AN ACOUSTIC DESIGN METHOD FOR LIGHT WEIGHT STRUCTURES SUPPORTING A VIBRATING SOURCE

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QUALITY IN ACOUSTIC

Today, acoustics play an important part in the commercial success of new manufactured articles. In fact, acoustic is part of the product quality and the consumers are interested in quality. Furthermore, the consumers sensitivity to quiet products has increased over the past few years because manufacturers have promoted the acoustical quality of their products.

However, there is a general problem with the integration of the acoustic in the design process. The development of a new product often neglects the acoustical aspect at the design stage to consider it only when a noise problem has appeared. The acoustical aspect has to be integrated in the design process by the development of an acoustical design method.

THE PROBLEM OF A LIGHT WEIGHT STRUCTURE SUPPORTING A VIBRATING SOURCE

Ventilation equipments are typical devices in which the noise level must be controlled to satisfy the acoustical comfort of the consumers. This type of devices generally include a light weight sheet-metal enveloping structure (a box-like structure) on which an electrical motor is mounted with a metal bracket (figure 1).

The acoustic problem with these ventilation devices is a very high noise level at 120 Hz and a variability of the level at this frequency from one device to another. The 120 Hz frequency is due to electromagnetic forces generated by the electrical motor and transmitted to the enveloping structure through the metal bracket.

There is a need to develop a systematic approach to obtain a design that is robust design and minimise the radiation of this type of light weight structure excited by a low frequency source. The design method should meet two objectives:

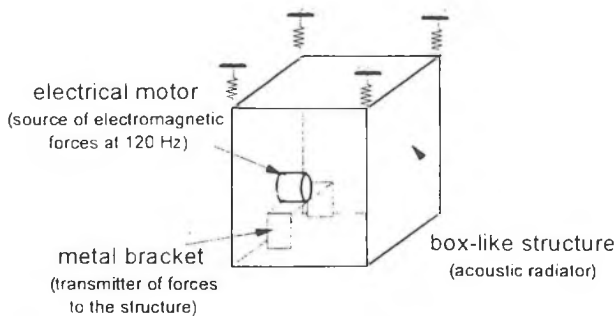1) Reduce the noise level at 120 Hz
2) Control the variability at 120 Hz

Figure 1: Basic vibro-acoustical model of a ventilation device

MOTIVATIONS

This research has two motivations. First, a scientific one of understanding the vibroacoustical behaviour of the structure as a function of geometrical and manufacturing parameters. Second, a technological motivation of improving the design approach to the development of quieter products.

DESIGN PROCESS

The proposed design method starts with the identification of basic design concepts based on acoustical engineering judgement. Then, two complementary approaches are used to analyse the effectiveness of these basic design concepts as well as the effect of various manufacturing and assembly parameters on the noise level. The first approach is to conduct statistically designed experiments to identify key parameters, their effects and their interactions. The second approach is a finite element modelisation including a sensitivity analysis of the quadratic velocity as a function of key parameters. The design process is illustrated in figure 2.

BASIC CONCEPTS

The basic concepts are based on the interpretation of the loads transmission between the connecting structure (bracket) and the receiving structure (box-like structure). The loads can be divided in forces and moments.

In the transmission of forces principle, normal forces are reduced by creating a bracket attached on the edges of the box. In this case any force transmitted to the box give rise to two in plane forces. In the transmission of moments principle, moments are reduced by using a very stiff bracket. These two principles are illustrated in figure 3.

Many other cases are possible and were derived and analysed using the same design principles.
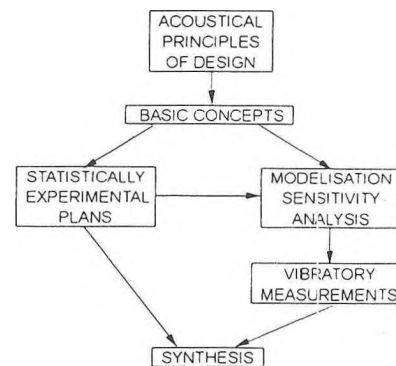

Figure 2: Design process

EXPERIMENTATION

Seven two-level variables were defined to characterize the response and the variability of the structure (figure 4). A 2^{7-3} fractionnary factorial plan was realised with two replications. The sound pressure level in the exhaust duct was the measured response.

The results for the mean analysis are shown in figure 5. It is interesting to note that the motor mount has a big influence on the response and that the elastic motor mount is very effective. This type of mount is effective because it eliminates the moment induced by the electrical motor. It is also interesting to note that the flexible bracket is very effective. At this stage, it is not possible to explain exactly why the stiff bracket is not effective but this will be done in the future with the modelisation. Also, the "at plate junctions bracket" is better than the "conventionel bracket" as it was supposed in the basic concepts. The difference may seem to be small, but this is because a first plan was realised to determine the optimal position of the conventional bracket.

The results for the variability analysis is given in figure 6. The motor mount, motor position and the number of assembling bolts variables have a big effects in comparison with the other factors. The problem is that although these effects are large, it is not possible to assign the variability of the response to any of these variables because the confidence level is lower than 90%. In conclusion of this analysis, the presence of an uncontrolled factor that influences the variability may be suspected.
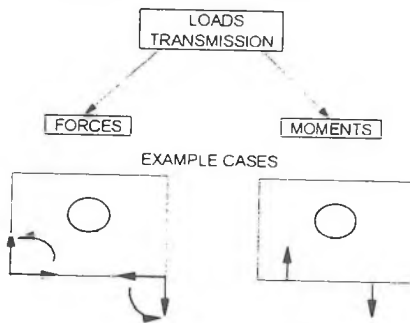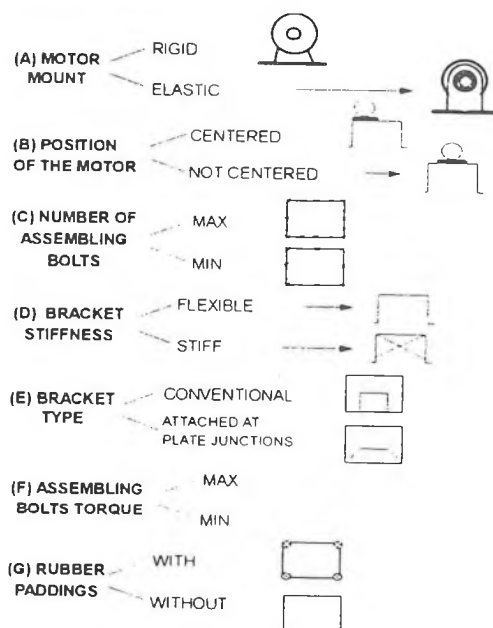

Figure 3: Basic concepts

Figure 4: Variables for the experiments

UNCONTROLLED FACTOR

The structure is very flexible and the assembly is not a precision mechanical one. Then, variable internal stresses and deformations may be induced by assembly. The problem is that it is not possible to make exactly the same configuration twice. This fact implies a shift of the natural frequencies for two identical setups made at two different times. This little shift in frequency induces a very high difference in amplitude.

MODELISATION

In the future, a finite element modelisation will be realised to understand of the results of the experimentation. Also, a sensitivity analysis of the quadratic velocity as a function of various parameters will be made

CONCLUSION

For the noise reduction objective, an analysis of the mean and the determination of the main effects lead to the conclusion that the motor mount variable is very important. These results will have to be verified with the modelisation in the future.

For the variability reduction objective, an analysis of the variance was performed and lead to the uncontrolled factor hypothesis. In the future, one way to better assess the effect of each factor would be to perform the same analysis with a new design of the structure in which the uncontrolled factor is eliminated.

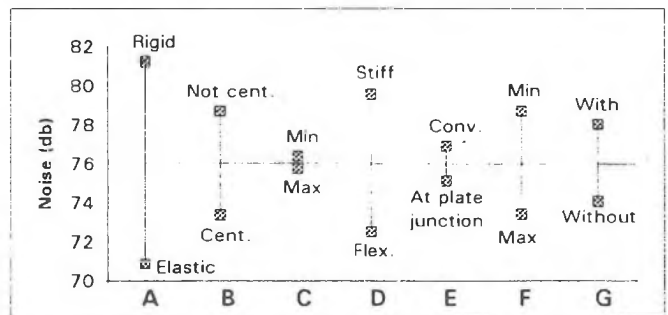| FACTOR	A motor mount	B motor position	C # bolts	D bracket stiffness	E bracket type	F torque	G rubber paddings
EFFECT (db)	10.40	-5.30	-0.71	7.02	1.78	-5.30	4.00
SIGN. (%)	99	99	<90	95	95	99	99
MEAN (db)	76.02						

Figure 5: Main effects on the mean

FACTOR	A motor mount	B motor position	C # bolts	D bracket stiffness	E bracket type	F torque	G rubber paddings
EFFECT (db)	-0.96	-1.08	-0.73	-0.10	0.35	0.29	0.05
SIGN.(%)	<90	<90	<90	<90	<90	<90	<90

Figure 6: Main effects on the variance