IMPROVEMENT OF SELF-LOOSENING PREVENTION EFFECTS OF THREADED FASTENERS THROUGH FINITE ELEMENT ANALYSIS

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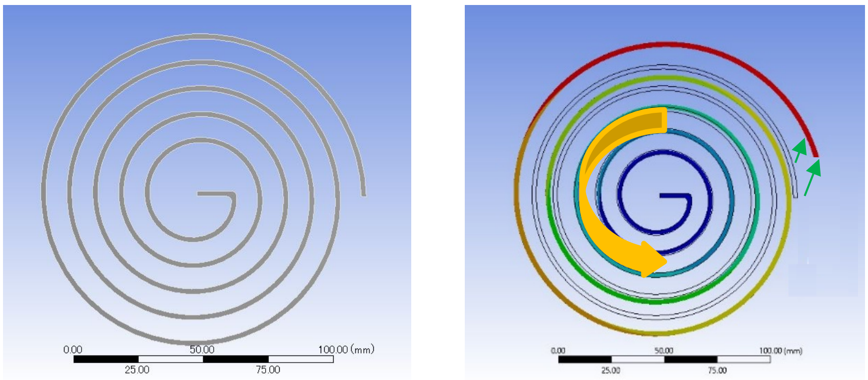
Abstract: Threaded fasteners using screws/bolts are used not only in industrial field but also in various fields such as precision instruments and medical field. Many accidents caused by the loosening of the screw/bolt threaded fasteners are actually reported. As one countermeasure, nut with spring washer is used, but there remains the problem that effective loosening prevention effects cannot be obtained in the case of increasing in the parts number or no-using of such nuts etc. Then further improvement on loosening prevention effects of screw/bolt threaded fasteners are desired. In this research, new screw/bolt structures having self-loosening prevention effects are designed by applying the spring characteristic swelling effects in loosening direction of springs. 3D CAD modeling and finite element analyses are carried out to evaluate the spring characteristic effects and self-loosening prevention effects of new designed screw/bolt structures. Analytical results indicated that self-loosening prevention effects can be affected by the shape/size design variables of applied helical cuttings introduced for new screw/bolt structures.

Keywords: Threaded fasteners, Screws/Bolts, Spring characteristic effect, Self-loosening prevention effects, 3D CAD modeling, Finite elements analysis

Introduction

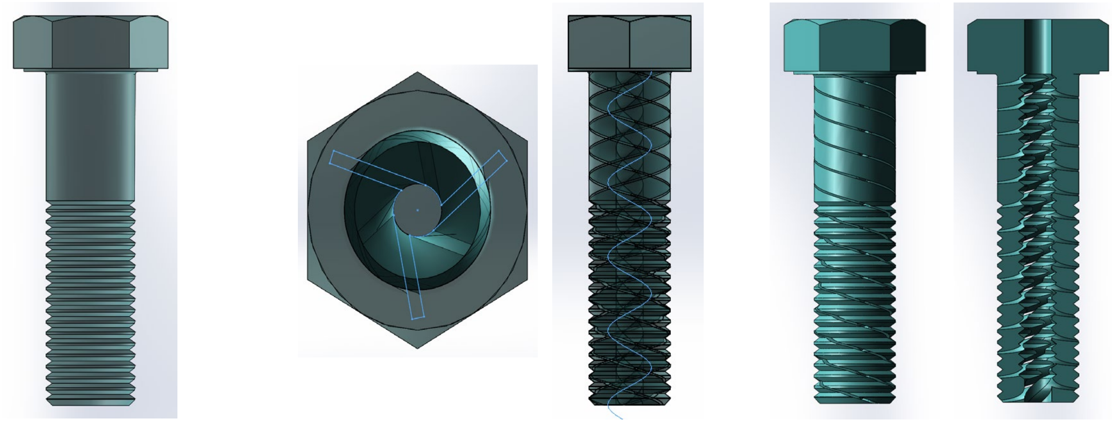
There are various kinds of fastening methods using screws/bolts for threaded fasteners, such as using bolts and nuts together or tapping screws. Designers can select different products or fastening methods assuming to different environments. Many of analytical and experimental investigations on self-loosening bolt fasteners problems [1]-[3], however, loosening problems of threaded fasteners are still unavoidable through the screws/bolts tightening methods under cyclic vibrations or external compact loadings. In our previous research [4], spring characteristic effects as shown in Figure1 are interested as applied to new designed screw/bolt structures, which can result to self-loosening preventive effects on threaded fasteners. The spring characteristic effect means that spring structure as shown in Figure 1(a) has the swelling effect under rotating counterclockwise (loosening direction) as shown in Figure 1(b).



(a) Spring structure (b) Swelling effect in loosening direction

Figure1. Conceptual diagram of spring characteristic effect

Concept structural designs on conventional M6 hexagon bolt for obtaining self-loosening preventable threaded fastener purposes were carried out by using 3D CAD software SolidWorks [4]. Helical cutting with cross-sectional shape and cross thread turning in reverse direction to thread rotation direction were introduced to general hexagon bolts as shown in Figure 2(a) and (b). As the result, new bolt structures provided by plurality of springs cross each other are designed with spring characteristic effects supposed to be imparted as shown in Figure 2(c). Spring characteristic effects of the helical-cutting applied bolts were firstly confirmed by analytical approaches under counterclockwise rotating loading.



(a) Conventional bolt (b) Cross-sectional cutting shape & thread turning (c) New designed bolt

Figure2. Helical-cutting applied bolt for self-loosening preventable threaded fasteners

In this research, parametrical studies are executed to evaluate the affections of different design variables, such as line width of cross-sectional cutting shape and helical pitch applied to screw structures, on the self-loosening preventive effects of threaded fasteners.

Parametrical investigation of helical cutting process on self-loosening prevention effects

Self-loosening preventable effects of threaded fasteners using the helical-cutting applied bolts can be confirmed through finite element analysis modeling on Junker vibration test, which is based on ISO 16130 standard including new designed bolt, nut, fixed plate and vibration plate as shown in Figure3. The friction generated on the contact surfaces between the stationary plate and the diaphragm and nut are considered not negligible and the friction coefficient are set to 0.17 obtained from experimental result [1]. The contacts between each surfaces are modeled as contact elements based on the penalty method. Table1 shows the constraint conditions used for analytical modeling of Junker vibration test. C45 and X12Cr13 materials are applied for designed bolts, nuts, and testing fixtures of Junker vibration test. Detail material properties are as shown in Table2 for self-loosening prevention effect evaluations.

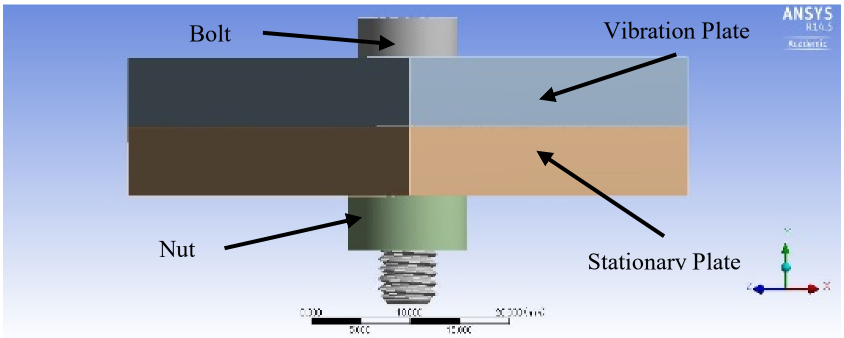


Figure3. Analytical model of Junker vibration test

Table1. Restraint conditions for analytical modeling of Junker vibration test

Test Type	ISO 16130 Junker Vibration Test
Number of Vibrations	1000
Direction of Vibrations	x Direction : $\pm$0.3mm
Fixed	Side of Fixed Plate
	Bolt End : x and z Directions
Fastening Axial Force	4330N

Table2. Material properties used for analytical modeling of Junker vibration test

Material	C45	X12Cr13
Young’s Modulus	205GPa	200GPa
Poisson’s Ratio	0.3	0.3
Density	7800 kg/m^3	7800 kg/m^3
Applied Parts	Bolt, Nut	Vibration Plate, Stationary Plate

Three dimensional modeling on Junker vibration test of threaded fasteners are executed using new designed M6 screw/bolt structures with different design variables based on the analytical method mentioned above. The design variable of line width of cross-sectional cutting shape as shown in Figure4 are changed from 0.5 mm to 0.9 mm with every 0.1 mm based on conventional M6 bolt. Design variable of helical cutting pitch as shown in Figure5 are changed from 11.0 mm to 19.0 mm with every 2.0 mm for numerical studied. 25 cases combined between line width of cross-sectional cutting shape and helical cutting pitch are considered in the analytical evaluations as shown in Table3.

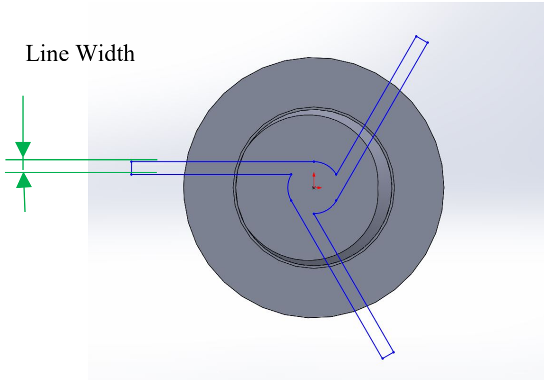


Figure4. Design variable of line width of cross-sectional shape for helical cutting process on M6 bolt

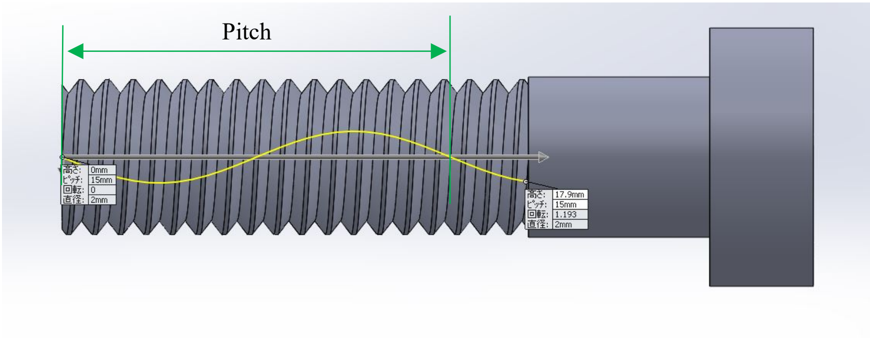


Figure5. Design variable of helical pitch for helical cutting process on M6 bolt

Table3. Design variables for analytical evaluation of Junker vibration test

<table>
<tr><th>Helical cutting pitch, mm</th><th colspan="5">Line width of cross-sectional cutting shape, mm</th></tr>
<tr><td>11</td><td rowspan="5">0.5</td><td rowspan="5">0.6</td><td rowspan="5">0.7</td><td rowspan="5">0.8</td><td rowspan="5">0.9</td></tr>
<tr><td>13</td></tr>
<tr><td>15</td></tr>
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Analytical results on self-loosening prevention effect evaluation of threaded fasteners using new designed bolts with helical cutting

Analytical results of the self-loosening prevention effects using the designed new bolt structures with different design variables are shown in Figure6 to Figure15 based on the analysis method above mentioned. Horizontal axis shows the iteration number of vibrations and vertical axis shows the axial forces of threaded fasteners representing the loosening conditions.

Figure6 to Figure10 show the analytical results for each helical cutting pitch with different line widths. From these results, it can be seen firstly that for small helical cutting pitch like 11.0 mm and 13.0 mm, self-loosening preventive functions are observed for most cases of different cross-sectional cutting line width. Secondly, the falling of axial forces due to the iterated vibrations becomes gentle with thicker line width of cross-sectional cutting shape in the cases of helical cutting pitch large than 15.0 mm. These results conclude that utilization of new designed screw/bolt structures with small helical cutting pitch are available to obtain self-loosening preventive threaded fasteners.

Figure11 to Figure15 show the analytical results for each line widths with different helical cutting pitch. From these results, it can be seen that for thicker line width more than 0.7 mm, self-loosening preventive functions can be obtained for more cases of different helical cutting pitch. Secondly, combination between helical cutting pitch and line width of cross-sectional cutting shape are very important for the self-loosening preventive effect of threaded fasteners.

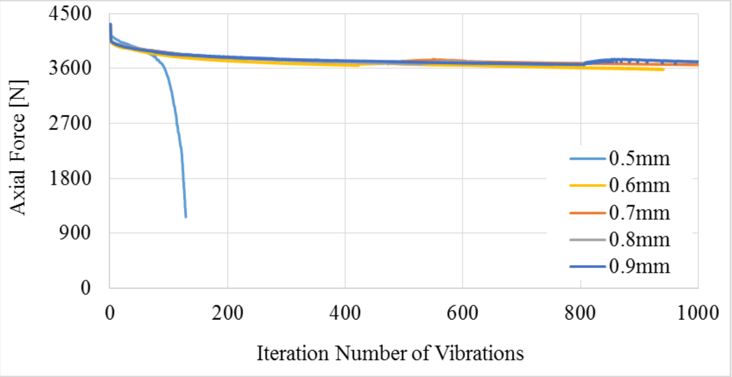

Figure6. Changes on axial forces for pitch of introduced helical cutting process: 11mm

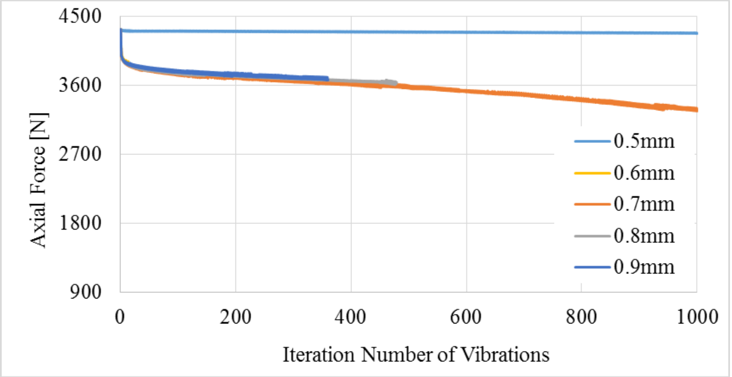

Figure7. Changes on axial forces for pitch of introduced helical cutting process: 13mm

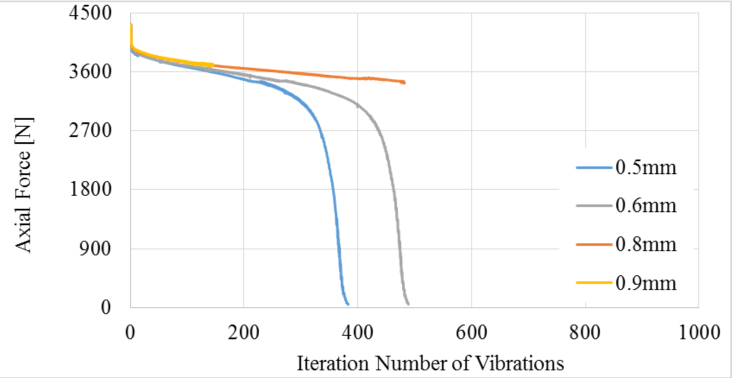

Figure8. Changes on axial forces for pitch of introduced helical cutting process: 15mm

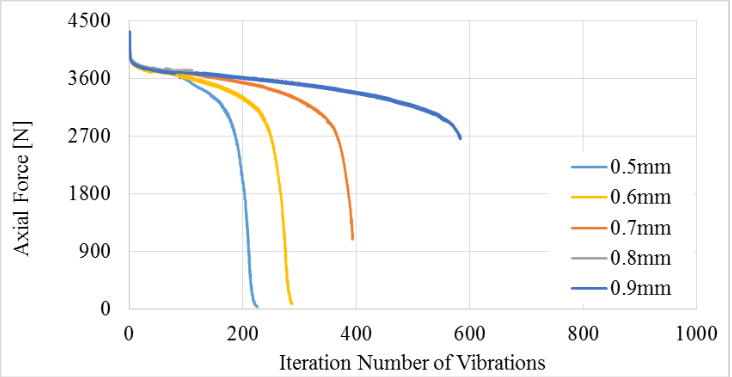

Figure9. Cahnges on axial forces for pitch of introduced helical cutting process: 17mm

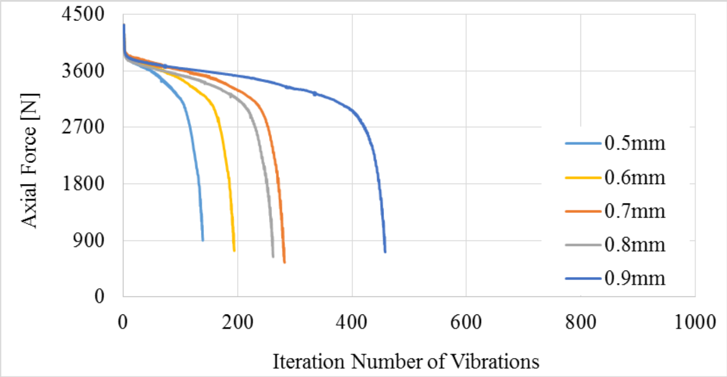

Figure10. Changes on axial forces for pitch of introduced helical cutting process: 19mm

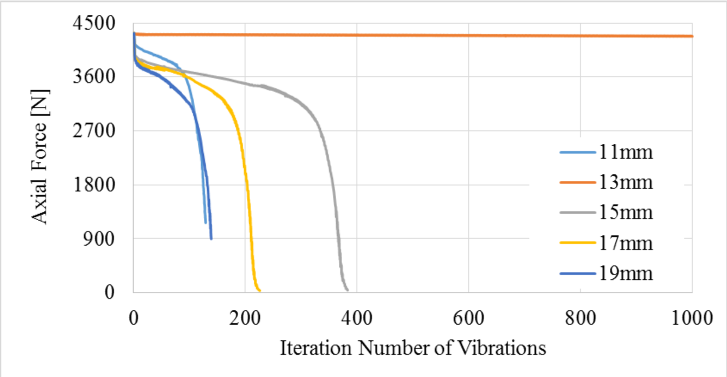

Figure11. Changes on axial forces for line width of cross-sectional cutting shape: 0.5mm

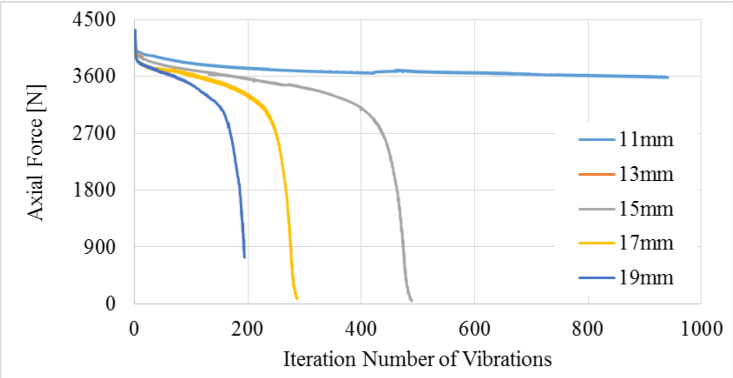

Figure12. Changes on axial forces for line width of cross-sectional cutting shape: 0.6mm

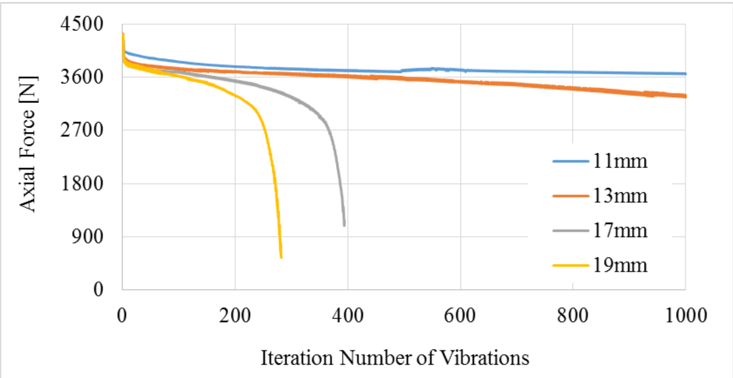

Figure13. Changes on axial forces for line width of cross-sectional cutting shape: 0.7mm

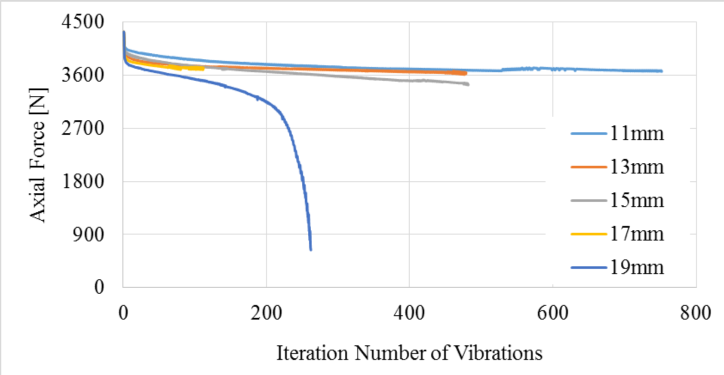

Figure14. Changes on axial forces for line width of cross-sectional cutting shape: 0.8mm

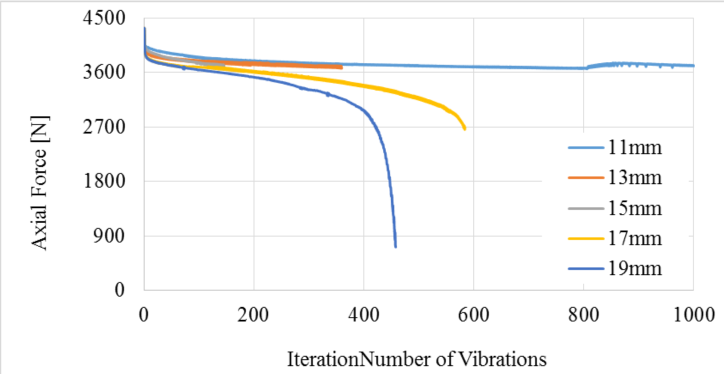

Figure15. Changes on axial forces for line width of cross-sectional cutting shape: 0.9mm

Conclusion

In this study, parametrical studies are executed to evaluate the affections of different design variables, such as line width of cross-sectional cutting shape and helical pitch applied to screw structures, on the self-loosening preventive effects of threaded fasteners. From analytical results, the following conclusions are obtained.

1. Utilization of new designed screw/bolt structures with small helical cutting pitch are very effective to obtain self-loosening preventive threaded fasteners.
2. For cross-sectional cutting shape with thicker line width, self-loosening preventive functions can be obtained for more cases of different helical cutting pitch.
3. Combination between helical cutting pitch and line width are very important for the self-loosening preventive effect of threaded fasteners using different screw/bolt structures.

Because the deterioration on strengths of bolts caused by the helical cutting processing on screw structures, strength evaluation should be carried out for threaded fasteners using the new designed screw/bolt structures in the future study.

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