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Loosening phenomenon of a thin plate bolted joint subjected to bending moment

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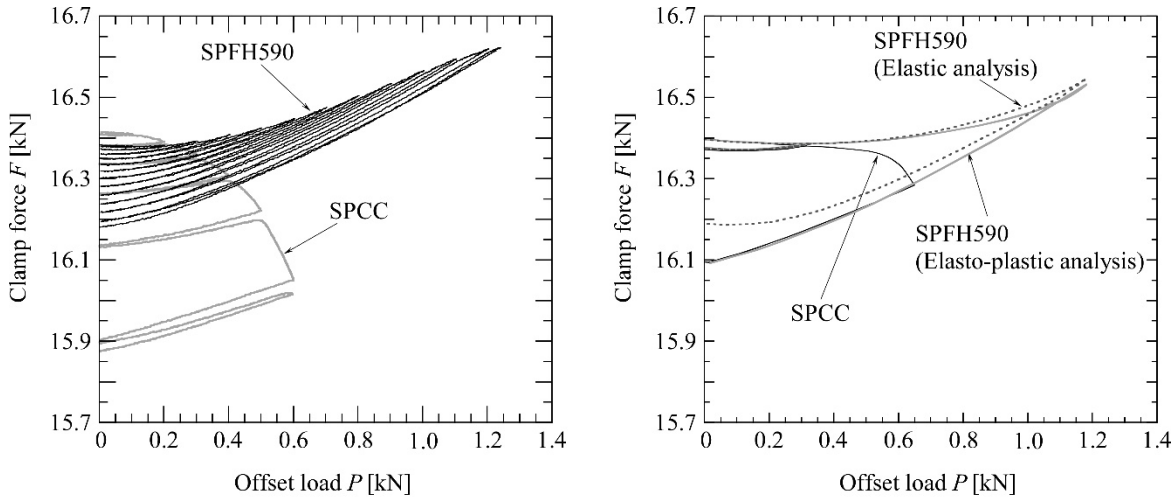
Loosening in bolted joints often cannot only cause the bolted joint to lose those functions but also induce fatigue failure of the bolt, ultimately leading to serious accidents. Loosening without bolt or nut rotation does not involve serious reduction in clamp force of the bolted joint, the reduction in clamp force is typically only a few percent to 10% or less. However, a reduction in the clamp force due to loosening without rotation can potentially induce loosening with rotation. Therefore, it is necessary to elucidate the mechanisms and prevent loosening without rotation as well. In our previous study, we investigated loosening in a model where thin plates were fastened with bolts and nuts to relatively rigid frame members, such as hat members, when an offset load was applied to the thin plates. The results showed that even without obvious plastic deformation of the thin plates due to the offset load, the slip generated at the thin-plate joint surface did not return to its original state even after the offset load was removed, resulting in a decrease in the tightening axial force. This loosening behavior and loosening mechanism have not been clarified before, this was considered as a completely new type of non-rotational loosening. Furthermore, we have also reported on the loosening behavior when clear plastic deformation occurs in the thin plates.

In this study, we have investigated an influence of materials on the loosening of thin plate bolted joints using a cold-rolled steel sheet SPCC and a 590 MPa class high-tensile steel sheet SPFH590. Experiments and finite element elasto-plastic analysises were conducted. Fig. 1(a) shows results in experimental and Fig. 1(b) shows results in finite element analysis. The results showed that the behavior of the clamp force when an offset load was applied to a bolted joint of a thin plate of cold-rolled steel sheet SPCC and a 590 MPa class high-tensile steel sheet SPFH590 differed significantly as shown in Fig. 1. It can be also seen that we could almost simulate the experimental result using FE analysis although the final remaining clamp force after unloading was different. If we used the thin plate made of SPCC, the decrease in clamp force after unloading was approximately 3.2% after the displacement at the loading point reached 5 mm. However, if we used the thin plate made of SPFH590, the decrease in clamp force after unloading was approximately 1.2% after the displacement of the offset load's point of application reached 5 mm. Finite element elastic analysis and elasto-plastic analysis results showed that plastic deformation was hardly involved in the decrease in clamp force if we used thin plate made of high-tensile steel SPFH590. Finite element elasto-plastic analyses revealed that the reduction in clamp force was caused due to a reduction in the contact area between the thin plate and the upper plate for both of the thin plates made of SPCC and SPFH590.



(a) Relationship between the clamp force F and the the offset load P in the experiment

(b) Relationship between the clamp force F and the the offset load P in the finite element analysis

Fig. 1 Clamp force behaviors of thin plate bolted joint subjected to offset load