TAPE MECHANICS OVER A FLAT RECORDING HEAD

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ABSTRACT

Tape mechanics over a flat-head is investigated. As a first order of approximation, a simplified system is analyzed; where a *uniform* subambient pressure is assumed to be acting on the tape, over the head region. This allows a closed form solution for the tape mechanics by itself. Tape and head-wear at the corners of the head, and wear of the magnetically active regions located at the central part of the flat-head are critical issues to be considered in designing a flat-head/tape interface. The closed-form solution, presented here, is particularly useful in obtaining estimates of the magnitudes of the reaction forces at the corners.

1. INTRODUCTION

It has been shown that when a *flat* recording head is used instead of a cylindrical one, reliable contact is obtained over the central region of the flat-head [1-5]. This phenomenon is due to the *self-acting, subambient foil bearing effect*. This recent finding has sparked interest in the mechanics and tribology of such systems. Flat-heads have been recently implemented in commercial tape recorders. There are several technical and commercial advantages to using flat-heads. In particular, faster tape speeds over flat-heads have been shown to provide more reliable contact, in direct contrast to tape behavior over cylindrical heads. Moreover, the flat contour is more forgiving for tapes with different thickness, enabling backward/forward compatibility of tapes. Finally, flat-heads are considerably easier to manufacture as compared to contoured heads. Tape and head-wear at the corners of the head, and wear of the magnetically active regions located at the central part of the flat-head are critical issues to be considered in designing a flat-head/tape interface. We address this issue among others in this paper.

The goal of this paper is to analyze the contact mechanics of the tape when it is being pushed against a flat head with a constant and uniform pressure p^* as shown in Fig. 1. Thus the effect of air lubrication, is represented by this constant pressure. This gross assumption is justified only because it allows a closed form solution of the tape mechanics. The contact of the tape has three possible *cases* as a function of the external pressure, as depicted in Figure 2. Note that "increasing pressure" implies increasing subambient pressure.

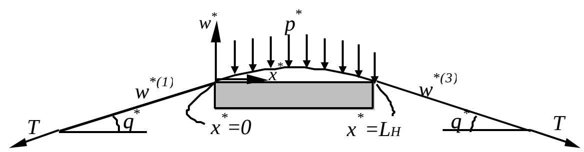

Fig. 1 Schematics of the tape over a flat-head.

Case-1, $0 < p \le p_{cr}^{(1)}$**:** As p increases from zero, the tape will deflect toward the head and, when $p = p_{cr}^{(1)}$, it will just touch the head at $x = 1/2$.

Case-2, $p_{cr}^{(1)} < p \le p_{cr}^{(2)}$**:** When, $p > p_{cr}^{(1)}$ a reaction force, F_L, develops between the tape and the head; and the tape deforms with a single contact point at the center. When $p = p_{cr}^{(2)}$, the tape curvature at the center becomes zero and the reaction force keeps increasing.

Case-3, $p > p_{cr}^{(2)}$**:** When $p > p_{cr}^{(2)}$, the contact point moves closer to the edges of the head; the tape contacts the head in the region, $L \le x \le 1 - L$, where $L < 1/2$. In this "flat" region $w = 0$. While $p > p_{cr}^{(2)}$ two distinct displacement bumps form near the edges of the head, in $0 \le x \le L$ and $1 - L \le x \le L$. In the flat region, the value of the contact pressure between the head and the tape is equal to the external pressure p. At the edges of the flat region reaction forces F_L develop.

2. THE MODEL OF TAPE OVER FLAT-HEAD

Thus, tape is modeled as an infinitely wide tensioned plate, travelling at steady state with speed,

$$\frac{d^4w}{dx^4} - \Delta^2 \frac{d^2w}{dx^2} = -p\left(H(x) - H(x-1)\right), \quad (1)$$

The following non-dimensional variables are introduced,

$$x = \frac{x^*}{L_H}, \quad w = \frac{w^*}{c}, \quad p = 12\left(1-n^2\right)\frac{p^*}{E^*}\left(\frac{L_H}{c}\right)^4,$$

$$q = \frac{L_H q^*}{c}, \quad \Delta = \frac{L_H}{b}, \quad b = \left(\frac{Ec^3}{12\left(1-n^2\right)\left(T - rV^2\right)}\right)^{1/2}$$

where c, E^*, n, T, V, r, w^* are tape thickness, elastic modulus, Poisson's ratio, tension per width, speed, areal density, and normal deformation, respectively. L_H is the width of the flat-head. The tape deformation for the three contact cases described above are obtained by solving equation (1) [6].

3. RESULTS

Expressions for the reaction forces on the edges of the head F_0, and the edges of the inner contact region F_L are found. For a given external load p, F_0 is considerably higher than F_L; and, the difference grows with increasing Δ. For low p values, the reaction force at the edge of the head F_0 approaches the normal component of the external tension ($q^* T_{eff}$); for large p values, F_0 is dominated by p. Note that the non-dimensional reaction forces are defined as $F_0 = F_0^* L_H^3 / Dc$ and $F_L = F_L^* L_H^3 / Dc$, where F_0^* and F_L^* are the reaction forces per unit width.

The reaction force F_0 for case-1 becomes:

$$F_0 = \frac{1}{2}\left(p + 2\Delta^2 q\right) \text{ for } 0 \le p \le p_{cr}^{(1)}. \tag{2}$$

The reaction force F_0 for case-2 becomes:

$$F_0 = a\left\{\left[\left[1 + 2e^{\Delta/2}\left(\frac{\Delta}{2} - 1\right) + e^{\Delta}\left(1 - 2\Delta - \frac{\Delta^2}{4}\right)\right]\right]\frac{p}{\Delta^2} + 2e^{\Delta/2}\Delta\left[1 + e^{\Delta/2}\left(\frac{\Delta}{2} - 1\right)\right]q\right\} \tag{3}$$

$$\text{for } p_{cr}^{(1)} < p \le p_{cr}^{(2)}$$

where $a = \Delta \Big/ \left(4e^{\Delta/2} - 1 + e^{\Delta}\left(2\Delta - 3\right)\right)$.

The reaction force F_0 for case-3 becomes:

$$F_0 = a\left\{\left[1 + 2e^{\Delta L}\left(\Delta L - 1\right) + e^{2\Delta L}\left(1 - 2\Delta - \Delta^2 L^2\right)\right]\frac{p}{\Delta^2} + 2e^{\Delta L}\Delta\left[1 + e^{\Delta L}\left(\Delta L - 1\right)\right]q\right\} \tag{4}$$

$$\text{for } p > p_{cr}^{(2)}$$

The solution provided here is useful to identify the effects of *some* of the operating parameters of the full self-acting subambient foil bearing problem, where the Reynolds equation and asperity contact are involved. In the future, the results of the current work will be compared with the results of a numerical solution, including the effects of the bearing number and asperity compliance.

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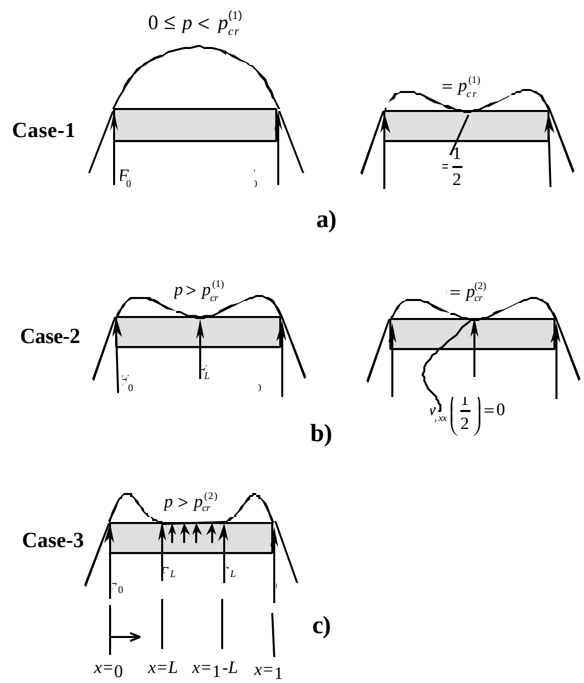

Fig. 2 Schematics of the three contact cases.

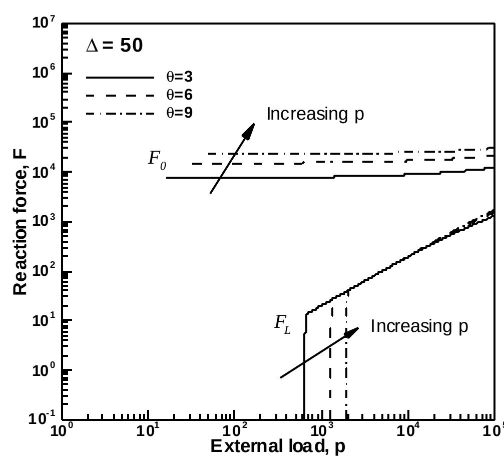

Fig. 3 Reaction force vs. external load