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THE USE OF ACOUSTIC EMISSION FOR DETECTION OF TAPE EDGE CONTACT

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Introduction

Lateral tape motion (LTM) is the time-dependent displacement of magnetic tape perpendicular to the tape transport direction. Lateral tape motion may cause track misregistration between the read/write head and a previously written track, thereby limiting the recording density that can be achieved [1]. Currently, the track density of typical magnetic tape drives is approximately 40 tracks/mm (1000 tracks per inch (tpi)). In order to increase the track density further, the lateral displacement of tape must be decreased [2]. Two types of lateral tape motion are generally considered, namely, low frequency and high frequency lateral tape motion. High frequency lateral tape motion with frequencies above 1000Hz cannot be followed by the servo actuator in a tape drive, while low frequency lateral tape motion can be followed. Thus, high frequency lateral tape motion is the more critical component of the two types.

Lakshmikumaran and Wickert studied edge buckling of imperfectly guided webs [3]. Wang, Taylor and Talke investigated the relationship between LTM and tape edge wear by applying a force on the tape edge using a tapered cantilever spring from a hard disk drive suspension [4]. Doyle experimentally determined the contact force during the transverse impact of plates using strain gauges. This technique is not applicable, however, when dealing with thin magnetic tape [5]. Goldade and Bhushan pointed out the importance of tape guiding in order to increase track density [6]. Taylor and Talke examined contact between tape and a reel and studied the effect of contact on LTM. They also investigated the cause of the so-called stack-shift phenomenon and its relationship with high and low frequency LTM [7]. Little published information exists concerning the magnitude of contact forces during tape edge/flange contact, even though this information would be desirable for the design of future high performance tape drives. This paper tries to fill the above gap and focuses on the occurrence and characterization of tape edge contact between a tape edge and the flange of a roller by means of acoustic emission (AE) techniques.

Acoustic emission

On a micro-scale, deformation is characterized by dislocations. The movement of dislocations generates transient elastic stress waves, referred to as acoustic emission (AE) [8]. Elastic stress waves propagate from a source as plane or spherical waves. The stress waves are picked up by the AE sensor and converted into a voltage proportional to the magnitude of the AE energy [9]. In this investigation, an AE sensor is used instead of a flange on a roller. When the tape makes contact with the flange which is replaced by the sensor, a voltage is generated. This voltage is analyzed and used as an indicator of the type and strength of contact occurring as a function of design parameters of the tape edge/roller flange interface.

Calibration

To determine the magnitude of contact force between a tape and a flange, an AE sensor was first calibrated by means of the "ball drop method" [10]. Fig. 1 illustrates the calibration procedure. A steel ball is dropped from different heights h on a load cell which measures the impact force (Fig. 1a) during contact. Next, a steel ball is dropped from varying heights h on the AE sensor and the maximum output voltage is measured (Fig 1b). To insure that the impact of the steel ball occurs at the same position for all experiments, we have used a small tube to guide the ball. Correlating the load cell and AE data, we have established the relationship between AE voltage and impact force (Fig 1c) [5]. The ball drop calibration method must be interpreted with care since the impact characteristics of a steel ball on an AE transducer is very different from that of a tape edge and an AE transducer. Basic information can be obtained, however, for the

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characteristics of tape edge contact with the roller flange, especially the timing and frequency of the signal due to a contact.

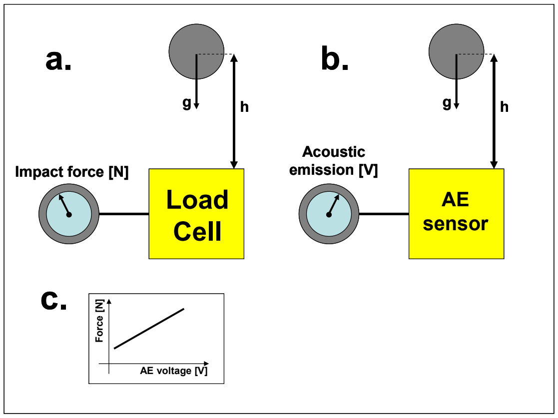

Fig. 1 "Ball drop method" calibration procedure

Fig. 2 shows the calibration curve of the AE sensor used in this paper, obtained with the "ball drop method". We observe that the calibration is nearly linear for voltage versus impact force.

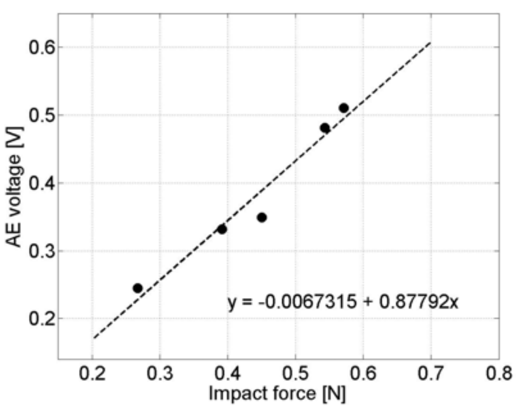

Fig. 2 Impact force calibration curve

Detection of tape/flange contact

Fig. 3 shows the experimental set-up used to study contact between a tape and the flange of a roller.

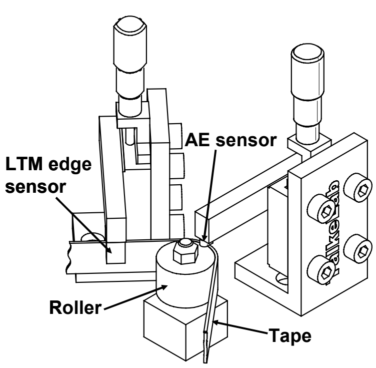

Fig. 3 Experimental set-up

Magnetic tape from the supply reel is guided over a smooth flangeless roller before being wound on the take-up reel. This tape path is the most fundamental and easiest path to investigate. The AE sensor is positioned above the roller and acts as an "artificial flange". An LTM edge sensor [1] is positioned over the tape to measure LTM.

Fig. 4 a) shows total LTM versus time. Figure 4 b) shows the LTM signal versus time after high-pass filtering at 1 kHz while Fig. 4 c) shows the impact force between the tape and the flange, also as a function of time. We observe that high frequency LTM bursts (Fig. 4 b)) occur at the same time when impacts occur between tape and flange (Fig. 4 c)). It is thus apparent that contact between tape and roller flange causes high frequency LTM.

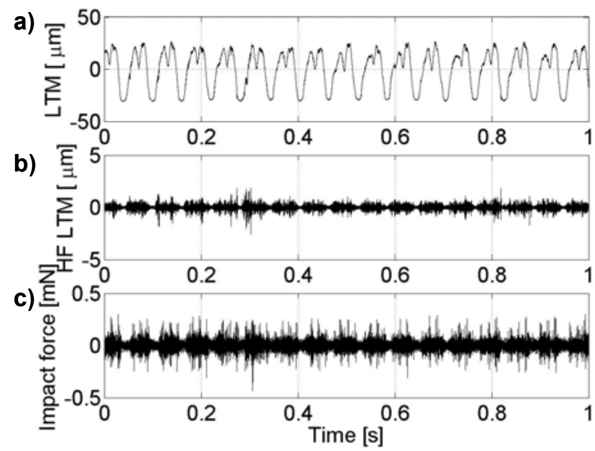

Fig. 4 LTM and impact force versus time

Fig. 5 a) shows the root mean square (rms) signal of the tape edge impact force, while Fig. 5 b) depicts the time frequency analysis of the LTM. We again observe that peaks in the rms impact force occur at the same instant as peaks in the FFT signal of the high frequency lateral tape motion.

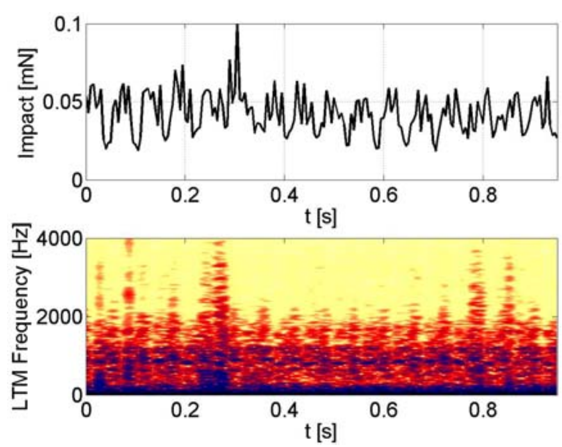

Fig. 5 rms impact force and FFT of LTM

Furthermore, we observe that high frequency components of LTM, caused by tape edge contact, occur predominantly in the 1 – 2 KHz range.

After establishing the usefulness of AE probes in monitoring tape edge contact, we have investigated the dependence of contact between the roller flange and a tape on the speed of the tape and the reel diameter, i.e., on whether the reel is full or empty. In Fig. 6, we show the average impact force versus the magnitude of the tape pack, for three different speeds. The average impact force was calculated over one second of data.

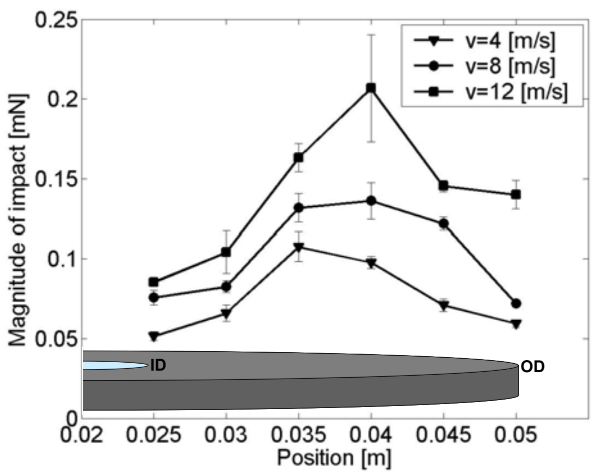

Fig. 6 Average impact force versus tape pack

We observe that the average impact force reaches a maximum when the tape reel diameter is halfway between an empty and a full tape reel. We also observe that the impact force increases with increasing tape speed.

A tape reel is typically misaligned for a given azimuth angle α, shown in Fig. 7. Therefore, the tape is leaving the rotating reel with a periodic lateral displacement. The amplitude of this lateral displacement A depends on the diameter D (position) of the tape pack on the reel. A full pack (outer diameter) causes the largest lateral displacement, while an empty pack (inner diameter) causes the smallest lateral displacement. To keep the tape speed constant, it is necessary that the rotational frequency ω of the tape reel is changed continuously while the pack changes its size. Thus, the frequency of impact between tape and roller flange increases for a decreasing pack size, since the rotational speed of the decreasing pack size must increase. Both of these effects oppose each other with respect to the magnitude of the impact force and cause the well-defined maximum of the contact force at a position when the tape reel is half full.

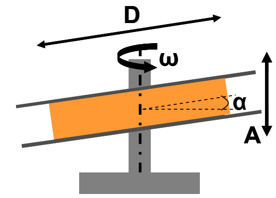

Fig. 7 Tape reel misalignment

Conclusion

From our investigation we conclude that:

- Acoustic emission is a useful technique to monitor and characterize tape edge contact.
- Tape edge contact induces undesirable high frequency lateral tape motion.
- The maximum of impact force between the flange of a roller and a tape edge was observed to occur for a half full tape reel.
- The magnitude of the impact force increases for increasing tape speed.

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