VLBA ACQUISITION MEMO #263

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Subject: Tape Winding Dynamics

When a tape is wound at speed an air film is formed between the layers which leaks out sideways. Because of the air film the picture of a reel in the rotating frame is quite interesting. In this frame the tape is tightening like a clock spring by the rotation of adjacent outer layers of tape. For the outer layer of tape the initial film thickness is given by Eshel's equation

$$h = 0.64r\left(\frac{12\mu U}{T/W}\right)^{2/3} = 90 \textit{ microns}$$

μ = viscosity (2.6×10^{-9} lb. sec/sq in)

U = tape speed (320 in/sec)

T = tension (0.44 lb (equivalent to 10" in vacuum column))

r = radius of layer (7")

W = tape width (1")

The air bleeds out sideways and if we assume plane Poiseuille flow the volume rate per unit tape length Q

$$Q = \frac{Ph^3 4}{12\mu\ W}$$

W = tape width (assume air travels ~ $W/4$)

P = interlayer pressure = (T/r for outer layer)

and since the air volume is approximately equal to $h\ W/2$

$$\frac{dh}{dt} = -\frac{Ph^3 8}{12\mu W^2}$$

and hence

$$\frac{h}{ho} = \left(8Pt/(3\mu W^2) + 1\right)^{-1/4}$$

ho = initial layer thickness

for constant P and the thickness as a function of time is as follows:

h Microns	Time
90	0
9	0.2 ms
0.9	1.6 sec
0.09	4.6 hours

for P = 0.06 psi. These times are shortened in a proportional manner for higher interlayer pressures. If we assume that interlayer pressure builds with every rotation then

$$P = P_o Ut/2\pi r$$

where

P_o = pressure from a single turn

and the solution is

$$\frac{h}{h_o} = \left(4P_o\ U\ t^2/(3\mu\ W^2\ 2\pi\ r) + 1\right)^{-1/4}$$

and at 320 IPS and a full reel

h Microns	Time	Number of Turns
90	0	0
9	7 ms	0.05
0.9	0.7 sec	5
0.09	1.2 min	500

If we assume that an air layer of 0.9 microns is sufficient for slippage (i.e. a film thickness greater than the backcoat roughness) then about 5 layers will be tightening. However, with smoother backcoats and any blockage of the air flow this number could increase.

The consequences of the suggestion that the outer layers are tightening by interlayer slippage, if proven valid, needs to be included in theories of the reel pack stability. Especially worrisome is the presence of dirt or roughness on the reel flanges which may alter the tightening process. At this time, I have no definitive experimental verification of this theory. However the presence of the air film layer and its persistence can be clearly seen by running a Q-tip against the winding tape pack and observing the presence of the film from the trail (seen in reflection) left by the Q-tip pressure. The trail will only be seen when winding - none is observed when unwinding.