# Flutter stability studies of long span bridge with central slotted box girder by CFD numerical simulation

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## Summary:

By secondary development of commercial computational fluid dynamics software FLUENT, this paper establishes two-dimensional bending and torsion fluid-structure interaction numerical model to calculate flutter critical wind speed of long span bridge with central slotted box girder. There are three main girder schemes: Scheme1: Close box girder; Scheme2:Central slotted box girder with 40% slotted rate. Scheme 3: Central slotted box girder with 100% slotted rate. According to time histories of vertical displacements and torsion displacements, We can judge whether the bridge is in the state of divergent vibration at a certain wind speed and decide critical flutter wind speed . Numerical calculation results indicate: For streamlined box girder, the central slotted girder with appropriate width can improve the flutter critical wind speed. When the slotted width reaches a certain value, the critical flutter wind speed will reach the maximum value. When the slotted width continue to increase, the flutter stability of bridge decrease. Numerical simulation results are consistent with the wind tunnel test.

**Keywords:** fluid-structure interaction; flutter critical wind speed; CFD numerical simulation closed box girder;central slotted box girder

## 1. Introduction

With the increase of bridge span, flutter stability is one of the key problems for wind-resistant design of long-span bridge. Streamlined steel box girder has a good aerodynamic performance and is the common girder section of long-span bridge. When the closed box section can not meet the requirements of flutter stability, central slotting is an effective measure to improve the flutter critical wind speed.Slotted box girder have been used in Xihou Men suspension bridge and Stonecutters cable-stayed bridge etc.It will be used in Messina Strait suspension bridge.

## 2. Numerical simulation

### 2.1 Numerical simulation principle

The schematic diagram of numerical simulation is shown in Fig.1.The governing structural equation for one-degree-of-freedom heaving mode and torsional mode is shown as (1) (2). The governing equations of the incompressible flow is the continuity equation and the Navier-Stokes equations as (3), (4).

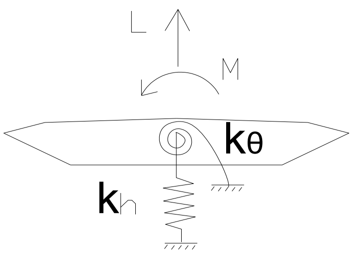



*Fig.1: Schematic diagram of numerical simulation*

$$m\ddot{y}+c_h\dot{y}+k_h y=F_h \quad (1) \qquad I_\theta\ddot{\theta}+c_\theta\dot{\theta}+k_\theta\theta=M_\theta \quad (2)$$

$$\nabla\cdot\vec{V}=0 \quad (3) \qquad \frac{\partial\vec{V}}{\partial t}+(\vec{V}\cdot\nabla)\vec{V}=-\frac{1}{\rho}\nabla p+\mu\nabla^2\vec{V} \quad (4)$$

Solve equation (3),(4),obtain pressure and velocity around object,calculate aerodynamic force acting on the object. This can be done by FLUENT.Then extract lift and moment into vibration equation (1) (2) and solve the vibration equation by Newmark method.The velocity is assigned to the object and simulate object move by FLUENT dynamic mesh technique. This can be done by secondary development of FLUENT which program code is embedded to the FLUENT by user defined function(UDF).

### 2.2 Numerical simulation model

Tongji University has done much research on flutter stability of central slotted box girder by wind tunnel test.Girder sections of wind tunnel test model is shown in Fig.2. Local mesh of three numerical simulation model is in Fig.3.

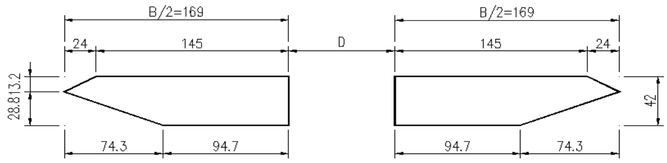
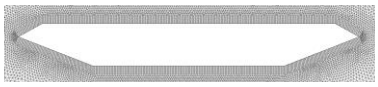
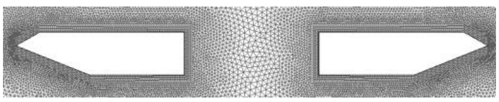



*Fig.2: Girder sections of wind tunnel test.(unit:mm)*

*Scheme 1(B/D=0)*



*Scheme 2(B/D=40%)*



*Scheme 3(B/D=100%)*

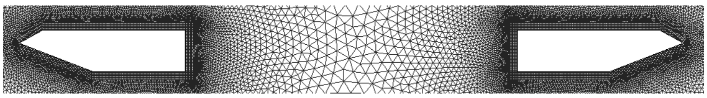


*Fig.3* Local *mesh of three numerical simulation model*

### 2.3 Numerical simulation results

*Table 1: Flutter critical wind speed (m/s)*

| Scheme | Scheme 1 | Scheme2 | Scheme 3 |
|---|---|---|---|
| Section model wind tunnel test | 15 | 19.8 | 17.9 |
| Numerical simulation | 14 ~ 16 | 18 ~ 20 | 16 ~ 18 |

As shown in Table1.Critical wind speed of flutter by numerical simulation is in agreement with wind tunnel test.

## 3. Conclusions

By numerical simulation analysis can we get the following conclusions:

1.Flutter critical wind speed by numerical simulation is in agreement with wind tunnel test.
2.For streamlined box girder, the central slotted girder with appropriate width can improve the flutter critical wind speed of the bridge.When the slotted width reaches a certain value, the critical flutter wind speed will reach the maximum value.When the slotted width continue to increase,the flutter stability of the bridge decrease.