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Introduction of efficient design tools for vertical probe and innovative probe material, Rhodeo6

PROBE INNOVATION

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1. Abstract

1.1. Efficient design tool for vertical probe

Inconveniences of conventional finite element method :

1) Much time and efforts required in data making.
2) Difficult to understand intuitively
physical meaning of design parameters.

New design tools based on mechanics of material have following merits:

(1) Easy and speedy design.
(2) Increased physical understanding to design parameters

1.2. Innovative probe material, Rhodeo6

Features of Rhodeo6

(1) Made of Rhodium more than 99.8 %.

(2) Small electrical resistance

(3) High elasticity

(4) High hardness.

(5) Low contact resistance

(6) Long probe life

Hopeful Application fields for Rhodeo6

(1) Power Semiconductor

(2) Narrow Pitch Device

2. Efficient design tools for vertical probe

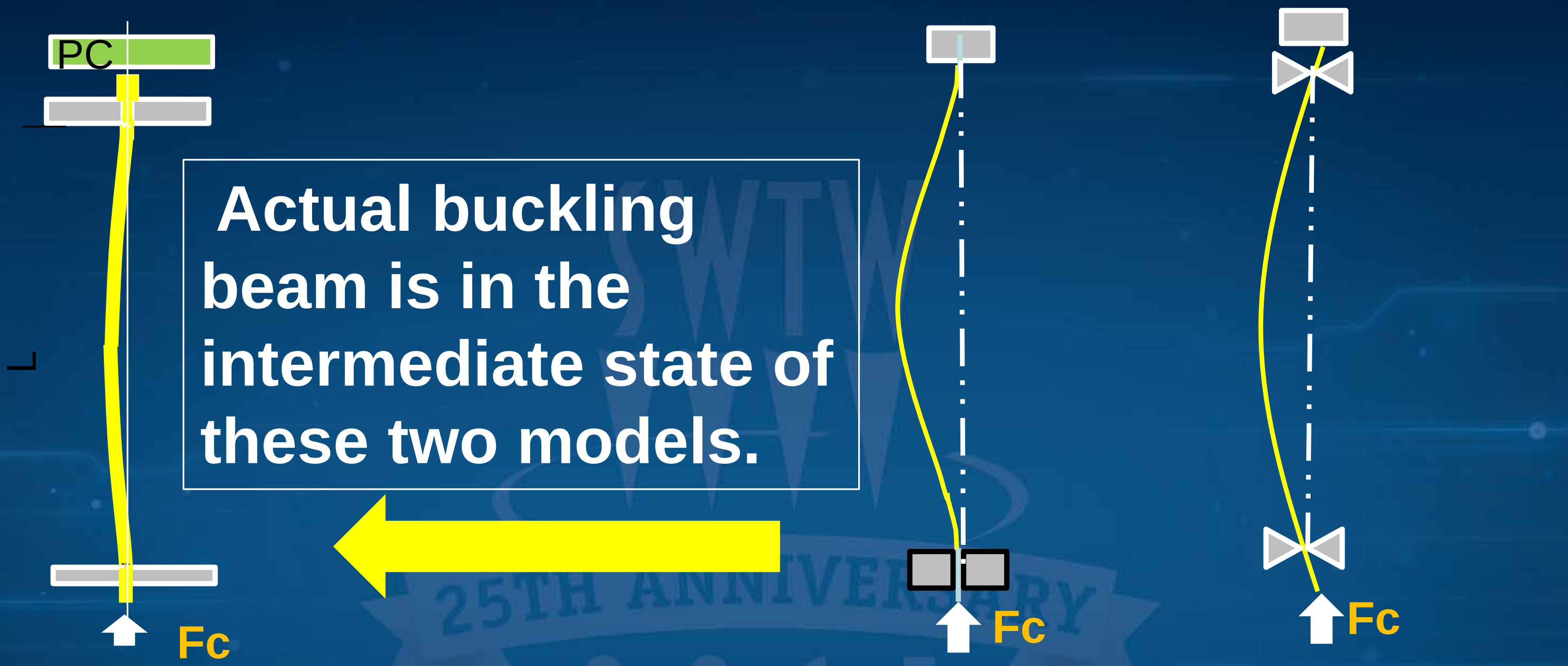
Two design tools have been developed based on mechanical models :

(1) Buckling Beam Design Tool

(2) Cobra Design Tool

Required time for calculation will be :

* For one case < one minute
* For try and error to decide parameters < fifteen minutes



(A) Buckling Beam model

(B) Both ends fixed model

(C) Both ends pin supported model

Figure 2-1 Buckling Beam Simulation Model

For cobra analysis, it is very useful to use

the theory of “transformation of thin arc beam”

developed by Kanazawa University in Japan *1).

*1) Reference URL: http://ads.w3.kanazawau.ac.jp/hojo/zairiki/text/05energy/energy03.htm

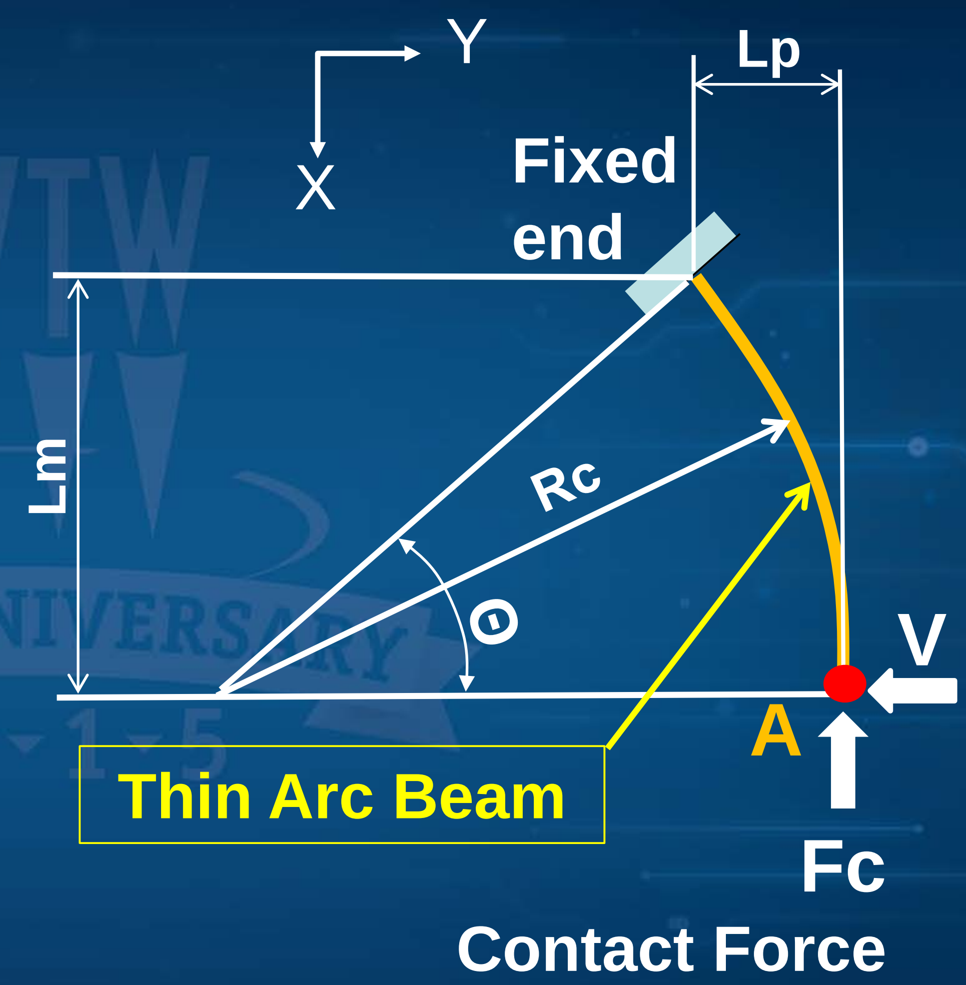
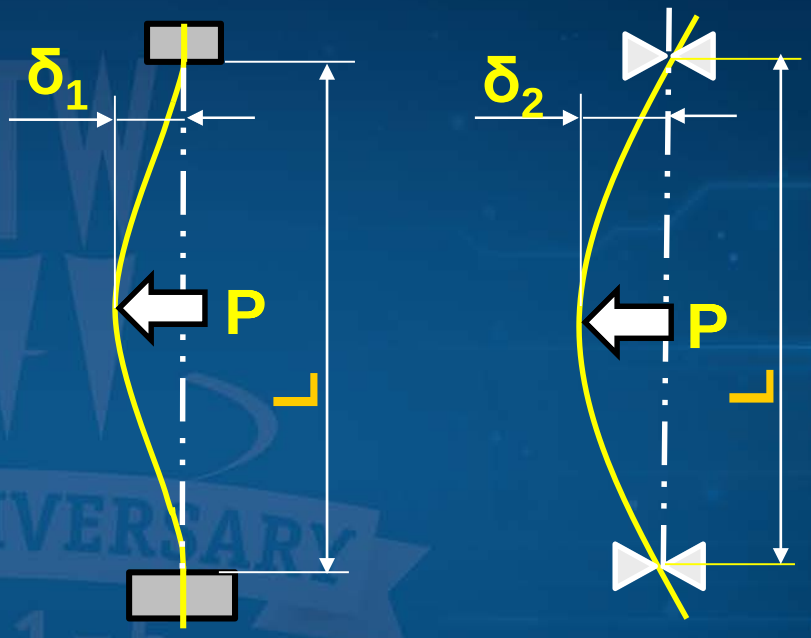


Figure 2-2 Cobra Simulation Model

2.2. Development of Buckling Beam Design Tool

2.2.1. The way to express actual buckling beam

Compare the compliance caused by outer force P.



$$\delta_1 = \frac{PL^3}{192EI}$$

$$\delta_2 = \frac{PL^3}{48EI}$$

(B) Both ends fixed model

(C) Both ends supported model

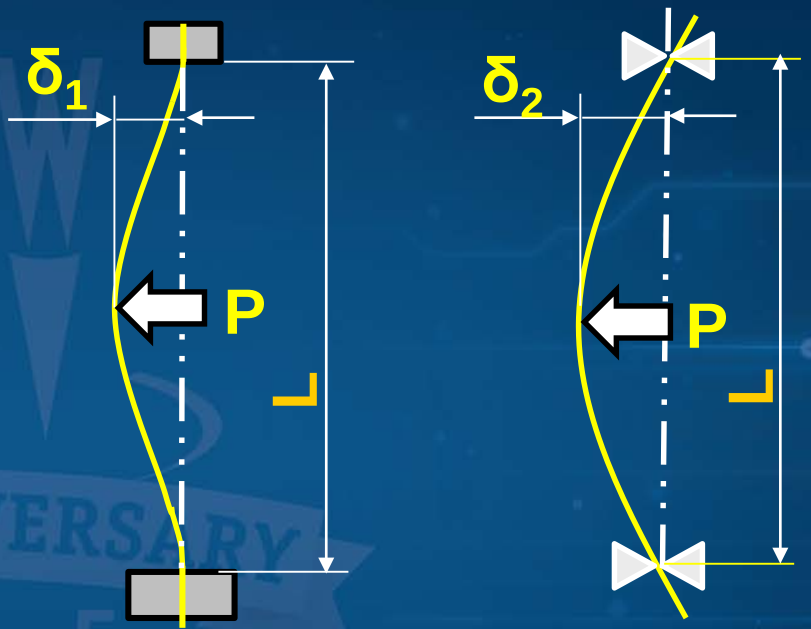
Figure 2-3 Comparison of compliance in two models

L ⇒ *a* · L

a : correction coefficient

a = 1 ~ 1.59

in case of starting from both ends fixed model.



$$\delta_1 = \frac{PL^3}{192EI} \qquad \delta_2 = \frac{PL^3}{48EI}$$

$$1.59 = (192/48)^{1/3}$$

- Diameter
  = 2.5 mil = 63 μm
- Beam length L
  = 5.4 mm
- Elasticity modulus
  = 229 GPa

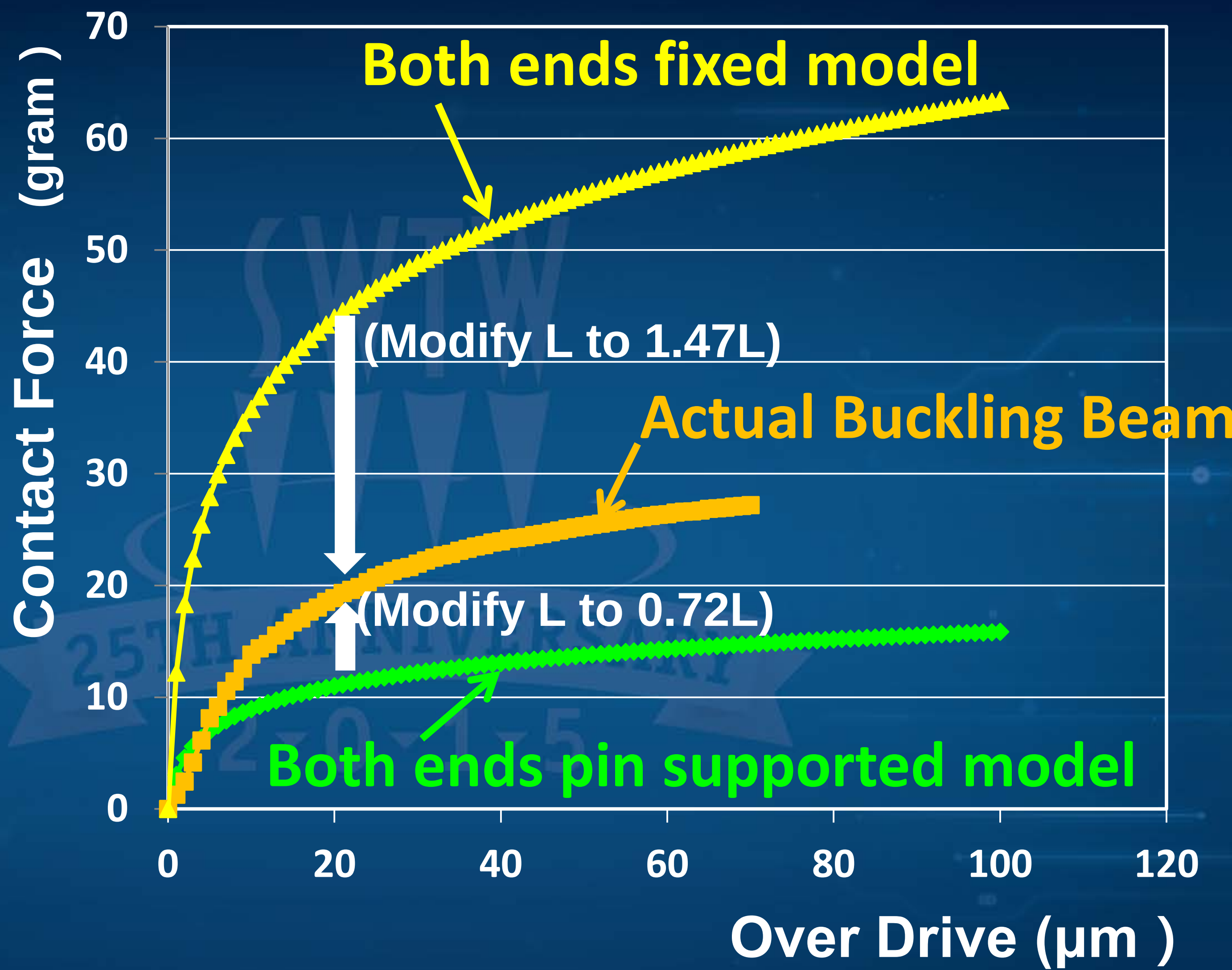
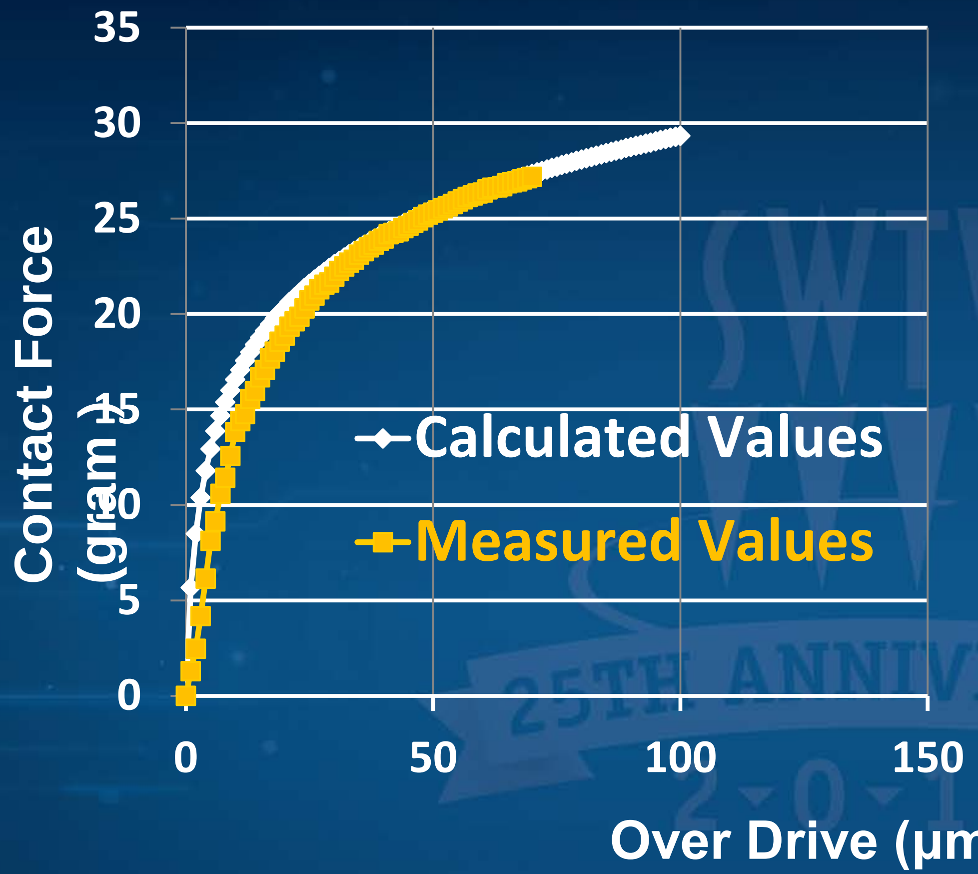


Figure 2-4 Curve of Contact Force versus Over Drive of different models compared with the actual measured values



*Material : Rhodeo6
*d=63μm (2.5 mil)
*Beam length modified
in calculation;

L ⇒ 1.47L

*Elasticity modulus = 229 GPa

Figure 2-5 Curve of Contact Force versus Over Drive

----- Comparison of calculated data by design tool and experimentally measured data

2.2.2. Model analysis for buckling beam

To get Performance Chart (curve of contact force versus over drive), following analysis is required:

1) Center Deviation e as function of Total Over Drive TOD

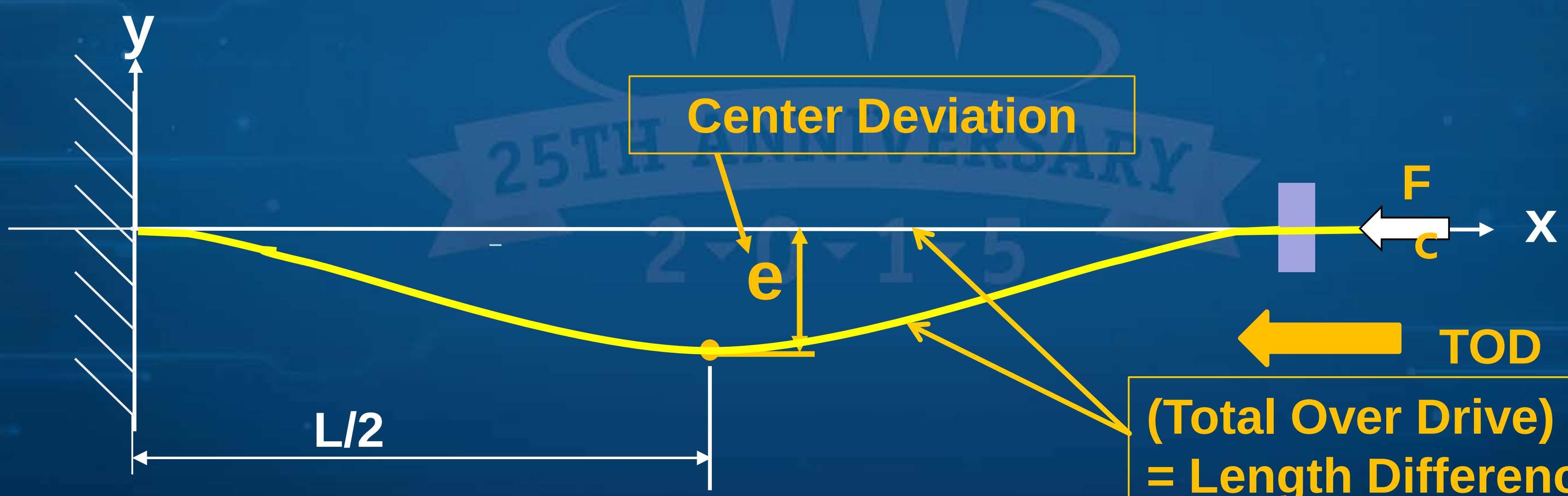


Figure 2-6-1 Buckling beam Model of Both Ends Fixed

To get Performance Chart numerically, following analysis is required:

2) Local Spring Constant K(e) as function of e.

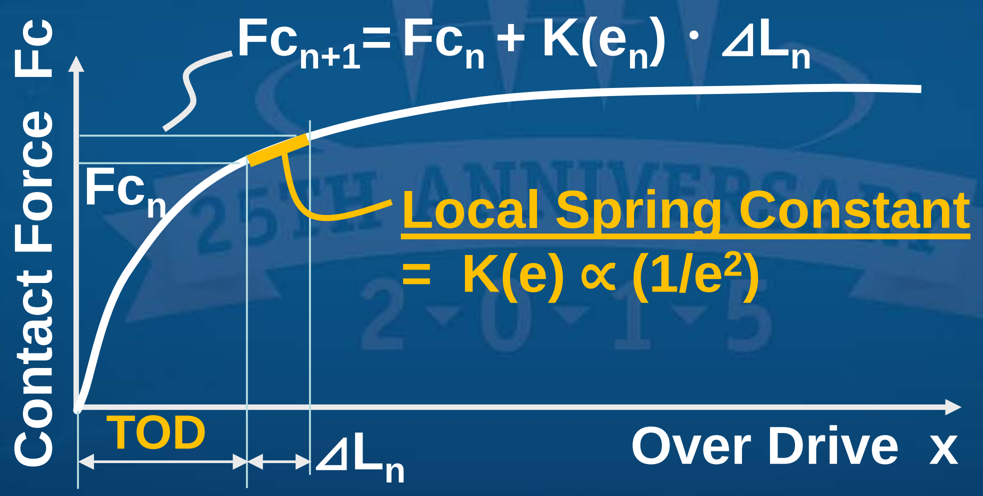
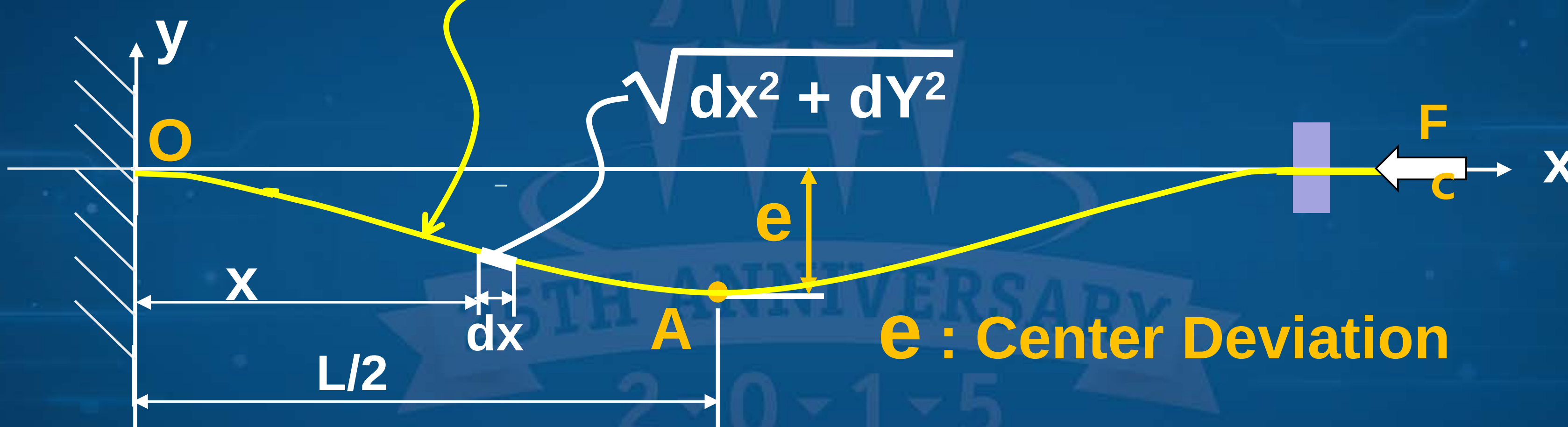


Figure 2-7-1 Numerical method to get performance chart

[Method to get e as function of Total Over Drive TOD]

$$TOD(e) = 2 \cdot (\overset{\frown}{OA} - L/2) = 2\int_0^{L/2} \left\{\sqrt{1 + (dY/dx)^2} - 1\right\} dx \quad \text{--- (2-1)}$$

$$Y(x) = -(e/2)\{1 - \cos(2\pi x/L)\} \quad \text{*2)} \quad \text{--- (2-2)}$$



e : Center Deviation

Figure 2-6-2 Buckling beam Model of Both Ends Fixed

Center Deviation $e = (2/\pi)\sqrt{L - TOD}$ ------ (2-3)

*2) Reference URL : http://kentiku-kouzou.jp/struc-oirazakuturyoutan.html

[Method to get Local Spring Constant K(e)]

By analyzing quarter model of Figure 2-8, Spring Constant K(e) is given.

$$K(e) = (\Delta Fc/\Delta L) = (8EI)/(Le^2) \qquad \text{----} \quad (2\text{-}4)$$

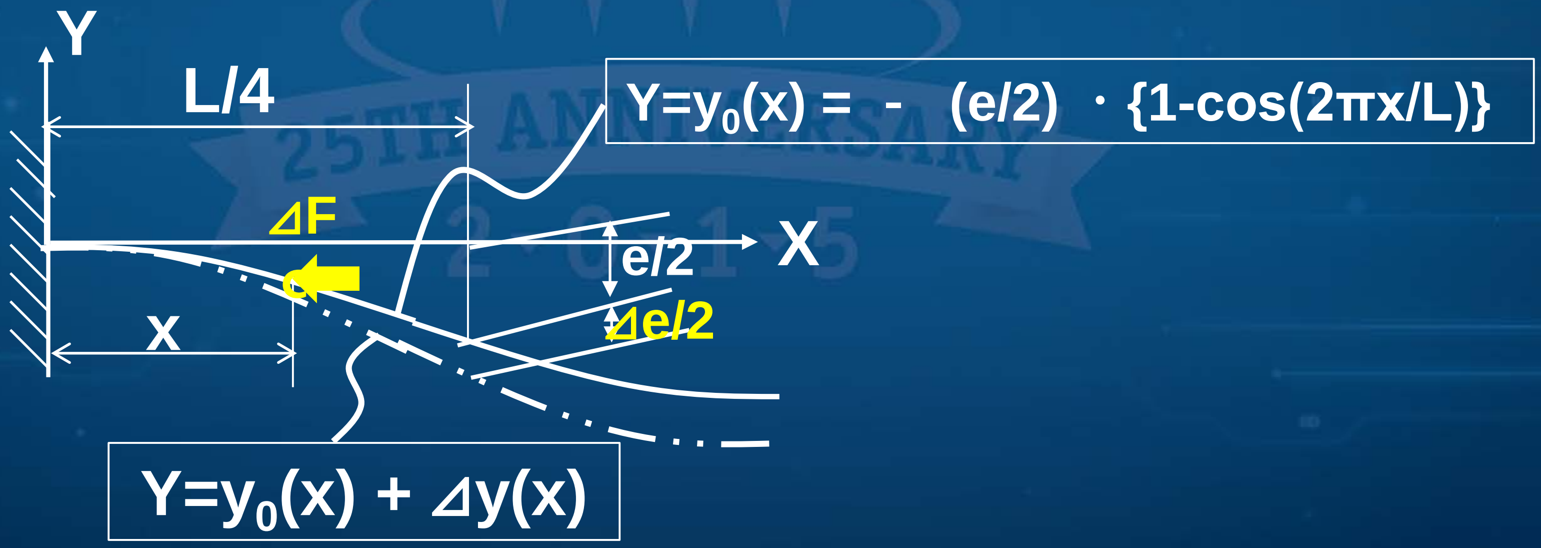


Figure 2-8 Quarter Model

2.2.3. Numerical Method to get Performance Chart

Over Drive axis is divided into each section,
$\varDelta L_1, \varDelta L_2, \cdot\cdot\cdot\cdot\cdot, \varDelta L_n$

Total Over Drive

$$TOD(n) = \sum_{i=1}^{n-1} \varDelta L_i \quad \text{---- (2-5)}$$

Center Deviation

$$e_n = (2/\pi)\sqrt{L - TOD(n)} \quad \text{--- (2-6)}$$

Local spring constant

$$K(e_n) = (8EI)/(Le_n^2) \quad \text{---- (2-7)}$$

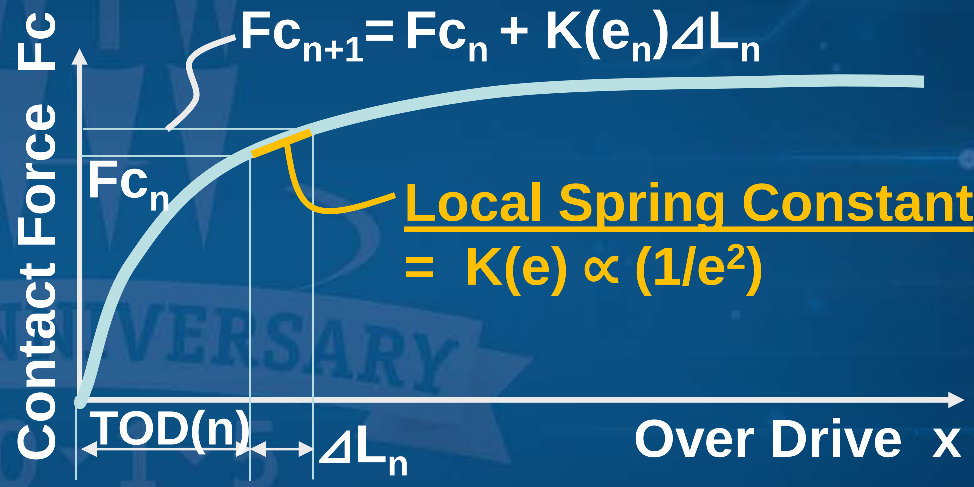


Figure 2-7-2 Numerical method to get performance chart

Contact Force

$$Fc_n = \sum_{i=1}^{n-1} K(e_i)\varDelta L_i \quad \text{---- (2-8)}$$

3. Innovative probe material, Rhodeo6

3.1. Comparison of physical properties

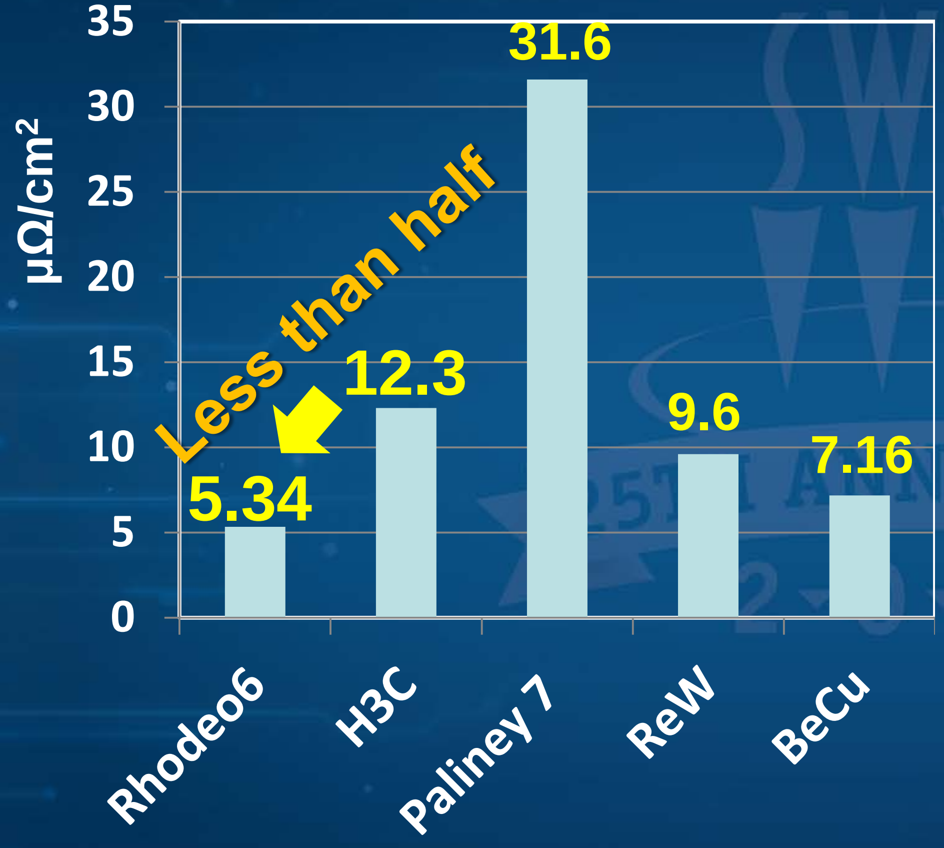


Figure 3-1 Comparison of **Electrical Resistance**

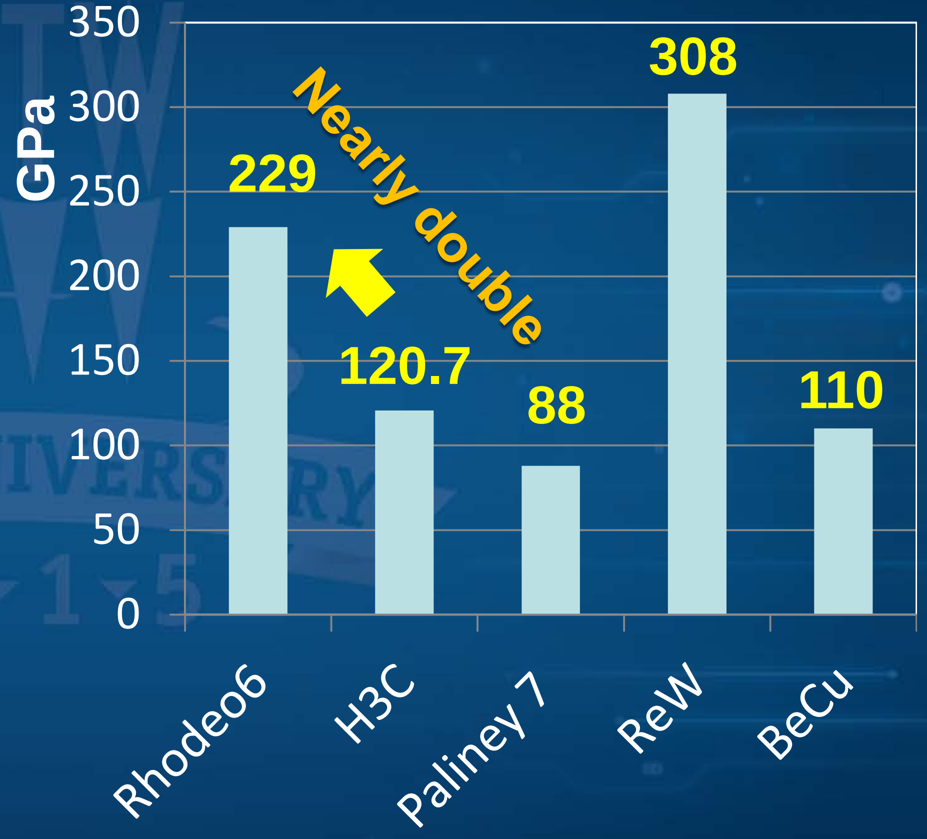


Figure 3-2 Comparison of **Elasticity**

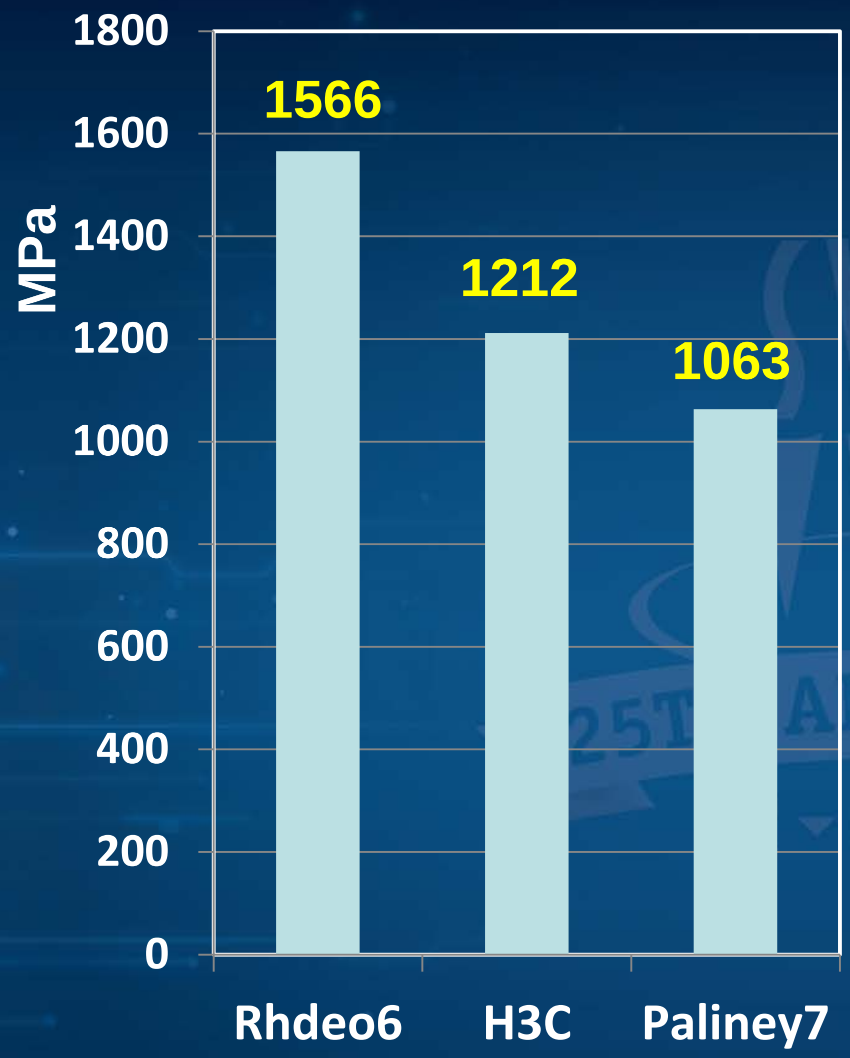


Figure 3-3 Comparison of

Yield Point Stress

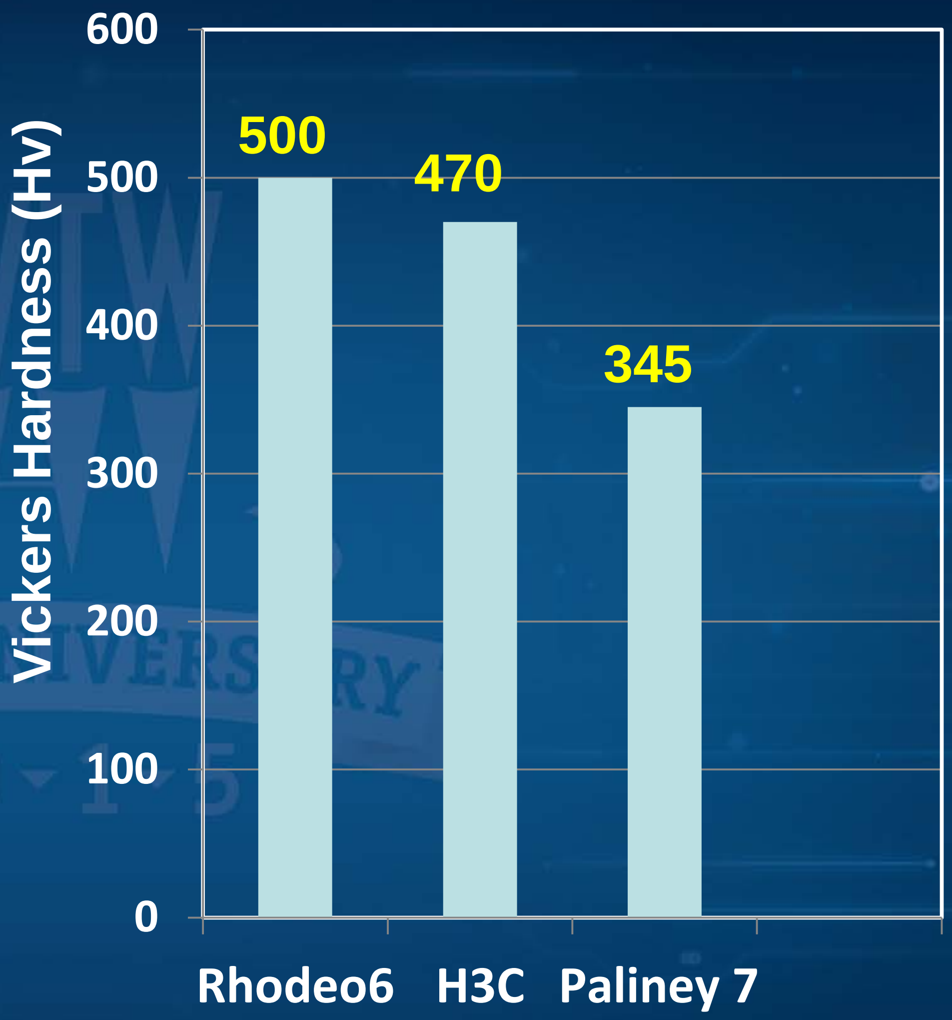


Figure 3-4 Comparison of

Hardness

3.2. Features of Rhodeo6

(1) Small electrical resistance ⇒ High CCC

(2) High elasticity

(3) High hardness

(4) Low contact resistance

(5) Long probe life

Chemical and Physical Stability

No Compound with other substance
No Oxidization Film is formed.

3.3. Technical Difficulties to get thin wire

(a) Stiffness increases during wire drawing.

(b) Misalignment or excessive drawing force could cause wire cut.

In drawing Rhodeo6, careful attentions required.

- Precise Alignment
- Timely Annealing or Drawing during heat

3.4. Development progress of Rhodedo6 at present

- 2 mil (50 µ) straight wires are already available.
- Manufacturing sample vertical probes of 2 mil will start in the middle of June 2015.
  (Made in USA)
  2 mil sample probes will be delivered to customers in the end of July 2015.
- Straight wires of 35 µ will be obtained in the end of June 2015.
- Development of 1 mil (25µ) wires will start in July 2015.

3.5. Hopeful application fields

Features of Rhodeo6

(1)Power Semiconductor

- High Current
- High Temperature

High CCC → High Current

Chemically Physically Stable → High Temperature

(2) Narrow Pitch Device

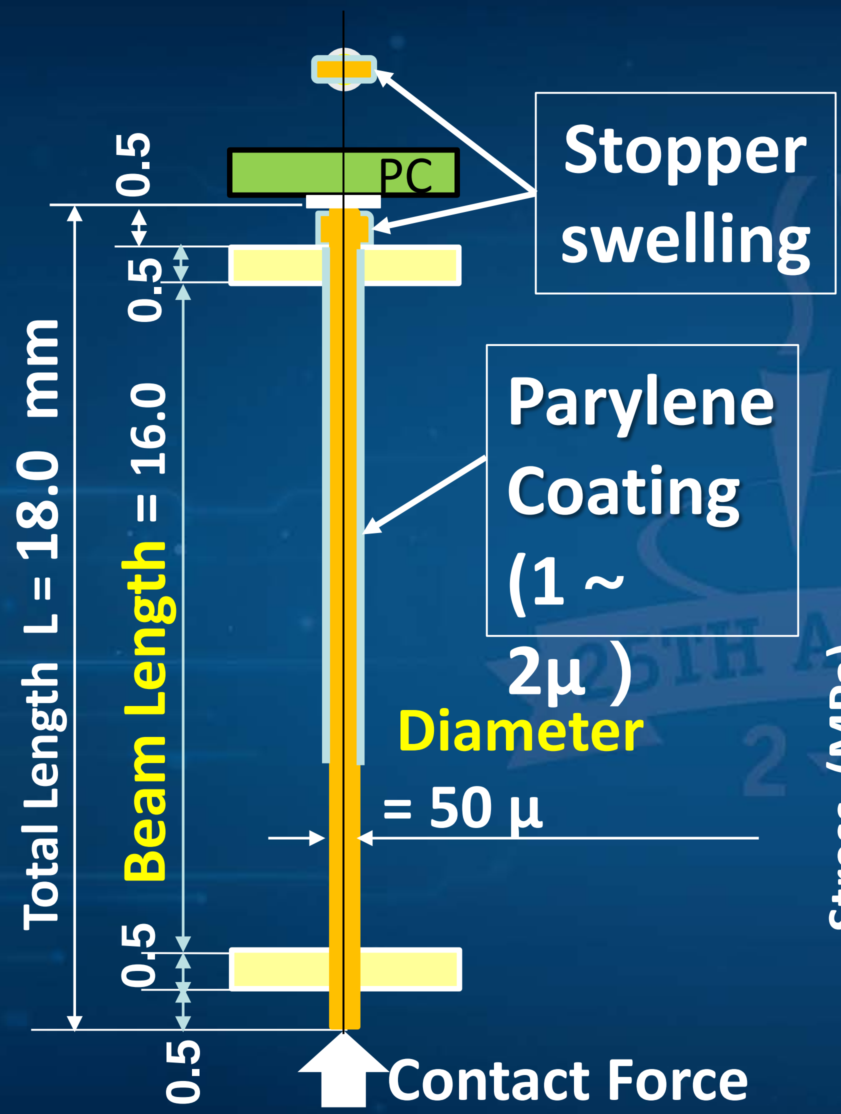
With Thin Probe

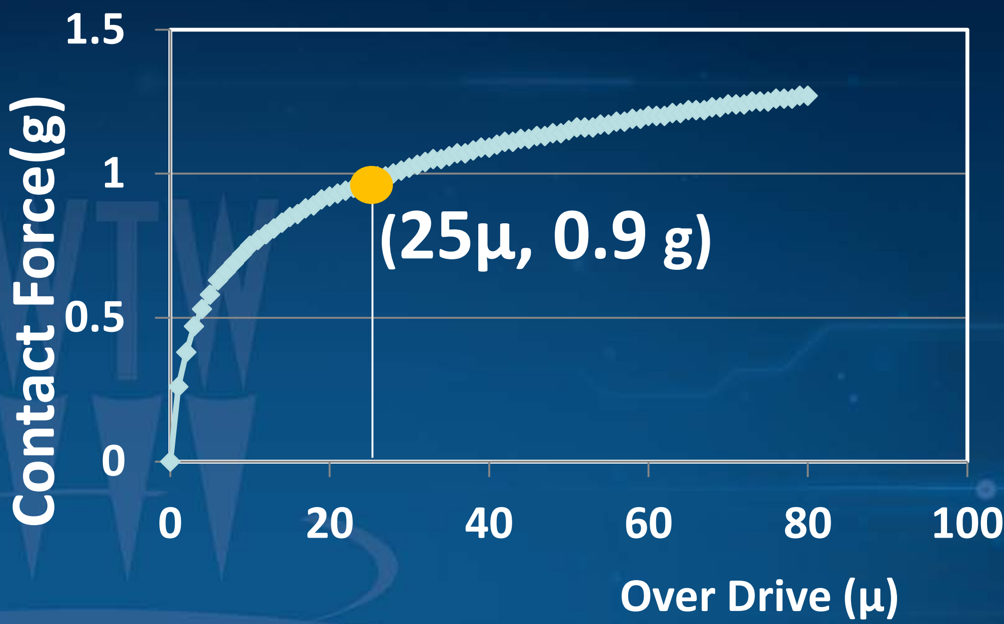
- Certain Contact required
- Signal Reliability required

High Elasticity Hardness → Certain Contact required

Low Resistance → Signal Reliability required

3.2. Application of Rhodeo6 to buckling beam design





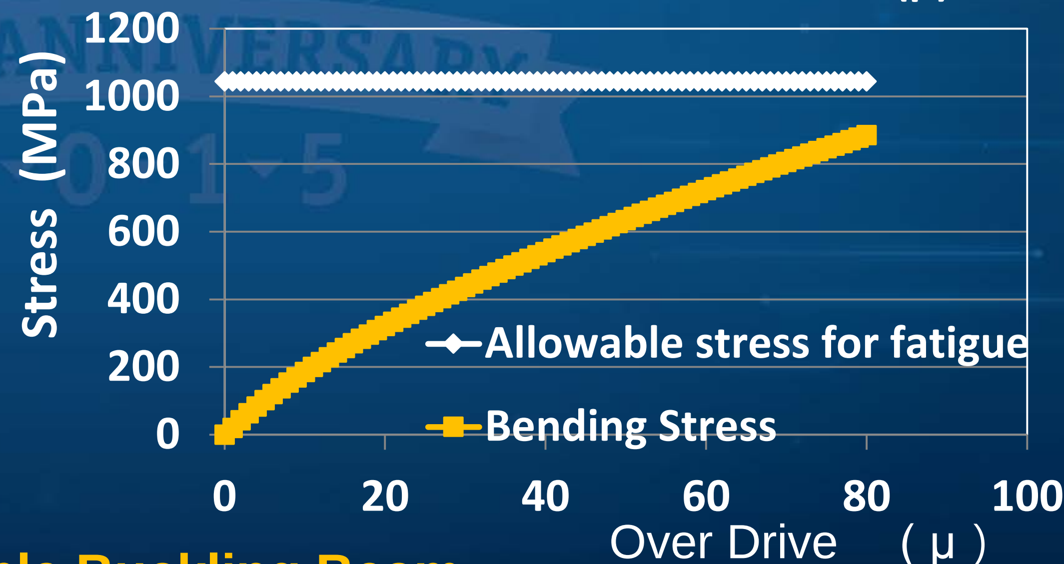


Figure 3-5 Design for Sample Buckling Beam

3.3. Application of Rhodeo6 to cobra design

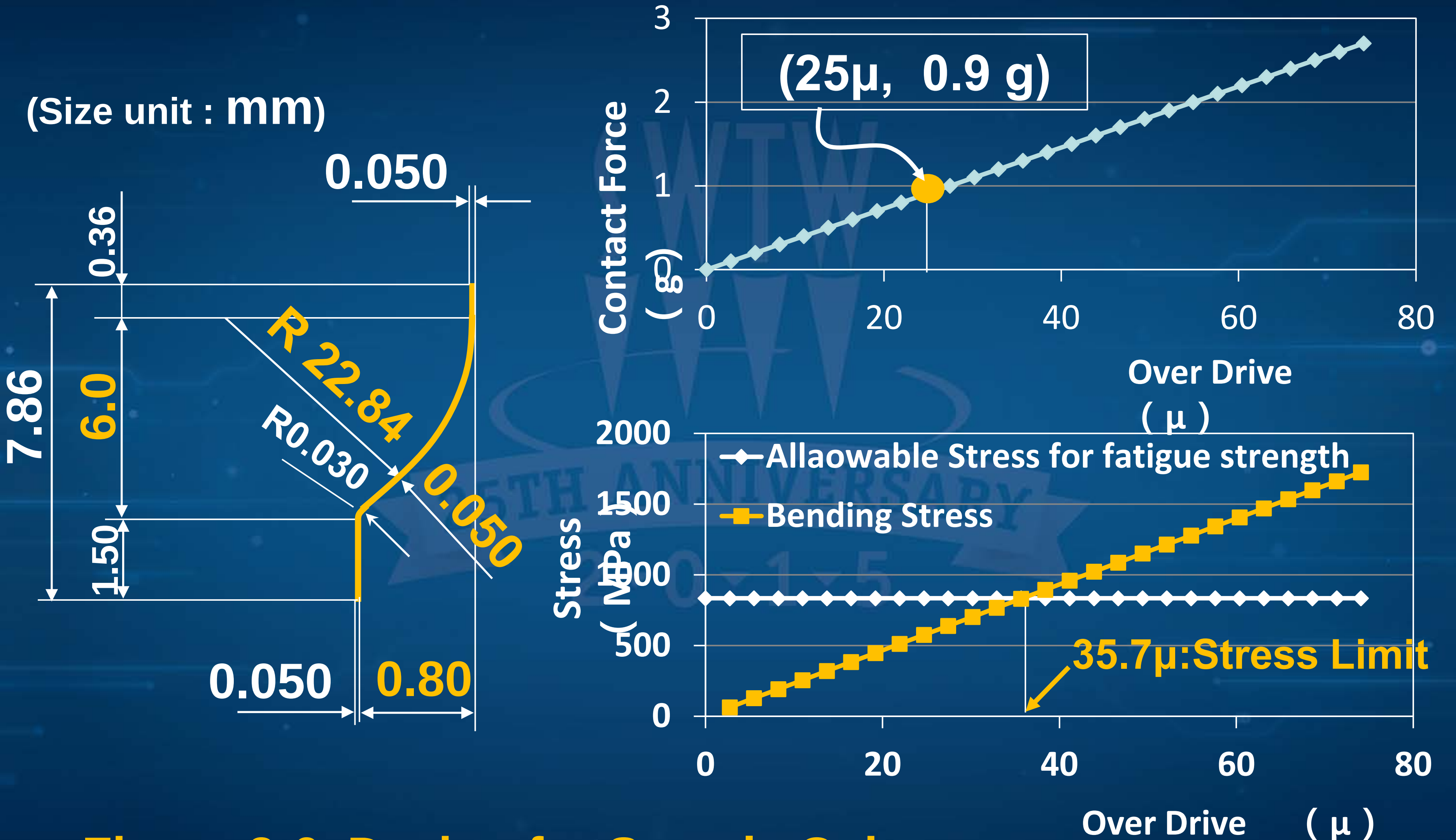


Figure 3-6 Design for Sample Cobra

4. Summary

・ New design tools for vertical probe based on mechanics of material have brought following merits:

(1) Easy and Handy:

- Input data = diameter, length and distance, etc.
- PC is available.

(2) Speedy

- one case < one minute, total < fifteen minutes

(3) Improved physical understanding to parameters

- **New probe material, Rhodeo6 has following features :**

  (1) Small electrical resistance ⇒ High CCC
  (2) High elasticity
  (3) High hardness
  (4) Low contact resistance
  (5) Long probe life

- **Trial vertical probe design showed performance below:**

  * Contact Force 0.9 g at Over Drive 25 μ

- **Hopeful application fields for Rhodeo6 will be :**

  1) Power Semiconductor
  2) Narrow Pitch Device