ASME Information Storage and Processing Systems Conference, 2005
Santa Clara, CA, June 28-29, 2005

CORRELATION OF LATERAL TAPE MOTION AND TAPE TENSION TRANSIENTS

Bart Raeymaekers[1], Ryan J. Taylor[1], Frank E. Talke[2]

[1]University of California, San Diego
Center for Magnetic Recording Research
9500 Gilman Drive, La Jolla, 92093-0401, United States
bart@talkelab.ucsd.edu

[2] University of California, San Diego
Center for Magnetic Recording Research
9500 Gilman Drive, La Jolla, 92093-0401, United States
ftalke@ucsd.edu

Introduction

High frequency lateral tape motion (LTM) is a problem in tape technology that limits track density in a tape drive. To reduce high frequency LTM, it is important to identify all sources of lateral tape motion. The most important sources of high frequency LTM are edge contact between tape and tape drive components, non-repeatable roller axial run-out, air induced flutter and tape tension transients.

The effect of tape tension on high frequency LTM is currently not well understood. Thus, a detailed study of the correlation between high frequency LTM and high frequency tension changes in a tape is highly desirable. Typical tension sensors use pressure measurements to indicate tension changes. The bandwidth of these sensors is not sufficient for the purposes of this investigation and an improved tension sensing device is necessary.

Smith and Sievers [1] attempted to measure tape tension using the digital read-back signal of a tape drive and a commercial flutter meter. The difference between write and read-back signal, with respect to 'bit distance', was used to provide information regarding tape tension. However, this approach is only correct if the velocity of the tape drive is perfectly constant or if velocity changes in time during writing and reading are exactly the same.
Boyle and Bhushan [2] investigated the lateral tape motion as a result of an impact on the tape. Tape tension, however, was not measured.
Imaino [3] developed a non-contact method to measure tension in a magnetic tape, using photoacoustically generated antisymmetric Lamb waves detected with a laser Doppler vibrometer.

In this paper an optical non-contact, high bandwidth tension sensor for magnetic tape is developed and the correlation between lateral tape motion (LTM) and tension transients is investigated.

Tension sensor

The concept of a non-contact tension measurement uses the following approach. A laser is directed at the magnetic tape surface and the light reflected from the tape is captured by a photo cell. As the tape tension increases, the divergence of the reflected light bundle increases, i.e., the amount of light seen by the photo cell changes with tape tension. Thus, measurement of the change of light reflected from a tape surface can be used as a measure of the tension change in a tape.

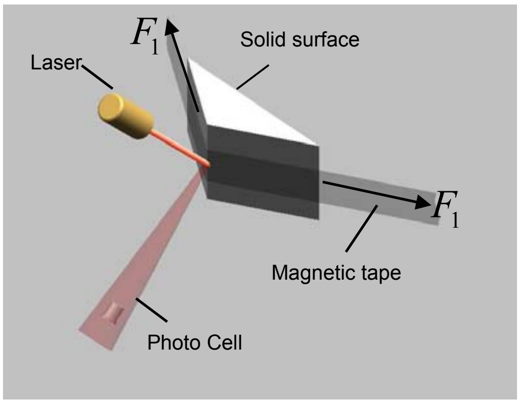

Fig.1 Divergence of light beam as a result of tension F1

Corresponding author: Bart Raeymaekers

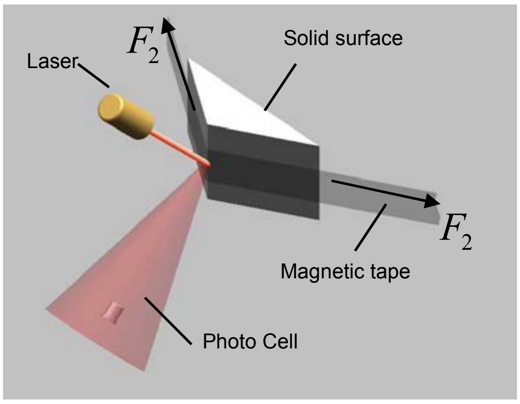

Fig.2 Divergence of light beam as a result of tension F2

The principle of the optical tension measurement is illustrated in Fig.1 and Fig.2. At low tension (Fig.1), the reflected light beam diverges less than at high tension (Fig. 2).

A typical calibration curve of the photo cell voltage versus the tape tension is shown in Fig 3.

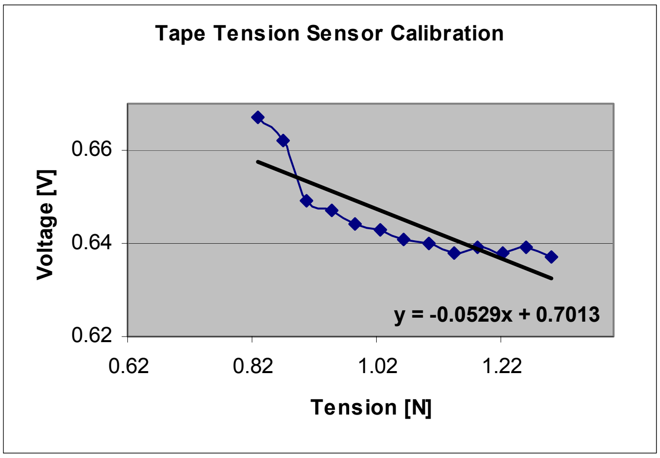

Fig.3 Typical calibration curve

Artificial disturbance

To investigate the correlation between dynamic tension changes and LTM changes, the effect of tension changes was amplified as follows. An eccentric pack was created by inserting a thin rod into the tape during winding. Using this eccentric pack, large tension disturbances were created in the tape at the reel rotation frequency. Fig. 4 shows a schematic of the test set-up used in this study. The tape path is configured with an actual tape head, to simulate an actual tape drive. Two LTM sensors [4] are mounted in close proximity of the head. The tension sensor is directed at the head.

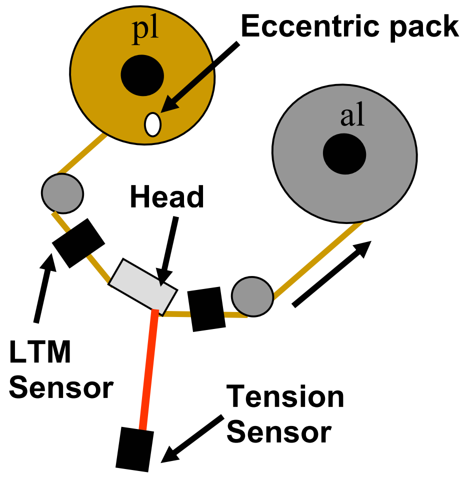

Fig.4 Schematic of test-set up

Tape speed was set at 4 m/s and a nominal tape tension of 1 N was used. The artificial disturbance created a tension force of about 0.5 N

Results

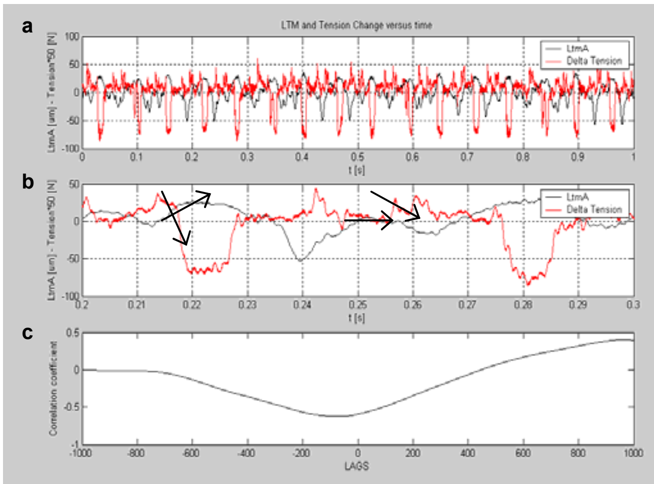

Fig.5 Tension and LTM 5000 Hz lowpass filtered

In Fig 5 (a), the LTM signal and the tension changes are shown. A blow-up of a short section of Fig. 5 (a) is depicted in Fig. 5 (b). In Fig. 5 (c) the correlation coefficient between tension changes and the LTM signal is plotted. We observe that the maximum correlation between tension changes and LTM is only 40%.

From the data shown in Fig. 5 (b) we observe that an increase in tape tension seems to always cause a change in LTM. The direction of this change is unclear; sometimes the changes are towards larger LTM values, sometimes towards smaller LTM values. The same behaviour is observed if the tape tension is decreased, i.e., a tension decrease causes always an LTM change, but this change can be towards larger or smaller LTM values. Hence, four different cases must be taken into account when calculating the correlation between tension changes and LTM changes:

1. Tension increases, tape moves down
2. Tension increases, tape moves up
3. Tension decreases, tape moves down
4. Tension decreases, tape moves up

It seems justifiable to investigate whether a correlation exists between the absolute values of both signals rather than the signals alone. The use of absolute values is justified since we are interested in the occurrence of tension and LTM changes regardless of their direction. In other words, tension changes induce LTM changes; the direction of these changes is currently not considered.

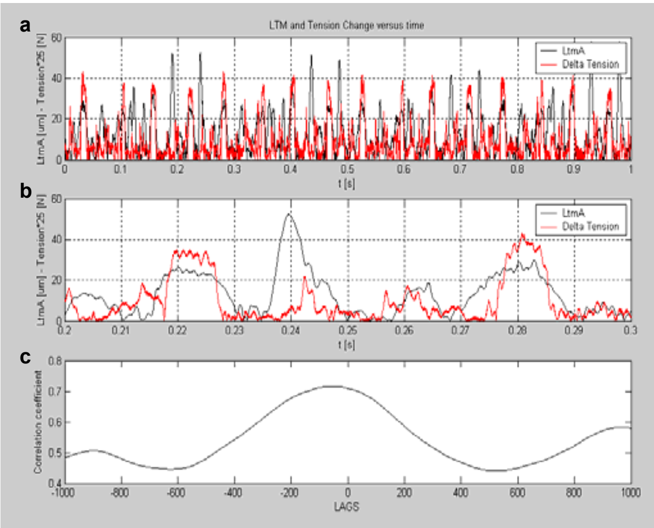

Fig.6 Tension and LTM 5000 Hz lowpass filtered

Fig.6 shows the correlation between the absolute values of both the tension changes and the LTM changes for the data shown in Fig. 5. We observe that the maximum correlation between the two signals is now 75%. Thus we conclude that tension changes cause LTM changes.

Frequency study

Frequency bands of 400 Hz were defined and the data was bandpass filtered between these bands. The maximum correlation coefficient between tension changes and LTM changes was calculated for each band and plotted in Fig.7.

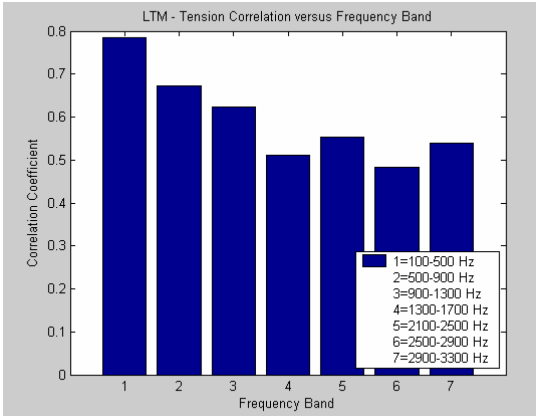

Fig.7 Frequency study

We observe that the maximum correlation between tension changes and LTM changes decreases with increasing frequency. This trend appears to be related to the effect of tape inertia: As the frequencies of tension changes increase, the tape should react faster to that change. However, the reaction of the tape is limited by its inertia.

Summary

A new non-contact high bandwidth tension sensing device was developed. The correlation between tension changes and LTM changes was investigated by analyzing the effect of an artificial tension change on LTM. A strong correlation was observed between the absolute values of both tension changes and LTM changes. The effect of the direction of the tension and LTM changes is currently not well understood and will be the subject of further research.

Acknowledgement

Bart Raeymaekers was supported by a Fellowship of the Belgian American Educational Foundation during the 2004-2005 academic year.

References

[1] D.P. Smith and J.A. Sievers, Spatially Coherent Longitudinal Vibrations in Magnetic Tape, 3M, St.Paul, Minnesota

[2] J.M. Boyle Jr. and B. Bhushan, Vibration Response due to Lateral Tape Motion and Impulse Force in a Linear Tape Drive, Microsystem Technologies 11 (2005), pp. 48-73, Springer Verlag

[3] W. Imaino, Photoacoustic Determination of Tension in Magnetic Tape, Microsystem Technologies 10 (2004), pp. 334-337, Springer Verlag

[4] R. Taylor et al., Measurement of Cross-Track Motion of Magnetic Tapes, J. Info. Storage Proc. Syst., Vol 2, 255-261, 2000