Jestr

Journal of Engineering Science and Technology Review 14 (2) (2021) 1 - 7

JOURNAL OF
Engineering Science and Technology Review

Research Article

www.jestr.org

Analysis on Influences of Fastening Bolt Pretightening Force on Dynamic Behaviors of Structures

Dengqi Guo[1], Xianqi Zhou[1,*], Zili Chen[1], Jinbi Ye[1] and Peijuan Cao[2]

[1]*Xiamen University of Technology, Xiamen 361024, China*
[2]*University of Florida, Gainesville, FL 32611, United States*

Received 10 February 2021; Accepted 24 April 2021

Abstract

Vibration has an effect on structures. Vibration can affect structural stability by loosening the fasteners and might even cause structural failure. Experimental analysis on the pre-tightening force of the bolts in actual engineering was conducted to reveal the effect of the pre-tightening force of the fastening bolts on the dynamic behaviors of the structure. The bolt vibration isolation design was conducted using the force analysis of the fastening bolts, and the bolt vibration isolation measurement model was established. The expression of the maximal working interval of the pre-tightening force was deduced from experimental measurements of the spring washer, elastic vibration isolation content, and pre-tightening force. The compression test of the testing spring was used to determine the corresponding frequency, and a time history diagram was developed. The testing data were later analyzed to obtain an effective working interval of the system, an optimal pre-tightening force of the spring, and an effective stroke of displacement. Results indicate that different preload forces exert different vibration isolation effects on the structure. The spring stiffness is close to infinity when the spring is compressed to 24 mm, and the effective stroke is zero. The study provides guidelines for the design steps of the vibration isolation system based on its dynamic requirements and serves as a guide for selecting the appropriate spring washers and elastic vibration isolation materials in the project to achieve appropriate vibration isolation and noise reduction.

Keywords: Bolt pre-tightening force, Effective travel, Vibration isolation materials, Effective working interval

1. Introduction

Bolted connection is widely applied in all industrial sectors. It has an been important part of machines over centuries because of its simple structure, convenient operation, and high connection strength [1-2]. Bolted connections are used to connect two or more components. The importance of bolted connection is undeniable, but problems concerning its use remain. Vibration is a physical phenomenon frequently encountered in people's lives and industrial production, causing inevitable losses in many fields. Threaded fasteners will experience looseness and instability under external dynamic loads, such as vibration, resulting in a decrease in clamping force; the looseness or over-tightening of bolts will cause the sliding of the connecting piece or damage the bolt strength, which will cause damage to the main structure [3-5].

Different bolt pre-tightening forces have various effects on the dynamic performances of the structure. The effective stroke of the vibration isolation spring will change after the application of the pre-tightening force to the structure. If the effective stroke is not sufficient, it will impact the structure and affect the vibration isolation effect. On the side where the preload is applied, it is usually necessary to add vibration isolation materials (e.g., springs or elastic washers). The vibration isolation material and the original vibration isolation spring are connected in parallel, and its elastic constant stroke will also significantly affect the vibration isolation effect of the structure.

Therefore, scholars have implemented enormous studies to explore bolt pre-tightening force and its effect on structural dynamic performances [6-9]. However, the previous studies failed to solve the actual problem of the pre-tightening force influence of the fastening bolt on the dynamic performances of the structure effectively. Therefore, the accurate prediction of bolt pre-tightening force and its relation with dynamic performances of structures in a practical operating state is an urgent problem to be solved.

This study uses the design of a vibration isolation system to test and analyze the pre-tightening force of bolts with elastic vibration isolation materials and spring washers to close the gap. This study aims to provide the effective range of bolt pre-tightening force and its maximum working interval. The current study also explains the influence of installing pre-tightening bolts of vibration isolation systems on the dynamic performance of the structure. Moreover, a theoretical basis for guiding engineers to select appropriate elastic vibration isolation materials is presented in this study.

2. State of the art

At present, scholars have conducted a considerable amount of work on bolt fasteners, with different methods and focus. The value of the tightening torque that must be applied can be determined through analysis and experience to generate a certain pre-tightening force in the fastener [10]. Cabaleiro M et al. [11-12] used finite element analysis software to study the bolt pre-tightening force via different simulation

*E-mail address: xianqizhou@163.com
ISSN: 1791-2377
doi:10.25103/jestr.142.01

methods. Yang Zhang et al. [13-14] proposed a new method to detect the fastening state of bolts. Jong-Kook Hong [15] studied the performances of pre-tightening bolts in the bolted holder by using the finite element analysis software but did not explore the vibration characteristics between the bolt and the structure. Atsushi Noma and Jianmei He [16] analyzed the spring characteristic effects of the spiral cutting bolt structure and the anti-loosening performance of threaded fasteners but lacked a detailed discussion and analysis on the bolt pre-tightening force characteristics. Fujian Zhuang and Puhui Chen [17] studied the effect of missing bolts on the mechanical properties of double-lapped multi-row composite bolt connections by numerical simulation but disregarded the bolt pre-tightening force and vibration characteristics. Yong-xiang Zhang et al. [18] analyzed the vibration transmission characteristics of bolt connection structures based on ANSYS software and found that the inherent frequency of the system increased with the pre-tightening force. However, the model was relatively simple and cannot effectively demonstrate the effect of bolt pre-tightening force on the transmission characteristics of structures. Si Mohamed Sah et al. [19] proposed a technology based on the general vibration response of bolts to evaluate the bolt tightening level (e.g., loosening or tightening) and quantify the bolt tension. However, the loosening problems caused by the spaces between bolts and the structure were not deliberated. Zhao Gong et al. [20] discussed the influencing laws of bolt pre-tightening force on the characteristic parameters of bolt interface through an experimental study and found that the characteristic frequency of bolt interface was positively related to bolt pre-tightening force. Yamagishi, T et al. [21] analyzed the mechanical behavior of bolt joints under lateral loads and proposed a critical relative slip where loosening occurs. Wang Qingwen et al. [22] respectively simulated the failure modes of two types of typical transient impact loads to obtain the failure laws of the connection structure. However, they did not study the failure modes of non-uniform bolts and variable structure parameters. Lu Xu et al. [23] investigated the vibration characteristics of bolted flange connection structures with shear pins (cones). Zhang Zhen et al. [24] explored the effect of initial preload and excitation frequency on the time-varying behavior of bolt relaxation through bending resonance test.

The above-mentioned results mainly focus on the study of the bolt tightening state and the mechanical characteristics of bolt connections. However, studies focusing on the effect of the dynamic performance of the structure, especially the correlation work on the influence of the bolt tightening force on the dynamic performance of the structure, are substantially limited. The bolt vibration isolation design method is adopted in this study to establish the bolt vibration isolation calculation model. Starting from the influence of the pre-tightening force on the dynamic performance of the structure, the effective action interval of the bolt pre-tightening force and the maximum working interval of the pre-tightening force are discussed. The relationship between the force and the effective range provides a basis for the influence of the bolt pre-tightening force on the dynamic performance of the structure.

The remainder of this study is organized as follows. Section 3 designs the bolt vibration isolation based on the force analysis of the fastening bolt and develops a bolt vibration isolation calculation model. Section 4 discusses the effective and maximum working intervals of bolt pre-tightening force based on its effect on the dynamic performance of the structure. Section 5 summarizes the study and offers pertinent conclusions.

3. Methodology

3.1 Stress condition analysis of fastening bolts

Fig. 1 shows that bolted connection is adopted between vibration isolation equipment I and base II. Elastic materials are found between I and II, with rigidity of k_1. Moreover, elastic materials (e.g., spring washer) with rigidity of k_2 are observed between the fastening bolt and the connected equipment I. The diameter and elasticity modulus of fastening bolts are d and E, respectively.

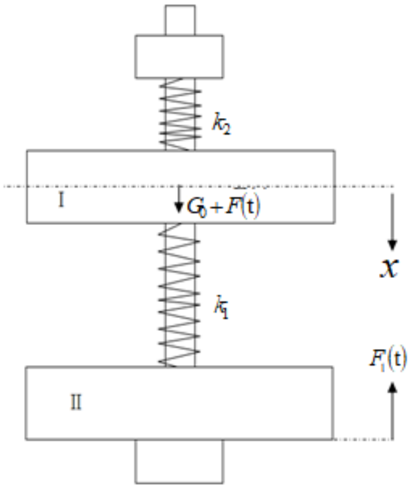
(1) The effective working load range of elastic materials with a rigidity of k_1 is $0 \le F_1 \le F_{10}$.

1) If $F_1 \le 0$, then the elastic materials and I are separated; thus, $F_1 = 0$ is set.

2) If $F_1 \ge F_{10}$, then the compression stiffness of the spring is substantially high and can be viewed as a rigid connection between the elastic materials and I.

(2) Similarly, the effective working load range of elastic materials with rigidity of k_2 is as follows.

1) If $F_2 \le 0$, then the elastic materials and I are separated. At this moment, $F_2 = 0$ is set;



(a) Connection diagram

(b) Equipment-base connection

Fig. 1. Connection diagram of the equipment and the base

2) If $F_2 \ge F_{20}$, then the rigidity $k_2 = \frac{E_2 S_2}{L_2}$ between the elastic materials and I is the tensile rigidity of the bolt. Hence, k_2 is relatively large and can be viewed as a rigid

connection, S_2 is the cross-section of the bolt, and L_2 is the bolt length.

(3) The vibration of I is considered.

1) The compressing forces of the compressed springs k_1 and k_2 must respectively have $F_1 \geq 0$ and $F_2 \geq 0$ to assure the stable operation of I. If $F_1 < 0$ or $F_2 < 0$, then I is separated from the elastic materials with the rigidity of k_1, thus generating an impact to influence the normal operation of the equipment.

2) The elastic coefficient significantly increases when the compressing forces of the compressed springs k_1 and k_2 change from $F_1 \leq F_{10}$ to $F_1 \geq F_{10}$ (or from $F_2 \leq F_{20}$ to $F_2 \geq F_{20}$) because the spring pressure exceeds the normal working range. The equipment I must have an impact on base II or the bolt.

The discussion on the influence of the bolt pre-tightening force on the dynamic performance of the structure and the relationship between the bolt pre-tightening force and the effective range of action is presented in the current study to prevent the equipment from detaching from the spring or impacting the bolt and the foundation.

3.2 Analysis of spring washer and elastic vibration isolation materials

Fig. 2 shows the properties of the elastic materials with a rigidity of k_1. O_1A_1 is the normal working range, and A_1B_1 is the compression constant of the equipment when the normal working range of materials, which could be ∞, is exceeded.

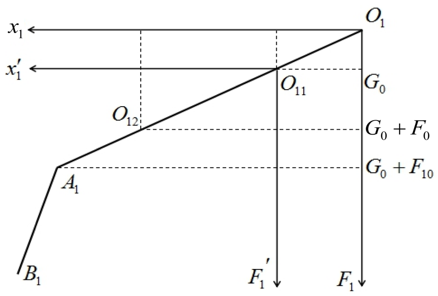


Fig. 2 Properties of spring k_1

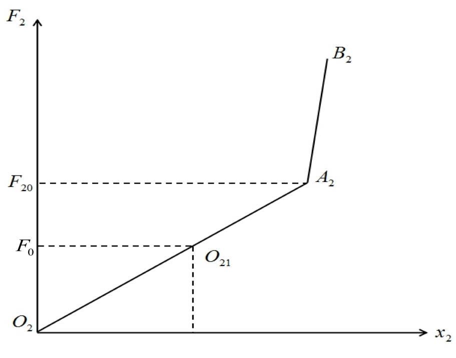


Fig. 3 Properties of spring k_2

Fig. 3 shows the properties of the fastening elastic material (k_2). O_2A_2 is the normal working range, and the section constant is $\frac{E_2S_2}{L_2}$. E_2, L_2, and S_2 are the elasticity modulus, working length, and cross-section of fastening bolts, respectively. However, the constant of section A_2B_2 is considerably large.

(1) The vibration isolation equipment is in the compression state due to the dead load. If the dead load of the bolt is G_0, then the compression displacement is $s = \frac{G_0}{k_1}$. Fig. 2 shows that point O_1 travels from line O_1A_1 to point O_{11} under the dead load G_0 and forms the $x_1' - F_1'$ coordinate system.

(2) Fig. 2 shows the gradual movement of balance point O_{12} to point A_1 along the O_1A_1 line after the steady application of the pretightening force (F_0). Fig. 3 reveals that the balance point O_{21} moves from point O_2 to point A_2 along the line O_2A_2. O_{12} and O_{21} are the balance points of the system.

(3) The sums of Figs. 2 and 3 are superimposed, and the coincidence of these figures forms the origin of the coordinate, which is the equilibrium point of the system, to obtain a diagram of the system as shown in Fig. 4. The broken line in the figure reflects the force changing with the load-displacement curve. The middle section of Fig. 4 represents the effective working range of the system.

$$-Min\left(F_{10}-F_0,F_0\right) \leq F \leq Min\left(F_{20}-F_0,G_0+F_0\right) \tag{1}$$

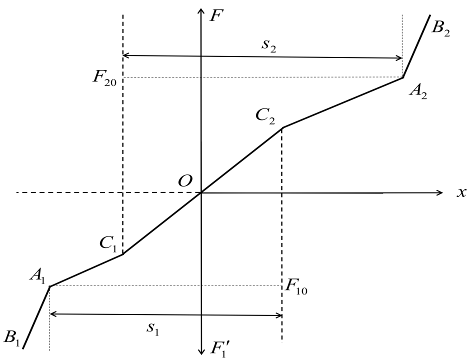


Fig. 4 $x-F$ of the system

3.3 Pre-tightening force analysis

From the above analysis, it can be seen that as the pre-tightening force gradually increases from 0, it is shown in Figure 2 as the segment increases and the segment decreases; in Figure 3 it is shown as the segment increases and the segment decreases; in Figure 4, it is shown as the segment increases. The segment and the segment decrease; in formula (1), it is expressed as and gradually increase, and gradually decrease

When $F_{10}-F_0=F_0$ or $F_{20}-F_0=G_0+F_0$

$$F_0=\frac{F_{10}}{2} \text{ or } F_0=\frac{F_{20}-G_0}{2} \tag{2}$$

The maximum is achieved when $Min\left(F_{10}-F_0, F_0\right)$ or $Min\left(F_{20}-F_0,G_0+F_0\right)$. Specifically, points O_{12} and A_1 in Fig. 2 and O_{21} and A_2 in Fig. 3 overlap. Moreover, points C_1 (C_2) and A_1 (A_2) in Fig . 4 overlap.

At this time, continue to increase the pre-tightening force, the effective working range is gradually reduced in the middle section of Fig . 4, showing that the point or the point gradually approaches the point, indicating that the effective working range of the system is gradually reduced. Finally, when the points or points reach the point, the connection between the vibration-isolated object and the foundation is shown as a connection of foundation stiffness or bolt tensile stiffness, which can be regarded as a rigid connection.

Therefore, the elastic materials (k_1 or k_2) have lost their effects of system vibration isolation and vibration reduction.

3.4 Design steps of the vibration isolation system
(1) Appropriate system elastic parameters (k) were chosen in accordance with the requirements of system dynamics, and amplitude (A) of the system was calculated.

(2) The system elasticity parameter (k) was distributed to realize $k = k_1 + k_2$.

(3) The effective working ranges of elastic materials and pretightening spring (F_{10} and F_{20}) were chosen in accordance with A, k_1, and k_2.

(4) The appropriate pretightening force (F_0) was chosen and calculated as follows:

$$\begin{aligned} a &= Min\left(F_{10} - F_0, F_0\right) \\ b &= Min\left(F_{20} - F_0, G_0 + F_0\right) \end{aligned} \tag{3}$$

(5) Verification: the appropriate safety coefficients (n_1 and n_2) were chosen for verification.

$$\begin{aligned} A &< min\left(\frac{a_1}{n_1}\right) \\ B &< min\left(\frac{a_2}{n_2}\right) \end{aligned} \tag{4}$$

(6) If the condition (4) is not met, then Steps (2)-(4) are repeated in accordance with the practical selected materials for verification.

3.5 Summary
(1) When $F_0 \le \frac{F_{10}}{2}$ or $F_0 \le \frac{F_{20} - G_0}{2}$, the effective working range of the system gradually increases with the bolt pretightening force. This finding indicates that increasing pretightening force is beneficial to vibration isolation and attention of systems.

(2) When $F_0 \ge \frac{F_{10}}{2}$ or $F_0 \ge \frac{F_{20} - G_0}{2}$, the effective working range of the system gradually decreases with the increase in bolt pretightening force. Therefore, increasing pretightening force decreases its effect in vibration isolation and system attention.

4. Result Analysis and Discussion

4.1 Experiment
The original test results were obtained by the microcomputer-controlled electronic universal testing machine to illustrate the influence of the bolt pre-tightening force of the spring washer and the elastic vibration isolation material on the dynamic performance of the structure, the effective range of the bolt pre-tightening force, and the maximum working range of the pre-tightening force. The corresponding frequencies (ω_1 and ω_2) were later obtained by systematic tests on the concrete vibration table of the dynamic signal tester. The mass (M) of the vibration part of the vibration platform and the spring stiffness coefficient of the original structure (k_1) were obtained in accordance with further calculations. The vibration frequencies when the spring was compressed by 0, 9, 18, 27, and 36 mm were then tested to obtain the corresponding time history diagrams, pre-tightening forces, and effective working intervals.

4.2 Experimental apparatus
The major equipment of this experiment mainly includes the following.

(1) HZ-1000 concrete magnetic vibration table

This table is mainly used for laboratory preparation of mold concrete specimens and conforms to the requirements of JG/T 245-2009 standards for the architecture industry. The major technological parameters include the following: table size: 1000×1000 mm; vibration frequency: 50 ± 2 Hz; vertical amplitude (empty loading): 0.5 ± 0.02 mm. The vibration time was set based on the requirements. The maximum vibration time was 99 s. The supply voltage, total power, and net weight were AC380V 50 Hz, 1.6 kW, and 345 kg, respectively.

(2) Metal spring

The major technical parameters are as follows: height of steel (H), diameter of spring (D), and diameter of spring steel wire (d) were set as 60, 30, and 6 mm, respectively. The stiffness coefficient of the spring equipped on the concrete vibration table was k_a, while that of existing spring was k_b.

(3) Microcomputer-controlled electronic universal testing machine

The microcomputer-controlled electronic universal testing machine made by Shanghai Hualong Test Instrument Co., Ltd and the WDW-20C mode were applied.

(4) Dynamic signal tester

The dynamic signal tester is made by Jiangsu Donghua Testing Technological Co., Ltd., and DH5927N mode is applied (dynamic vibration meter).

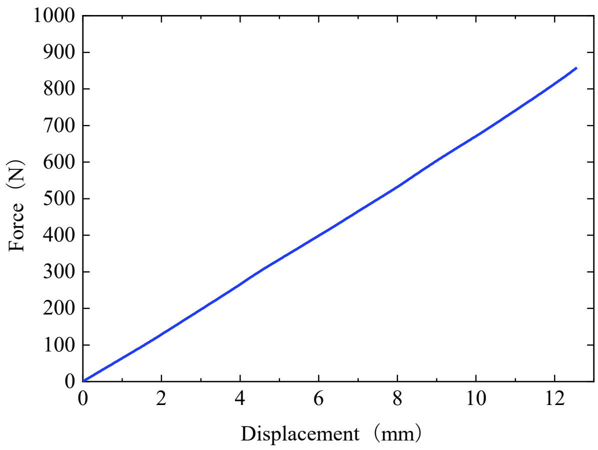
4.3 Test results and data analysis
(1) Elastic constant test of pretightening spring

The measurement of the microcomputer-controlled electronic universal testing machine shows that $k_a = 70.3$ kN/m and $k_b = 7.04$ kN/m.

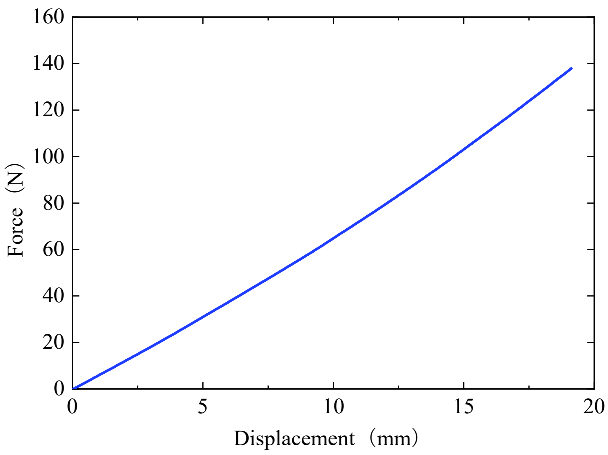
(a) Microcomputer-controlled electronic universal testing machine

(b) Testbed

Fig. 5 Experimental equipment of pretightening spring



(a) Spring k_a is the pretightening spring of the original structure

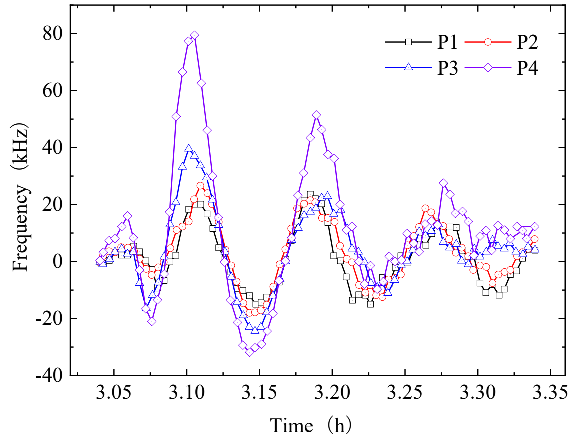


(b) Spring k_b for test pretightening spring

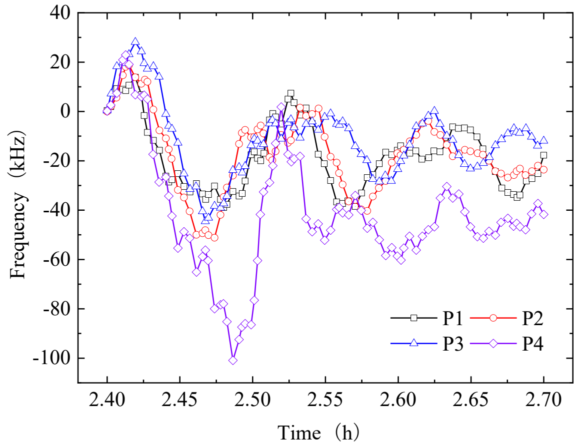
Fig. 6 Test results of two pretightening springs

(2) Systematic test and analysis

The frequency in the presence (f_1) and absence (f_2) of spring on the vibration table was tested by the dynamic signal tester to obtain the corresponding time history diagram. The results are shown in Fig. 7 .



(a) With Spring



(b) Without spring

Fig. 7 Time history diagrams of springs under two situations

The excitation mass of the vibration table is $m = 60$ kg. The test revealed that $\omega_1 = 0.105$ rad/s and $\omega_1 = 0.084$ rad/s which can be observed in the formula $\omega = \sqrt{\frac{k}{m}}$, that is,

$$\omega_1^2 = 4\frac{k_1 + k_2}{M} \tag{5}$$

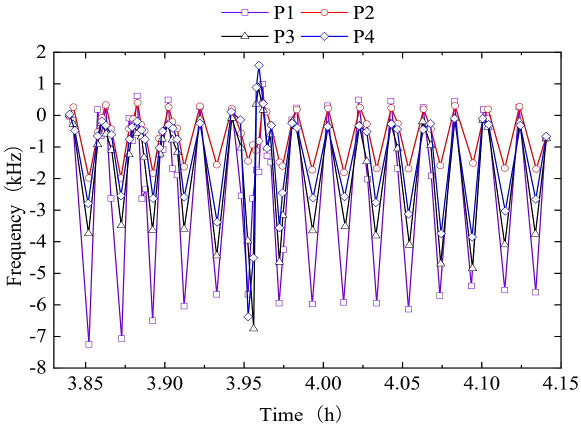
$$\omega_2^2 = 4\frac{k_1 + k_2}{M} \tag{6}$$

Eqs. (5) and (6) respectively show that $k_1 = 1.224 \times 10^5$ N/m and $M = 67.4$ kg.

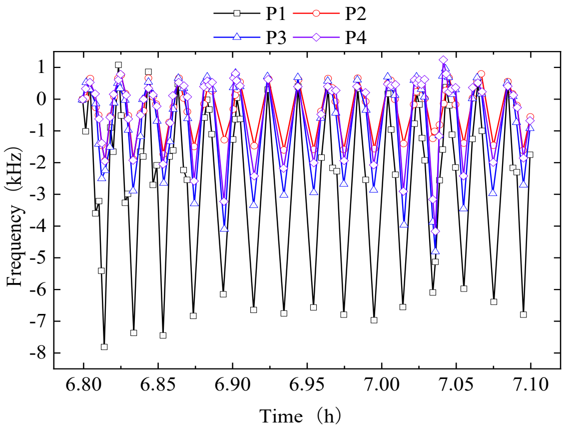
The test revealed that the frequency after k_1 is dismantled is 13.3 Hz, which is smaller than the previous one (16.7 Hz). This finding reflects the influence of pretightening spring on the vibration performance, which decreases the vibration frequency of the vibration table. Hence, studying effective travel of the pretightening spring is necessary.

(3) Testing spring was verified by four experiments

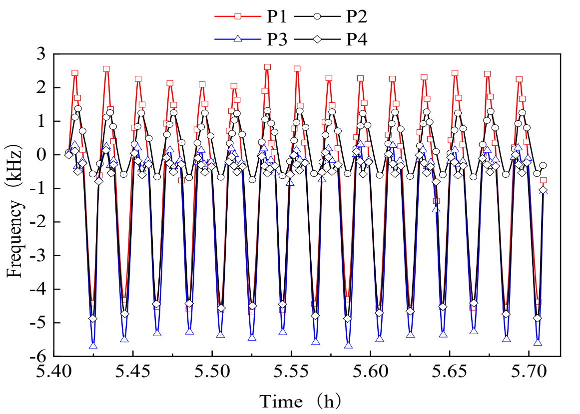
The segmented compression test of spring was also performed. The frequencies when the spring length is 6, 5.1, 4.2, and 3.3 cm were tested by the dynamic signal tester (Fig. 8).



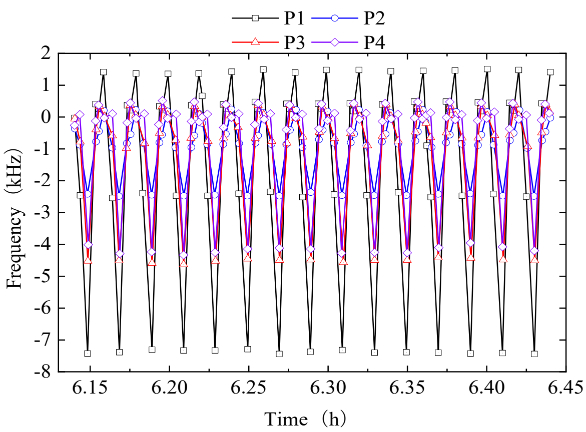
(a) Spring length = 6 cm



(b) Spring length = 5.1 cm



(c) Spring length = 4.2 cm



(d) Spring length = 3.3 cm

Fig. 8 Time history diagram under four length springs

The pre-tightening forces corresponding to the four aforementioned different spring lengths are 0, 63.27, 126.54, and 189.81 (N). Hence, the effective travel of pretightening force is -18,18 mm. The corresponding optimal pre-tightening force is $F_{0\max}=\frac{F_{10}}{2}=94.905$ N based on the verification, and the effective working interval of the system is (-94.905 N, 755.425 N). The spring stiffness is close to infinity when the spring is compressed to 24 mm, and the effective stroke is zero. The vibrating table fuse automatically burns to protect the instrument because the vibrating table is displacement control. This finding indicates that the effective stroke of the system is insufficient, and the vibrating table has a shock phenomenon.

5. Conclusion

A calculation model of vibration isolation of bolts was constructed from the design to explore the characteristics of tightening bolts and disclose the influences of bolt pre-tightening force on the dynamic performance of the structure. The effective and maximum working intervals of the bolt pre-tightening force were analyzed. The conclusions could be drawn as follows.

(1) The stress conditions of bolts were analyzed to prevent the separation of equipment I from the spring or affect bolt column and base II.

(2) The effective working range of the system when $F_0\le\frac{F_{10}}{2}$ or $F_0\le\frac{F_{20}-G_0}{2}$ is proportional to bolt pre-tightening force, while that when $F_0\ge\frac{F_{10}}{2}$ or $F_0\ge\frac{F_{20}-G_0}{2}$ is inversely proportional to bolt pre-tightening force.

(3) Design steps of the vibration isolation system are proposed in accordance with the dynamic requirements of the system. Theoretically, these steps can provide references for engineers to select the appropriate spring washer and elastic materials, thus realizing the goal of appropriate vibration isolation and denoising.

(4) Compared with the unloaded original structure spring, removing the original structure spring reduces the vibration frequency of the vibrating table. The spring stiffness is close to infinity when the spring is compressed to 24 mm, and the effective stroke is zero.

This study introduces a new understanding of fastening bolt vibration isolation by combining laboratory experiments and theoretical work. Such an understanding can serve as a reference for engineers to select appropriate spring washers and elastic vibration isolation materials. One of the limitations of this study is the use of single bolts. In future studies, a variety of bolts of different materials shall be selected and modified with this model to obtain an accurate understanding of the effect of bolt tightening force on the dynamic performance of the structure.

Acknowledgments

This work was supported by the Natural Science Foundation of Fujian (2020J01280) and the Fujian Provincial Department of education project (JT180442).

References

1. Monville, J. M., "Optimal tightening process of bolted joints". *International Journal for Simulation and Multidisciplinary Design Optimization*, (7), 2016, pp.A4.
2. Sah, S. M., Thomsen, J. J., Fidlin, A., "Transverse vibrations of tightened bolts: Simplified modeling of tension-dependent boundary stiffness and damping". *Engineering Structures*, 205(C), 2020, pp.110049.
3. Miao, R., Shen, R., Zhang, S., Xue, S., "A Review of Bolt Tightening Force Measurement and Loosening Detection". *Sensors-Basel*, 20(11), 2020, pp.3165.
4. Panja, B., Das, S., "Development of an anti-loosening fastener and comparing its performance with different other threaded fasteners". *Sādhanā*, 42(10), 2017, pp.1793-1801.
5. Baek, K. H., Jeong, N. T., Hong, H. R., Choi, S. B., Lee, E. S., Kim, H. M., Kwon, J. W., Song, S. Y., Jang, H. S., Lee, H. Y., "Loosening Mechanism of Threaded Fastener for Complex Structures". *Journal of Mechanical Science and Technology*, 33(4), 2019, pp.1689-1702.
6. Wang, Y. Q., Wu, J. K., Liu, H. B., Kuang, K., Cui, X. W., Han, L. S., "Analysis of Elastic Interaction Stiffness and its Effect On Bolt Preloading". *International Journal of Mechanical Sciences*, 130, 2017, pp.307-314.
7. Shahani, A. R., Shakeri, I., "Experimental Evaluation of the Effect of Preload On the Fatigue Life of Bolts". *International journal of steel structures*, 15(3), 2015, pp.693-701.
8. Luo, W., Feng, P., Zhang, J., Ren, Y., Wu, Z., "Research on a Radiation Model for Bolt-Tightening Force Attenuation of Wheel-Type Parts". *IEEE Access*, (7), 2019, pp.157459-157470.
9. Wu, S., Liu, W., Wang, X., "The Best Preload of Bolted Joint Plate for Anti-Resonance". *IOP Conference Series Materials Science and Engineering*, 576(1), 2019, pp.012004.
10. Güler, B., Gürsel, K. T., "Experimental analysis of the friction coefficient effect of the zinc-lamella coated fasteners on bolt preload and tightening moment". *Materialwissenschaft und Werkstofftechnik*, 50(6), 2019, pp.696-705.
11. Cabaleiro, M., Conde, B., Riveiro, B., Caamao, J. C., "Analysis of Steel Connections with Girder Clamps According to the Bolts Preload-ScienceDirect". *Journal of Constructional Steel Research*, 168, 2020, pp.105866.
12. Ajaei, B. B., Soyoz, S., "Effects of Preload Deficiency On Fatigue Demands of Wind Turbine Tower Bolts". *Journal of Constructional Steel Research*, (166), 2020, pp.105933.1-105933.10.
13. Zhang, Y., Zhao, X., "Bolt Loosening Detection Based On Audio Classification". *Advances in Structural Engineering*, 22(13), 2019, pp.2882-2891.
14. Jeong, S. P., Sohn, J. W., "Prediction of Bolt Fastening State Using Structural Vibration Signals". *Journal of Mechanical Science and Technology*, 33(8), 2019, pp.3963-3970.
15. Hong, J. K., "Force and Deformation Demands of Bolts in Steel Bolted Bracket Moment Connections". *International Journal of Steel Structures*, 19(1), 2019, pp.319-328.
16. Noma, A., He, J., "Conceptual Design Study On Screws for Self-Loosing Preventable Fasteners Using 3D CAD Tools". *The Proceedings of The Computational Mechanics Conference*, 30(0), 2017, pp.178.
17. Zhuang, F. J., Chen, P. H., "Effects of missing fasteners on the mechanical behavior of double-lap, multi-row composite bolted joints". *Journal of Composite Materials*, 52(28), 2018, pp.3919-3933.
18. Zhang, Y. X., Zhu, D. C., Zhang, S., Qian, Y. P., "Research On Vibration Transfer Characteristics of the Bolt Connection Structure". *Journal of Failure Analysis & Prevention*, 17(1), 2017, pp.68-78.
19. Mohamed, S. S., Juel, T. J., Marie, B. N., Alexander, F., Dmitri, T., "Estimating Bolt Tightness Using Transverse Natural Frequencies". *Journal of Sound and Vibration*, (431), 2018, pp.137-149.
20. Zhao, G., Wang, B. R., Yu, G., Yang, H., Huang, X. Y., "Study on the influence of bolt preload force on bolt interface". *Journal of Mechanical Strength*, 40(02), 2018, pp.392-397.
21. Yamagishi, T., Asahina, T., Araki, D., Sano, H., Hattori, T., "Loosening and Sliding Behaviour of Bolt-Nut Fastener Under Transverse Loading". *Mechanical Engineering Journal*, 5(3), 2018, pp.16-00622-16-00622.
22. Wang, Q. W., Yuan, J. H., Zhou, S. M., "Numerical simulation for the failure of bolted flange connection structure under typical impact load". *Structure & Environment Engineering*, 44(05), 2017, pp.21-27.
23. Lu, X., Zhang, Y. H., Chen, Y., Mao, P. C., Yu, F., Guan, Z. Q., "Coupled vibration of bolted flange connections containing shear pins (cone)". *Journal of Vibration and Shock*, 36(02), 2017, pp.139-146+184.
24. Zhang, Z., Xiao, Y., Liu, Y. Q., Su, Z. Q., "Preload relaxation characteristics in composite bolted joints based on vibration fatigue test". *Acta Materiae Compositae Sinica*, 33(01), 2016, pp.163-173.