Study of Screw Tightening Sequence on the Looseness of the Top Cover in the Hard Disk Drive Assembly

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Abstract

In hard disk drive (HDD) assembly process, the top cover is attached to the base assembly via screws. Screw tightening sequence could result in looseness of previously fastened screws and thus rework of the process. The current work focuses on the study of behavior and effects of screw tightening sequences to the screw looseness by using nonlinear finite element method. The three-dimensional 3.5-inch HDD assembly including top cover, base, rubber seal and screws are modeled and analyzed. It can be concluded that the later sequences of screw tightening affect the looseness of the previously fastened screws to some extent. Higher lose of tightening torque is observed at the screws located near the currently tightened screw. Alteration of the screw fastening sequence as well as the applied torques can reduce the looseness and therefore prevent the top cover slip.

Keywords*:* Screw looseness, Hard disk drive, Tightening sequence, Finite element analysis

1. Introduction

In hard disk drive (HDD) manufacturing process, the screw fastening procedure to attach the top cover to the base of the HDD consists of applying some specified pre-torque to all the screws to preliminarily fasten the top cover to the base and final screw fastening with a larger torque so that the top cover is tightly secured the base. However, looseness of the top cover is occasionally observed as the loosening torque of some screws is detected to be as low as half of the applied torques. The disk must then be returned to rework the screw fastening procedure which increases the cost and time in manufacturing process. However, screw fastening using too much tightening torque may lead to deformations of the top cover or chipping of the material between the contact surfaces that cause contamination. This study aims to use Finite Element Analysis (FEA) to investigate the effects of changing the screw tightening sequence on the deformations of the top cover and the screw loosening torque.

Montgomery [1] studied the influences of boundary conditions on the shank stress in 3D solid bolt to decrease run-time in finite element

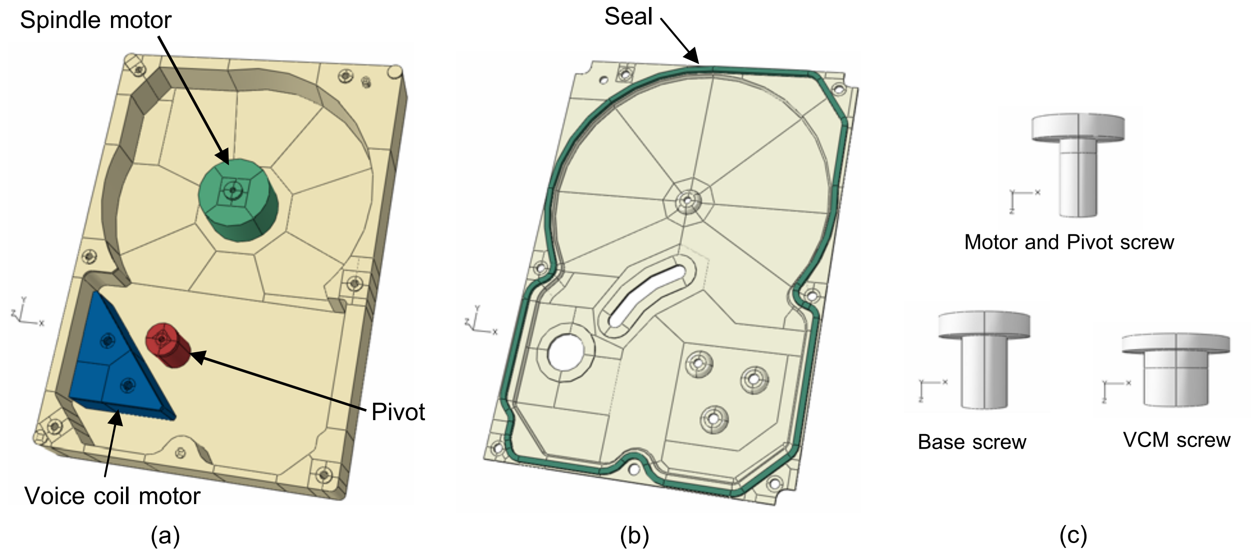


Fig.1 The parts of HDD model (a) base (b) top cover (c) screw.

method. It was shown that the use of smear contact at the thread region creating the same stress distribution as the exercise of thread modeling. Application of tied contact provides a slightly higher stress in the vicinity of the thread. However, results from both types of contacts are comparable at some distance from the thread. Wierszycki [2] analyzed the screw loosening and fatigue of a three dimensional dental implant model for problems caused by mechanical reason. Izumi [3] found that the loosening due to shear loading is initiated when complete thread slip is achieved prior to bolt-head slip.

The current research examines the effects of screw tightening sequence of a 3.5-inch HDD assembly to the top cover screw looseness by using a commercial finite element analysis program, ABAQUS [4]. A nonlinear analysis is performed for two cases, herein defined as Model I and Model II. In Model I, all screws are simultaneously tightened while screw tightening sequence is specified in Model II. Displacements of the top cover and the screw loosening torques are compared and discussed.

2. Modeling and Analysis

The 3.5-inch HDD model employed in the present analysis is shown in Fig. 1. The model consists of the base, the top cover, and the screws. To simulate the rigid parts of the assembly, the spindle motor, pivot and voice coil motor are attached to the base model. Ten screws are used in the HDD assembly. They are numbered according to the tightening sequence as illustrated in Fig. 2.

Six screws, S4 to S9, fasten the top cover and the base together. The screws S2 and S3 assemble the top cover to the voice coil motor. The screws S1 and S10 are used to fix the top cover to the spindle motor and the pivot, respectively. A rubber seal beneath the top cover is used to prevent leakage of the air inside the assembly chamber. In Model II, screws S1 to S9, are fastened consecutively. After that, screws S2, S3, S4 and S9 are re-tightened with the same torque and a higher torque is applied to screws S1 and S6. Then, screw S10 is fastened at the final step.

2.1 Boundary Conditions and Contact Surfaces

During the screw tightening process, the assembly is put in a slot and clamped on both the left and the right sides. In the analysis, the boundary conditions are thus specified as fixed at the bottom, and on the left and the right surfaces as shown in Fig. 2. The contact surfaces between the screw head and the top cover is set as frictional contacts with the friction coefficient of 0.15. The contact surface between the base and the rubber seal on the top cover are set frictionless. The interactions between the screw thread regions and the base are assigned as tied contact.

2.2. Material Properties

The base of HDD is made of aluminum alloy ADC12. The top cover and the screws are stainless steel SUS XM7. The seal is made of rubber. The properties of the materials used in the simulation are listed in Table. 1.

2.3 Meshing

Meshing of the FE model is shown in Fig. 3. Meshing is refined at the contact areas, especially those between the screws and other parts. The element type used in the analysis is a three-dimensional 8-node stress element. The element shapes are mixed between hexahedral and tetrahedral elements.

2.4 Loading Conditions and Analysis Steps

In the tightening process, the tightening torque applied to the screws S1 and S6 is 8 kgf.cm and the torque for other screws is 6 kgf.cm. To simplify the analysis, the tightening torque is changed to a bolt load applied to the partition between the head and the shank of the screw. The applied bolt load, P, is calculated from [5]

$$P = \frac{T}{Kd} \quad (1)$$

where T is the tightening torque, d is the screw diameter, and K is the torque coefficient obtained as

$$K = \left(\frac{d_m}{2d}\right)\left(\frac{\tan\lambda + f\sec\alpha}{1 + f\tan\lambda\sec\alpha}\right) + 0.625 f_c \quad (2)$$

The parameter d_m is the average screw diameter, λ is the screw lead angle, α is the thread angle, f is friction coefficient of the thread and f_c is friction coefficient of the bearing.

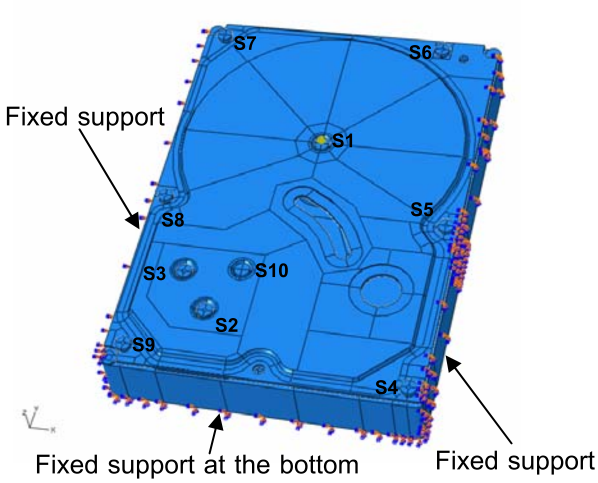
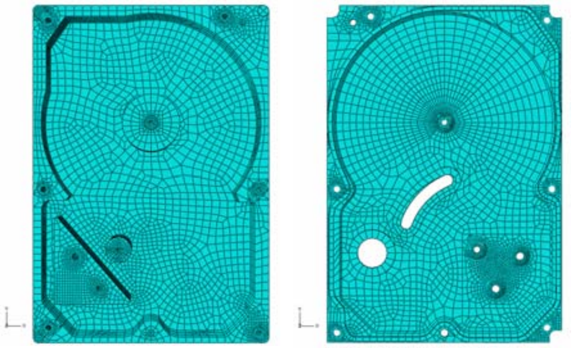


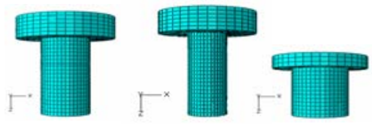
Fig. 2 Three-dimensional 3.5-inch HDD model

Table. 1 Mechanical properties of materials

Properties	SUS XM7	ADC12	Rubber
Density (g/cm^3)	8.00	2.70	1.50
Modulus of Elasticity (GPa)	193.00	69.16	2.14
Poisson’s ratio	0.30	0.33	0.44



(a) (b)



(c)

Fig.3 Meshing of the FE model (a) base (b) top cover (c) screws

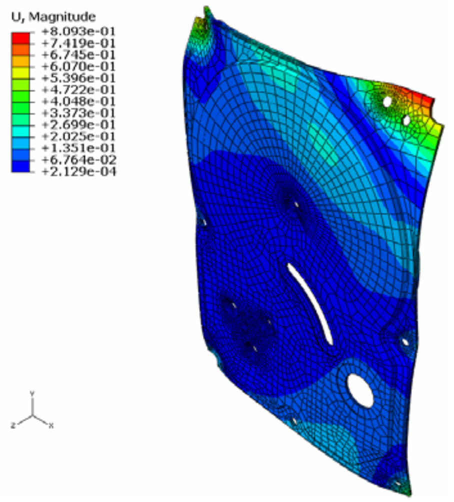
For example, for a screw with diameter 2.5 mm and d_m of 2.2565 mm, λ is 3.632º, α is 60º, and f and f_c are 0.15. Therefore, the value of the torque coefficient K, from Eq. (2), is equal to 0.1973. When the screw is subjected to a tightening torque of 6 kgf.cm, the bolt load P computed from Eq. (1) is 1193 N. Parameters for all screws in the HDD assembly as well as the applied tightening torque are listed in Table. 2. In the analysis of Model I, all bolt loads are applied to the screws at the same analysis step to simulate the concurrent fastening of all screws. For Model II, the corresponding bolt loads are applied in a consecutive order from S1 to S10.

3. Results and Discussions

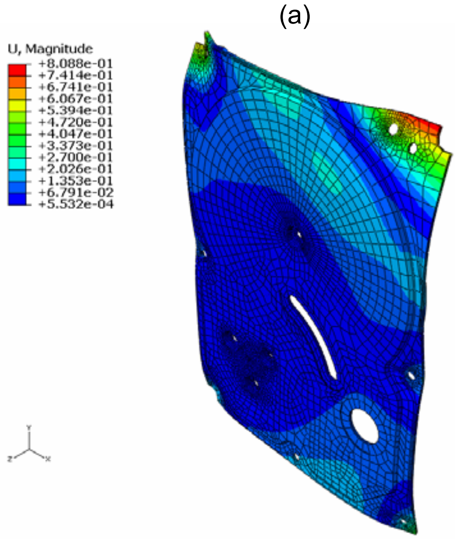
The deformed shapes and the displacement magnitude of the top cover for both models are shown in Fig. 4. It can be seen that the deformed shapes of the top cover from the two models are similar. Displacement in the negative z-direction is observed in the neighborhood of all tightened screws.

Table.2 Bolt loads applied to the screw model

Screw number	Diameter (mm)	Applied torque (kgf.cm)	Bolt load (N)
S1	2	8	1947
S2, S3	3	6	991
S4, S5, S7-S9	2.5	6	1193
S6	2.5	8	1590
S10	2	6	1460



(a)



(b)

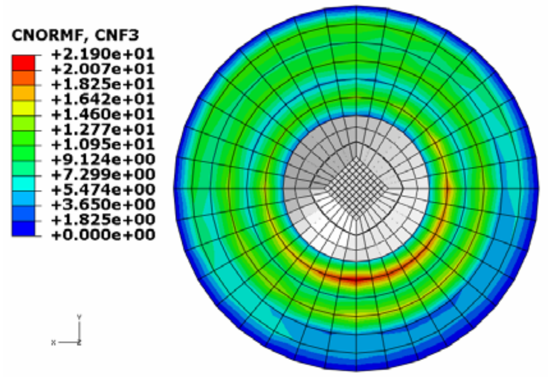
Fig. 4 The deformed shapes and displacements of the top cover (magnified 10 times) for (a) Model I (b) Model II

A smaller displacement occurs in the middle area of the top cover where there are rigid supports of spindle motor, voice coil motor and pivot. A larger displacement takes place around the top cover edges due to the rubber seal deformation from a compression transferred from bolt loads applied at the screws. The maximum displacement occurring near the screw S6 (at the top right corner of the top cover) is noticeably larger than those of the other parts.

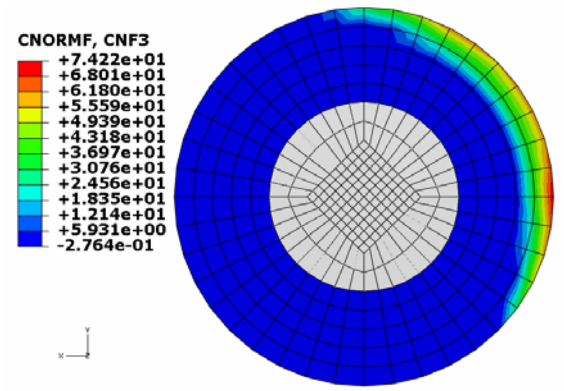
The contact normal force distributions of all screw heads from both models are also examined. For the screws located in the middle of the HDD, S1, S2, S3 and S10, the highest contact normal force is near the shank and decreases as the distance from the shank increases. An example of the contact normal force distribution at the screw head S1 is illustrated in Fig. 5 (a). For screw S4 to S9 located along the edges of the HDD assembly, the contact normal force distributions are not as uniform. High contact normal forces are noticed only at the rims of the screws and a higher contact force is detected on the side near the rubber seal support as shown in Fig. 5 (b).

The screw looseness of Model I and II are examined by the change of the summation of all the contact normal force at the contact areas between the top cover and the screw head. For Model I, the total contact forces at all screw heads are the same as the applied bolt loads as expected. Lower contact forces at the screw heads which indicate the screw looseness can be noticed in Model II. In Model II, the contact force at the screw head arises as the bolt load is applied to the screw. Contact forces of the screws previously fastened are also affected by the screw that is tightened in the current step. In general, the contact forces of the screws close to the current one decrease as the top cover is pressed toward the base. The contact forces of the screws farther away from the current screw are mostly increased due to bouncing of the top cover.

An example of the change in contact forces at the screw heads for step 8 (tightening of screw S8), step 9 (tightening of screw S9) and step 10 (re-tightening of screw S2) is shown in Fig.6. When the contact forces of step 8 and 9 are compared, a decrease in contact forces of screws in the vicinity of S9, i.e., S2, S3, S4 and S8 is perceived. A slight increase in contact forces for the other screws can also be noticed.



(a)



(b)

Fig.5 Contact force distribution at the screw head (a) S1 (b) S4

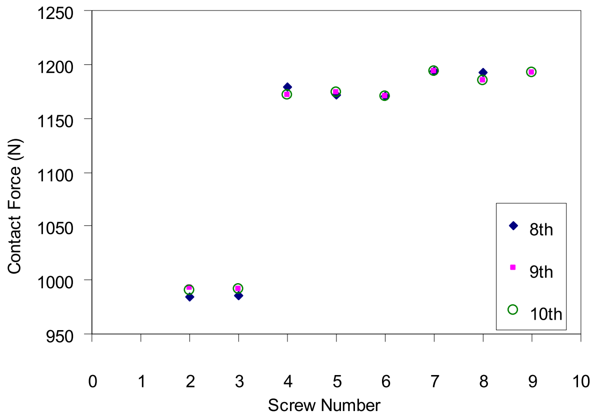


Fig. 6 Contact forces of screws in the 8th, 9th and 10th step

In addition, when the screws are re-fastened with the same torque in step 10, the change in the contact force is noticed to be limited to only the tightened screws as all other contact forces in step 9 and 10 are the same. Therefore, screw re-tightening process is suggested to be used after all screws are fastened to regain the loosened torque.

4. Conclusions

The screw tightening process to attach the top cover of a 3.5-inch HDD to its base is modeled and analyzed. Large deformations of the top cover are noticed along the edges, especially at the corners, where the contact force between the screw heads and the top cover take place only at the perimeters of the screw heads. Moreover, when a screw is tightened, torque loosening of other screws in a close proximity to the current screw is observed. The step of screw re-fastening can restore the screw tightness without any effect to other screws. Further study on the optimum tightening sequence and applied torques to improve the contact pressure distribution and minimize the looseness is recommended.

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