Surface Roughness Effects on the Head-Tape Interface

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Outlines

- **Head-tape interface modeling (mechanics)**
- **Head-tape contact and tape asperity compliance**
- **Asperity compliance: experimental determination**
- **Head-tape spacing for a transversely slotted head**
- **Head-tape spacing for a cylindrical head**
- **Surface roughness and tape asperity compliance**
- **Conclusions**

Objectives

- **Investigate the effect of surface roughness on the head-tape interface using tapes with different surface roughness against**
  - **transversely slotted head**
  - **cylindrical head**
- **Determine the tape surface asperity compliance**
- **Establish relationship between asperity compliance and surface roughness parameters**
- **Develop numerical model for head-tape interface including the effect of surface roughness**

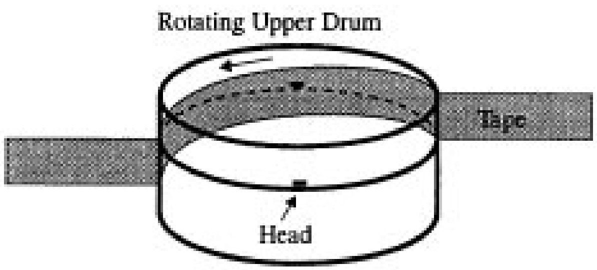
Head-Tape Interface Configuration

Longitudinal

- **head stationary**
- **tape moves**
- **low data rate for single head, use heads in parallel**

Helical Scan

- **head on rotating scanner**
- **tape moves slowly**
- **high data rate for single head**

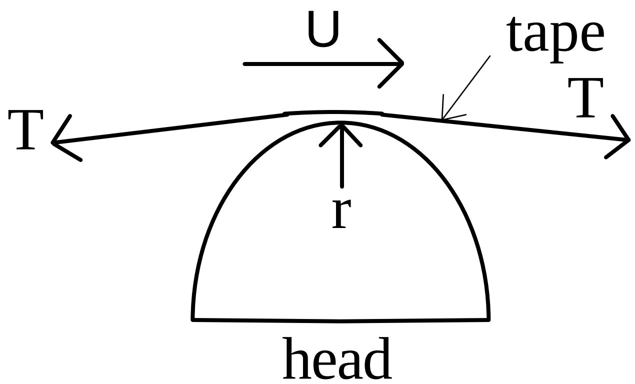


(Both pictures taken from *C. Lacey*: Head/Tape Interface)

Linear Head-Tape Interface (No Contact)

- **Hydrodynamic lubrication equation**

$$\frac{\partial}{\partial x}\left[ph^3\left(1+\frac{6\lambda}{h}\right)\frac{\partial p}{\partial x}\right] = 6\mu U\frac{\partial(ph)}{\partial x}$$



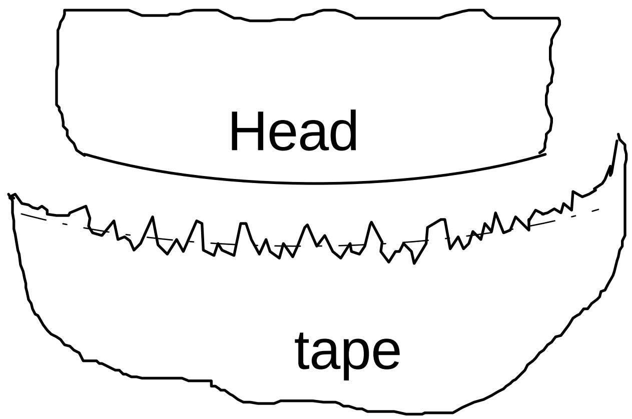
where **h = head-tape spacing,**
$p = p_a$ = air bearing pressure,
λ = mean free path of air,
μ = air viscosity, and
U = tape velocity.

- **Tape elasticity equation**

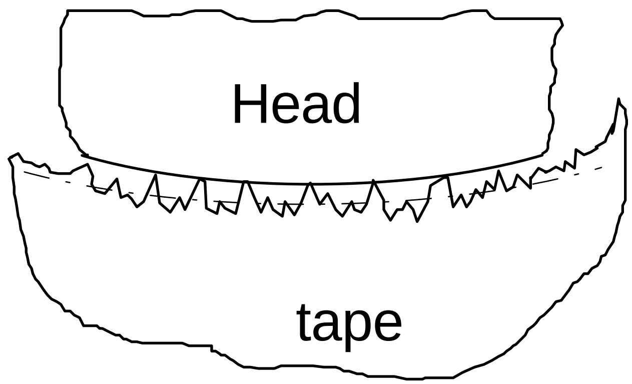
$$D\frac{\partial^4 w}{\partial x^4} - (T - \rho U^2)\frac{\partial^2 w}{\partial x^2} = p - p_{atm}$$

where **D = tape bending stiffness,** **w = tape deflection,**
T = tape tension, **ρ = tape density,**
U = speed, **p_{atm} = atmospheric pressure.**

Schematic of Head-Tape Configuration



no contact



contact

Linear Head-Tape Interface (with Contact)

- **Hydrodynamic lubrication equation**

$$\frac{\partial}{\partial x}\left[ph^3\left(1+\frac{6\lambda}{h}\right)\frac{\partial p}{\partial x}\right] = 6\mu U\frac{\partial (ph)}{\partial x}$$

where h = head-tape spacing, p = p_a = air bearing pressure, λ = mean free path of air, μ = air viscosity, and U = tape velocity.

- **Tape elasticity equation**

$$D\frac{\partial^4 w}{\partial x^4} - (T - \rho U^2)\frac{\partial^2 w}{\partial x^2} = p - p_{atm} + p_c$$

where D = tape bending stiffness, w = tape deflection, T = tape tension, ρ = tape density, U = speed, p_{atm} = atmospheric pressure and p_c = head-tape contact pressure.

- **Head-tape contact equation (see next slide)**

Head-tape Contact Models

- **Empirical model:**

$$p_c = \begin{cases} 0, & h \geq \alpha, \\ \beta(1 - h/\alpha)^2, & h < \alpha. \end{cases}$$

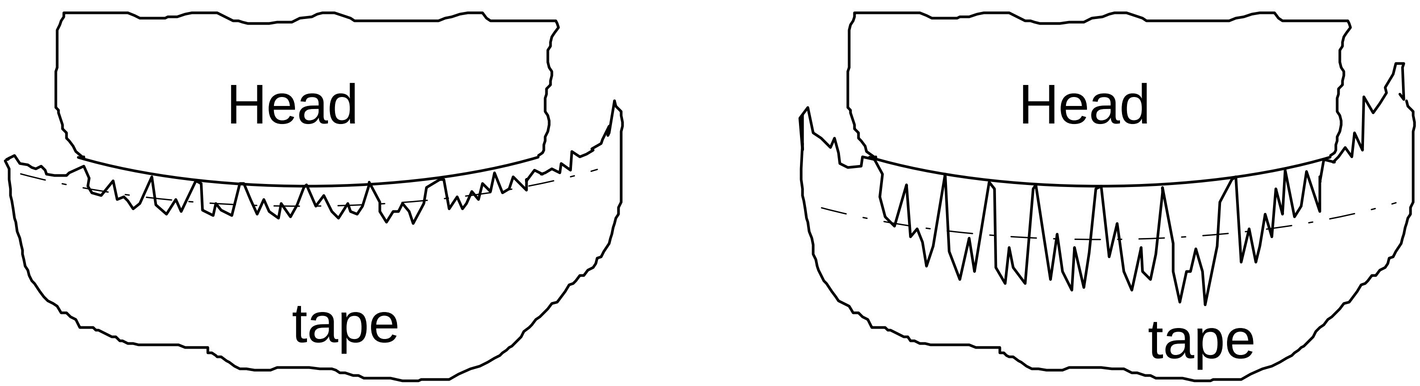
where α a constant denoting the spacing for which initial contact occurs between the head and the tape and β is a constant denoting the contact pressure that exists if the head-tape spacing is zero.

- **Greenwood-Williamson model:**

$$p_c\left(\frac{h}{\sigma}\right) = K \int_{\frac{h}{\sigma}}^{\infty} \left(z^* - \frac{h}{\sigma}\right)^{\frac{3}{2}} \Phi(z^*)\, dz^*$$

where σ is a roughness parameter, K is the contact pressure coefficient.

Schematic of Head-Tape Contact



smooth tape **rough tape**

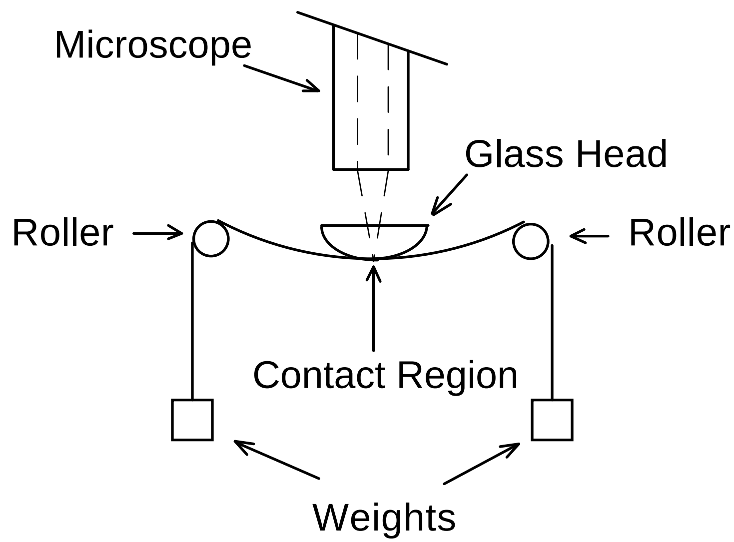
Tape Asperity Compliance: Experimental Determination

A. Tape Tension Method

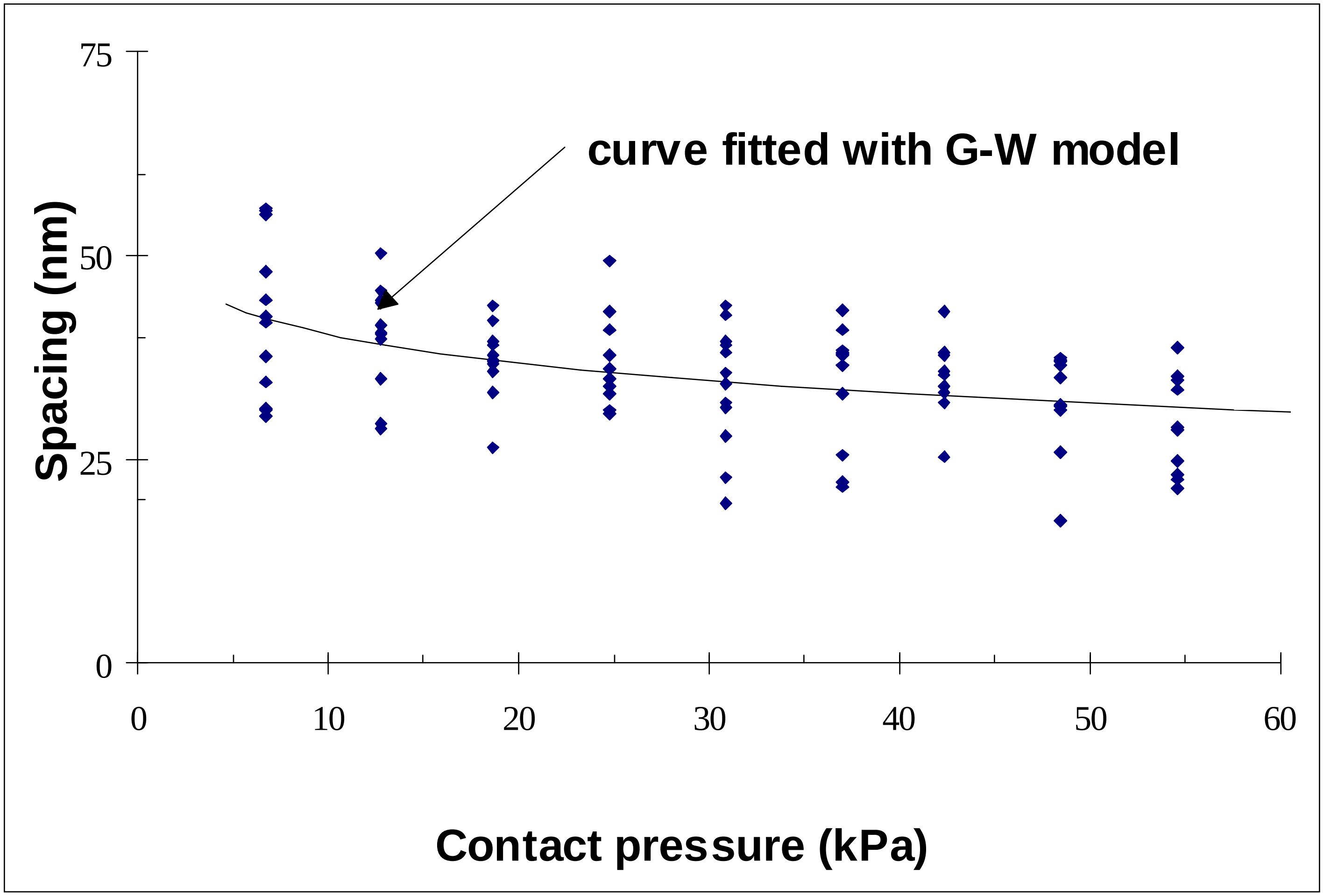
The contact pressure (p) is determined using the equation

$$p = \frac{T}{r}$$

where T is tension and r is the radius of the head

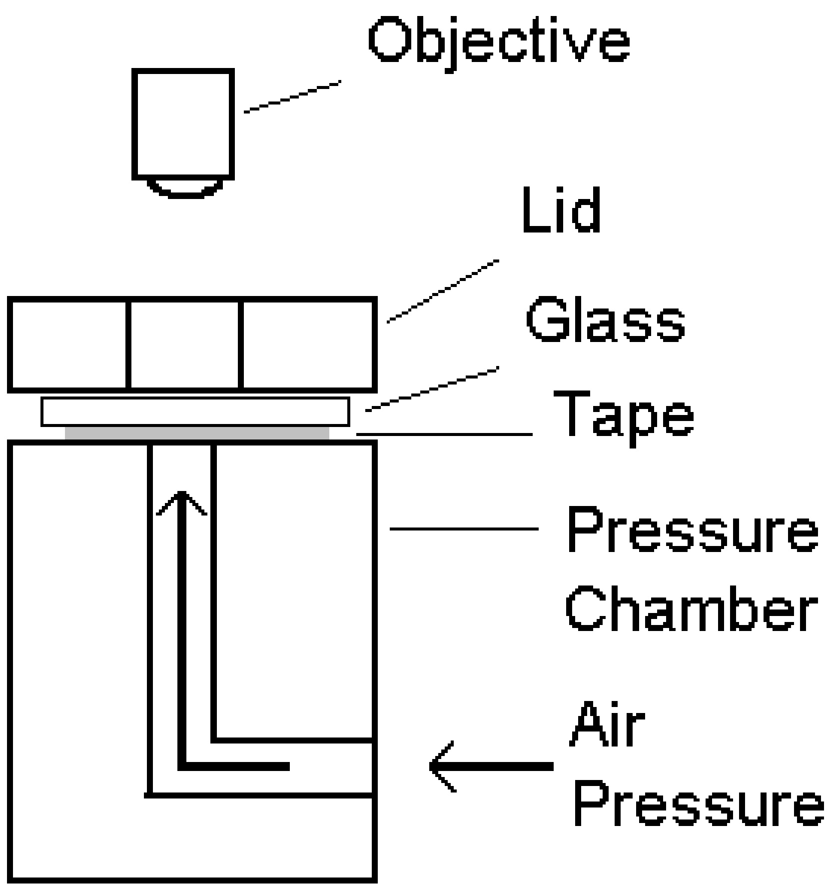


Asperity Compliance Using Tension Method

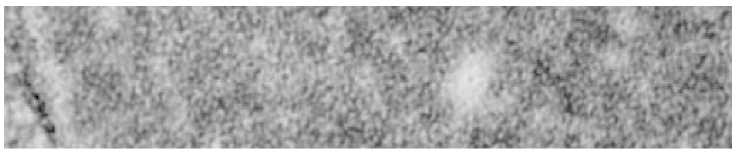


Note: High contact pressure is difficult to obtain

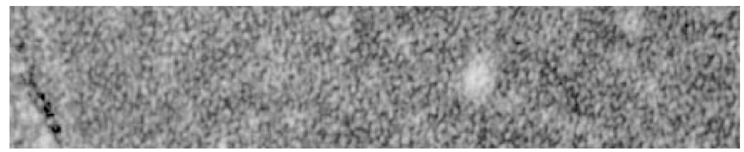
Improved Method: Pneumatic Method



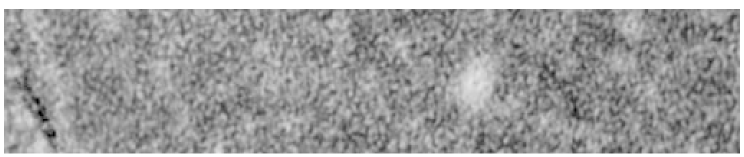
Observation: Contact Region Becomes Darker as the Pressure Increases



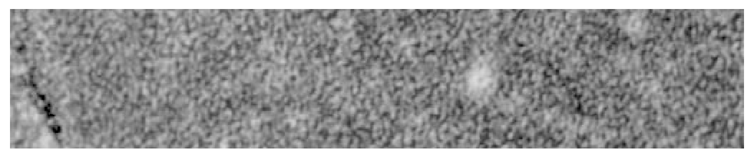
5.05 psi



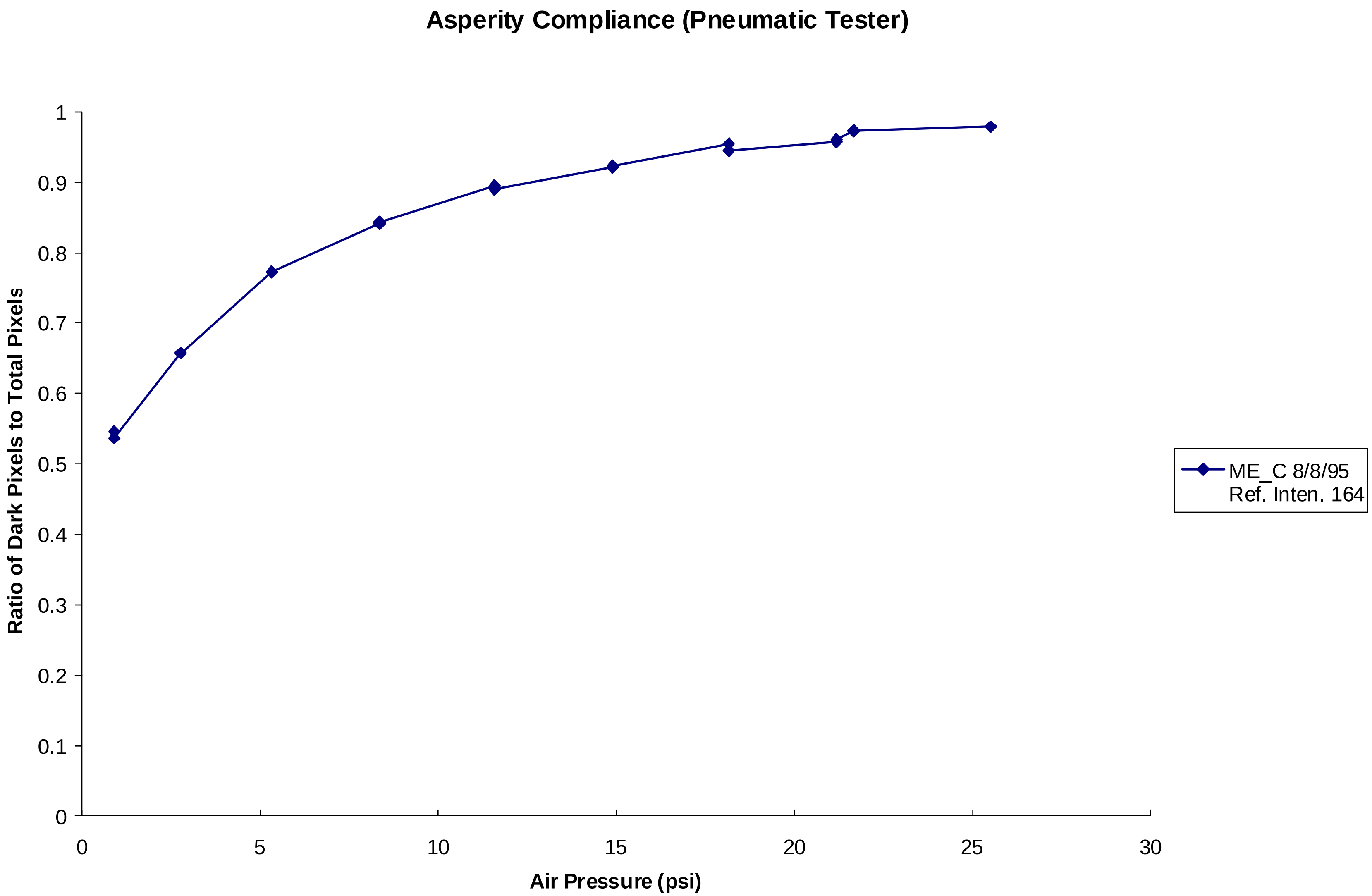
19.57 psi

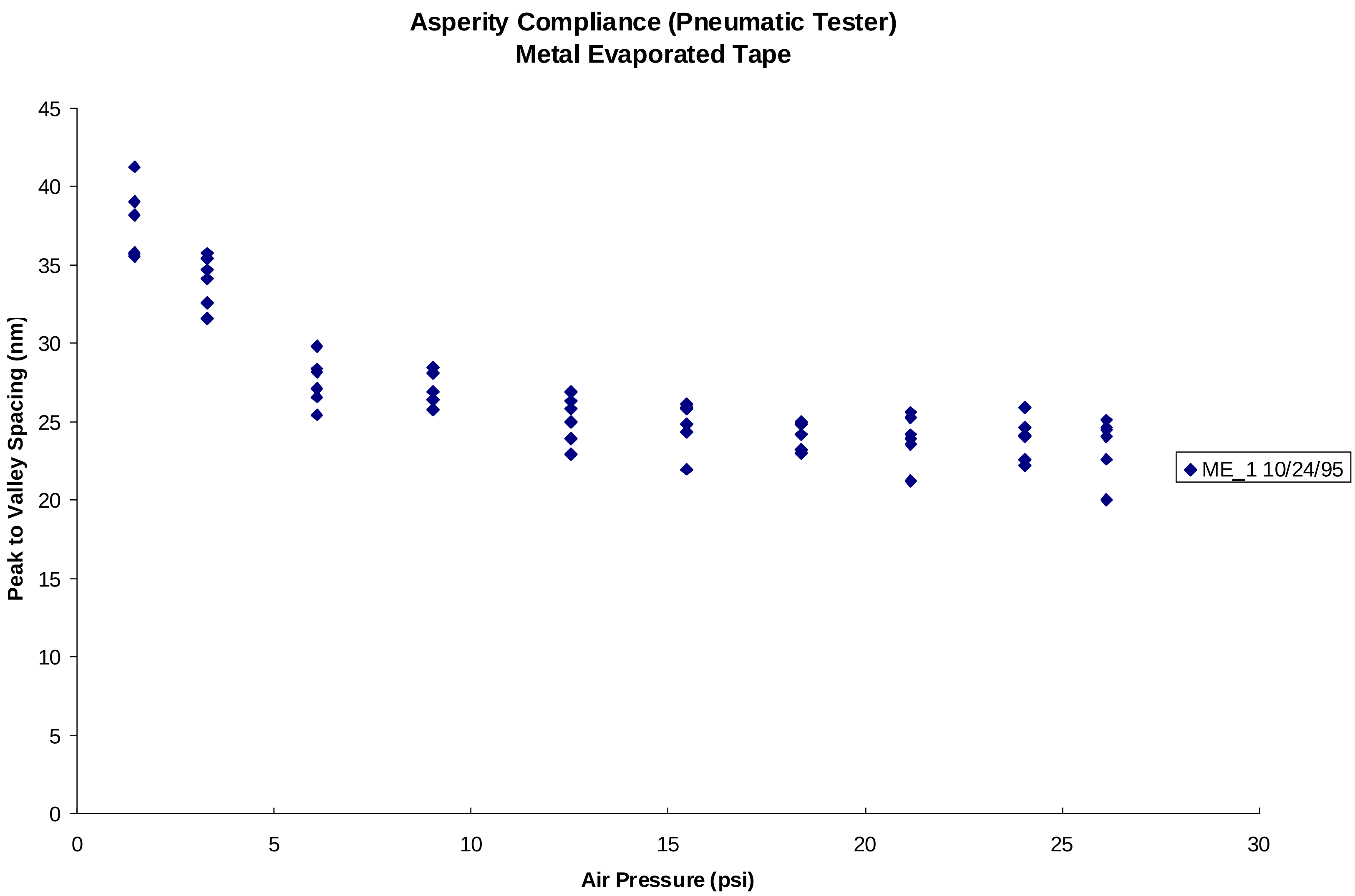


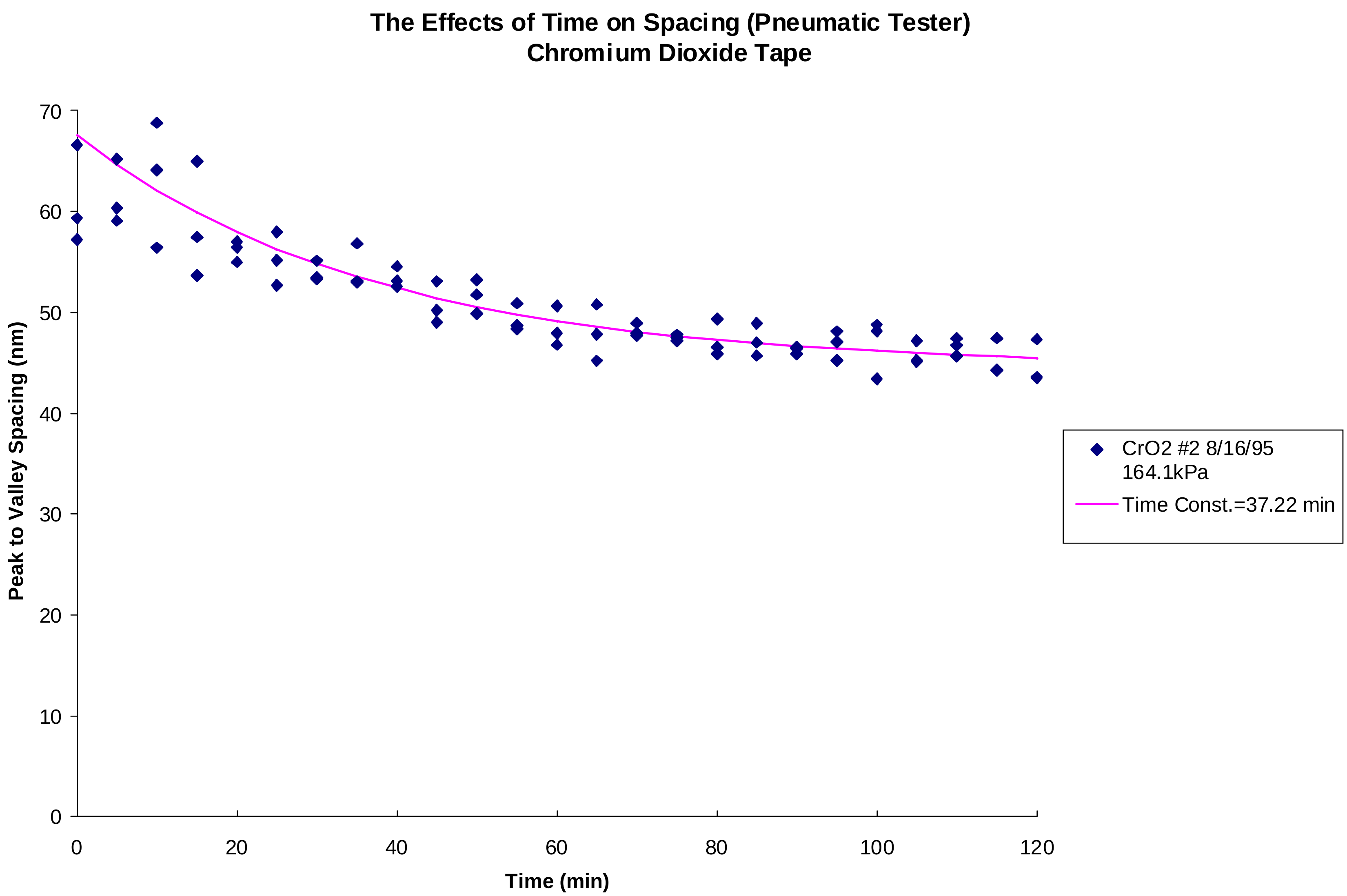
10.49 psi



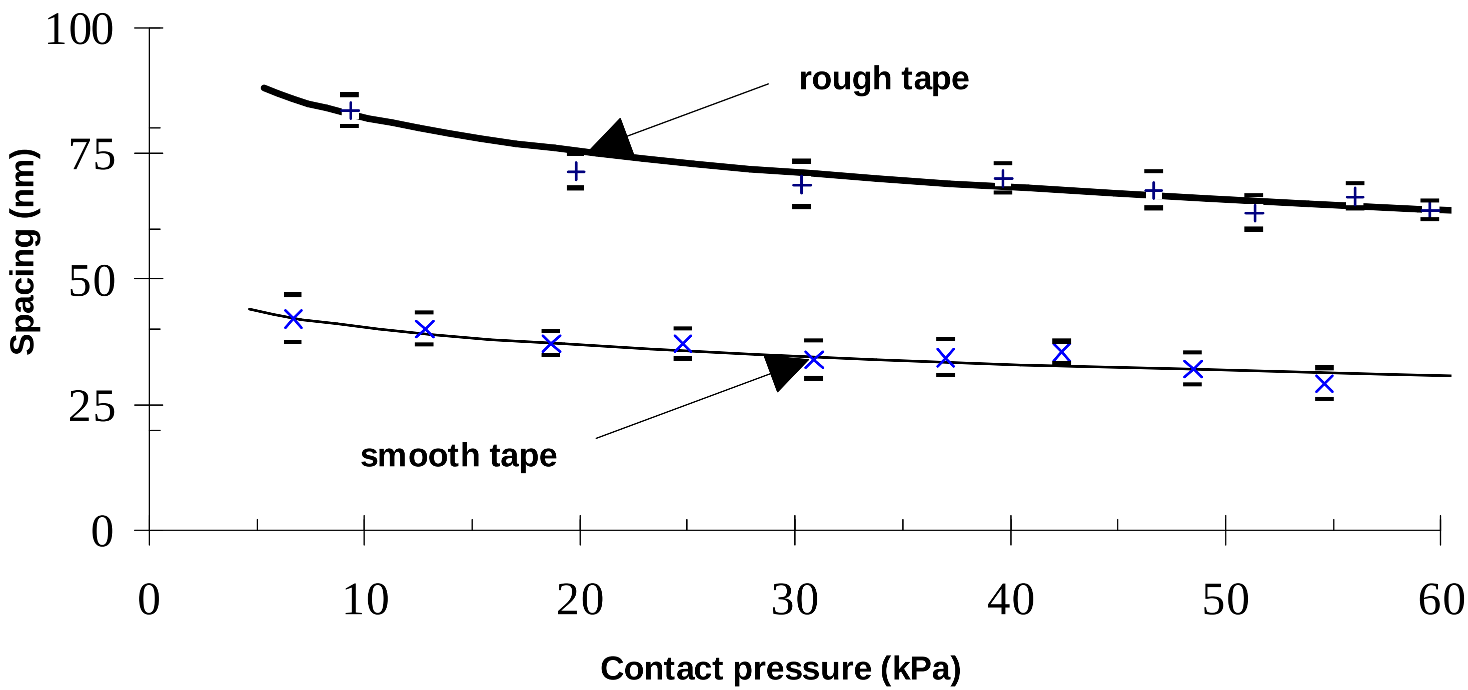
25.35 psi


Asperity Compliance (Pneumatic Tester)
Ratio of Dark Pixels to Total Pixels
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
30
Air Pressure (psi)
ME_C 8/8/95
Ref. Inten. 164

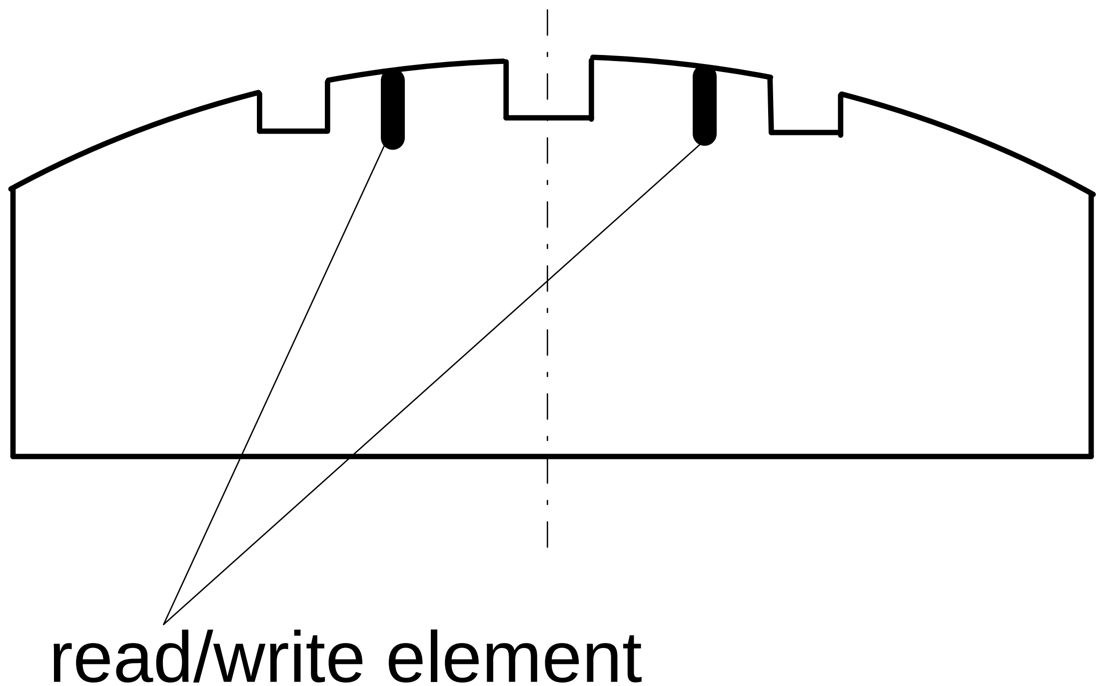

Asperity Compliance (Pneumatic Tester)
Metal Evaporated Tape
Peak to Valley Spacing (nm)
0
5
10
15
20
25
30
35
40
45
Air Pressure (psi)
0
5
10
15
20
25
30
ME_1 10/24/95


The Effects of Time on Spacing (Pneumatic Tester)
Chromium Dioxide Tape
Peak to Valley Spacing (nm)
0
10
20
30
40
50
60
70
0
20
40
60
80
100
120
Time (min)
CrO2 #2 8/16/95
164.1kPa
Time Const.=37.22 min

Asperity Compliance Curves of Two Tapes with Different Surface Roughness

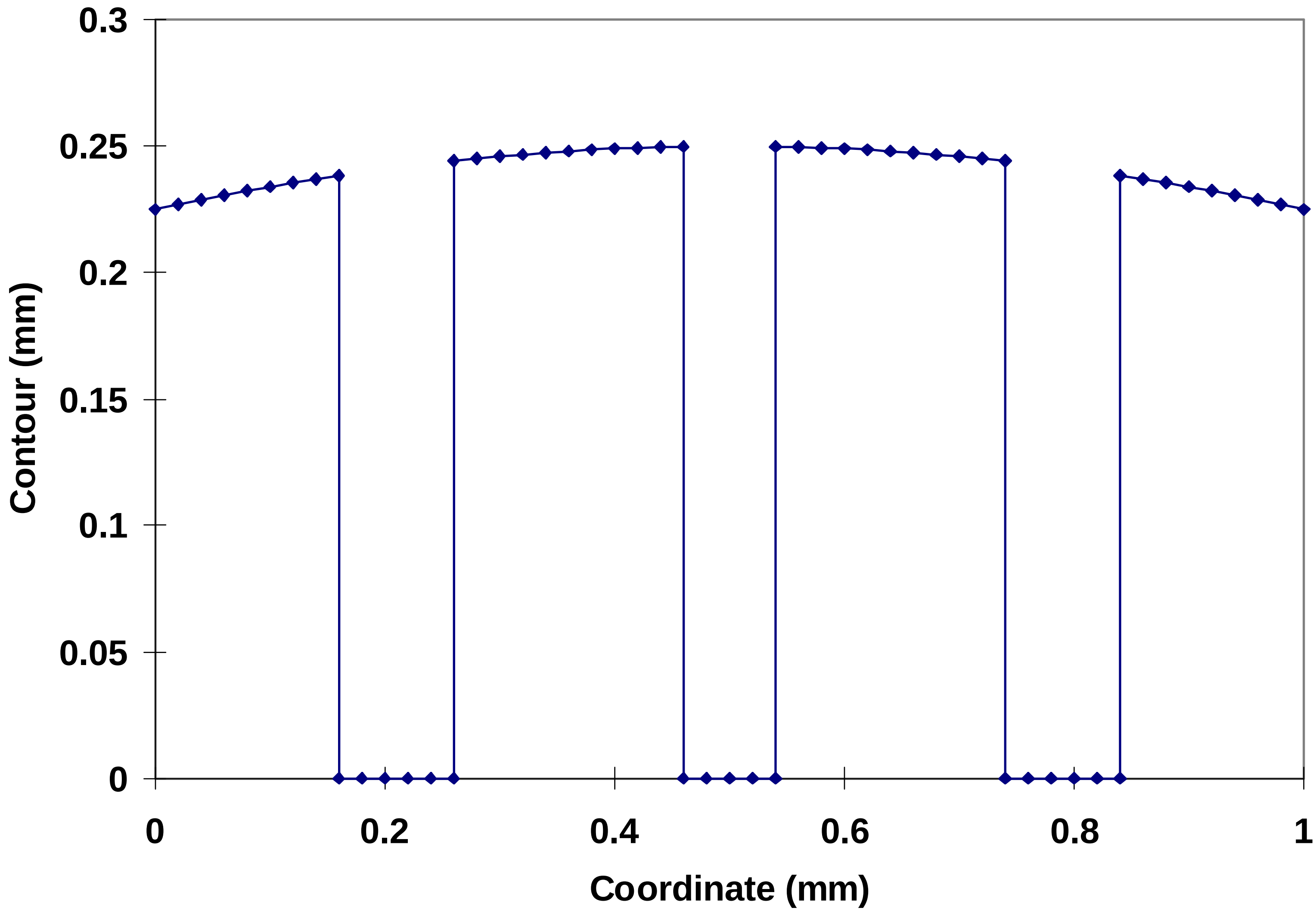


Head Contour Schematic

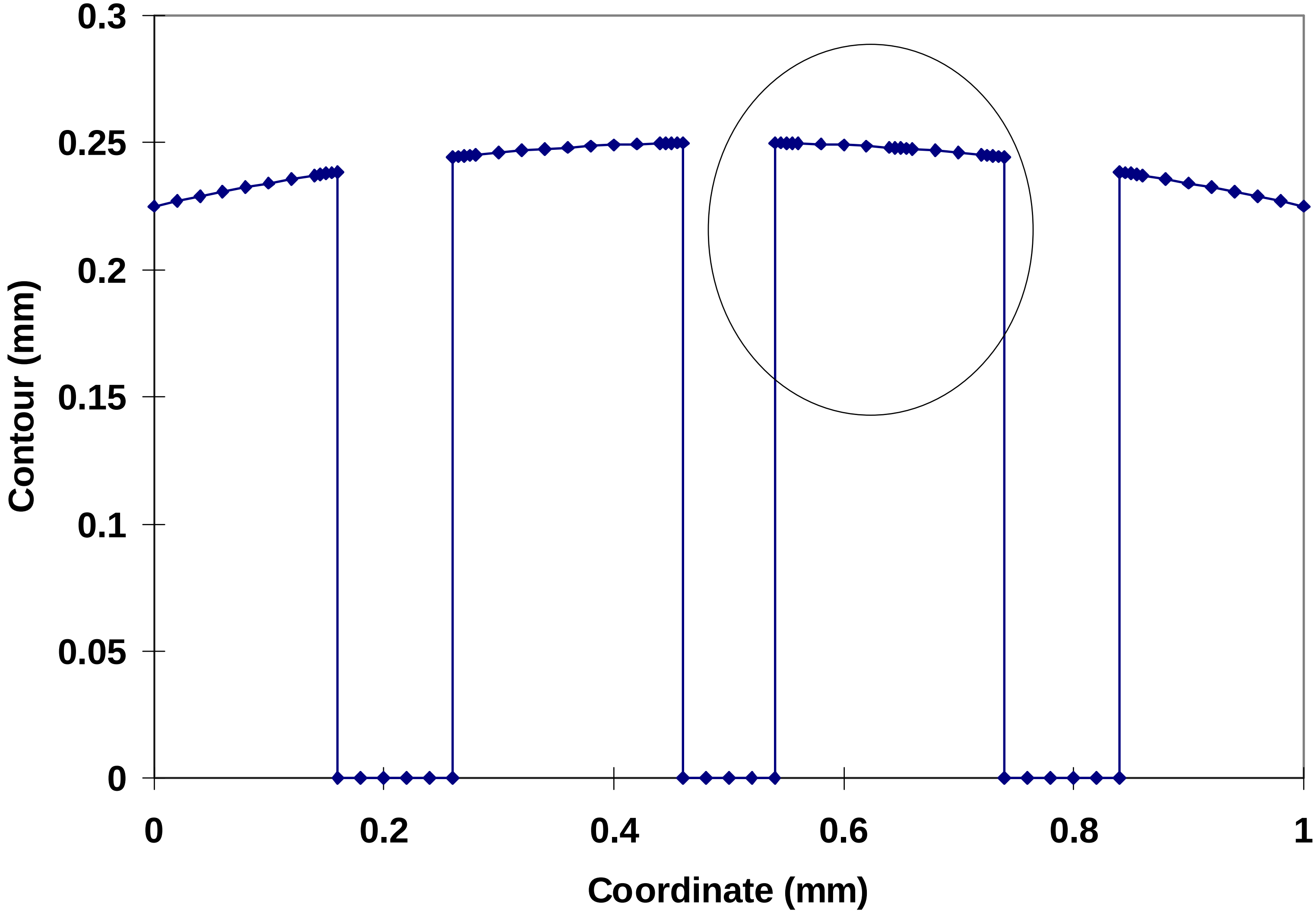


Cross-section of head with transverse slots

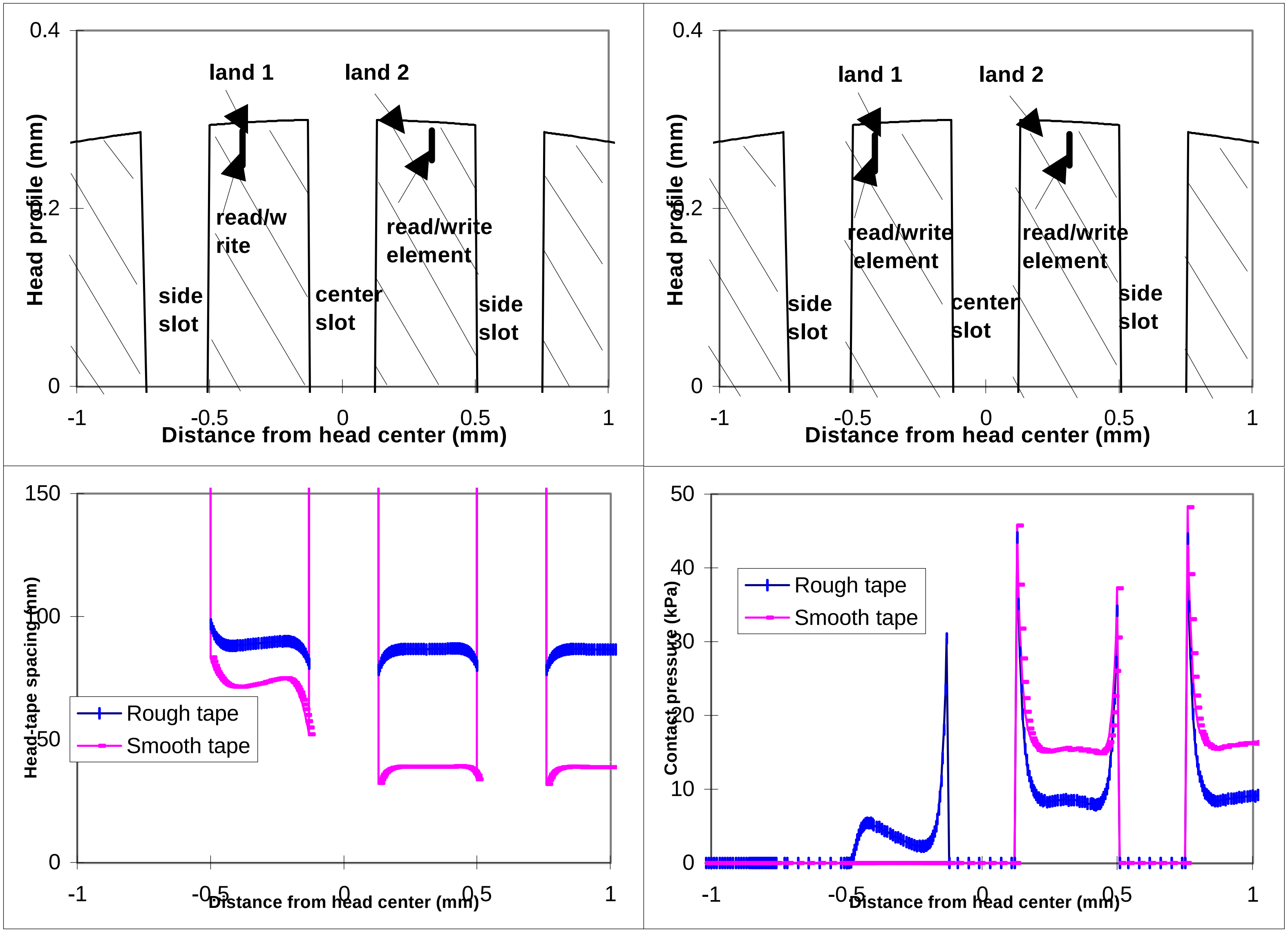
Head Contour Discretization: Uniform Grid



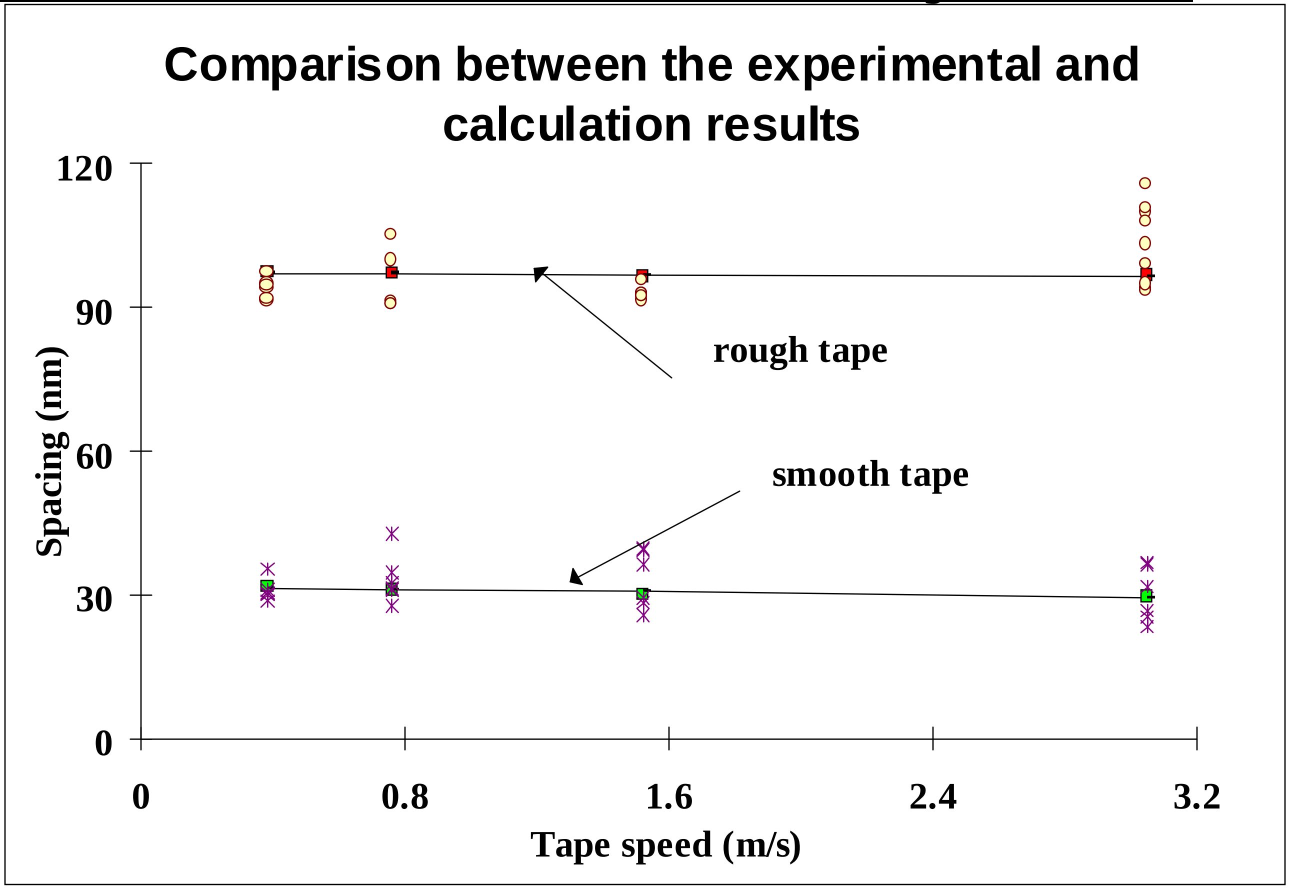
Head Contour Discretization: Non-uniform Grid



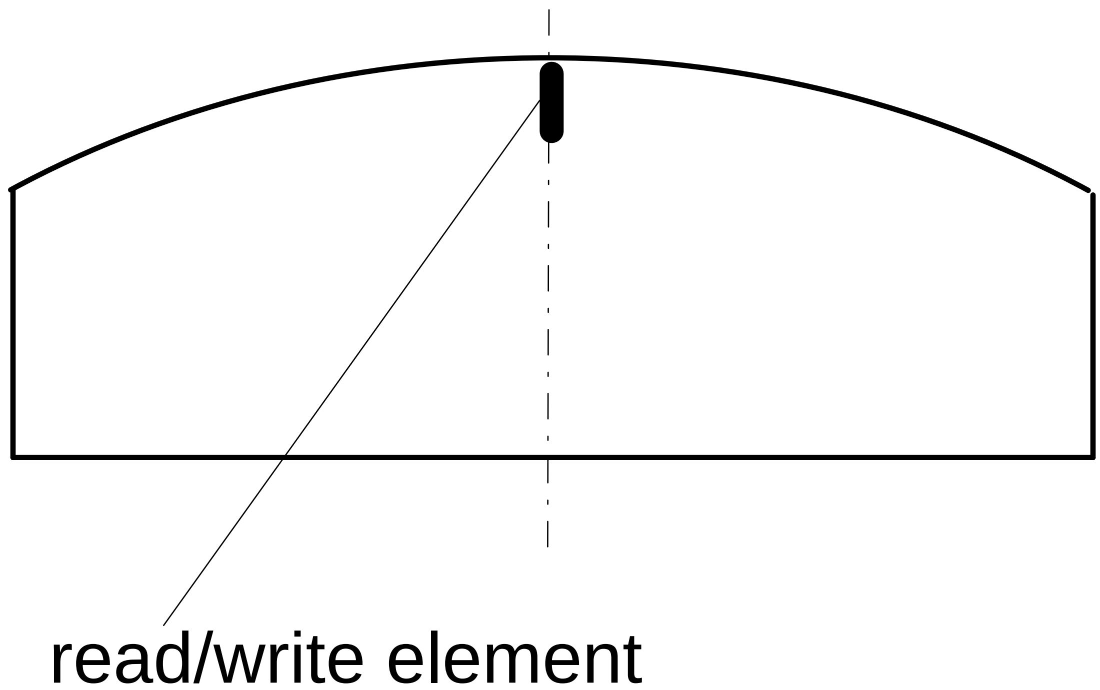
Calculation Results



Head-Tape Spacing versus Tape Speed for a Head with Transversely Slots

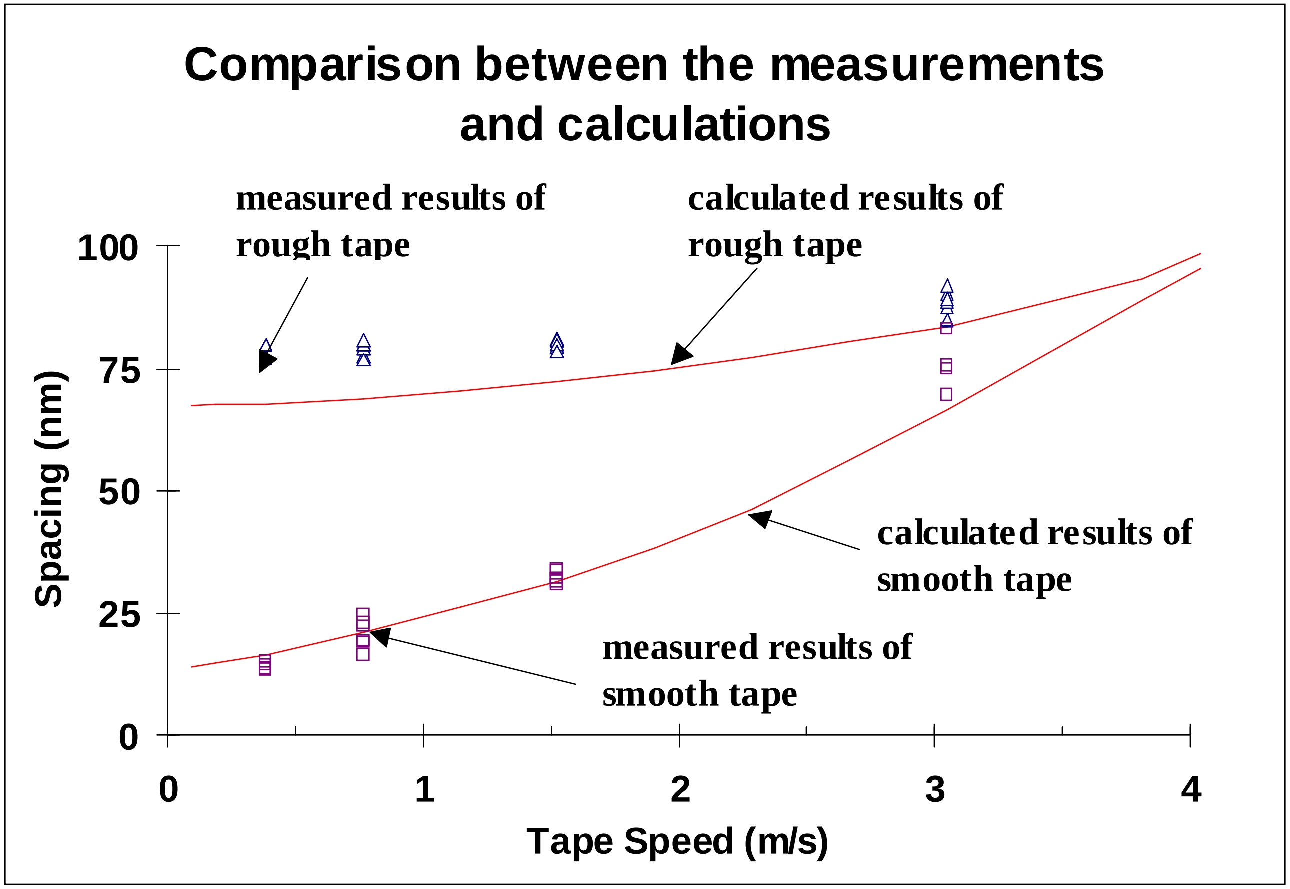


Head Contour Schematic

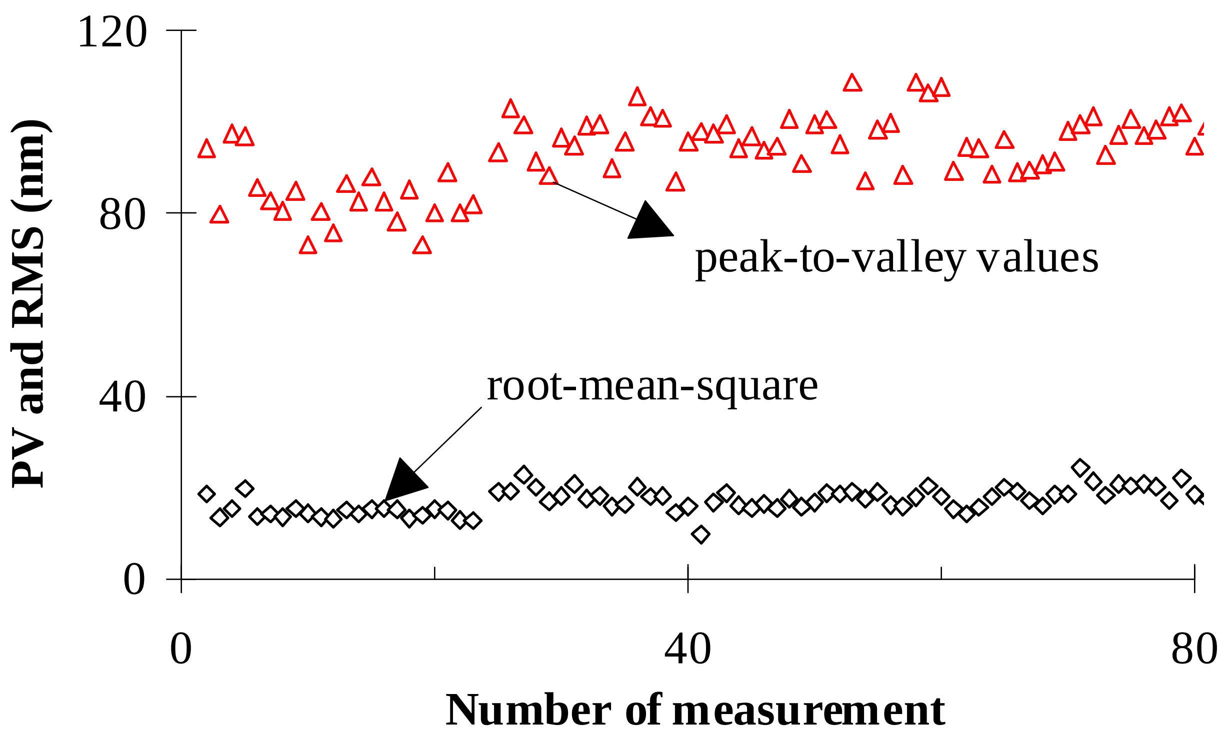


Cross-section of a cylindrical head

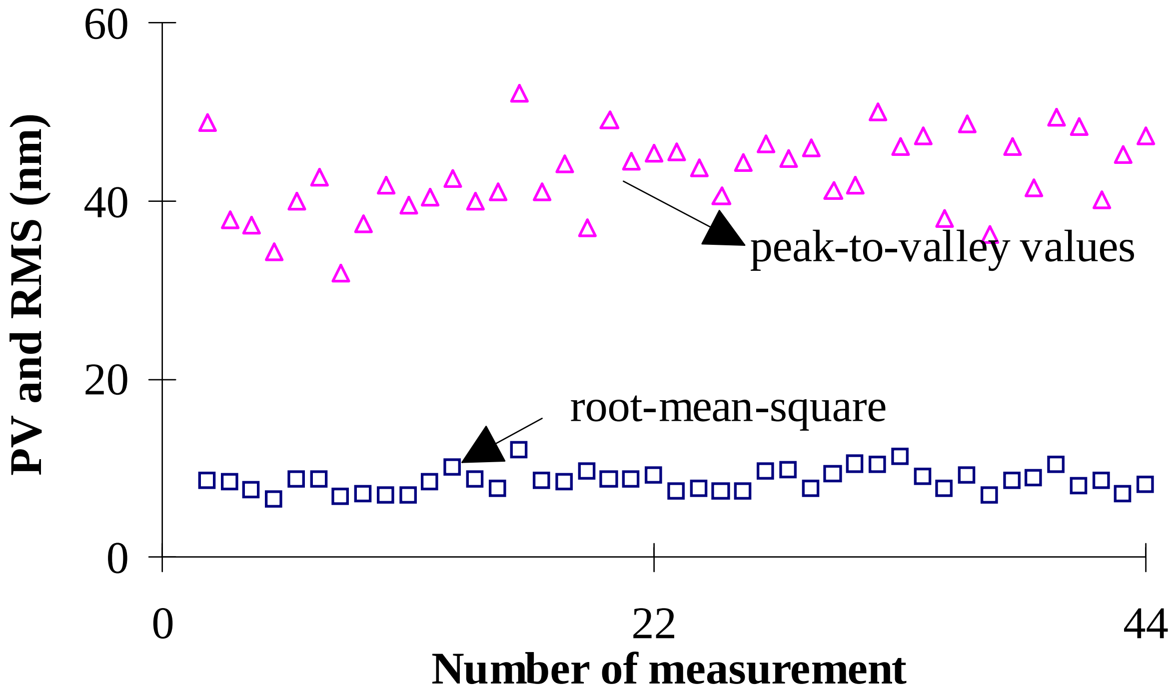
Head-Tape Spacing versus Tape Speed for a Cylindrical Head



Surface Roughness of Rough Tape



Surface Roughness of Smooth Tape



Comparison of Surface Roughness Values and Asperity Compliance Parameters

Table 1: Surface roughness of typical tapes

Tape	rough	smooth
RMS (nm)	17.9	8.55
P-V (nm)	95.8	43.0
α (nm) (“parabolic” model)	93.4	48.0
3σ (nm) (G-W model)	94.5	48.0

Conclusions

- Surface roughness is an important parameter in the head-tape interface
- Rough tape ⇔ large spacing

  Smooth tape ⇔ small spacing
- Head-tape spacing is surface roughness limited,

  i. e., to obtain small spacing, tape surface roughness must be reduced
- Peak-to-valley roughness rather than RMS or CLA(center line average) roughness determines the head-tape spacing
- Variable grid mesh is efficient for head wear calculation using finite element based simulator