1 Introduction

A major portion of the sound that reaches our ears – be it a chord from a guitar, the squeel from brakes or a lively discussion at the neighbours – originates from or is transmitted through vibrating solid structures. This field of physics, which encompasses generation, transmission, propagation and radiation of wave motions in solid structures is termed Structure-Borne Sound. In the name, the word “sound” indicates that the major emphasis is on the audible frequency range i.e., approximately between 16 Hz and 16 kHz. These limits, however, should not be taken as cast in stone. In contrast, it is often so that methods, developed for the audible range for one case, are applicable and suitable for the infra-sound (e.g. seismology) or ultra-sound (e.g. material science) ranges for other.

Even with the limits of the audible range imposed, the frequency range is very big and the field of structure-borne sound extremely rich. The latter is true for both the phenomena entangled and for the applications. The abundance of phenomena is partly a consequence of the multitude of materials and material combinations encountered, the almost unlimited structural configurations and, last but not least, the number of wave types that can exist in solids. With respect to applications, structure-borne sound is central to noise control in conjunction with practically all active artefacts, to material testing, to machine or process monitoring, to under-water radiation from ships or in conjunction with geo-prospecting, to medical diagnostics and to a specific class of fatigue problems related, for example, to aeronautics. The latter applications constitute the 'transition zone' to the field of non-linear vibrations. Although a single individual oscillation can be treated as linear, the, over time, extremely large number of oscillations will leave irreversible changes. Also in this non-linear field, the methods of structure-borne sound can be employed allowing for some minor amendments.

The associated particle oscillations and acting oscillating forces are usually very small but similarly, a limitation of the amplitude range to that of linear processes still leaves a vast range. With respect to particle motions, this range spans from 10^{-11} m for small, high frequency vibrations to 10^{-3} m by low frequency, vigorous vibrations. Accordingly, the particle velocity traverses a range from 0,1 μm/s up to 1 m/s. Astonishingly, this means that the acceleration can be expected to be in the range from a mm/s^2 to 10 km/s^2. Herein are treated essentially linear processes so that a constant change in force results in a corresponding constant change in motion. If it is accounted for eventual changes in material parameters due to e.g., static loading, then most applications in practice involve linear processes. With the processes being linear, the applicability is warranted of the superposition principle.

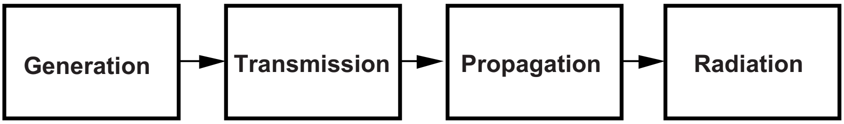

Fig. 1.1. Structural acoustic process

The structural acoustic process can be subdivided into four main stages as shown in Fig. 1.1. The first stage – generation – comprises the origin of an oscillation i.e., the mechanism behind it. The second – transmission – covers the transfer of oscillatory energy from the mechanisms of generation to a (passive) structure. In the structure, be it the passive part of the source or an attached receiving structure, the third stage – propagation – is recognised whereby energy is distributed throughout this structural system. Fourth, any structural part vibrating in a fluid environment (air) will impart power to that fluid - radiation - that is perceived as audible sound.

The complexity of the process generally calls for some kind of substructuring in order to concentrate on the, at each stage, essential physical phenomena. However, sub-structuring is often also dictated by the various parties involved. The source and the receiver are commonly associated with different companies, organisations or authorities with possibly different responsibilities. As an example, building services machinery can involve the manufacturer, the installation engineer, the constructor and the architect or proprietor.

Upon generalising, one may identify three types of situations;

- a machine (source) installed in a particular environment (receiver),
- a machine part (source) installed in a machinery (receiver),
- a sensitive piece of equipment (receiver) attached to a vibrating system (source).

In the first situation the source is causing unwanted sound or vibrations at or remote from the source location, e.g., a compressor in a building or a ship. The second type of situation relates to e.g., electric motors, pumps or fans which are installed and enclosed in a unit, as for example a washing machine or a printer. Finally, the third category, which is expanding, are encountered in conjunction with precision industry such as micro-electronics and in the construction branch due to harder exploitation of land.

Although the three situations are clearly very different from the point of view of the parties involved and thus the sub-structuring will lead to different results, the subdivision of the structural acoustic process remains valid and unaffected for all situations. Moreover, the system considered as a source in one situation may contain a part which constitutes the source in another.