Hybrid technique for verifying the interactions between oscillating square prism and surrounding 2D flow

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ABSTRACT: In this paper, the experimental system using the NHAT (New Hybrid Aerodynamic vibration Technique) is introduced. This technique can verify the interactions between the oscillating 2D square prism and the surrounding flow. Moreover, the accuracy verifications of dynamic behaviors for the mechanism of NHAT without the non-linear effect due to the aerodynamic force is conducted, and then, the aerodynamic characteristics of the stasis and the oscillating cylinders (i.e. characteristics of pressure distributions and aerodynamic forces, the damping and mass ratio dependent of the response displacement, the lock-in, and the hysteresis of the response displacement) are verified using NHAT. The experimental results are compared with the results of the previous wind tunnel tests to argue the validities of the results using NHAT. On NHAT, the dynamic characteristics of the square prism such as the mass, the damping, and the stiffness can be set easily and precisely. Especially, in case of the non-linear restoring force is set on the equation of motion of the square prism, it is possible to simulate the aerodynamic behaviors of the elastoplastic structure, too. The interactions between the elastic structure and the surrounding 2D flow are simulated here.

1. INTRODUCTION
The hybrid technique is the combination of plural distinct-simulation techniques such as numerical simulations and experiments \textsuperscript{1}. In this technique, it makes possible to get the best of every approach. Kanda et al. developed the hybrid technique to simulate the complex interactions between the structure and the air flow \textsuperscript{2}. It is called ‘New Hybrid Aerodynamic vibration Technique; NHAT’. In this technique, the model is set in the air flow prepared by the wind tunnel equipment. The external wind force is measured by differential pressure instruments (64ch), and the values of the force are passed along the computer and the response deformation is calculated by the numerical calculation on the PC. And then, based on the results of the calculations, the model is moved forcibly. Finally, the interactive phenomena between structural model and air flow can be reproduced on our technique. On the other hand, the dynamic parameters of the structure such as mass, damping, and stiffness are set numerically on the PC. As the results, the pressure distributions and aerodynamic forces can be measured systematically. This technique is able to become the effective tools for this problem in the wind engineering field.
2. CONCEPT OF NEW HYBRID AERODYNAMIC VIBRATION TECHNIQUE (NHAT)

2.1 Outline of NHAT

NHAT consists of two elements. The first one is the experimental equipment including the wind tunnel device. The second one is the PC for calculating the response of the virtual structure. The measured data of the air pressure and the displacement are transmitted to PC via A/D board. Based on the data of the air pressure, the drag and lift force, and the torque acting on the cylinder are derived. These three forces are treated as the external force for the equations of motion. From these equations, the response velocities are derived. These values are sent to the shaking mechanism, and then the structural model which is based on these values in three directions is moved. One cycle of this procedure as shown in Fig. 1 is 4msec.

Fig. 1 Flowchart of real time hybrid simulation (NHAT)

2.2 Experimental part of NHAT

The model of the square prism has three degrees of freedom (X axis; flow direction, Z axis; across-flow direction, and θ axis; torsional direction) as shown in Fig. 2a. The apparatus is opened up to the air flow of the wind tunnel. To maintain the properties of uniform flow around the experimental model, the model is surrounded by the end plates as shown in Fig. 2b. Fig. 3a shows the configuration of the 2D model.

Fig. 2 Experimental part of NHAT

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|x| Displacement
|---|---|
| ẋ| Velocity

xₜₐₜ: Measured Displacement
xₖ: Calculated Displacement
F: External Force
P: Air Pressure
A: Distribution Area
2.3 Numerical simulation part of NHAT
NHAT is the real-time simulation. So there are some requirements on numerical integrate method such as no convergent calculations, explicit time integration method, high level of numerical stability, and high accuracy for high-frequency electronic noise. As a means of qualifying method, α-OS method is employed.

3. VERIFICATIONS FOR DEVELOPED EXPERIMENTAL SYSTEM
To examine the accuracy of the pressure-measurement mechanism, the results using NHAT system are compared with the results of previous experiments in Figs. 4a. Fig. 4b indicates the aerodynamic coefficients based on the pressure distributions. As shown in these figures, it is good agreement of the results in previous studies. Moreover Strouhal number in NHAT is 0.12. As shown in these results, this value coincides with the value of the previous studies.

It is also checked that following capabilities of exciter and the accuracy verifications of dynamic motions for SDOF system in NHAT. Good agreements are confirmed as shown in Fig. 5. Finally, the aerodynamic simulations are shown in Fig. 6. The nonlinearities of aerodynamic phenomenon are reproduced on NHAT properly. In case that the $Sc$ is less than 16.0, once the vortex-induced oscillations occur, the response level of oscillations increases and diverges by the galloping oscillations. In case that the $Sc$ is more than 16.0, the response level increases around the resonant wind velocity ($Vr = 8.0$). As shown in Fig. 6b and c, the hysteresis of response and lock-in phenomena occur in the wind tunnel test using NHAT.
4. SURFACE PRESSURE AND AERODYNAMIC FORCE OF OSCILLATING CYLINDER

The time histories of displacement, pressure distribution, and aerodynamic force can be measured simultaneously using NHAT. Fig. 7a shows the distributions of stationary and oscillating cylinder. Fig. 7b shows the lift force and its dominant frequency component characteristics. We are going to conduct comprehensive exams on this theme.

REFERENCES

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