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A study on the influencing factors on natural frequencies of bolted joints

Background and Purpose

- **Bolted joint is an important part of the connection of various parts, and its connection quality is the guarantee of structural performance.**
  - Research showed that for machine tools, the bolted joint stiffness accounts for 30-50% of the machine stiffness, and the damping ratio exceeds 90%
  - As a weak link in the structure, it is more likely to fail
- **The influence of the dynamic behavior of bolted connections on the overall structure is difficult to quantitatively assess**
  - Threaded fasteners are used in huge quantities
  - Various structures and forms of contact
- **The exploration of their dynamic performance helps to design a more reasonable structure and avoid the possible resonance phenomenon.**
  - Spindle speed in use can be adjusted according to the natural frequencies
  - Structure can be redesigned to change dynamic performance parameters
- **FEA was used to investigate the influence of commonly considered parameters on natural frequencies**
  - The coefficient of friction of the bolted joint will be changed when the lubricant is used
  - Loss of clamping force for threaded fasteners under external load during the long-term service

FEA Results: Mode shape of the structure

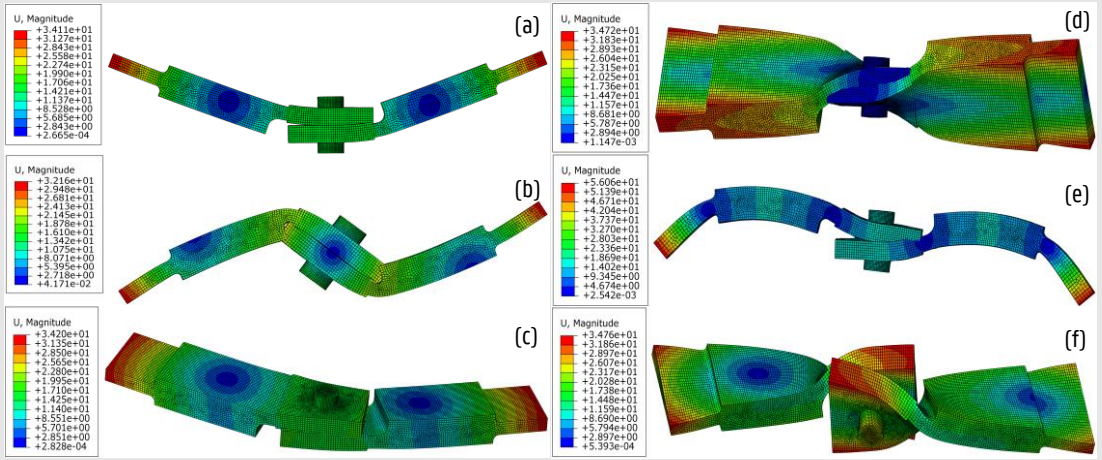

Fig. 2. The first six natural frequencies and their mode shapes of bolted joints, (a) to (f) corresponding to 1st order and 6th order

- **ABAQUS software was used for the prestress modal analysis, a total of 3 contact pairs were established, and the clamping force was applied at the mid-plane of the bolt.**
- **The natural frequency values and mode shapes under different conditions are extracted in the post-processing results.**

FEA Results: Values of natural frequencies

Table 1 Natural frequencies of bolted joints under different combinations

MTL	F	μ	1	2	3	4	5	6
CS-CS	55kN	0.09	485.75	1462.9	1518.5	2030	3374.2	3506.7
CS-CS	55kN	0.21	488.7	1465.3	1532.5	2043.6	3395.2	3525.8
Al-Al	55kN	0.15	469.39	1425.1	1462.5	2004.9	3278.3	3334.9
CS-CS	40kN	0.15	486.45	1463.4	1522.1	2033.6	3379.3	3511.9
CS-CS	60kN	0.15	487.63	1464.4	1527.9	2039.2	3387.8	3519.5

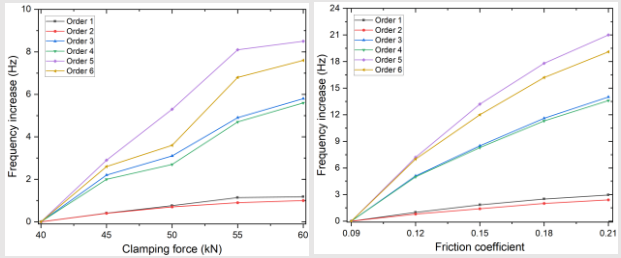

Fig. 2. The amount of natural frequencies increase, (a) Clamping force, (b) friction coefficient

Finite Element Model and Analysis method

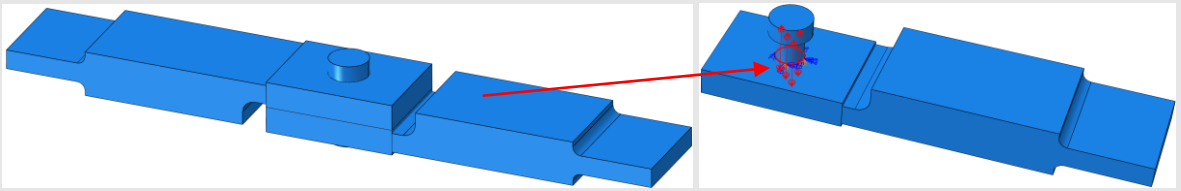

Fig. 1. Load and boundary conditions of the bolted joint

Two analysis steps were adopted, firstly, the bolt preload is applied; subsequently, the natural frequencies of the structure were solved.

Conclusions

- **The natural frequencies of each order of the bolted connection increase with the clamping force. The natural frequency boost of some orders is more pronounced, while others are smaller.**
- **As the friction coefficient of the bolted joint increases, the evolution of the natural frequency exhibits a behavior similar to that of the clamping force.**
- **The natural frequency of the structure is positively correlated with the elastic modulus of the material of the connected parts.**
- **The influence of the contact friction coefficient is relatively small.**

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