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Effect of Load on Particle Morphology in Screw Tightening Process in Hard Disc Drive Assembly

[1]S. Laksanasittiphan, [2]K. Tuchinda, [3]A. Manonukul, [1]S. Suranuntchai

[1]*Department of Tool and Materials Engineering, King Mongkut's University of Technology Thonburi, 126 PrachaUthit Road, Bang Mod, ThungKhru, Bangkok 10140, Thailand.*
[2]*Department of Mechanical and Process Engineering, The Sirindhorn International Thai-German Graduate School of Engineering (TGGS), King Mongkut's University of Technology North Bangkok, Bangkok 10800, Thailand.*
[3]*National Metal and Materials Technology Center (MTEC), National Science and Technology Development Agency, 114 Thailand Science Park, Paholythin Road, Klong 1, KlongLuang, Pathumthani 12120, Thailand.*

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ABSTRACT

The aim of this research is to study the load of the "bit" effect on particle morphology in screw tightening process in hard disc drive assembly (HDD). Experimental investigation under a class 100 clean room was carried out using a component-level HDD in the production line. The parameters studied include aspect ratio and the appearance cross sectional area of a particle. The appearance cross sectional area of particles was found to increase with increasing load due to higher contact pressure at asperity. The surface of the particles with various sizes suggested that different wear mechanisms are involved. Small particles werecaused by adhesive wear, while the larger ones were generated by fatigue wear.

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INTRODUCTION

Areal density of hard disc drive (HDD) continues to offer higher capacities.The particle contamination becomes as one of most major reliability problem.Particle can damage media and head with severity dependent on the hardness, ductility, shape and dimension of particles.Many studies concerning the particle in the HDD have been performed over the last decade. In 1999, the particle generation in a HDD during the disc drive start/stop period wasstudied by using a condensation nucleus counter. It was found that most of particles were generated whenever the drive started or stopped and the number of particles detected by the condensation nucleus counter depended on parameters including sampling location and sampling velocity(Park *et al*., 1999). Zhang *et al* (1999) studied the damage induced by fine particles of aluminium, stainless steel, silicon and "slider"ceramic. Sputtered particles were introduced at the head/disc interface of hard disc drives. It was found that the type of damage introduced on the disc and slider was unique for each particle material, and also closely related to the relative hardness of the interacting materials.

Later a component-level test was used to study soft particle induced damage, it was found that there was data loss without any physical damage to media. The frictional heating due to particlehead/disk interface (HDI) interaction could lead to partial demagnetisation of the data. It was also observed that the occurrence of this failure mode could be reduced by decreasing loading speed (Roy and Brand, 2007). In 2005,a hard particle interacting with a slider and a disc in the head/disc interface of HDD was investigated. It was found that hard particle could produce a scratch on the disc resulting in data loss. Not only the hardness of the particles but their shape and dimension also have a significant effect on the induced damage(Zeng *et al*., 2005). The size, shape and surface texture of wear particles can indicate wear modes, wear mechanisms and wear severity can be obtained from the analysis of particle morphology (Raadnui, 2005).Recently the particle generated under cyclic sliding motions using ball-on-disc tester was studied. The materials in contact were stainless steel (SUS304) disc and tungsten carbide (WC) ball. The effect of the effective stress and sliding velocity on the particle area and aspect ratio was investigated. It was shown that the increase in stress and speed will result in a larger particle size and more slender shape(Bootchai*et al*., 2013).

However, the effect of in service parameters during screw tightening process has not yet been

Corresponding Author: S. Laksanasittiphan, Department of Tool and Materials Engineering, King Mongkut's University of Technology Thonburi, 126 PrachaUthit Road, Bang Mod, ThungKhru, Bangkok 10140, Thailand.
Tel: +66867778309; E-mail: Laksanasittiphan.s@gmail.com

reported. Hence, this research aims to study the effect of the load of the "bit" on the morphology of particles generated during screw tightening process in hard disc drive assembly. The understanding of such effect will be very useful in the design related to screwing process in HDD assembly process.

Experimental Procedures:

The experiment was done under simulated screw tightening process in production conditions, i.e. using component-level HDD, class 100 clean room condition.The generated wear particles were collected by the carbon tape as shown in Fig. 1 and were later investigated using scanning electron microscope (SEM).

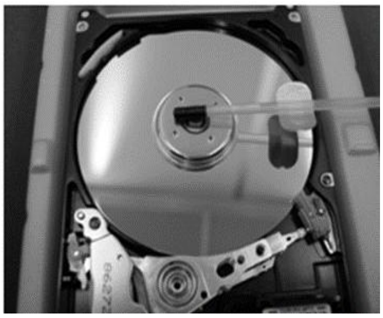


Fig. 1: Illustration of particle collection using the carbon tape.

To ensure cleanliness prior to each test, the component-level HDD components, i.e. the "Motor to Base" (MBA), the screw, the disc clamp, were thoroughly cleaned with isopropyl alcohol (IPA). The load of the "bit" was applied by controlling the air pressure in the chamber of air cylinder using the air regulator similar to the loadcontrol of the "bit" in the actual production. The force was measured by aload cell. In this work, the beginning and the final speeds of the "bit" were fixed at 500 and 350 rpm respectively. The tests were performed at different loads of the "bit", i.e. 1.5, 1.75, 2.0, 2.25 and 2.5 kgf, respectively.

In this study, the parameters indicate particle morphology include aspect ratio (AR) and the appearance cross sectional area of a particle.The image of each individual particle was analysed using an image analysis software. The appearance cross sectional area was directly obtained from the image based on the total number of pixels enclosed by the particle boundary (Manjunath, 2010). The aspect ratio was calculated using from equation (1) (Russ, 2011).

$$AR = \frac{L_{\mathrm{mj}}}{L_{\mathrm{mn}}} \quad (1)$$

Where L_{mj} is the major axis and L_{mn} is the minor axis. The major and minor axises are defined as the 2 perpendicular lines with the longest line called major axis and thelongest perpendicular line with the major axis called minor axis (see Fig. 2).

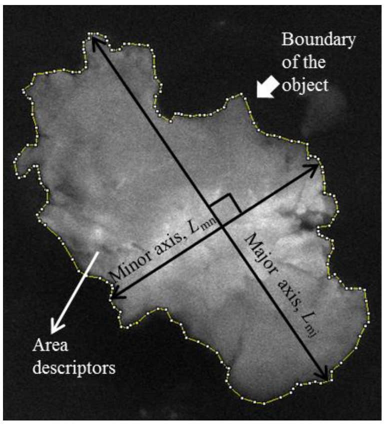


Fig. 2: SEM micrograph of wear debris illustrating the major axis, minor axis and the appearance cross sectional area.

RESULTS AND DISCUSSION

A typical image of the screw surface after test is shown in Fig. 3. Surface damage could be observed in contact area between "bit" and screw as indicated by arrowsin Fig. 3.

The particles found were investigated using Energy Dispersive Spectroscopy (EDS) analysis to identifythe chemical composition and hencesource of particle. The particle material was found to be stainless steel grade 410(screw material), suggesting screw wear during the test. The ESD result is shown here inFig. 4and the particles micrographs generate using different loads are shown in Fig. 5. It can be seen that the load had significant effect on particle morphology, the particle was more slender at lower load and bigger area at higher load.

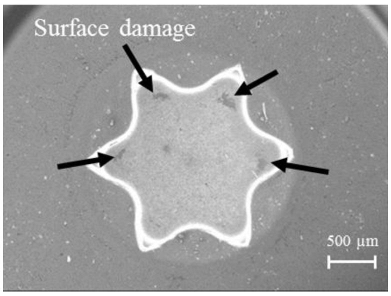


Fig. 3: SEM image of the surface of screw after test.

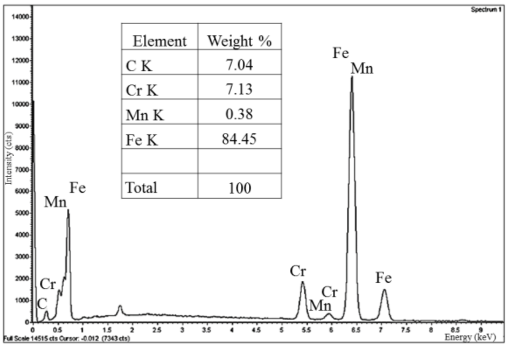


Fig. 4: Energy dispersive spectroscopy analysis.

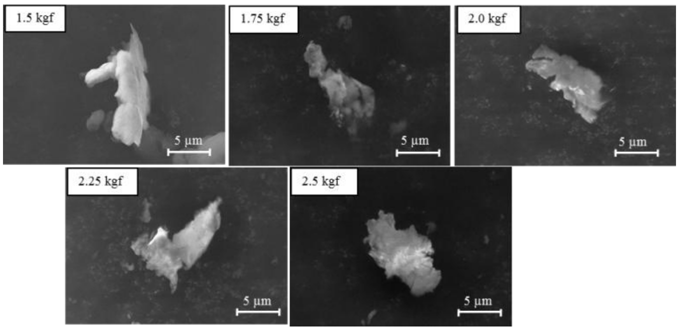


Fig. 5: SEM images of wear particles with different load.

Continuous curve plotted by connecting the midpoints of each histogram bar was used to represent the particle distributions (see Fig. 6).The numbers representing the intervals (bin) and interval width (range) were calculated using Sturges' rule, i.e. (Sturges, 1926).

$J = 1 + 3.3log_{10}n$ (2)

Range = (Max value – Min value) / J (3)

where$J$ is the number of bins and n is the total number of measurements.

The distributions of the particle morphology at various loads of the “bit” were analysed and are shown in Fig. 7.It can be seen that the maximum population for 1.75, 2.0, 2.25 and 2.5 kgffalls in the same range. The maximum population for AR and area were in the range of 1.2-2.0 and 1-50 µm^2, respectively.Except load of 1.5 kgfshows the AR range of 1.6-2.4 and area range of 1-50 µm^2.

However, the maximum percentage of particle count found for such range varies with different load of the “bit” for both AR and area. For example, for aspect ratio, the maximum population of 41% was found at the load of 1.75 kgf, whereas only 29% was found at the load of 2.0 kgf (Fig. 7(a)). From

Fig. 7(b), the maximumparticle count for area was found to be 55% at the load of 2.25, whereas the maximum particles count of 82 % was found at the load of 1.5 kgf.

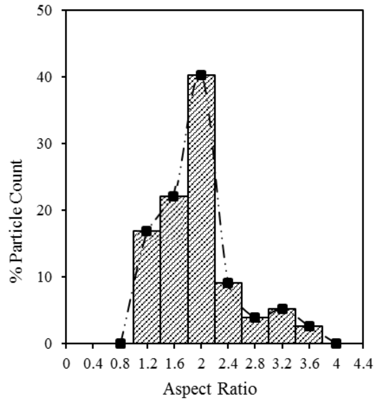
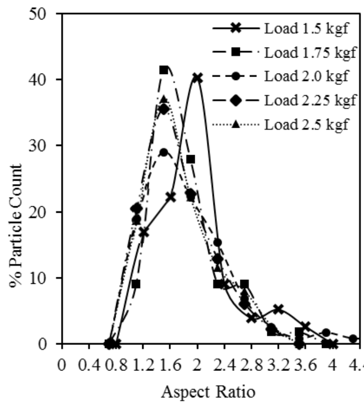
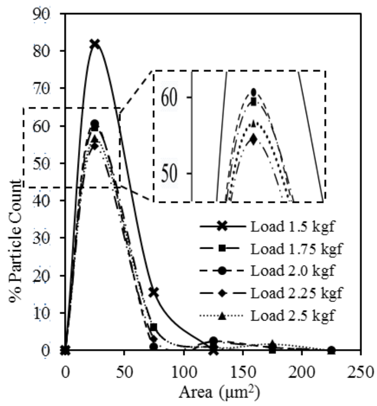


Fig. 6: Histogram distributed data with continuous curve overlaid on the bins.

The average value was use for clearer effect for each case. Therelationship between the particle morphology and load of the "bit" is shown inFig. 8. It can be seen that the particles have lower value of aspect ratio at higher load (Fig. 8(a)). From Fig. 8(b), it can be seen that an increase in the load of the "bit" results in bigger particles generated, i.e. the maximum particles area of 28.83 μm^2 was found for the load of the "bit" 2.5 kgf, whereas 22.54μm^2 was found for the load of the "bit" 1.5 kgf. This is caused by higher contact pressure at asperity at higher load.



(a) Aspect ratio.

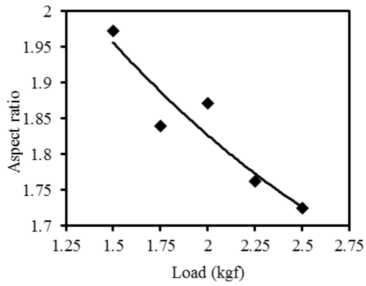


(b) Appearance cross sectional area.

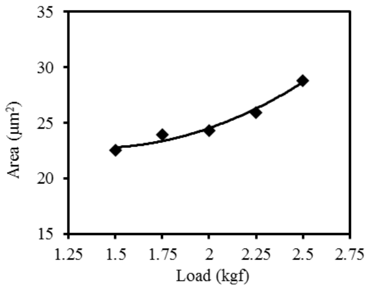
Fig. 7: The plot of % particle count vs (a) aspect ratio and (b) appearance cross sectional area of particles found at varied load of the "bit".

Form the results, surface analysis with scanning electron microscopy (SEM) used to showed that the particles could be classified into two different groups: smooth and rough surfaceas shown in Fig.

9.The frequency distribution graph of gray scale and the number of pixel.A ratio between the range of gray scale (x) and the maximum number of pixels (y) was calculated. The *x*/*y* ratio could be used to classify the particle surface. For a particle with smooth surface, the *x/y* ratio was ≤ 1. If the *x/y*ratio was >1, the particle surface was considered rough.



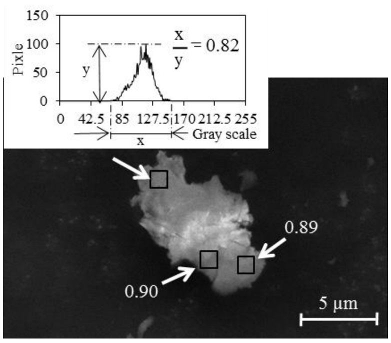
(a) Aspect ratio.



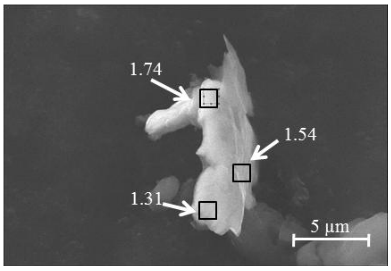
(b) Appearance cross sectional area.

Fig. 8: The average value of the (a) aspect ratio and (b)appearance cross sectional area of the particles at varied load of the "bit".

From the results, the particles with smooth surface were found to be large and those with rough surface were found to be small. The smaller particle was caused by adhesive wear and the rough surface,whichis a result of large deformation related to wear mechanism. The large particles show brittle manner of failure with smooth surface observed. Hence, they weregenerated by fatigue wear (Stachowiak and Batchelor, 2005,Stachowiak and Podsiadlo, 2008). Large particles are mostly found at the higher load.



(a) Smooth surface in large particles.



(b) Rough surface in small particles.

Fig. 9: Examples of typical surface of particles showing (a) smooth surface in large particles and (b) rough surface in small particles.

Summary:

In this work, the morphology of particle generated during the tightening screw with different load of the "bit" for hard disc drive assembly was studied using a component-level HDD in the production line. The particles were found to have lower value of aspect ratio at higher load. It was also observed that the increase in the load of the "bit" results in bigger particles generated. The smaller particle were found to have rough surface that they were caused by adhesive wear. The large particles was caused by fatigue wear as their surface appeared to be smooth.

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