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SOME COMMON CHARACTERISTICS OF MULTI-POINT AND COMPONENT STRUCTURE-BORNE SOUND SOURCES

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1. INTRODUCTION

The success of noise and vibration control most often depends on proper characterisation of the sources. This is particularly important in cases with sources of structure-borne sound and where the transmission to receiving structures takes place at multiple interfaces and involves multiple components of excitation and motion. In the linear domain, a proper characterisation of sources of structure-borne sound necessitates two sets of data - measures of the source's activity and the dynamic properties of the source structure. The two sets of data can be combined to form the source descriptor, a quantity which yields the source's ability to impart power and which enables analysis of the effects of multi-point and component transmission [1].

For the multi-point and multi-component case, the introduction of the effective mobility [2], defined by,

$$Y_{ii}^{nn\Sigma} = Y_{ii}^{nn} + \sum_{k=1\ k\neq n}^{N} Y_{ii}^{nk} \frac{F_i^k}{F_i^n} + \sum_{j=1\ j\neq i}^{6} Y_{ij}^{nn} \frac{F_j^n}{F_i^n} + \sum_{k=1\ k\neq n}^{N} \sum_{j=1\ j\neq i}^{6} Y_{ij}^{nk} \frac{F_j^k}{F_i^n}, \qquad (1)$$

means that the transparency of the single-point, single-component formulation can be retained when a contact point is considered but now taking the interaction with other points and components into account. F and Y are the generalised forces and mobilities respectively and super- and sub-indices denote contact points and components of excitation and motion respectively. The source descriptor [1] is expressed as,

$$S^{\Sigma} = \left|v_{FS}^{nn}\right|^2 \Big/ 2Y_{S,ii}^{nn\Sigma^*}, \qquad (2)$$

where v is the velocity at a contact point free from supporting or adjoining structures. The fact that the effective mobility involves the forces at the contact points strictly implies that the source descriptor is not independent of supporting and connecting structures and hence only allows approximate assessments when the force ratios are not detailed. Theoretically as well as experimentally it has been established, however, that those ratios overall vary within limits which allow meaningful analyses of the associated effects [1,3,4]. Thus, the deviations from the generic single point, single component case can be studied in terms of,

$$S^{nn\Sigma}/S^{nn} = Y_{ii}^{nn}/Y_{S,ii}^{nn\Sigma}, \tag{3}$$

i.e., the ratio of structural characteristics seen at a separated contact point to those when the interaction between all the contact points as well as all components are included. The focus of this paper is on a few characteristics of structure-borne sound sources for which there are strong indications of generality.

2. SIMILARITY IN STRUCTURAL CHARACTERISTICS

Besides the source activity, conventionally measured as 'free velocity', which indicates the collective response of all the vibration generating mechanisms, the source descriptor is influenced by the structural characteristics of the source. Experimentally obtained ordinary point, transfer and cross-transfer mobilities have been compared for samples within classes of real sources with different structural designs as well as between classes. In Figure 1 are exemplified the point and transfer moment mobilities for two radically different source systems from two classes of machines - a compact electric motor and a built-up fan unit. It is seen that although different in detail, both systems display mass- (mc), stiffness- (sc) and resonance-controlled (rc) regions. These regions occupy different frequency ranges which depend on global and local properties of the structures. Consequently it is not only scientifically more correct to distinguish between sources in mass-, stiffness- or resonance-controlled region but above all more helpful for the designer or noise and vibration engineer, cf. [2]. Moreover, the comparison of point and transfer mobilities highlights another similarity namely the significance of transfer and cross-transfer mobilities in those three regions. For the mass-controlled region, the transfer and cross-transfer mobilities are all equally important for the dynamic behaviour of the source as the point quantities. In the stiffness-controlled region on the other hand, mainly the point quantities are of importance. Finally, in the resonant region, point and transfer quantities are again both influential.

3. THE EFFECT OF MULTI-POINT CONTACT

In Figure 2 are shown the single point, single component source descriptors measured for two radically different source structures. It is seen that the dynamic range is large and that the two kinds of sources have altogether different signatures, the built-up source being broad-band and the compact source more tonal.

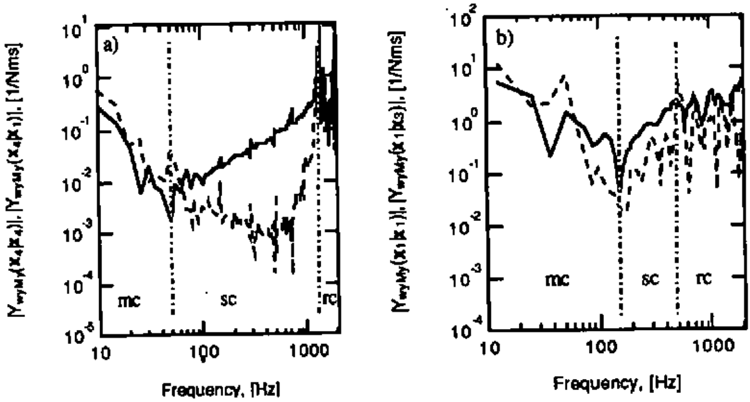

Fig. 1. Magnitude of point (——) and transfer (- - - -) moment mobility for a mount point on a compact source (a) and built-up source (b), [5-6].

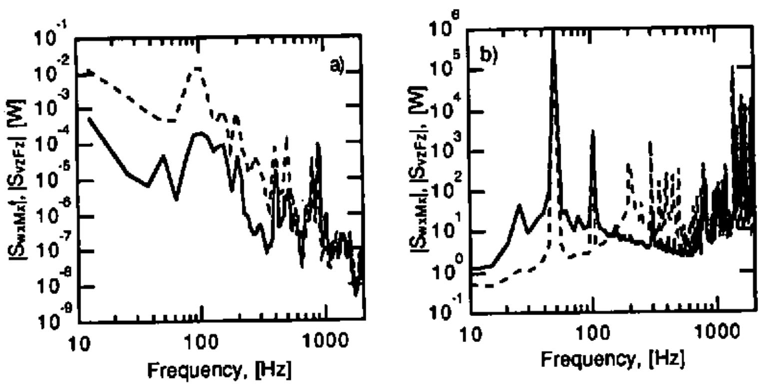

Fig. 2. Moment (——) and force (- - - -) source descriptors at a mount point of a built-up source (a) and a compact source (b).

Figure 3 exemplifies the shift of emphasis in the source descriptor spectra to high frequencies when the interaction between the contact points is strong.

This effect is clearly demonstrated also for a larger batch of real sources, and theoretical considerations of the significance of ordinary transfer mobilities in the mass and stiffness controlled regions reveal their markedly reduced influence in the latter region. Accordingly it is concluded that one consequence of multi-point installed sources is a need to consider a broader frequency range than would be expected from an analysis based on single point data. It is observed in Figures 2 and 3 that force and moment source descriptors are comparable in magnitude also when the interaction among different contact points is taken into account which means that there is no possibility, from a source point of view only, to omit any component a priori.

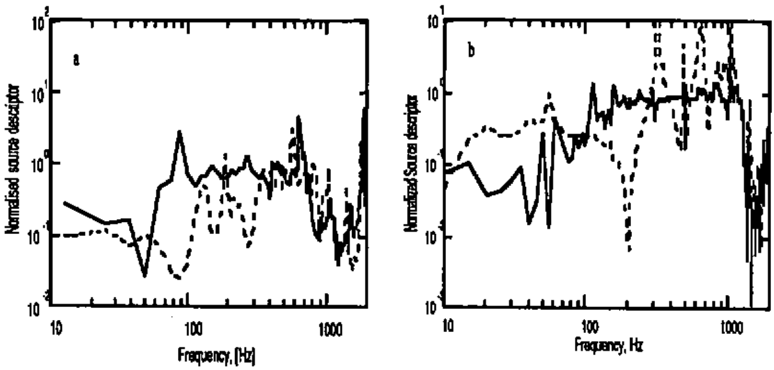

Fig. 3. Normalised moment (———) and force (- - - -) source descriptors of a built-up source (a) and a compact source (b) as function of frequency.

4. THE EFFECT OF MULTI-COMPONENT INTERACTION

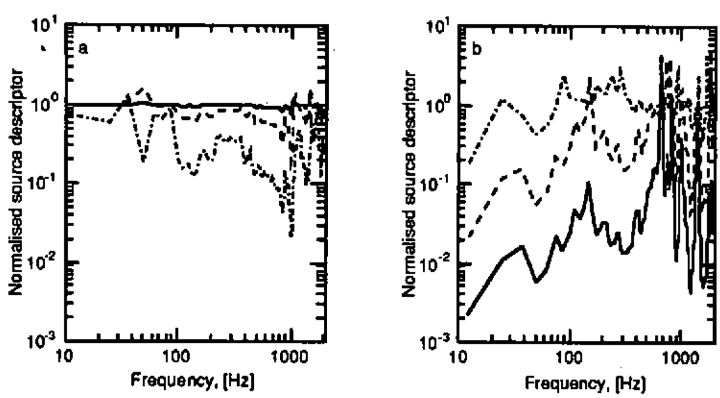

Figure 4. Normalised moment (a) and force (b) source descriptors for a built-up system. Moment to force ratio: (———) 1m, (- - - -) 0.1m and (-·-·-·-) 0.01m.

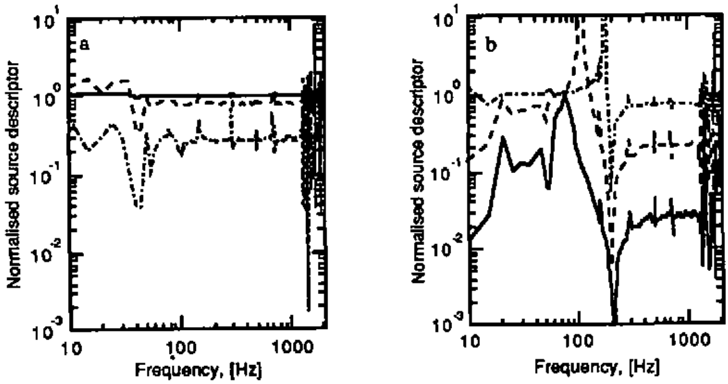

Figure 5. Normalised moment (a) and force (b) source descriptors for a compact system. Moment to force ratio: (———) 1m, (- - - -) 0.1m and (-·-·-·-) 0.01m.

In Figures 4 and 5 is shown the interesting complementarity of moment and force source descriptors when cross-coupling between components of motion and excitation is accounted for i.e., an increase of the moment to force ratio leads to a reduced force source descriptor and an increased moment source descriptor and vice versa. Again, the effects are demonstrated for both built-up and compact sources. One may note, however, that the effect is not quantitatively complemetary since for both kinds of sources, the force source descriptor is more severely influenced by the cross-transfer mobilities than is the moment source descriptor.

4. CONCLUDING REMARKS

In this presentation it is illustrated that although radically different in design, size and shape, sources of structure-borne sound share some important features which can have a profound influence on the power transmitted to receiver systems as well as the mode of transmission. Especially, the complementarity of force and moment source descriptors establishes a possibility to re-direct the transmission to a less offending mode. The results further suggest a modification of the concept of source of structure-borne sound. Rather than treating a physical unit consisting of one or more source mechanisms and a passive structural base or enclosure as a source of structure-borne sound, it is preferable to distinguish its mass-, stiffness- and resonance-controlled regions and thus obtain a set of three fundamental sources of structure-borne sound.

5. REFERENCES

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