Dynamic Model for Stress Analysis in Universal Feed System

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Abstract

This paper deals with prediction of durability in multibody system. In this paper, feed system of hard disk drive suspension assembly process is a case study. When feed system runs in the process, cam follower of locating pins bar unit, one of the components in feed system, has to work under high dynamic stress which effect its lifetime. To predict durability of cam follower, model has to be constructed and analyzed based on fatigue failure analysis (1),(3),(4). Although, analyzing the full model of feed system can yield the accurate result, but it is very difficult and expensive in hardware resource and computational time. Therefore, the model has to be simplified by eliminating unnecessary parts and features. The model is then transferred to ANSYS software to create finite element model and analyzed to find out dynamic stress time history which is the input of fatigue analysis (2) for predicting lifetime of feed system.

Keywords: Multibody System, Dynamic Stress Finite Element, Fatigue Analysis.

Introduction

In the recent years, Hard Disk Drives (HDDs) which are the device used in digital data storage increase in quantity of usage dramatically. Inside HDDs compose of many components. One important component which plays an important role in HDDs operation is suspension.

The primary role of the suspension is to position the read/write head above the rapidly spinning disks in hard disk drives helping to maintain a consistent "flying height" (Yung et al. ,2005). The suspension must hold the head at a precise microscopic distance above the disk without allowing unintended movement of the head in any direction. Some intended movement of the head is allowed in response to undulations and irregularities in the disk's surface and in response to shock events such as might occur when a laptop computer is knocked. However, it is the suspension's role to maintain the position of the head within a safe range during these periods to keep it from hitting the disk's surface thus preventing damage which could result in what is commonly known as a "head crash".

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In suspension assembly process, a specific machine is required for feeding suspension to do the operations including laser welding, de-tab, preload and backend process. This specific machine is called "Universal Feed System" or UFS of which the most importance part is main feed. Main feed comprise of 4 main components which are frame with cam# 1 and 2, feeding pins bar with counter balance weight, locating pins bar and reference plate (Raymond and Al , 2006).

Main feed function is to move a boat, which is suspension container, along a longitudinal of main feed with very high precision of micron level so that a small load can effect the operation of main feed. To simulate loading effect, dynamic model is necessary. Dynamic model can be used to describe dynamic behaviors which are relative motions and dynamic loading.

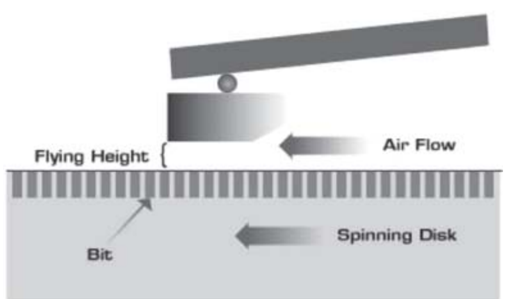


Figure 1. Suspension on disk media

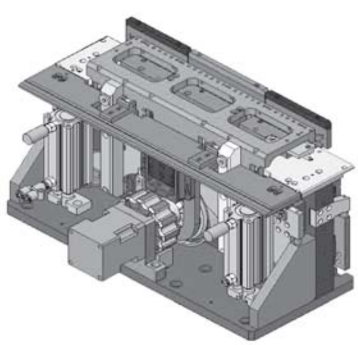


Figure 2. Universal Feed System

The one of the important results of the dynamic model is dynamic loading time history which is the key parameter of fatigue failure analysis (Jaap,2004). Fatigue failure analysis can be used to predict the durability of the main feed components which related to mean time before fail that is the important performance parameter of UFS machine.

UFS Model

Universal feed system machines (UFS) are required for suspension assembly process which are welding, de-tap, preload and backend. Inside of UFS, there is one main machine which is called "Main Feed". To develop main feed model, UFS is separated into 4 main components, as shown in Figure3, which are:

(1) Frame with cam# 1 and 2

(2) Feeding pins bar with counter balance weight

(3) Locating pins bar

(4) Reference plate

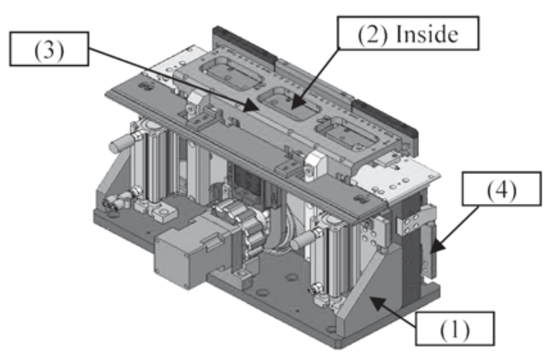


Figure 3. Main Components of UFS

Simulating the full model of main feed is very difficult and consuming a lot of time. Therefore, in this research, only cam follower of locating pins bar unit will be analyzed as a case study because this component is a weak point of UFS which is the main factor of UFS failure and the principle of this analysis can be applied to all parts of UFS.

After simplifying the UFS model, all of the kinematics joints of UFS have to be configured. They are two translational joints, two cylindrical joints, revolute joint and fixed joint. Both of translational joints, which located between linear slider ways and sliders, and cylindrical joints, which located between cylinder rods and housings of pneumatic cylinders, have friction of 0.1 and 0.25, respectively. For revolute joint, it is located between bearing and shaft of cam # 1 and 2 of which friction is defined to zero because it is very slippery and does not affect the action force on cam follower. And the last one, fixed joint located between U-shape and cam follower, is defined for observing the action force on cam follower.

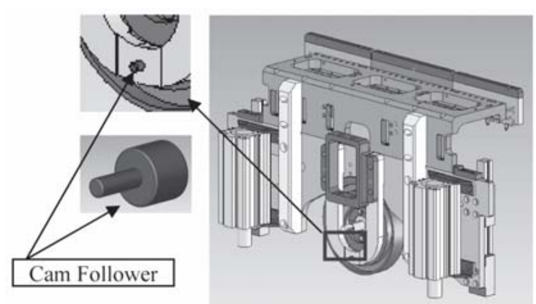


Figure 4. Simplified UFS Model

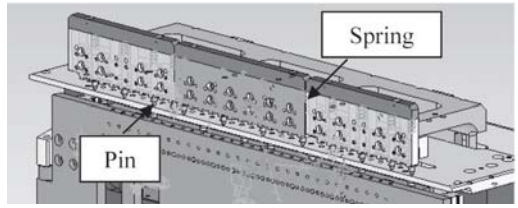


Figure 5. Springs in Pin Holes

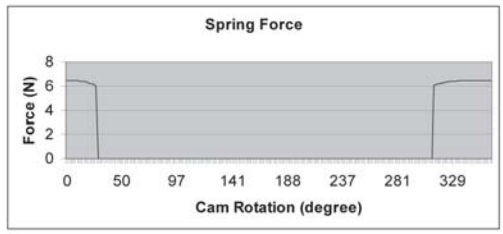


Figure 6. Spring Force

In addition, there are loading from spring which placed in pin hole, as shown in Figure 4, for pressing boat which is suspension container before doing any operations. From Figure 6, there was no spring force because locating pins bar was left up, so pins did not touch the base plate.

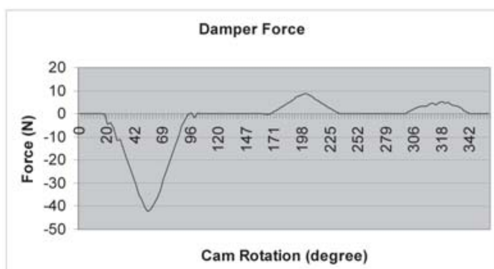


Figure 7. Damper Force

Finally, pneumatic cylinders are modeled as a damper which work for in-stroke and out-stroke differently, so damping coefficients for two conditions are different also which are 0.1 and 0.4 N-sec/mm, respectively.

Dynamic Loading Time History Analysis

After finishing modeling UFS, rotational motion of 600 degrees/second is applied to shaft of cam # 1 and 2 to generate motion path and reaction force of cam follower which are shown in Figure 8 and 9, respectively.

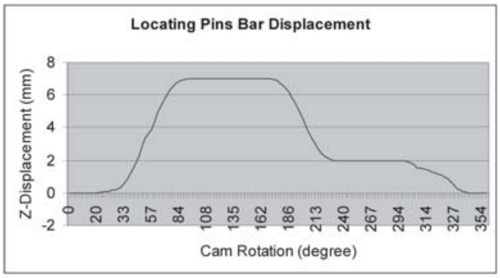


Figure 8. Locating Pins Bar Displacement

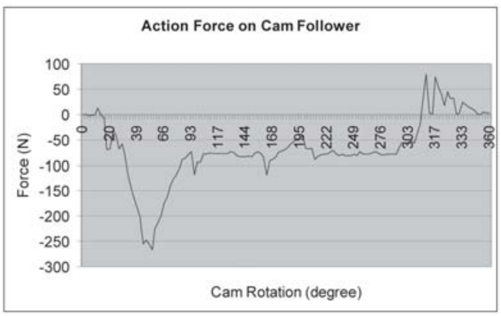


Figure 9. Action Force on Cam Follower

From Figure9, the highest force on cam follower occurs when cam follower is moved up because cam follower moves locating pins bar up with acceleration against g-force and has to push out the compressed air inside the pneumatic cylinders. When cam follower moved down, action force on cam follower is lower than moved up because it is moved in the same direction with g-force. For the periods which have no any movement, forces on cam follower change a little because cam follower just hold locating pins bar.

Fatigue failure analysis

In real process, one cycle of UFS is very fast. In one hour, it runs 2,000 cycles and works for 21 hours per day. However, sometimes it cannot run for a long period because some parts fail. One of the major contributions is cam follower. To predict life time of cam follower, fatigue failure analysis will be used.

For fatigue failure analysis, three major approaches are in current use: (1) the strain-based approach, (2) the stress-based (S-N curve) approach, and (3) the fracture mechanics approach.

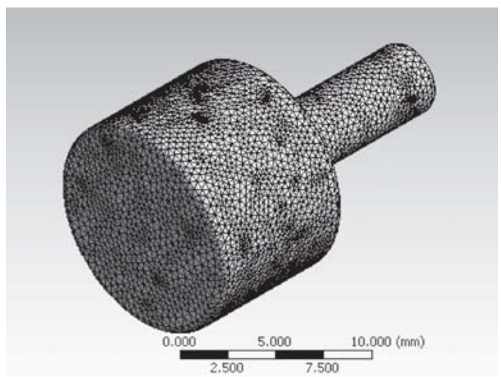


Figure 10. Finite Element Model of Cam Follower

In this research, Stress life, which based on S-N curves (Stress-Cycle curves) with high cycle stress and Miner's Linear Damage Rule shown in equation (1), will be conducted to estimate fatigue life of cam follower.

$$\sum_{i=1}^{k} \frac{n_i}{N_i} = 1 \qquad (1)$$

n_i : the number of cycles at each of a constant stress reversal S_i

N_i : the number of cycles to failure of a constant stress reversal S_i

To perform fatigue failure analysis, material properties of the component to be analyzed has to be known. In case of cam follower, high carbon steel is used. The S-N curves of high carbon steel are shown in Figure11.

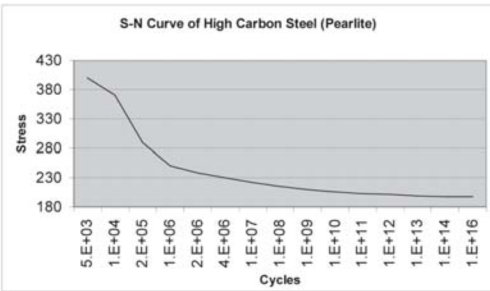
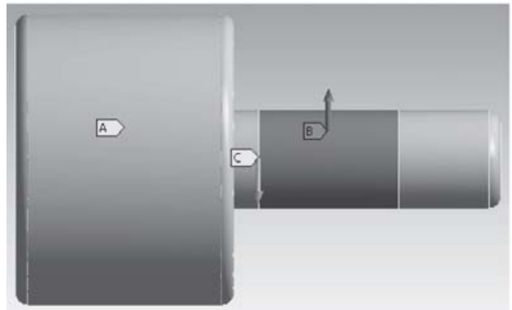


Figure 11. S-N curve of cam follower

In addition, displacement and loading time history shown in Figure 7 and 8 are needed to be applied to the model as shown in Figure 12. Later, the model is analyzed by flexible dynamic analysis to obtain dynamic stress time history which describes how much stresses of every node in finite element model of cam follower occur at each time step. In this case, normal stress in Z direction was used as dynamic stress time history because it can describe both tension and compression, and S-N curve was developed from axial loading. Next, dynamic stress time history will be used to perform fatigue failure analysis.

The result of fatigue failure analysis describes the lifetime of cam follower as shown in Figure 13. Red color shows the minimum fatigue life and blue color shows the maximum fatigue life. Fatigue life of the red color is 3.2653e+6 cycles. When UFS run at speed of 2000 cycles per hour and 21 hours long run per day, UFS can run continuously 77 days without failure.



A: Displacement
B: Dynamic Loading Time History
C: Standard Gravity

Figure 12. Service Environment of Cam Follower

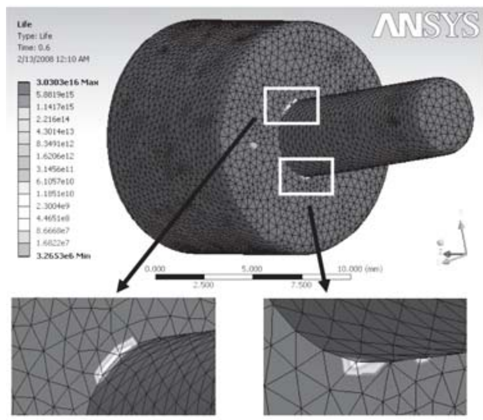


Figure 13. Fatigue Life of Cam Follower

Conclusion

This research presents the methodology of fatigue life prediction in multibody system. In this case, main feed which is the main component of Universal Feed System (UFS) is a case study. The model of main feed had been developed by SolidWorks software and then was analyzed by COSMOSMotion software. The results from this step are displacement, velocity, acceleration, action force and reaction force. Next, dynamic loading time history which is reaction force will be used for predicting fatigue life which was analyzed by ANSYS fatigue module. After finishing this step, lifetime of cam follower will be obtained that helps the user to arrange maintenance period.

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