoustic measurements the simulations show coupled acoustic and vibrational modes in the low frequency regime. In the case of the Dräger Isolette C2000 the vibration modes at 97 Hz and 127 Hz resonate particularly strongly. These modes are critical with respect to noise pollution inside the incubator and contribute to a detrimental effect on the infants' sensory and cognitive development.

Literature

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