Active tape control for magnetic tape storage

Reduction of lateral tape motion with a tilting roller

Graduate Candidates

Diego Dolp

Noah Samuel Heuberger

Introduction: In data centers and cloud-environments where enormous amounts of cold data need to be backed up or archived, magnetic tapes are still one of the safest, most energy-efficient and economic technologies. IBM's newest generation of TS1160 tape drives are able to store up to 20 TB of data on one cartridge.

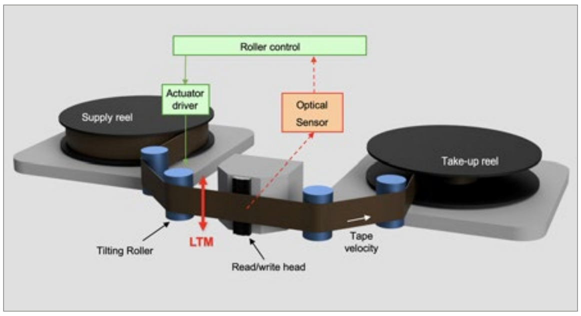
During operation, the magnetic tape of approximately 5 µm of thickness moves from the supply reel of the cartridge to the take-up reel inside the drive, and vice versa. Between the two reels, the tape is guided by four rollers and travels over the read/write head mounted in the center of the assembly. In order to achieve a high track density to maximize storage capacity, lateral tape motion (LTM) – the tape's movement perpendicular to its traveling direction – needs to be measured and the position of the head adjusted by a track-following actuator.

Approach / Technology: The objective of our project is to reduce LTM during tape transport: By measuring the height of the travelling tape with an optical sensor placed at the lower tape edge and using this information to control the angle of a current-controlled tilting roller, we aim to mitigate large lateral tape excursions originating from so called «stack-shifts» in the tape pack of the reels, and therefore constrain the tape's remaining LTM to a narrow range.

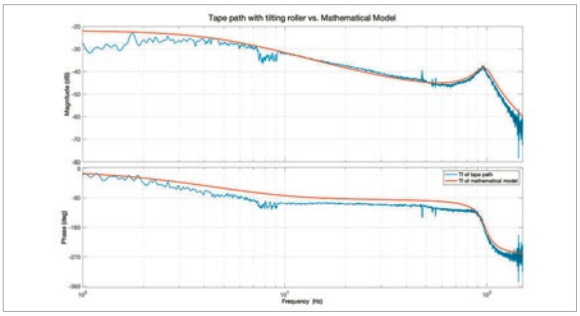
For a simplified workflow during measurement, controller-prototyping and simulation, we chose Simulink's real-time platform Speedgoat. After an initial testing phase for sensor- and roller-positions, two decisions were made: (1) The sensor was placed in the center of the assembly to approximate tape behavior at the read/write head's location, and (2) the location of the rollers was chosen such that the wrap-angle – the angle the tape travels around the actuated roller – is constant over the whole length of the tape. With this geometry, a simplified mathematical model of a moving web combined with a 2nd-order approximation of the actuator provided the most accurate fit to the tape path's measured transfer function. We recorded the LTM of two tapes for a validation baseline of our controller designs. For controllers, we used a PI design with integrated anti-windup, and a root locus design compensating the poles of the physical system. Finally, the two controllers were discretized and implemented in C on an STM microcontroller.

Conclusion: Both of our controller designs eliminate stack shifts and reduce the remaining LTM further: Compared to a standard deviation of 129.8 µm on the uncontrolled tape, the root locus controller achieves a standard deviation of 5.4 µm – approximately equal to the thickness of the tape. Together with the controller's µC-implementation, our project provides a complete closed-loop LTM-control system that can eliminate large disturbances. Less LTM at the read/write head reduces the dynamic range requirement of the track-following actuator and potentially enables higher track-following accuracy.

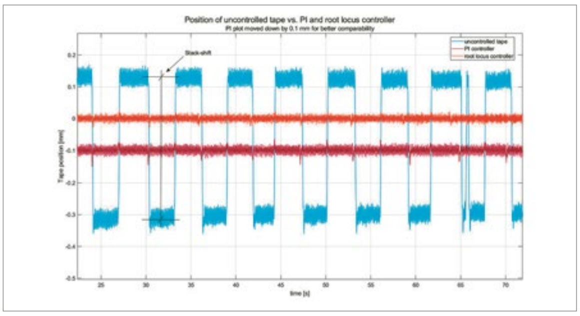
Tape path assembly
IBM Research Europe, Zurich, Switzerland



Comparison of the tape path with our mathematical model
Own presentment



Uncontrolled LTM vs. PI and root locus controlled tape
Own presentment



Examiner
Prof. Dr. Markus Kottmann

Co-Advisor
Dr. Markus A. Müller, Frei Patentanwaltsbüro AG, Zürich

Subject Area
Regelungstechnik / Control Theory

Project Partner
IBM Research Europe, Zurich, Switzerland, Rüschlikon, ZH