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A COMPUTER AIDED ANALYSIS ON VIBRATION OF ELEMENT AND INTEGRATED STRUCTURE OF MACHINE TOOL BY THE FEM - PART 2

有限要素法による工作機械構造の振動解析

—Study on Columns and Integrated Structures—

—脚と全体構造について—

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1. Introduction

In the previous paper[1] the objective of this study was described and the natural frequencies and the normal modes of bed structures were computed about small size perspex model. It showed that the FEM is effective for the analysis of the vibration characteristic of such structures. The extensive analysis on the columns and the integrated structure system is made in this report. The columns are dealt with as thin plate structure again. The integrated system is composed by equivalent beam system in the computation approach. It is shown that the substitution is effective for the approximate estimate of the vibration characteristics by reducing the complicated structure system to simple one without loosing its original property, which save computation time and computer size.

2. Analysis on the Supporting Column

In this study the supporting columns are simulated by short box type structure as shown in Fig. 1. It compares the results by the experiment and the analysis as for the corresponding modes of thick column. The results for the natural frequency is corrected as for Young's modulus of the perspex again. However, the surprisingly good coincidence can be found in the mode shape. The blank circle means the mode amplitude is negligibly small. Looking at every corresponding mode, slight discrepancy can be seen. This is caused by the fact that the boundary condition, the precision of the model and the method of the excitation cannot be made same in the experiment as in the analysis.

Comparing the mode for both results, the natural frequency only by the analysis will be mentioned in the following. For the mode of 410 Hz the cross section deforms like the shape which is subjected to internal pressure in one direction and to external one in another. The mode of 717 Hz corresponds to that of second order for this type. The upper edge and the center of a panel oscillate keeping reverse phase.

The difference between the mode of 410 and 510 Hz is that for the former the panel facing each other deforms reverse direction and for the latter

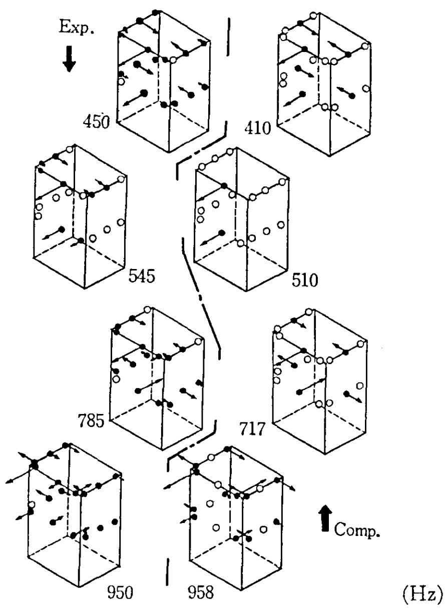

Fig. 1 The natural frequencies and the normal modes by the computation and the experiment for the thick column.

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one pair is standstill and another expands to same direction. This is closest to simple mode out of various ones which can be obtained by the analysis as the plate structure. Then 510 Hz is taken as the natural frequency of an equivalent beam in the direction shown in the figure. The same sort of equivalent beam can be given for the simple mode in another direction and the torsional mode. When the total system is integrated, these equivalent systms are adopted for the column. Various modes except these as plate structure are all neglected.

Same sort of computation and experiment are carried out for the slender column. Again both results agree well. The results by the computation makes it obvious that 1 Hz difference of the natural frequency causes alien mode, that is, 1,162 Hz has torsional mode and 1,163 Hz corresponds to a mode deforming the cross section. This means that the computation method should be compatible for taking such characteristic into consideration.

3. Analysis on the Integrated Total System

Now the perspex model of three element structures which are studied on the respective vibration characteristic is built up as shown in Fig. 2. The jointed points and lines are bonded by solvent. The analysis made so far tells us that the FEM for plate structure would also be effective for the integrated system as far as the memory capacity of computer is allowed.

Then each element system is replaced by equivalent beam system based on the analysis made previously. The equivalent beam is defined as solid cantilever which has same natural frequency as that of principal mode for the each element structure. The natural frequencies adopted are rearranged in Table 1.

Once the system is represented by the beam, various methods which have been developed so far are applicable and the memory capacity of computer can be saved. In this study the FEM for beam structure system is made use of. The beams equivalent to the bed and the supporting column are treated as the system with seven and two divided elements respectively. Now the joints connecting bed and columns are represented by points, which are located along the bed and correspond to just center of the cross section of the columns.

Table 1 The natural frequency of the equivalent beam integrating the total structure system.

Dominant Mode / Element Str.	Bending	Bending	Torsion
Bed	26.7	154	158
Thick Supporting Column	418	556	715
Slender Supporting Column	546	546	842

(Hz)

Fig. 2 compares the natural frequencies and the normal modes by the computation and the model experiment as for the several principal results. Although the modes by the computation are obtained for the beam system, they are overlapped on the

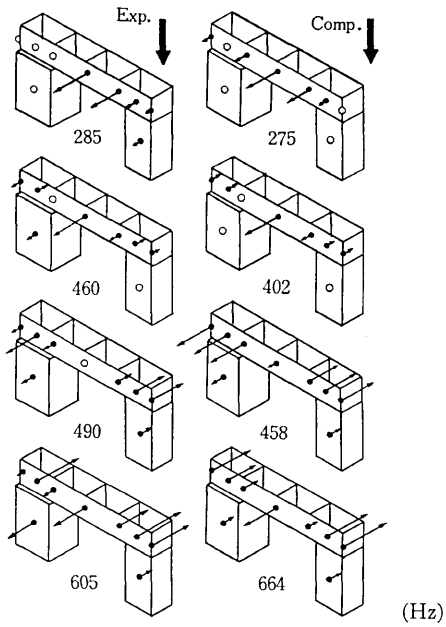

Fig. 2 The natural frequencies and the normal modes by the computation and the experiment for the integrated system.

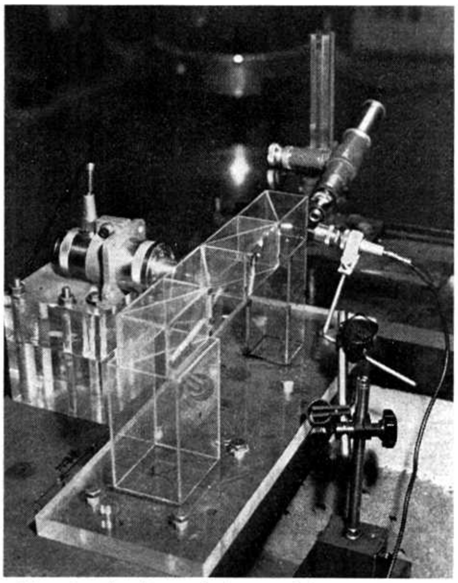
Fig. 3 A view of the model experiment.

perspective of the total system for the convenience of comparison. The direction of the amplitude is shown only for that measured in the experiment.

As for the first natural frequency both the frequency and the normal mode agree well. Some difference is found for the amplitude at the left end of bed, that is, it is almost zero for the experiment and small amplitude appears for the computation. This would be inevitable because the computation is carried out under different boundary condition around the joints. Taking this into account, the mode for the second frequency also coincides well each other, though 13% difference is seen about the frequency.

The third one which is regarded as the mode accompanying torsional defromation of the bed and is often observed in actual system shows good agreement. As for the fourth one the simlarity of the mode shape is disturbed at the left end, which seems to give a limit of adequacy of the beam model. The disturbance grows more for the mode of higher natural frequency than this. Although the natural frequencies in high frequency range are successively obtained for the computation, it is difficult and useless to compare these with the results by the experiment.

The coincidence between the computation and the model experiment is also found for the first mode of the system using bed type shown in Fig. 3 (b) in the previous paper 340 Hz for the former and 320 Hz for the latter. Comparing this with the first mode illustrated in Fig. 2, rise of the natural frequency can be clearly recognized.

4. Conclusions and Acknowledgement

The total structure system expressed by the equivalent beams is analyzed by the FEM for beam structure. It is concluded from this that the natural frequency and the normal mode agree well with those by the experiment especially as for the principal behaviour. This procedure saves the memory capacity of computer and makes it possible to estimate the vibration properties of the integrated system without loosing the characteristic of each complex element structure.

On the other hand, there remain some problems to be investigated further such that the natural frequency of the torsional mode is estimated considerably higher by the FEM in spite this the analysis for the integrated beam system making use of this estimation gives good results, whether the equivalent length of the columns should be taken same as the original, because the equivalent beam for the bed is not placed along the center of the cross section, but along its bottom in the analysis, and so on. The applicability of the method to the actual structure should be studied, too. It is expected that the developement of the analysis makes it possible to review and to find optimum dynamic structural design of machine, too. These study will be successively conducted.

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Referenccs

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