Effect of Truss Number on the Dynamic Response of Truss

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Keywords: Truss, Truss number, Finite element model, Dynamic response.

Abstract. The safety of truss is determined by dynamic response of truss during the engineering application. Truss number is an important parameter for the engineering application of truss, which is related with the economy and convenience. The effect of truss number on the dynamic response of truss can be analyzed by means of commercial finite element software. Here, a finite element model (FEM) was employed to simulate the dynamic response of truss structure. By using the proposed FEM, the effects of truss number on the maximum displacement and Mises stress were researched. Based on the numerical results, the dynamic responses are different from each other for different truss numbers. The maximum displacement and Mises stress increase with the increasing truss number; however, the maximum displacement and Mises stress keep on a stable value when truss number is more than a certain number.

Introduction

Truss structure is widely used in bridge, aerospace and construction because of its high ratio of stiffness to mass. Truss structure can be under dynamic loading during its usage. Maximum displacement is an important parameter during the design of truss structure. If the maximum displacement of truss structure is not satisfied with the available standard, there would be a risk during the usage of truss structure. Therefore, the effect of impact speed on the maximum displacement should be analyzed to make sure the safety of truss structure.

For uniform beam structure, there is a classical theory to calculate the mechanical response [1]. The theoretical model is useful for the homogeneous beam section. For truss structure, the sections of truss are inhomogeneous; therefore, the available theory is useless to calculate the mechanical response of truss structure. Fortunately, it has been demonstrated that finite element model (FEM) is a valid technology to analyze mechanical properties of truss structure [2-5]. From then on, the FEMs of truss structure have been widely researched. In order to analyze the elasto-plastic small deformation, an extended multiscale finite element method was developed for 2D periodic lattice truss materials [6]. Before using FEM to predict the deformation of truss structure, the differences between matrix displacement method and finite element method were analyzed [7]. Based on the stiffness and load matrix of bridge frames, a FEM was established to calculate the lateral displacement under the loading of wind [8]. The initial yield surface of periodic 2D trusses of beams and evolution of the yield surface with ongoing hardening were both added into an asymptotic discrete expansion FEM to simulate the elastoplastic homogenized response of lattice truss structure [9]. In order to realize the geometrical nonlinear analysis of the structures with lattice truss materials, an equivalent continuum multiscale formulation was presented by combining the extended multiscale finite element method with the co-rotational approach [10]. The static response of truss structure has been widely investigated; however, the effect of truss number on dynamic response of truss structure has not been explored.

In this paper, we employed a finite element model (FEM) to calculate the dynamic response of truss structure. A series of FEMs have been established to analyze the dynamic response of truss structure at different truss numbers. Finally, the effect of truss number on the dynamic response was discussed.
Finite Element Model

The finite element model (FEM) aimed to simulate the mechanical behavior of truss structure, has been developed by means of Abaqus 6.11-1 [11,12]. In order to research the mechanical properties of truss structure, a 3D FEM has been defined accounting for the truss geometry, materials and boundary conditions. A deformable 3D truss model was generated by means of planar commands. Concerning the meshing of the beam, the truss has been discretized by means of shear-flexible elements adopting the global seeds meshing technique. In order to favor convergence and reduce the computational time, the simplest element type has been chosen, for example the B31, that is a 2-node linear beam in space. Figure 1 illustrates FEM of truss structure. The boundaries for simply supported beam was used here. The bar with the length of 400 m and the diameter of 50mm is above the truss structure. The length of truss structure is 10m and the transverse section of truss structure is 1m×1m. The spacing of the adjacent truss is 20 m. The impact speed V is about 14 m/s. In this study, the parameters of truss structure and bar are fixed. Only the number of truss is varied, e.t., 1~9. The different FEMs are shown in Table 1. The model consisted of approximately 8200 elements and 7961 nodes. A dynamic explicit procedure type was chosen to calculate the dynamic response of truss structure. When the calculations of the dynamic response have been accomplished, the Mises stress and maximum displacement of truss structure are obtained by picking up data from the output databases. Based on the calculated results, the effect of truss number on the dynamic response was analyzed.

![Figure 1. Finite element model (FEM) of 3D truss structure.](image)

| No. of FEM | 1 | 2 | 3 | 4 | 5 |
|------------|---|---|---|---|---|
| Number of truss | 1 | 3 | 5 | 7 | 9 |

Dynamic Response

Using 3D ABAQUS finite element model of the truss structure, the dynamic response was researched. Figure 2 shows Mises stress distribution for the FEM with truss number of three. The maximum stress appears in the middle of truss. Figure 3 shows the the stress-time relationship during the process of impact. Before the impact of bar, the stress are zero. Once the bar hits against the truss structure, the stress increase greatly. As shown in Figs. 3, the periodic fluctuations of stress appear in the time travel curves. The maximum stress happen at the first time of impact. The amplitude of fluctuation varies with the increasing impact time, which indicates that the truss structure vibrates during the process of bar impact.
The effect of truss number on the dynamic response of truss structure is illustrated in Figure 4. The relationship between maximum displacement and truss number is nonlinear. The maximum displacement increases greatly with the truss number if the truss number is less than 5. The maximum displacement keeps a stable value if the truss number is more than 5. This explains that five trusses are enough to absorb the energy of impact bar. According to the simulated results in Figure 4, the maximum displacement is about 13.34 mm.

Concluding Remarks

Based on finite element method of ABAQUS 6.11-1, a finite element model (FEM) was employed to research the effect of truss number on the maximum displacement. According to the simulated results from FEM, the dynamic response was investigated. The maximum stress appears in the middle of truss. The maximum stress happens at the first time of impact. The amplitude of fluctuation varies with the increasing impact time. The relationship between maximum displacement and truss number is nonlinear. With the increasing truss number, the maximum displacement increases greatly at first.
and then keeps a stable value if truss number is more than a certain value. The certain value here is five and the stable maximum displacement is $13.34$ mm.

![Figure 4. Maximum displacement at different truss numbers.](image)

**Acknowledgement**

This research was financially supported by Fundamental Research Funds for for undergraduates.

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