

## ***Kornucopia® In Action!***

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# Typical Uses of Kornucopia®

## Processing Experimental Data

Reusable, well documented Mathcad analysis worksheet

File with beginning and ending markers for each dataset

```

BeginSample
  SampleName, "ProjectBlueFish.msc"
  MethodName, "ASTM method XYZ.msc"
  Col1, "col1" Col2, "col2" Col3, "col3" Col4, "col4" Col5, "col5" Col6, "col6"
  SampleID, "blue_M0-D12"
  SampleInfo, "Tested by: J. Smith"
  BeginSpecimen
    AdjGage, 0.253, "in"
    Area, 0.890, "cm^2"
    BeginData
      Time, Load, Extension, S
      0.12600, 2.319, 0.000, -0.0
      0.14000, 2.299, 0.000, -0.0
      0.14400, 2.297, 0.000, -0.0
      ...
      1.88400, 13722.152, 0.141, 0
      1.88800, 9378.264, 0.141, 0
      1.89000, 6354.958, 0.142, 0
    EndData
  EndSpecimen
  AdjGage, 0.251, "in"
  Area, 0.893, "cm^2"
  BeginData
    Time, Load, Extension, S
    0.12800, 0.875, 0.000, -0.0
    0.13200, 0.856, 0.000, -0.0
    ...
    1.88000, 3678.273, 0.140, 0
    1.88000, 3678.273, 0.140, 0
  EndData
EndSpecimen
...
A bunch more specimens
Ends
    
```

Unpack and separate datasets

Plot raw datasets

Challenging data to read  
(multiple datasets, header text and data, ...)

Trim & clean datasets

Clean data and convert to Stress vs. Strain

```

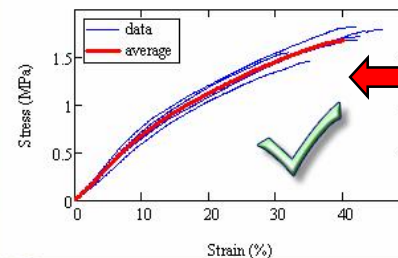
heal1 := tmp ← trim_k[dataA1, (dataA1)(2), 1000, "max", ""]
tmp ← tweakXY_k["start", tmp, 2, 0, 0.05, ("excess: 3", "order: 1")]
shiftData_k[tmp, "start", 0, ""]
    
```

$$T := "" \quad T_i := \frac{(\text{heal}_i)^{(2)} \cdot \text{LOAD}}{A_{o_i}} \quad \epsilon := "" \quad \epsilon_i := \frac{(\text{heal}_i)^{(4)} \cdot \text{DISP}}{L_{o_i}}$$

$$\epsilon T := "" \quad \epsilon T_i := \text{augment}\left(\epsilon_i, \frac{T_i}{\text{MPa}}\right)$$

ave := averageXY\_k[εT, "x", "norm: yes"] plt := nestPlot\_k(εT, "")

Stress vs Strain



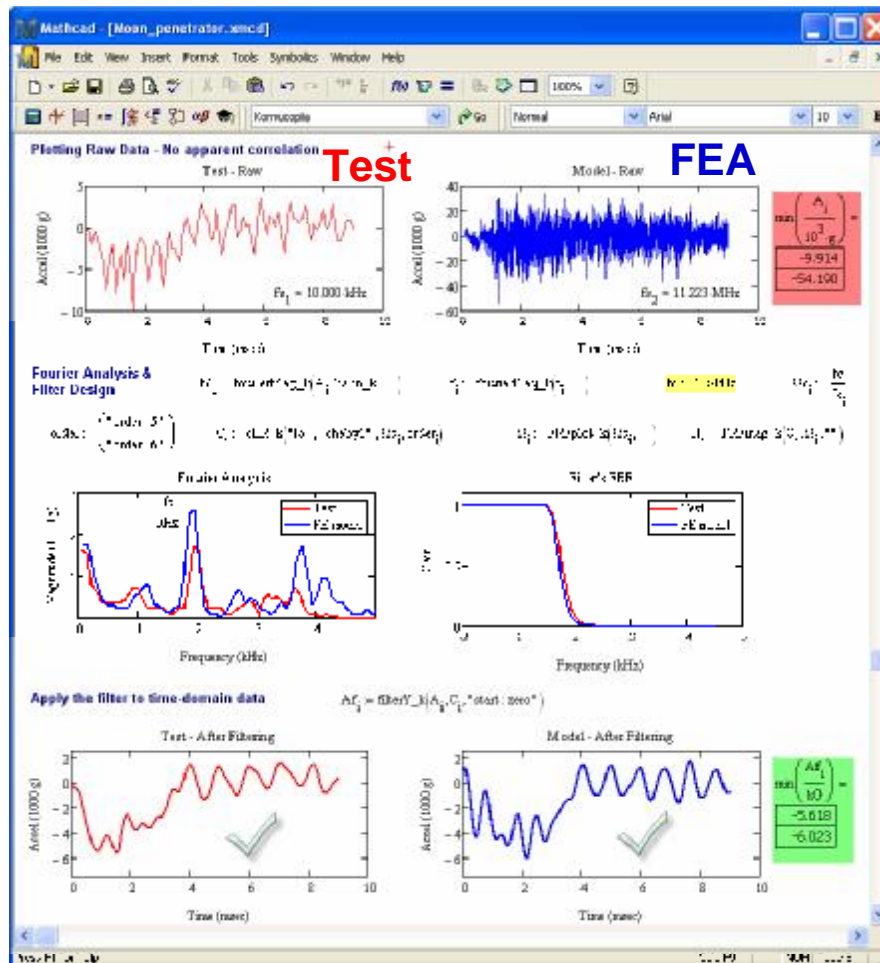
Average datasets and plot final results



# Typical Uses of Kornucopia®

Reusable, well documented  
Mathcad analysis worksheet

## Analyzing Noisy FEA Results and Test Data



Challenging data from a  
penetration event

- Initial comparison in time-domain
- Fourier Analysis to understand frequency content
- Filter to remove higher frequency differences
- Reassess filtered data in time-domain



# Kornucopia® - Powerful and Easy-To-Use Tools

**Steps Demonstrated**

- Read files
- Isolate data & headers
- Plot raw data
- Clean-up data
- Compute an average curve
- Tweak data to extend it
- Integrate  $F$  vs  $\delta$  to obtain work
- Utilize units

**Processing Multiple Files via Kornucopia®**

**Raw Data**

**Cleaned & Averaged**

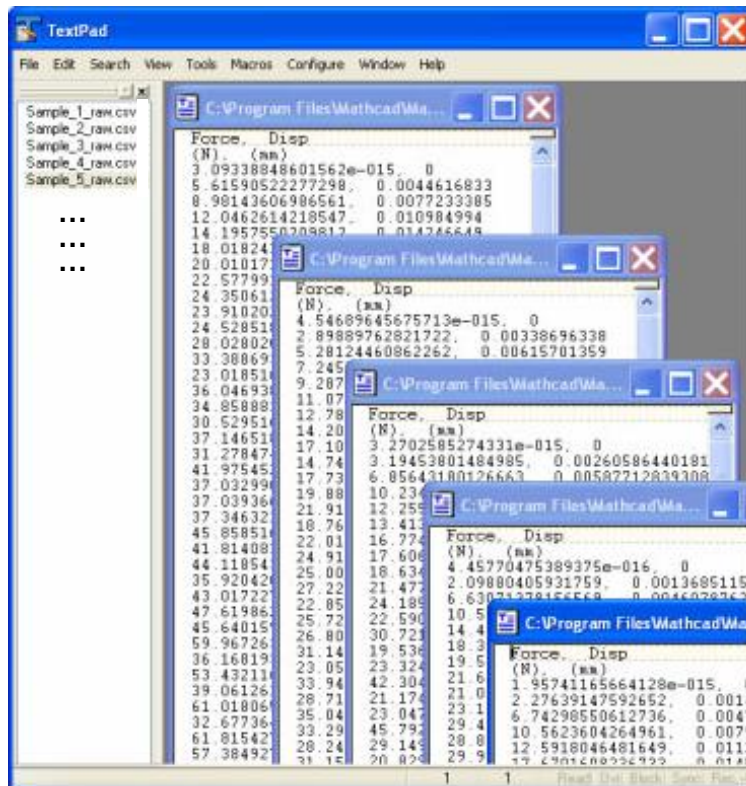
**Video Demo**



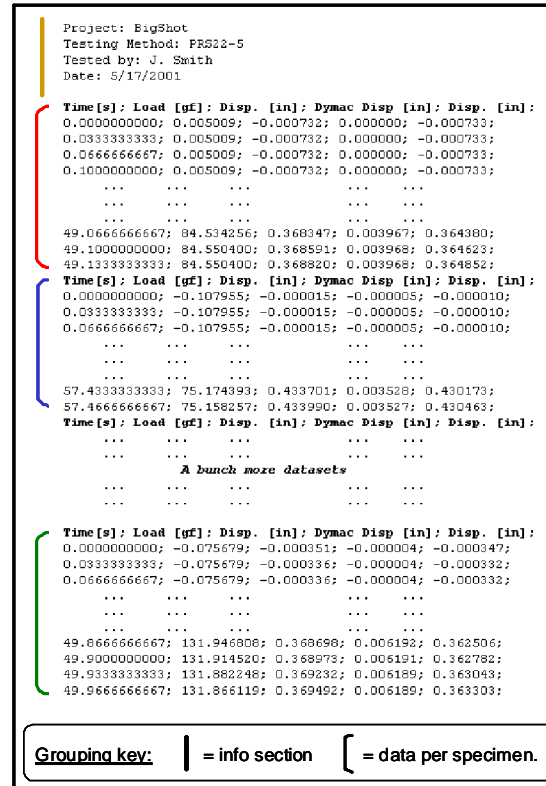


# Kornucopia Readily Handles Large Amounts of Data

Numerous files with  
one or more specimens



One file, numerous  
specimens per file



# Analyzing Tension Data

File with only beginning markers for each dataset

Project: BigShot  
Testing Method: PRS22-5  
Tested by: J. Smith  
Date: 5/17/2001

Time[s]; Load [gf]; Disp. [in]; Dymac Disp [in]; Disp. [in];  
0.0000000000; 0.005009; -0.000732; 0.000000; -0.000733;  
0.0333333333; 0.005009; -0.000732; 0.000000; -0.000733;  
0.0666666667; 0.005009; -0.000732; 0.000000; -0.000733;  
0.1000000000; 0.005009; -0.000732; 0.000000; -0.000733;

... ..  
... ..  
... ..  
... ..  
49.0666666667; 84.534256; 0.368347; 0.003967; 0.364380;  
49.1000000000; 84.550400; 0.368591; 0.003968; 0.364623;  
49.1333333333; 84.550400; 0.368920; 0.003968; 0.364952;

Time[s]; Load [gf]; Disp. [in]; Dymac Disp [in]; Disp. [in];  
0.0000000000; -0.107955; -0.000015; -0.000005; -0.000010;  
0.0333333333; -0.107955; -0.000015; -0.000005; -0.000010;  
0.0666666667; -0.107955; -0.000015; -0.000005; -0.000010;

... ..  
... ..  
... ..  
... ..  
57.4333333333; 75.174393; 0.433701; 0.003528; 0.430173;  
57.4666666667; 75.158257; 0.433990; 0.003527; 0.430463;

Time[s]; Load [gf]; Disp. [in]; Dymac Disp [in]; Disp. [in];  
... ..  
... ..  
... ..  
... ..  
*A bunch more datasets*  
... ..  
... ..  
... ..

Time[s]; Load [gf]; Disp. [in]; Dymac Disp [in]; Disp. [in];  
0.0000000000; -0.075679; -0.000351; -0.000004; -0.000347;  
0.0333333333; -0.075679; -0.000336; -0.000004; -0.000332;  
0.0666666667; -0.075679; -0.000336; -0.000004; -0.000332;

... ..  
... ..  
... ..  
... ..  
49.8666666667; 131.946808; 0.368698; 0.006192; 0.362506;  
49.9000000000; 131.914520; 0.368973; 0.006191; 0.362782;  
49.9333333333; 131.882248; 0.369232; 0.006189; 0.363043;  
49.9666666667; 131.866119; 0.369492; 0.006189; 0.363303;

Grouping key: | = info section [ = data per specimen.



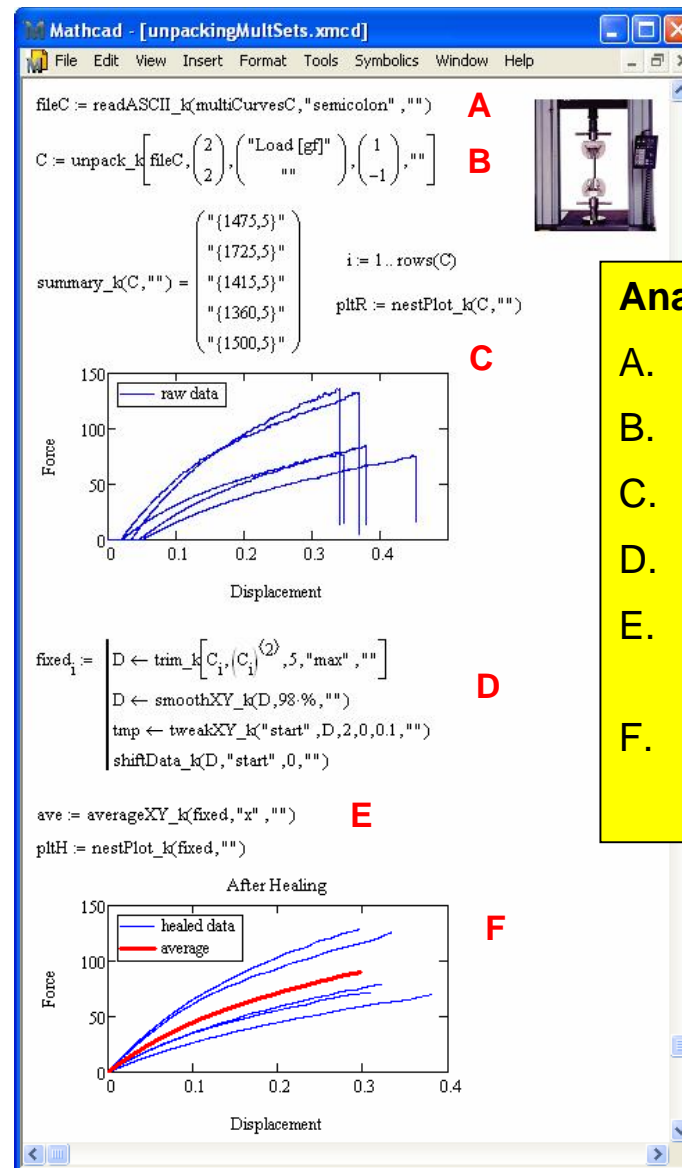
# Analyzing Tension Data

File with only beginning markers for each dataset

```
Project: BigShot
Testing Method: PRS22-5
Tested by: J. Smith
Date: 5/17/2001

Time[s]; Load [gf]; Disp. [in]; Dymac Disp [in]; Disp. [in];
0.0000000000; 0.005009; -0.000732; 0.000000; -0.000733;
0.0333333333; 0.005009; -0.000732; 0.000000; -0.000733;
0.0666666667; 0.005009; -0.000732; 0.000000; -0.000733;
0.1000000000; 0.005009; -0.000732; 0.000000; -0.000733;
...
...
...
49.0666666667; 84.534256; 0.368347; 0.003967; 0.364380;
49.1000000000; 84.550400; 0.368591; 0.003968; 0.364623;
49.1333333333; 84.550400; 0.368920; 0.003968; 0.364952;
Time[s]; Load [gf]; Disp. [in]; Dymac Disp [in]; Disp. [in];
0.0000000000; -0.107955; -0.000015; -0.000005; -0.000010;
0.0333333333; -0.107955; -0.000015; -0.000005; -0.000010;
0.0666666667; -0.107955; -0.000015; -0.000005; -0.000010;
...
...
...
57.4333333333; 75.174393; 0.433701; 0.003528; 0.430173;
57.4666666667; 75.158257; 0.433990; 0.003527; 0.430463;
Time[s]; Load [gf]; Disp. [in]; Dymac Disp [in]; Disp. [in];
...
...
...
A bunch more datasets
...
...
...
Time[s]; Load [gf]; Disp. [in]; Dymac Disp [in]; Disp. [in];
0.0000000000; -0.075679; -0.000351; -0.000004; -0.000347;
0.0333333333; -0.075679; -0.000336; -0.000004; -0.000332;
0.0666666667; -0.075679; -0.000336; -0.000004; -0.000332;
...
...
...
49.8666666667; 131.946808; 0.368698; 0.006192; 0.362506;
49.9000000000; 131.914520; 0.368973; 0.006191; 0.362782;
49.9333333333; 131.882248; 0.369232; 0.006189; 0.363043;
49.9666666667; 131.866119; 0.369492; 0.006189; 0.363303;
```

Grouping key: | = info section [ = data per specimen.



## Analysis Steps

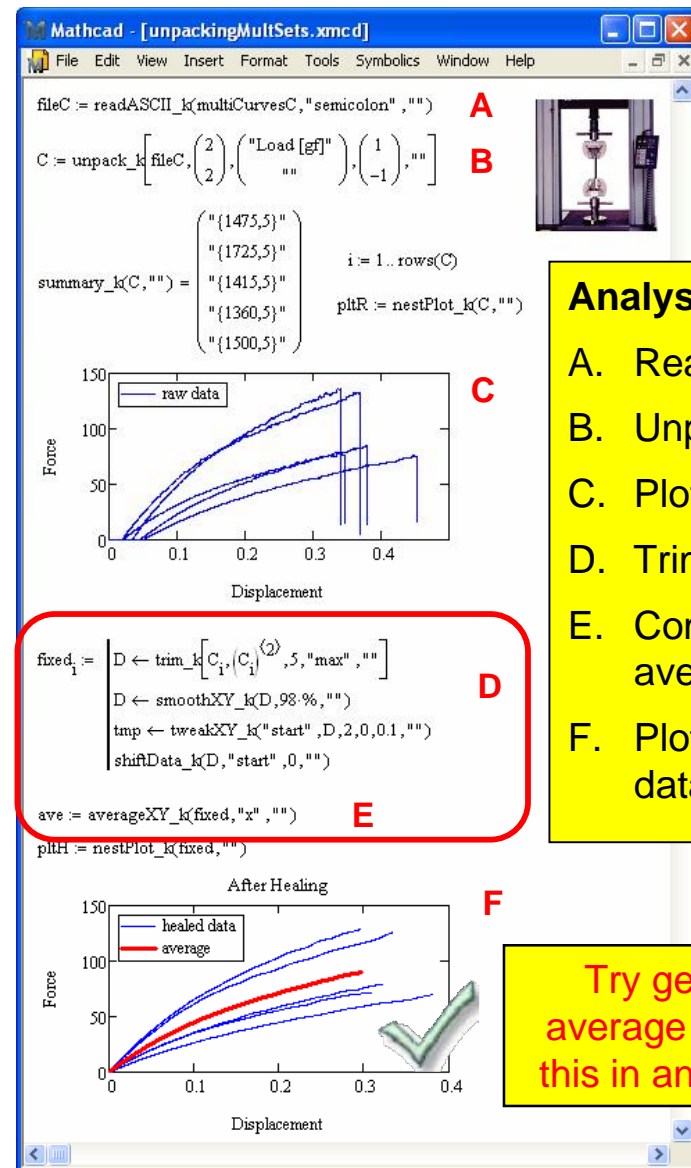
- Read data file
- Unpack data
- Plot raw data
- Trim & clean it
- Compute an average curve
- Plot cleaned data & average



# Analyzing Tension Data

## Key Benefits:

- Clear documentation of analysis process
- Reusable automated worksheet
  - Saves times
  - Reduces errors
  - Deployable to others
- Improved characterizations for:
  - Analytical Calculations
  - FEA Simulations
  - Quality Assurance



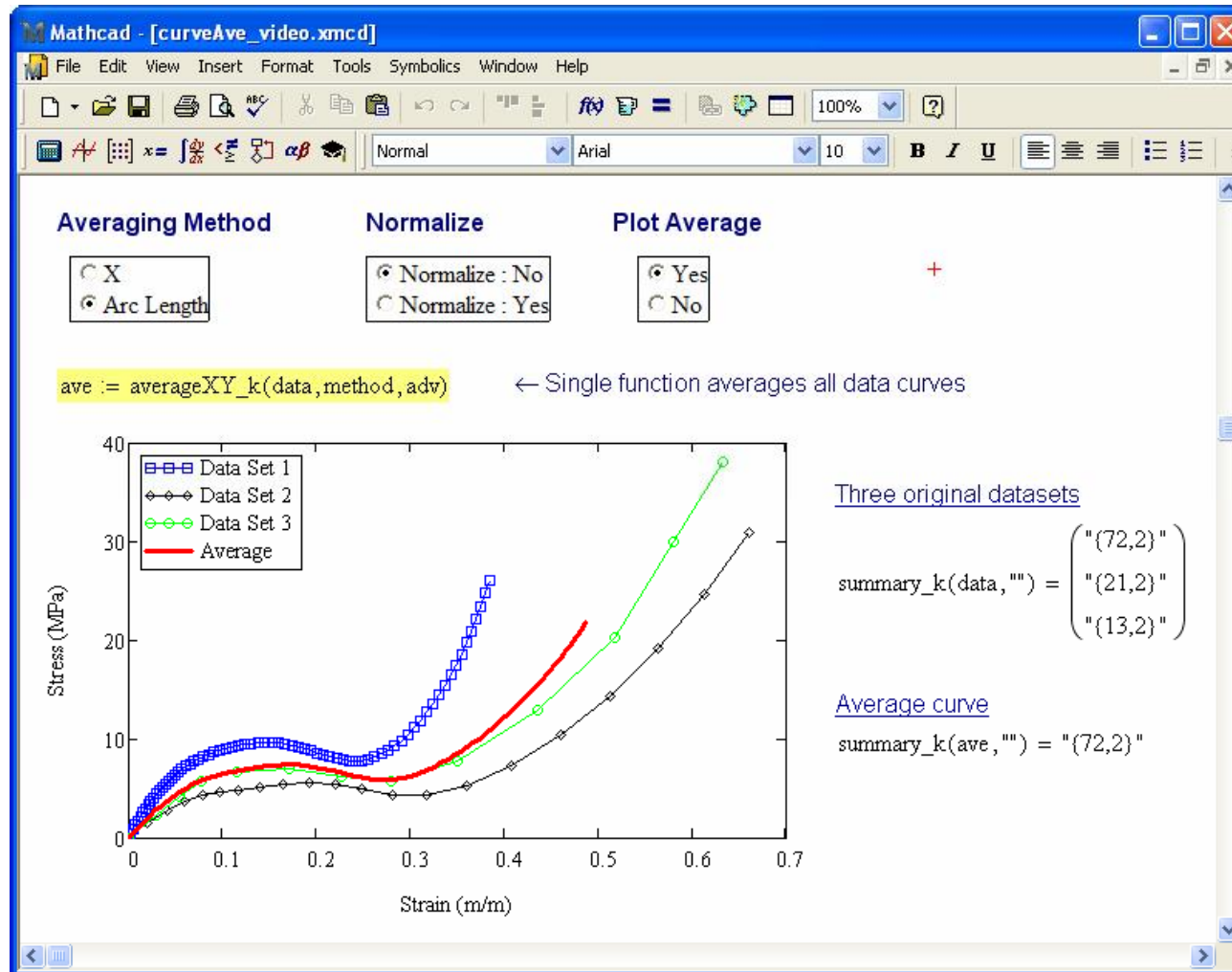
## Analysis Steps

- Read data file
- Unpack data
- Plot raw data
- Trim & clean it
- Compute an average curve
- Plot cleaned data & average

Try getting an average curve like this in another tool!



# General Purpose Averaging – A Powerful Feature





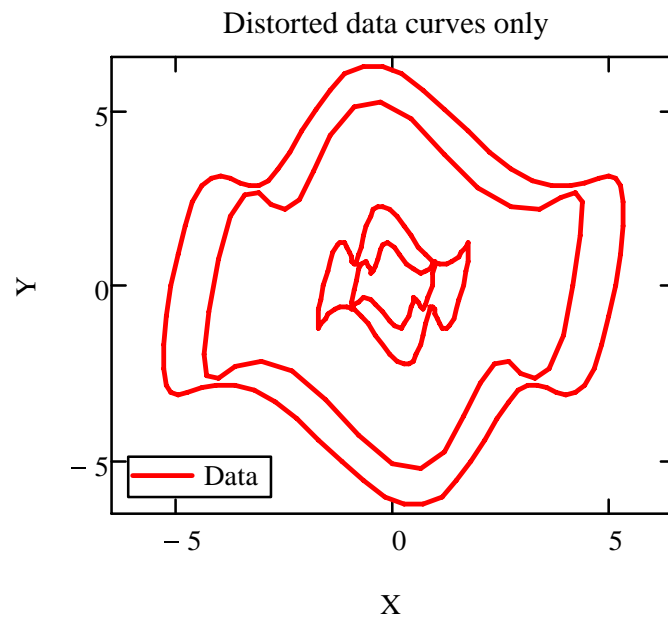
## General Purpose Averaging

$$\text{summary\_k}(\text{Data}, "") = \begin{pmatrix} \text{"{50,2}"} \\ \text{"{75,2}"} \\ \text{"{83,2}"} \\ \text{"{42,2}"} \end{pmatrix}^m$$

$\text{Data}_4 =$

	1	2
1	4.160	0.000
2	4.319	1.392
3	4.338	2.346
4	4.187	2.661
5	3.854	2.477
6	3.347	2.190
7	2.697	...

$m$

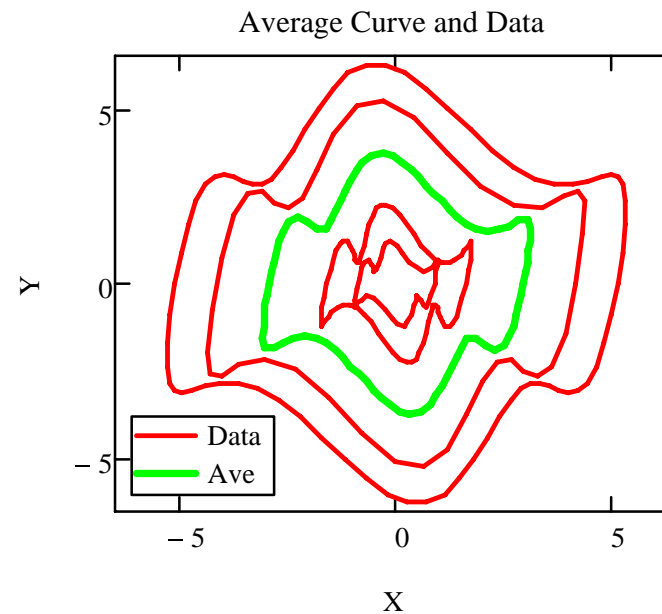
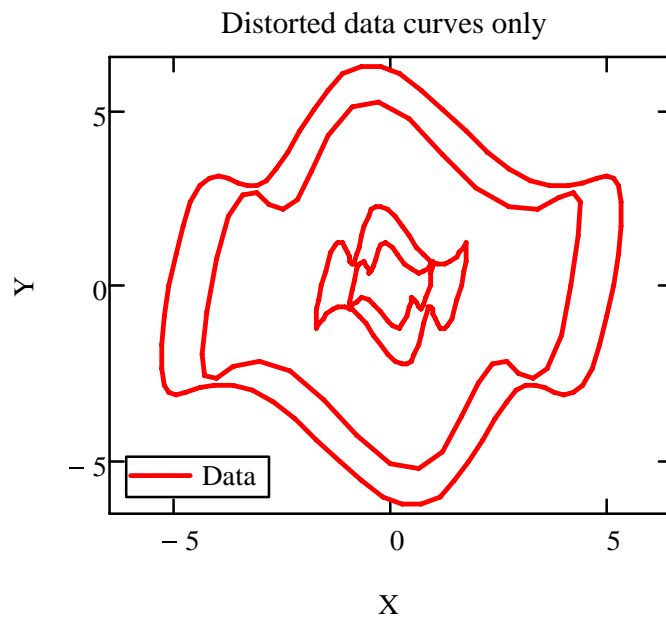


What is the average of  
this set of 4 data  
curves?

## General Purpose Averaging

$$\text{summary\_k}(\text{Data}, "" ) = \begin{pmatrix} "{50,2}" \\ "{75,2}" \\ "{83,2}" \\ "{42,2}" \end{pmatrix} m$$

**Ave := averageXY\_k(Data, "arc" , "norm : yes" )**

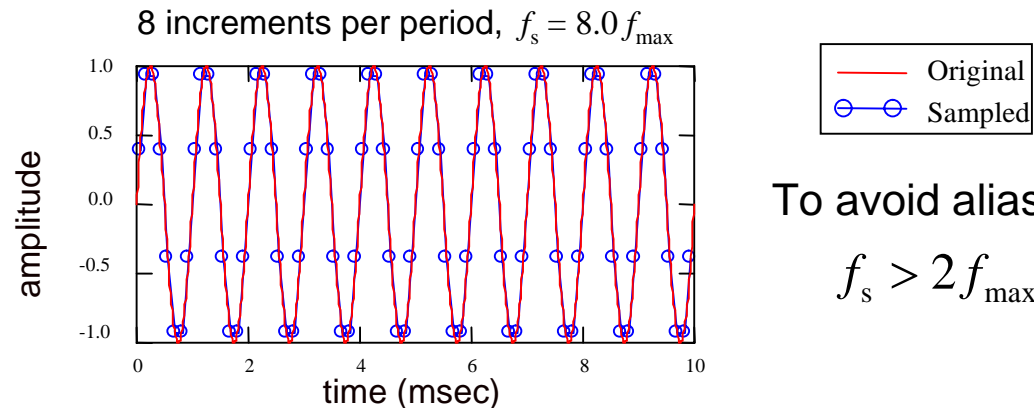


## Aliasing – A Lurking Problem with Digital Data

$$A(t) = a_o \cdot \sin(2\pi \cdot f_o \cdot t)$$

$$f_o = 1.0 \text{ kHz}$$

$$f_s = 1.0 \text{ kHz}$$

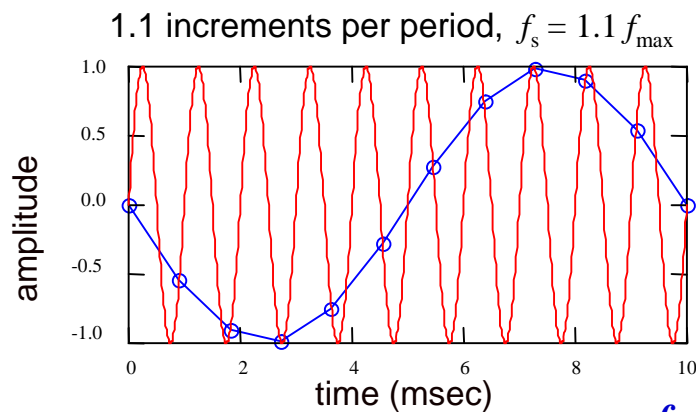


To avoid aliasing

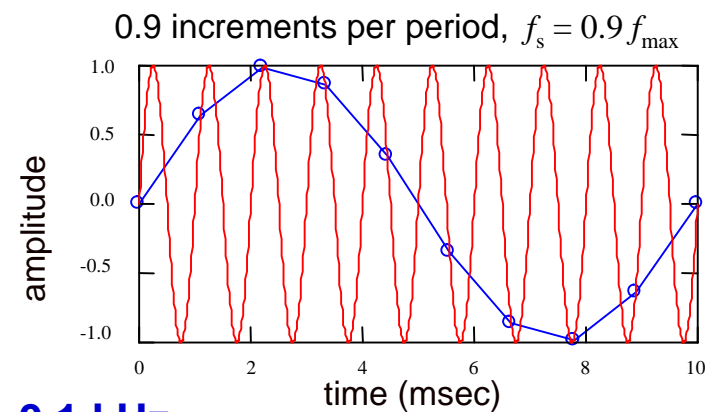
$$f_s > 2f_{\max}$$

**Satisfying the sampling theorem avoids aliasing**

**Violating the sampling theorem creates aliasing**



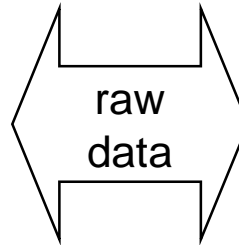
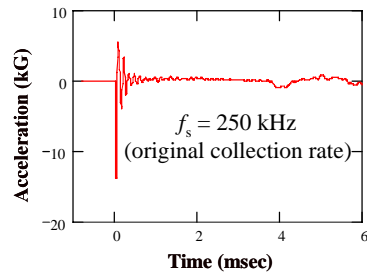
$$f_{alias} = 0.1 \text{ kHz}$$



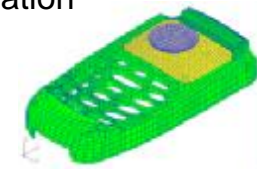
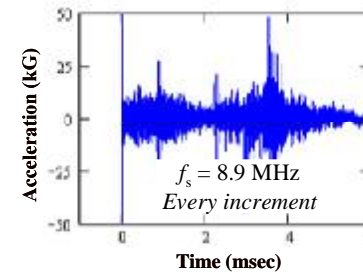
# Examples of Noisy and Challenging Data



Experimental measurement



Explicit Dynamics FEA Simulation

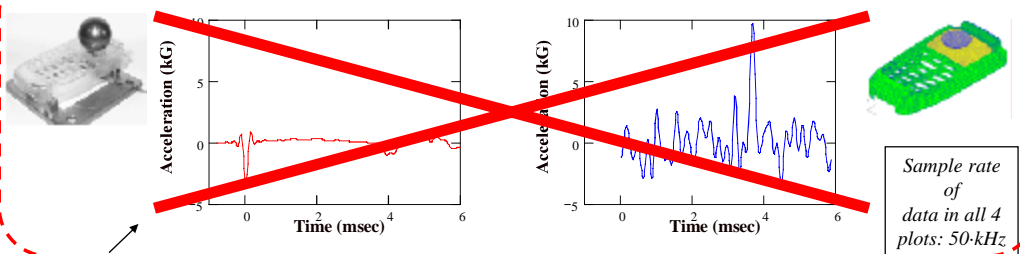


Cell phone lens impact

**Why do 2 engineers find completely different results starting with same data?**

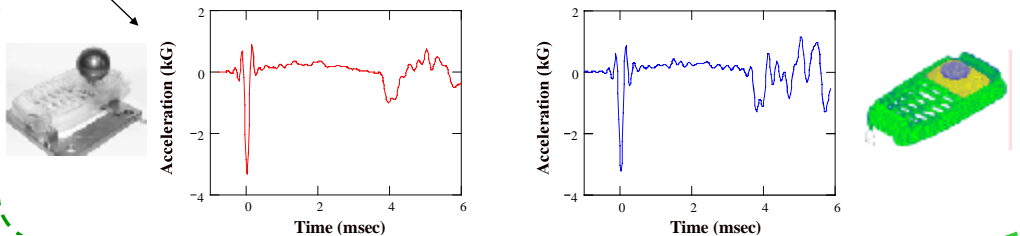
- Result after lowpass filtering with 6<sup>th</sup>-order Butterworth filter, 5 kHz cutoff.

**Typical result of Experiment/CAE comparison (improper or no DSP training)**



Note different Y-axis limits

**Improved Experiment/CAE comparison (proper DSP usage)**



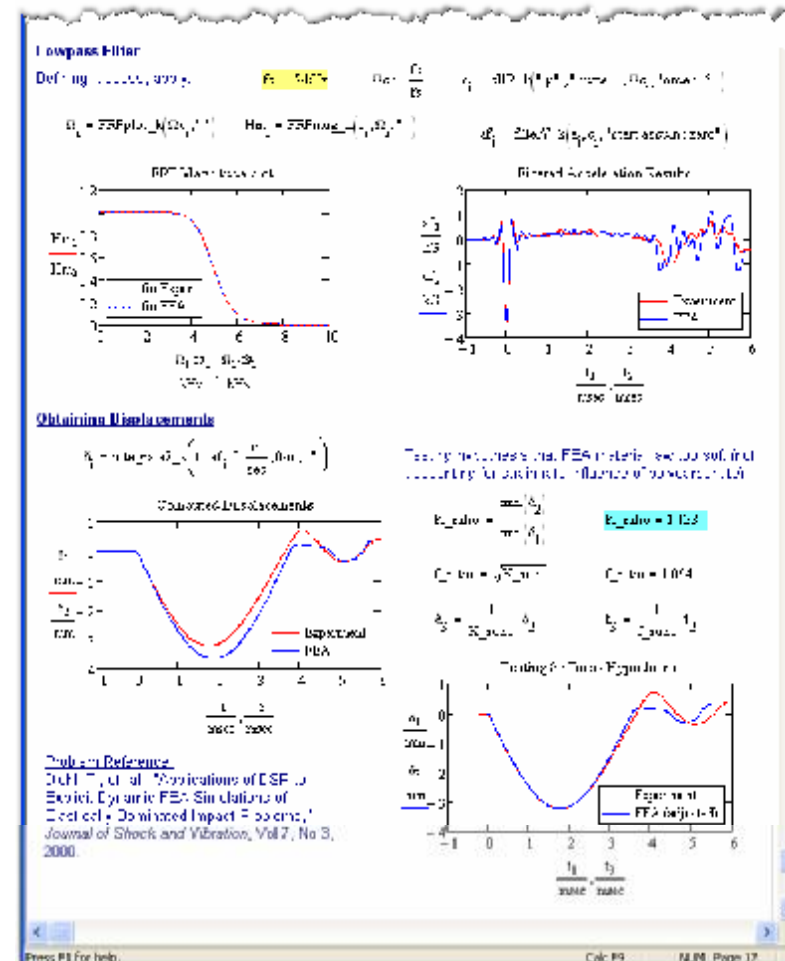
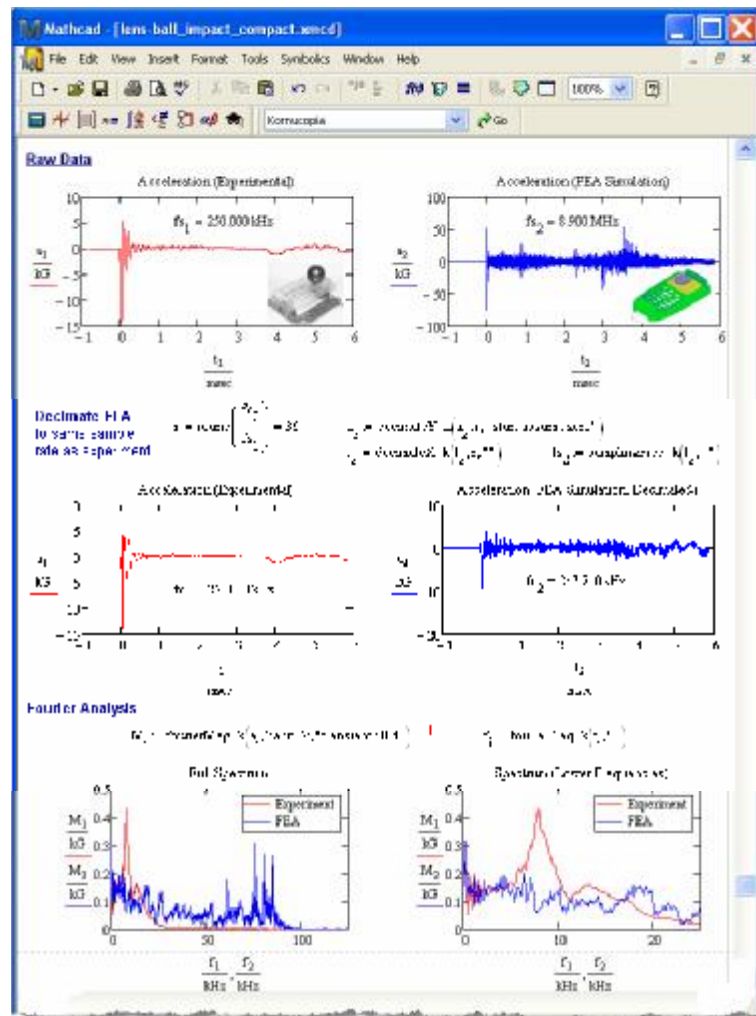
Engineer A  
**“NO correlation”**

**Aliasing distorted analysis**

Engineer B  
**“Good Match”**



# Kornucopia® Improves Analysis of Challenging Data

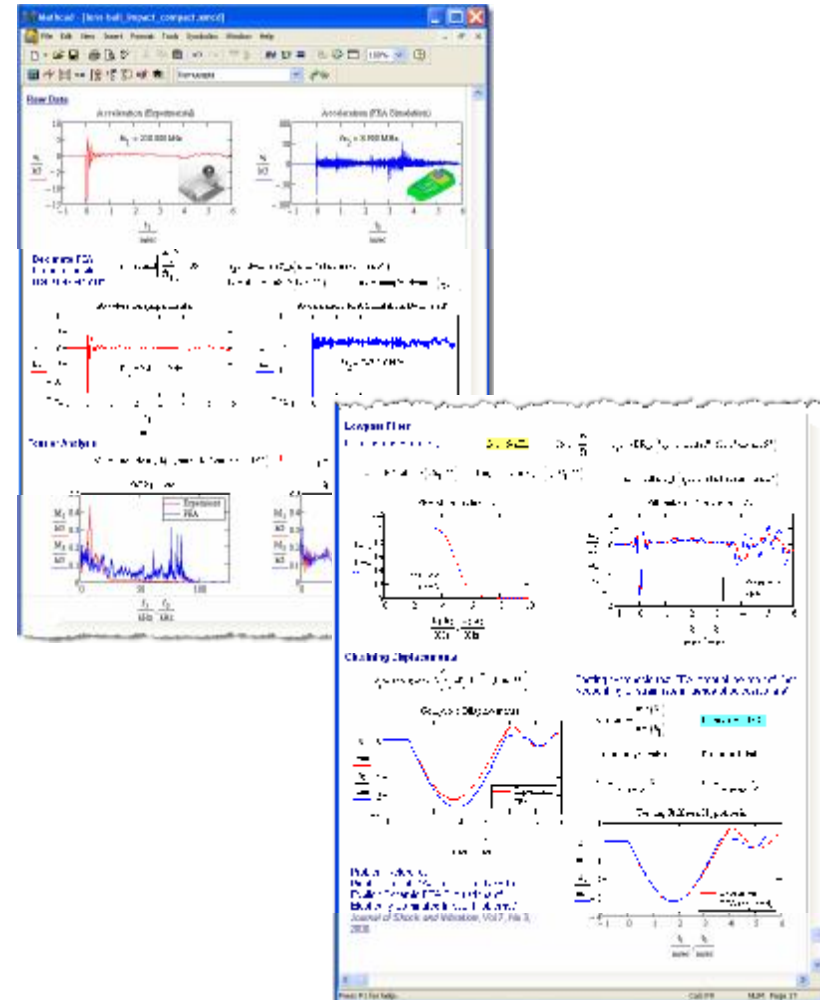




# Kornucopia® Improves Analysis of Challenging Data

## Key Benefits:

- Clear documentation of analysis process
- Reusable automated worksheet
  - Saves times
  - Reduces errors
  - Deployable to others
- Confidence in both Testing and Modeling Approach
  - They Correlated!
- Improved FEA material law via stiffness correction factor



# Filtering Tools for EVERYONE Not Just Experts

## Decimating and Smoothing Data

Decimation and  
then smoothing

$r := 300$

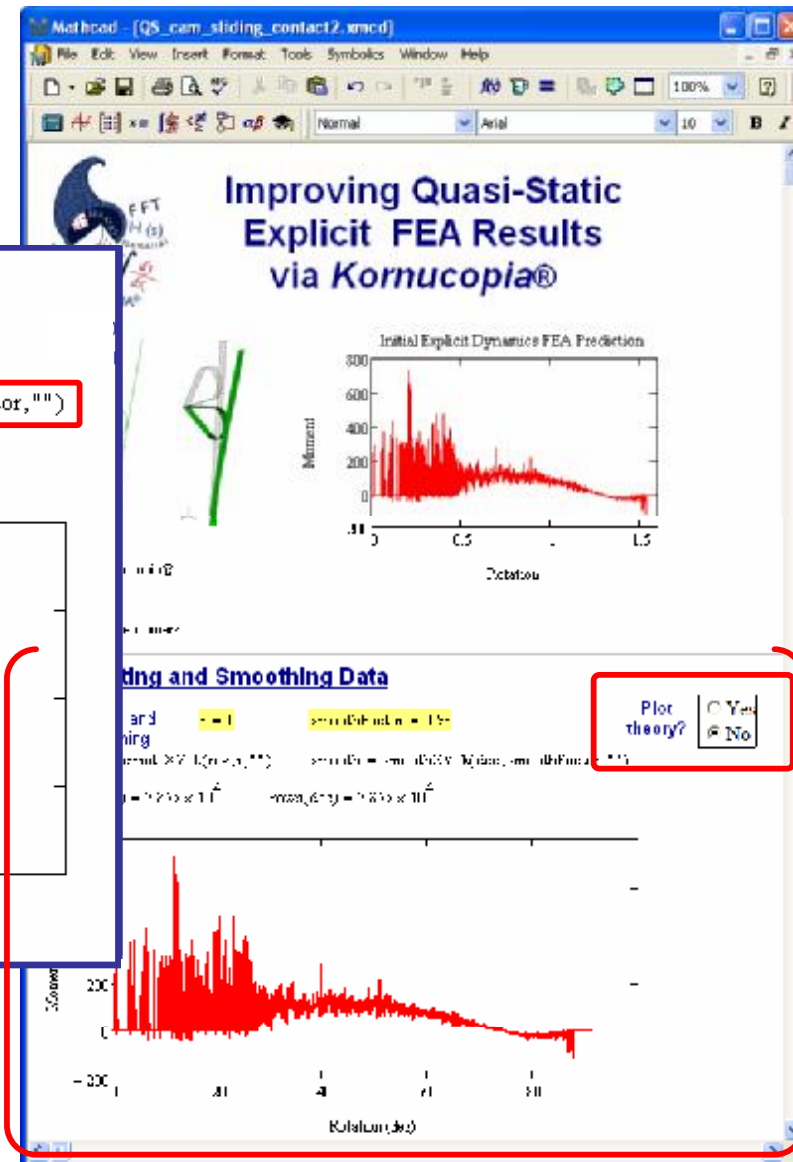
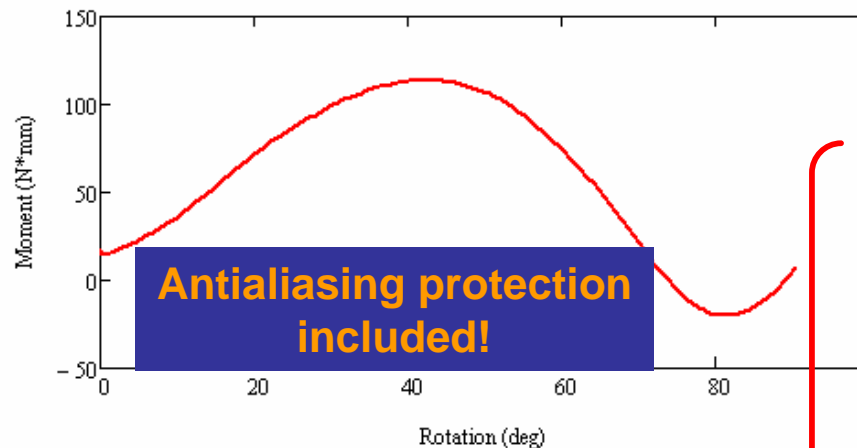
smoothFactor := 90-%

`dec := decimateXY_k(reg,r,"")`

`smooth := smoothXY_k(dec,smoothFactor,"")`

`rows(reg) =  $3.855 \times 10^4$`

`rows(dec) = 129`



# Filtering Tools for EVERYONE Not Just Experts

original reference of a vector previously within the current window of the FFT window

Rigid body radius and moment  
beginning of problem

Center of rotation for rigid circle

Rigid body distance from the center  
of rotation and the circle center

Angle of rigid beam relative to Y axis  
at beginning of problem

Offset of flexible beam A/B's at Y=0

Relationship between circle center  $\xi_c$  and Y  
the X-axis.

$\xi_c(\psi) = R \sin(\psi) + \xi_{c0}$

$\eta_c(\psi) = -R \cos(\psi) + \eta_{c0}$

**Complete (Exact) Solution to Problem:**

Transcendental equation

Given

$$\eta_c = \sqrt{\left(\frac{L}{2}\right)^2 - (\xi_c - \xi_{c0})^2} = \frac{L}{2} \left[ \xi_c - \xi_{c0} \right] \left[ \xi_c - \xi_{c0} \right] \left[ \frac{L}{2} - (\xi_c - \xi_{c0})^2 \right]^{-\frac{1}{2}}$$

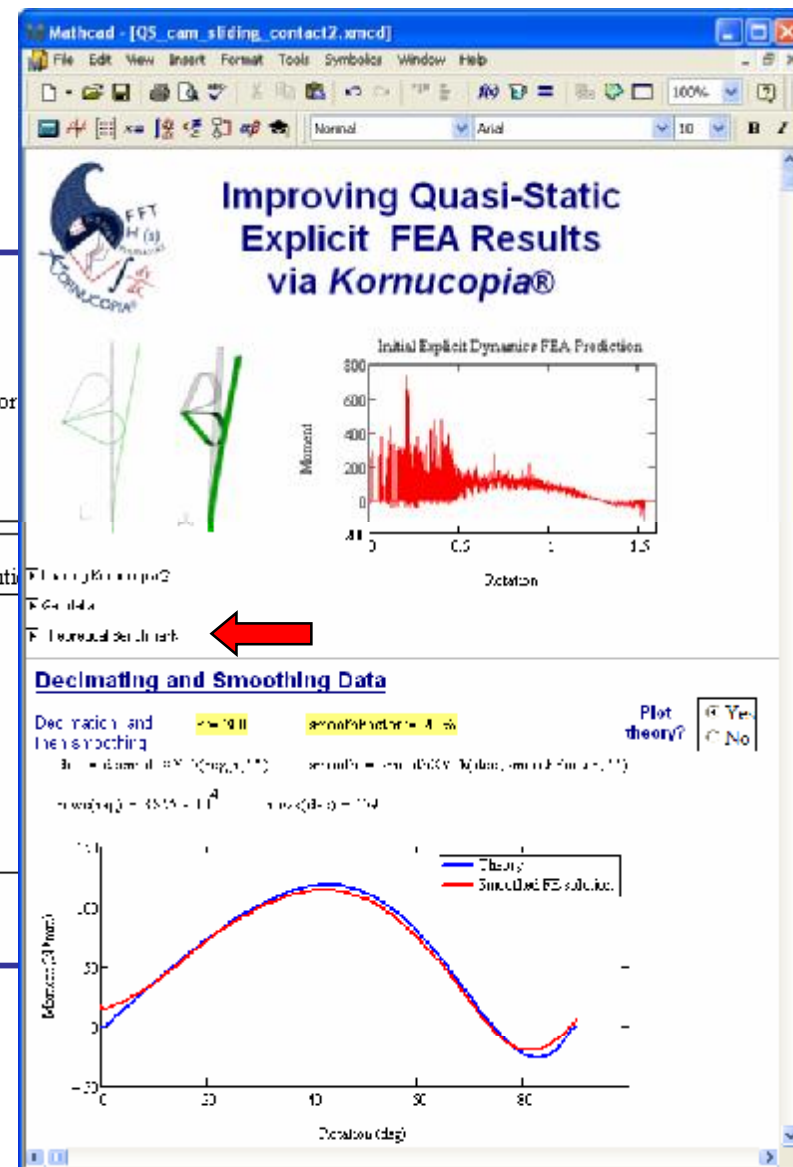
$\xi_{c0} = \xi_c(\xi_{c0}, \eta_{c0}) = \text{Find}(\xi_{c0})$

Final behavior of the equation in the equation

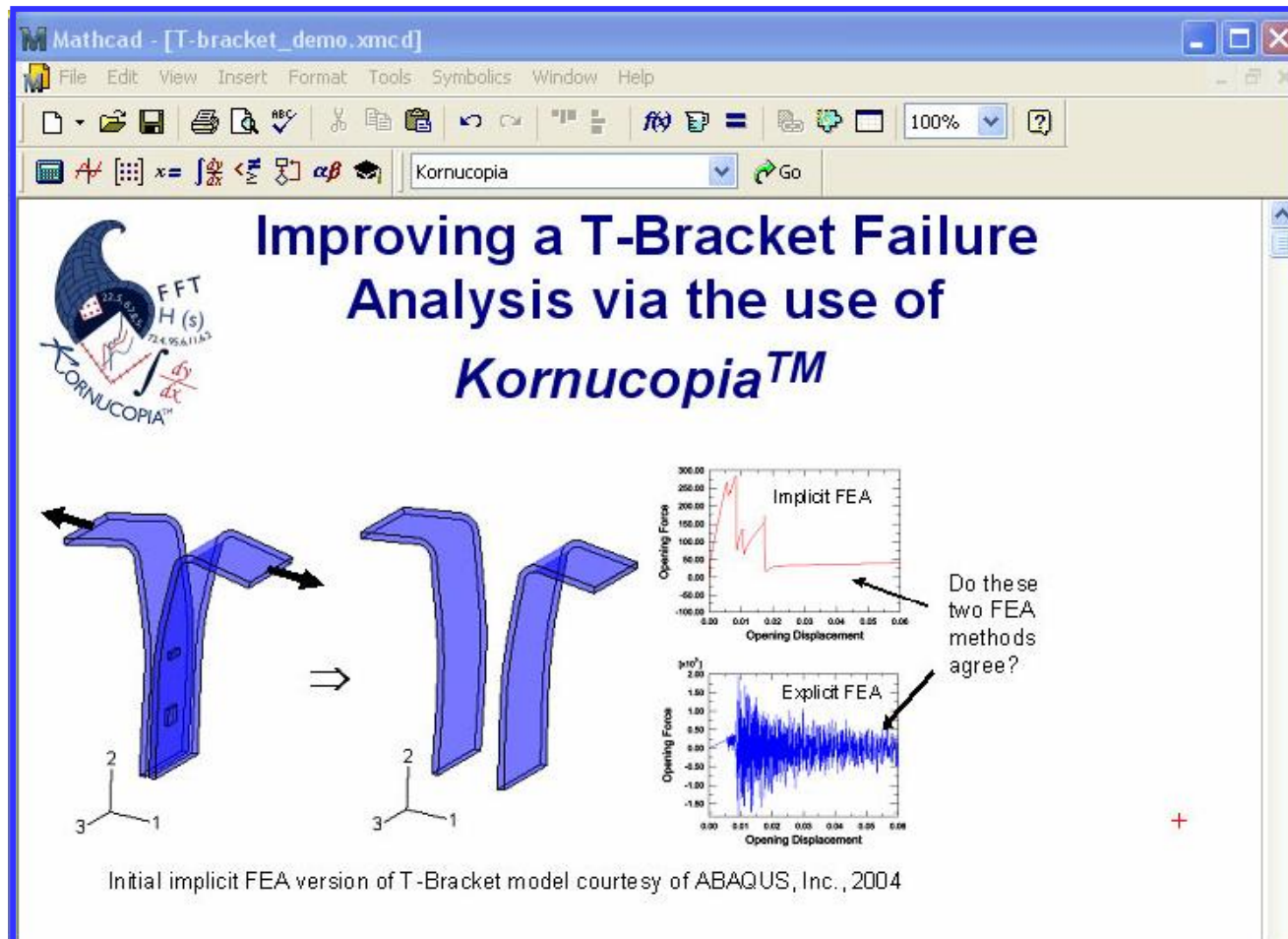
$$\eta_c = \sqrt{\left(\frac{L}{2}\right)^2 - (\xi_c - \xi_{c0})^2} = \frac{L}{2} \left[ \xi_c - \xi_{c0} \right] \left[ \xi_c - \xi_{c0} \right] \left[ \frac{L}{2} - (\xi_c - \xi_{c0})^2 \right]^{-\frac{1}{2}}$$

NOTE: for this particular problem,  $\eta_{c0}$  will be 0

**Mathcad easily  
solves nonlinear  
transcendental  
equations!**

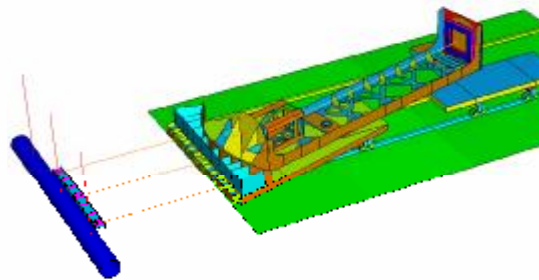


# T-bracket Failure Analysis



## Development of Naval Surface Warfare Center WOX Shock Tester

- Analysis of Abaqus/Explicit FEA model of a Missile Shock Test Machine at NSWC, Dahlgren Division
- Perform 50+ DOEs
  - 30 output sensors:  
~50,000 rows,  
31 cols
  - Decimate, LP filter, find local max/min velocities & mean acceleration over several regions.



```
names = {
  "model1.rpt"
  "model2.rpt"
  "model3.rpt"
}
```

```
i := 1..rows(names)
```

```
data = {
  {2511,31}
  {2502,31}
  {2498,31}
}
```

### Select sensors of interest

```
sensors := reorder_k[sensors,"keep","cols",(1 5 13 6),"]"]
```

```
data_1 := reorder_k[data_1,"keep","cols",(1 5 13 6),"]"]
```

```
sensors^T = {
  "Time"
  "TopRear, X"
  "Front, X"
  "TopRear, Y"
}
```

### Perform DSP

```
fs_1 := samplingFreq_k[(data_1)^1]·sec,""]
```

```
fs = {
  10.043
  10.006
  9.956
}·kHz
```

Define cutoff  
frequency

fc := 50·Hz

```
C_1 := cIIR_k("lp","butter",fc,fs_1,""]
```

```
dataf_1 := filterXY_k(data_1,C_1,"start assumpt: zero")
```

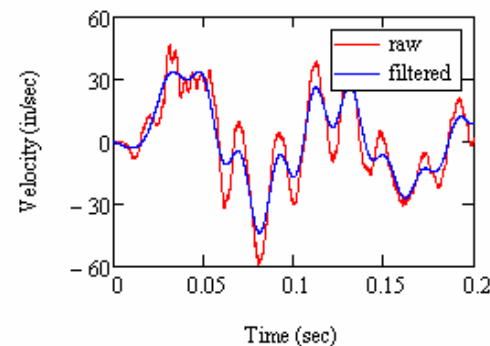
select a sensor to view

s := 4

sensors<sup>(s)</sup> = ("TopRear, Y")

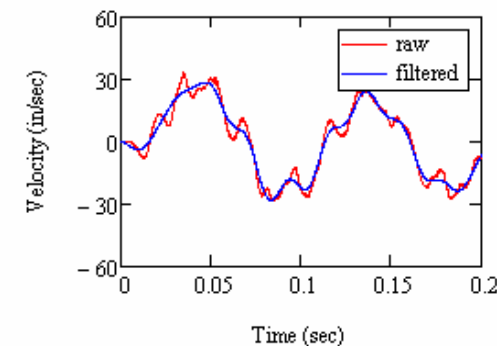
set<sub>a</sub> := 1

names<sub>set<sub>a</sub></sub> = "model1.rpt"



set<sub>b</sub> := 3

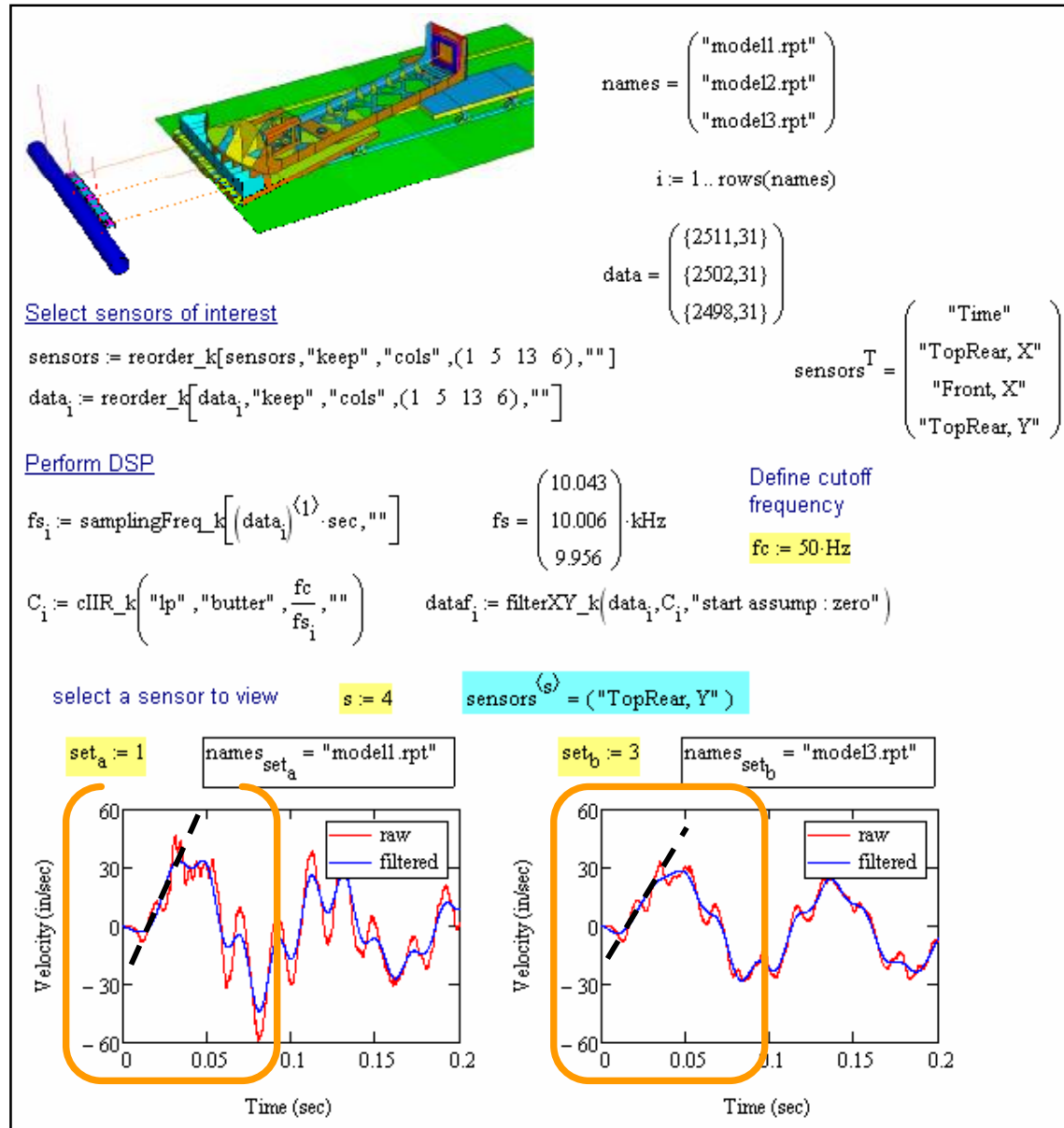
names<sub>set<sub>b</sub></sub> = "model3.rpt"



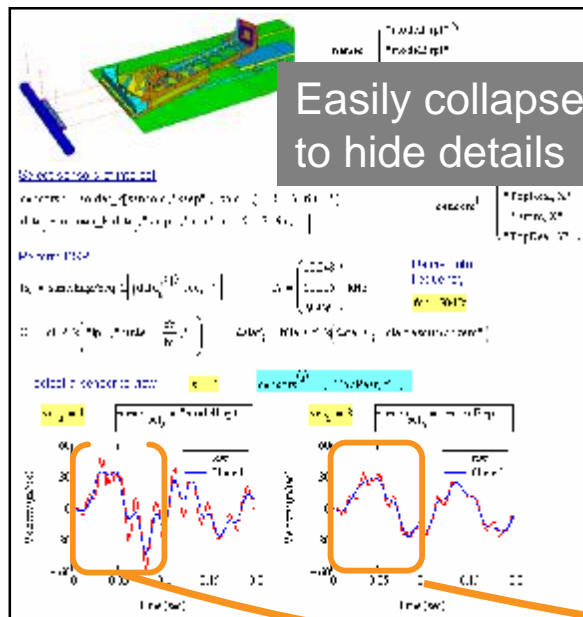


## Development of Naval Surface Warfare Center WOX Shock Tester

- Analysis of  
Abaqus/Explicit FEA  
model of a Missile  
Shock Test Machine at  
NSWC, Dahlgren  
Division
- Perform 50+ DOEs
  - 30 output sensors:  
~50,000 rows,  
31 cols
  - Decimate, LP filter,  
find local max/min  
velocities & mean  
acceleration over  
several regions.



# Development of Naval Surface Warfare Center WOX Shock Tester



Analysis of WOX Shock Tester with permission from Jon Yagla, Naval Surface Warfare Center, Dahlgren Div.

Specify a rough maximum time trigger  $t_{max} := 0.1$

Specify minimum velocity trigger  $trigger := 5$

counter to loop through sensors

$j := 2..cols(dataf_1)$

Trim out the data section in each curve to be analyzed

$$analyze_{1,j} := \begin{cases} rough \leftarrow trim\_k[dataf_1, (dataf_1)^{(1)}, "", t_{max}, ""] \\ trim\_k(rough, rough^{(j)}, trigger, "max", "") \end{cases}$$

Assigning time and sensor velocity variables

$$t_{1,j} := (analyze_{1,j})^{(1)} \quad V_{1,j} := (analyze_{1,j})^{(j)}$$

Computing mean acceleration values

$$Gave_{1,j} := slope\left(t_{1,j} \cdot sec, V_{1,j} \cdot \frac{in}{sec}\right)$$

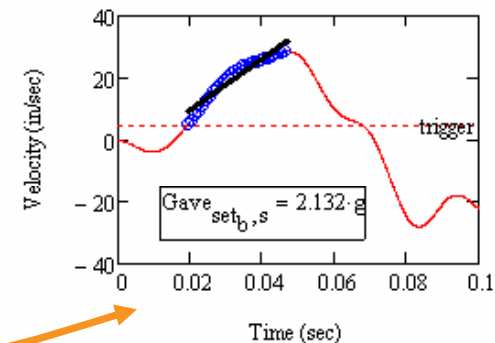
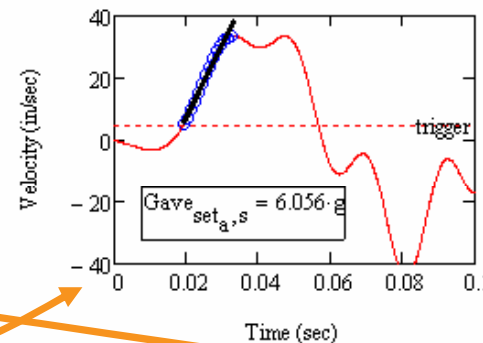
$$Gplot(t, V) := \begin{cases} M \leftarrow slope(t, V) \\ B \leftarrow intercept(t, V) \\ M \cdot t + B \end{cases}$$

$$Gplt_{1,j} := Gplot(t_{1,j}, V_{1,j})$$

names  $set_a = "model1.rpt"$

sensors  $\langle s \rangle = ("TopRear, Y")$

names  $set_b = "model3.rpt"$



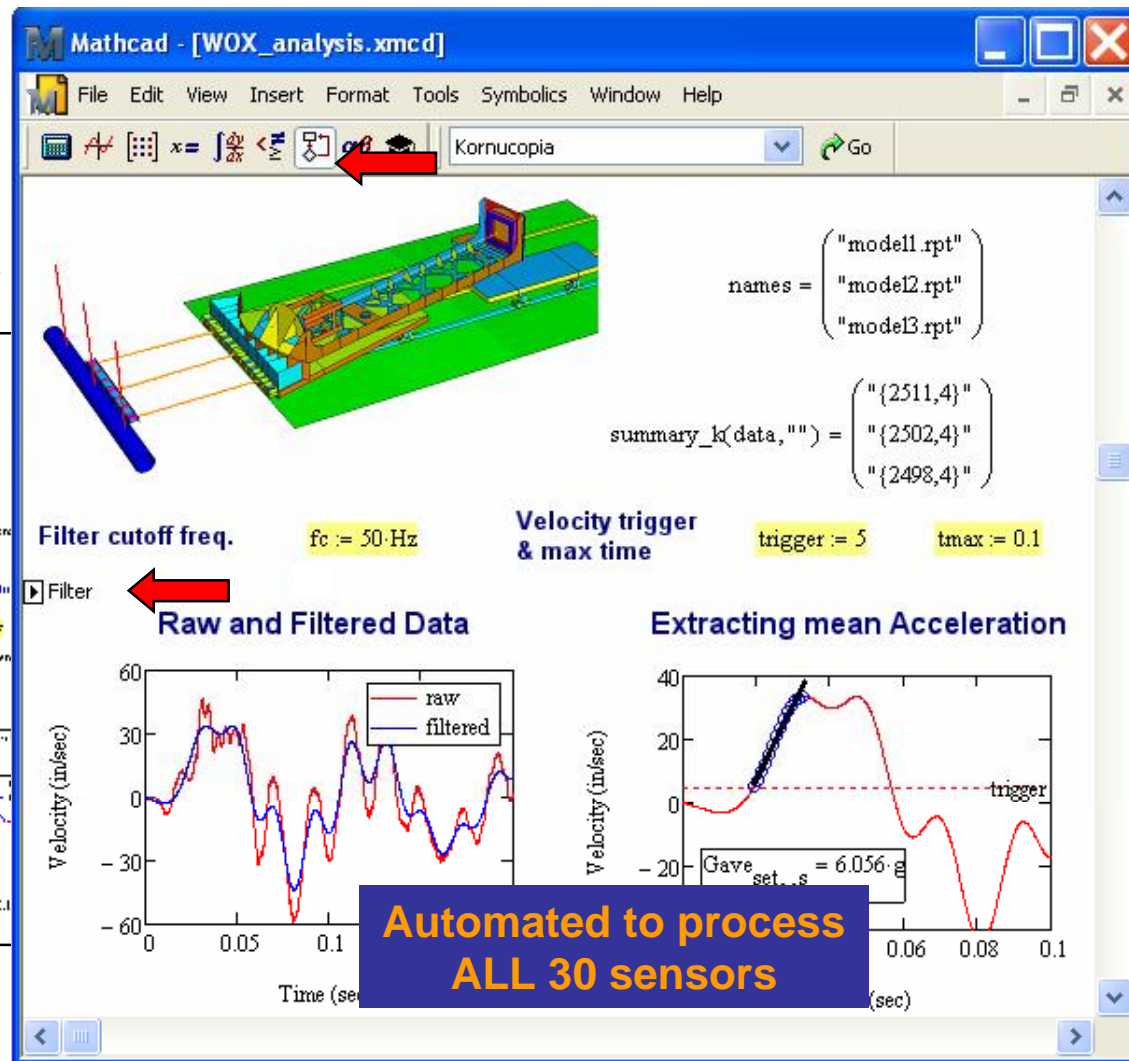
Acceleration Summary (units = g)			
	TopRear, X	Front, X	TopRear, Y
model1.rpt	8.67	24.69	6.06
model2.rpt	1.00	20.81	2.15
model3.rpt	0.99	20.78	2.13



# Development of Naval Surface Warfare Center WOX Shock Tester

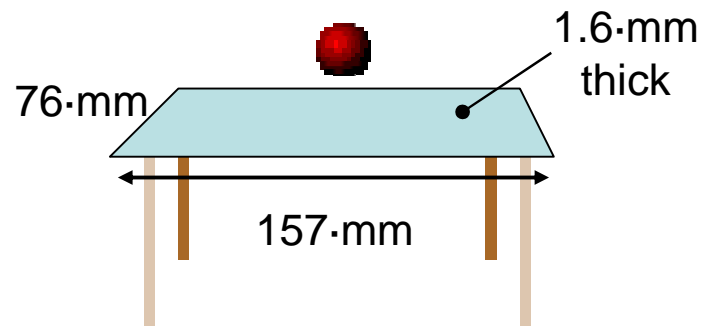


Analysis of WOX Shock Tester  
with permission from Jon Yagla,  
Naval Surface Warfare Center,  
Dahlgren Div.



## Integrating Acceleration Data – Another Big Challenge!

**Why does this measured acceleration produce a ridiculous displacement?**

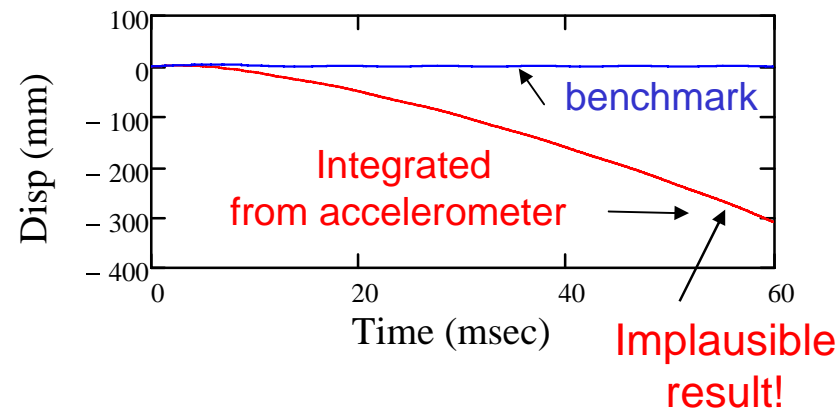
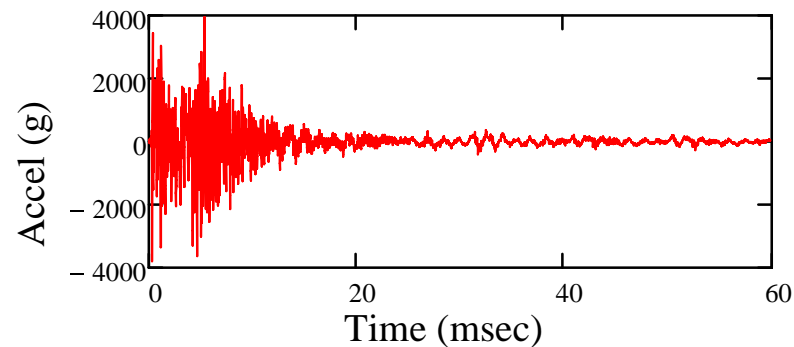


**Steel ball impacting  
aluminum plate**

### **Answer:**

Low frequency distortion in  
accelerometer data

- Very common with  
measured data



# Example Templates in Library Help Meet the Challenge!

**Kornucopia Help**

Hide Locate Back Forward Stop Refresh Home Print Options

Contents Index Search

- TOC
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    - Cantilever Beam Analysis
    - Catenary Analysis
    - Cleaning, Averaging, and Tweaking
    - Creating Elastic/Plastic Material De
    - DCB Failure
    - Decimating Data
    - Derivatives and Integrals of Discre
    - General Interpolation via Paramete
    - Highpass Filter of Plate Shock
    - Hysteretic and Cyclic Data Proces
    - Improving User-Friendliness of VVc
    - Learning DSP
    - Lens-Ball Impact
    - Moon Penetrator
    - Processing Multiple Files Efficiently
    - Processing a Packed File Efficientl
    - Protective Boxer
    - Salvaging PE Shock
      - SalvagePEshock\_Compact
      - SalvagePEshock\_Detailed
    - Sliding Contact
    - T-bracket Failure
    - Tricks for Plotting Multiple Curves

## Salvaging PE Shock Data Using Highpass Filtering (Compact version)

**ALL Template Example Files**

- Can Open LIVE in Mathcad®
- Modify as desired by user

**en Template in Mathcad (modify as needed by user)**

This example worksheet demonstrates how the use of highpass filtering as a method to potentially salvage severe drifting in integrated displacement data.

**Plausible Result**

This is an HTML version of the worksheet. It is intended to be used for fast browsing.  
[Click here to work interactively in Mathcad® with this worksheet.](#)

**Video Demo**

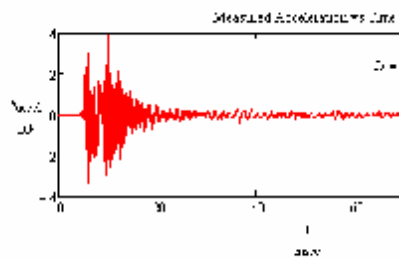




# Integrating Acceleration Data – Another Big Challenge!

Plot of Raw Acceleration Data

Plot of Raw Acceleration Data



Successive Integration to obtain displacements

Fourier

Fourier

To help

$\delta_{quad}$

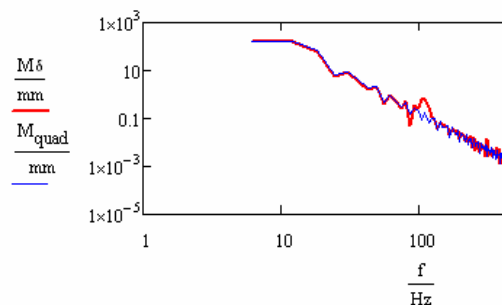
## Fourier Analysis

Fourier of the actual data

$M\delta := \text{fourierMag}_k(\delta, \text{har})$

To help interpret the Fourier Signature, we compute the Fourier

$$\delta_{quad} := -700 \text{ mm} \cdot \left( \frac{t}{100 \text{ msec}} \right)^2 \quad M_{quad} := \text{fourierMag}_k(\delta_{quad}, \text{har})$$



## Highpass Filtering to Remove Drift

Guided by the Fourier analysis above, it looks like we should start filtering around 100 Hz.

- Try the following filter cutoffs: 100 Hz, 50 Hz, 25 Hz, 10 Hz, 25 Hz, 30 Hz, 28 Hz.
- Your goal when removing drift is to use as low a cutoff as possible so that the low frequency portion causing the drift is removed but the higher frequency, physical components are not removed.

Define filter cutoff  $fc := 28 \text{ Hz}$   $\Omega_c := \frac{fc}{fs}$

Define filter coefficients  $c := \text{cIIR}_k(\text{"hp"}, \text{"butter"}, \Omega_c, \text{""})$

Apply filter to data  $\delta_f := \text{filterY}_k(\delta, c, \text{""})$

Select the curves you desire to appear in the plot.

Select which signals to use to drive Y-axis scaling

Select which signals to turn on in the plot below

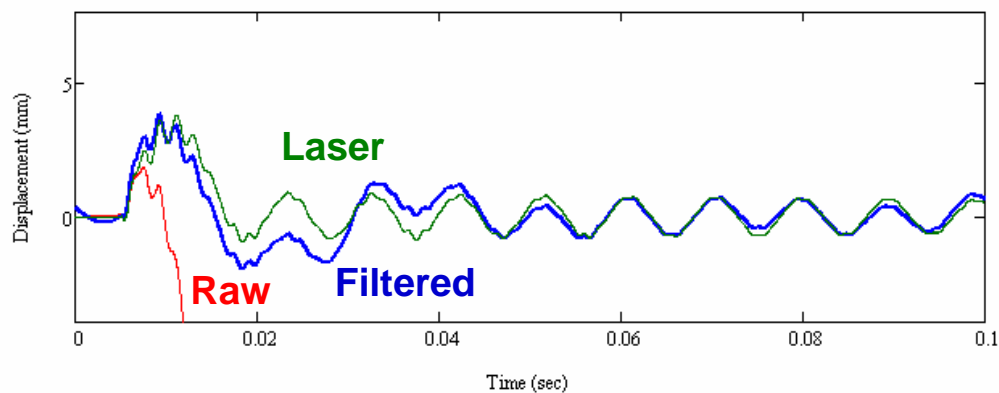
☒ Unfiltered

☒ Filtered

☒ Laser

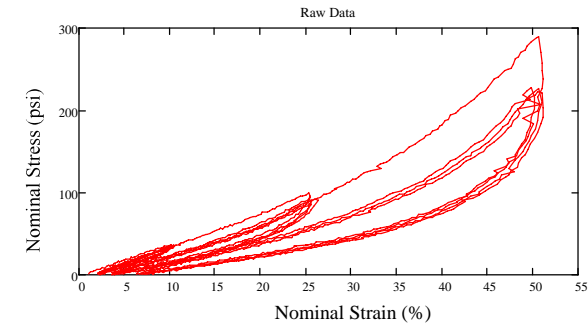
- ☐ All
- ☐ 2x Laser
- ☒ 2x Filtered & laser
- ☐ 5x Filtered & laser

Unfiltered, Filtered and Benchmark

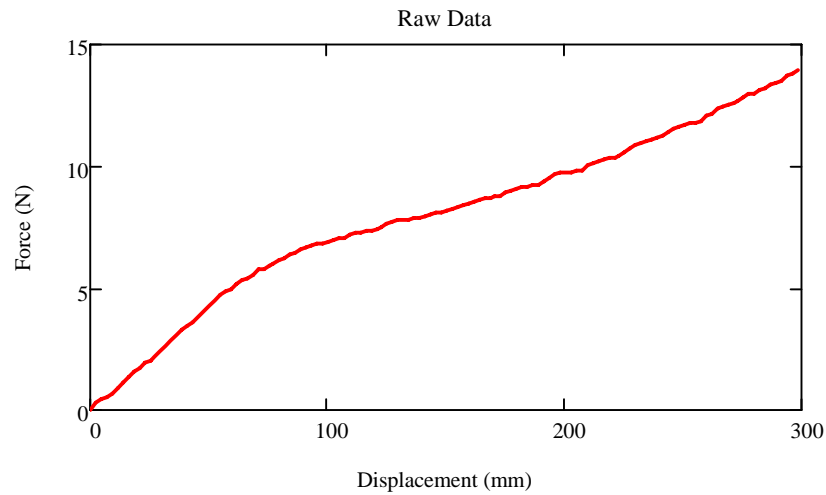


## Noisy and Challenging Data

- **Comes from many sources & for many reasons**
  - Physical and artificial
  - Measurements and simulations
- **Found in many places**
  - Impact events
  - Entities with Motion
    - Aircraft, cars, ships, machinery, hand-held drills, engines, valves, etc.
  - Characterization of rough surfaces, peel testing, etc.
  - Material characterizations of advanced materials
- **Quantities**
  - Most noisy – accelerometers
  - Moderate noise – string pots, laser “gauges” (velocity, strain, ...), force transducers
- ***Computing the derivative of data can easily create a noisy result***

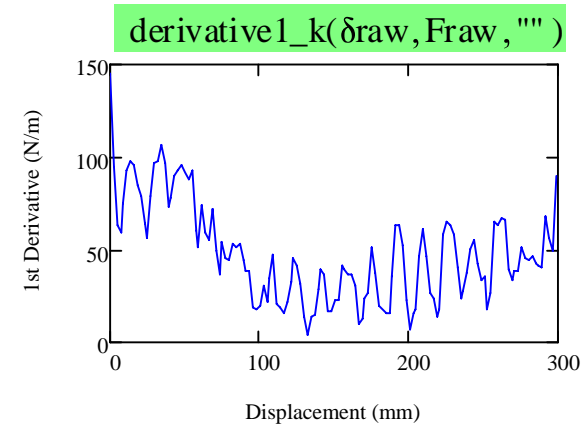


## Other Challenging Data

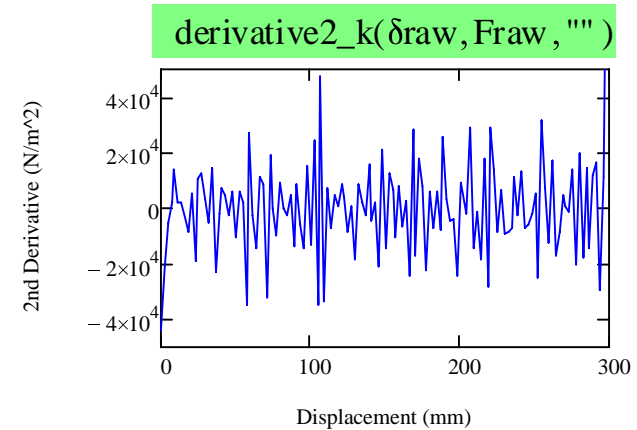


**These derivatives looks terrible?**  
– Can I do anything about it?

$$\frac{dF}{d\delta}$$



$$\frac{d^2F}{d\delta^2}$$



# Kornucopia® Help and Templates Provides Guidance

The screenshot shows the Kornucopia Help window with a blue title bar and a navigation toolbar. The left sidebar contains a 'Contents' pane with a tree view of topics. The main content area features a title, a logo, two graphs, and descriptive text.

**Kornucopia Help**

Hide Locate Back Forward Stop Refresh Home Print Options

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    - Cantilever Beam /
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    - Cleaning, Averagi
    - Creating Elastic/Pl
    - DCB Failure
    - Decimating Data
    - Derivatives and In
    - derivativesAn
    - derivativesAn
    - General Interpolat
    - Highpass Filter of
    - Hysteretic and Cy
    - Improving User-Fr
    - Learning DSP
    - Lens-Ball Impact
    - Moon Penetrator
    - Processing Multipl
    - Processing a Pacl
    - Protective Barrier
    - Salvaging PE Sho
    - Sliding Contact
    - T-bracket Failure

## A Detailed Look at Computing Derivatives and Integrals of Discrete Data via Mathcad and Kornucopia®

**Raw Data**

Force (N)

Displacement (mm)

**1st Derivative**

1st Derivative (N/mm)

Displacement (mm)

Derivative (raw)  
Derivative with filtering

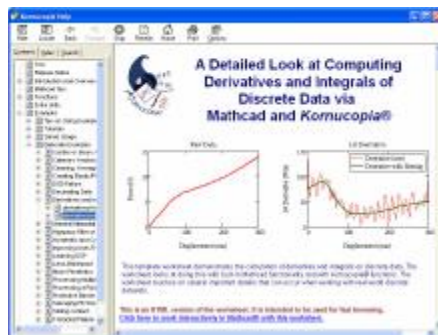
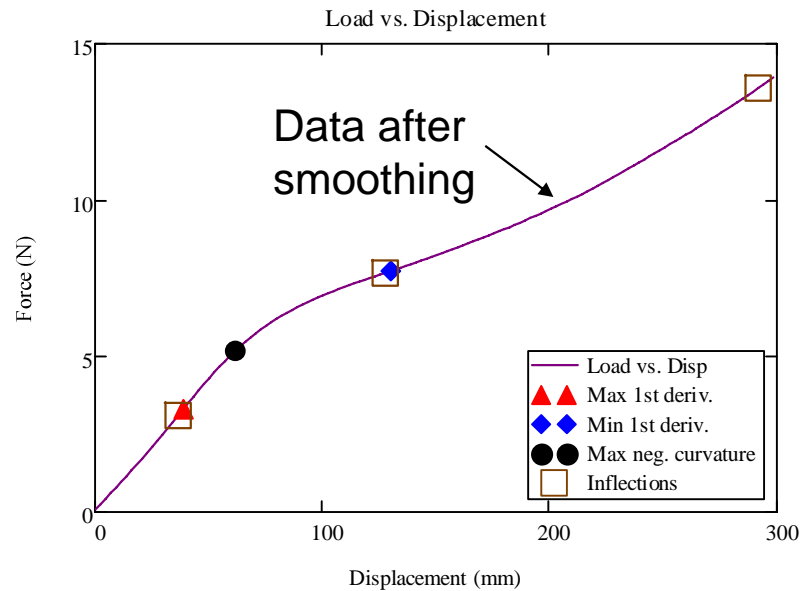
This template worksheet demonstrates the calculation of derivatives and integrals on discrete data. The worksheet looks at doing this with built-in Mathcad functionality and with Kornucopia® functions. The worksheet touches on several important details that can occur when working with real-world discrete datasets.

**This is an HTML version of the worksheet. It is intended to be used for fast browsing.**  
[Click here to work interactively in Mathcad® with this worksheet.](#)

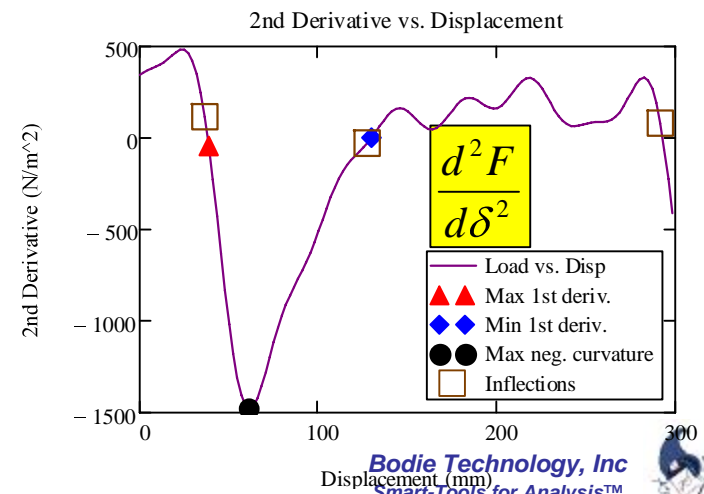
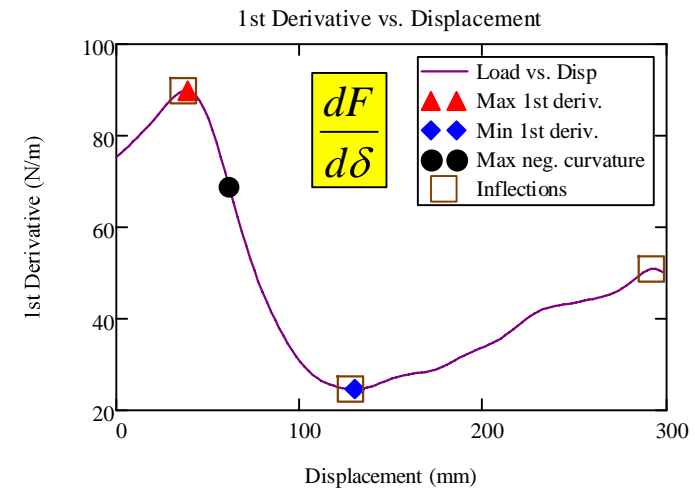


# Noisy Derivative Challenge

## Kornucopia® Meets the Challenge!

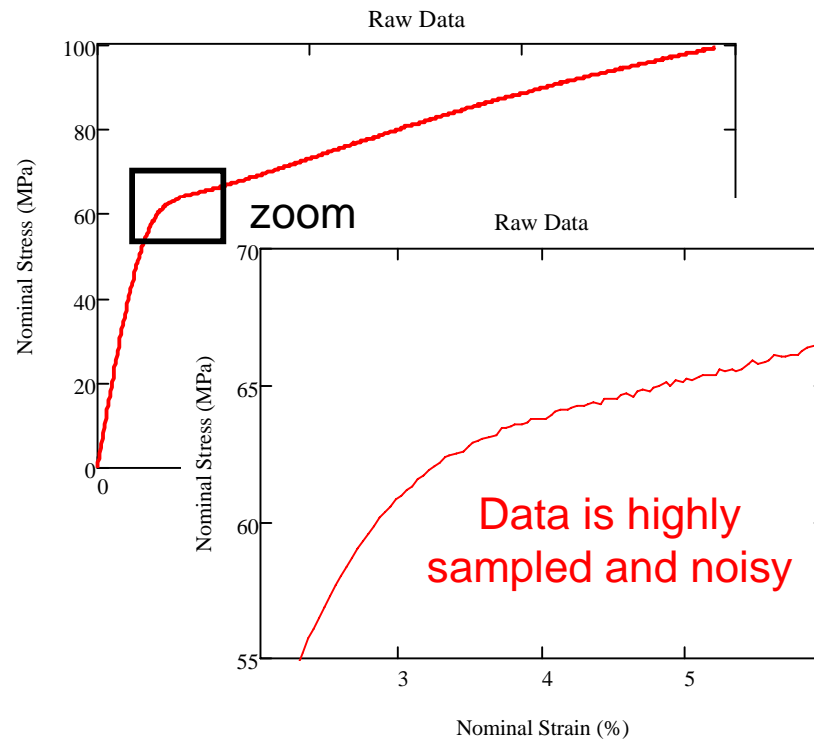


Solution Using Both Filtering & Derivative Functionality in Kornucopia®



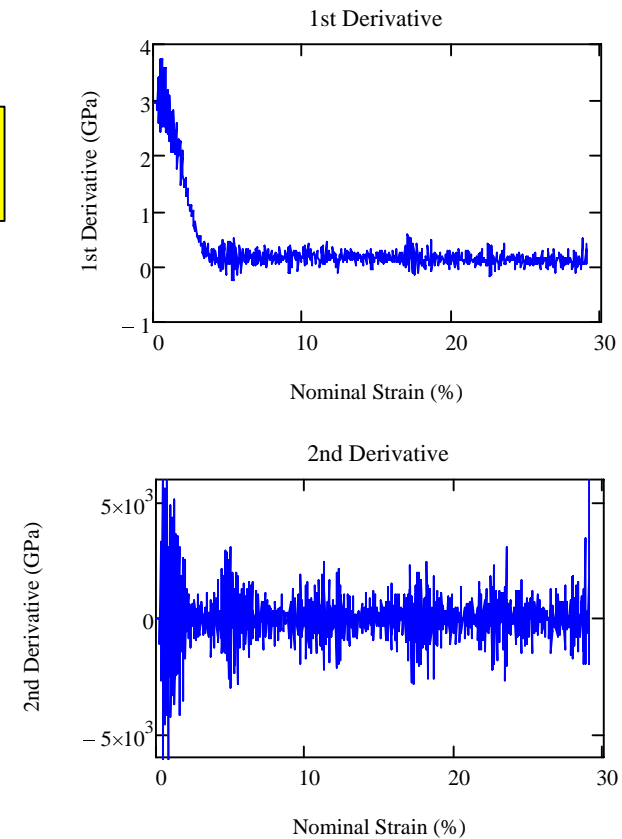
## Here is a Simple Dataset that Looks Smooth

Why do these derivatives look so noisy?



$$\frac{dT}{d\varepsilon}$$

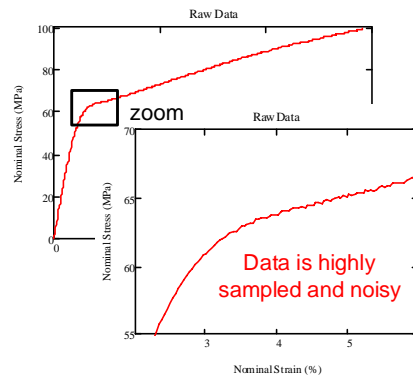
$$\frac{d^2T}{d\varepsilon^2}$$





# Kornucopia® Library Suggests Suitable Work-Flows

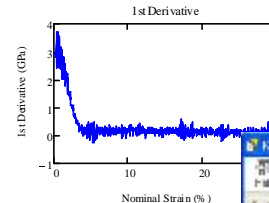
Here is a Simple Dataset that Looks Smooth



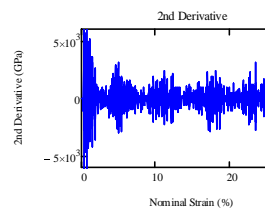
Copyright © 2004 - 2009 Bodie Technology, Inc.

Why do these derivatives looks so noisy?

$$\frac{dT}{d\varepsilon}$$

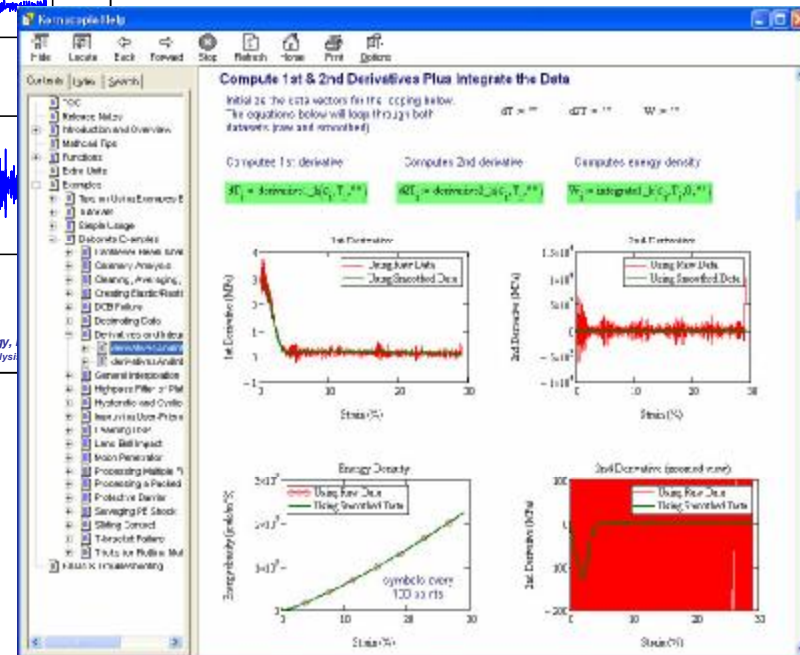


$$\frac{d^2T}{d\varepsilon^2}$$

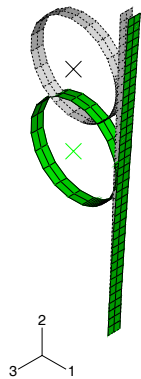


Bodie Technology,  
Smart-Tools for Analysis

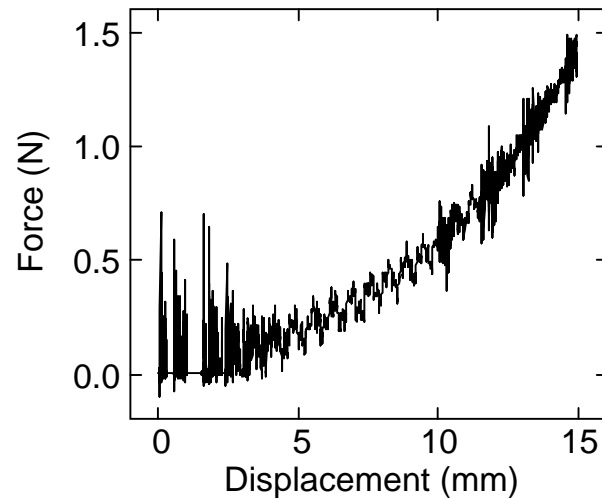
Kornucopia® Example shows solution using both Filtering & Derivative Functionality



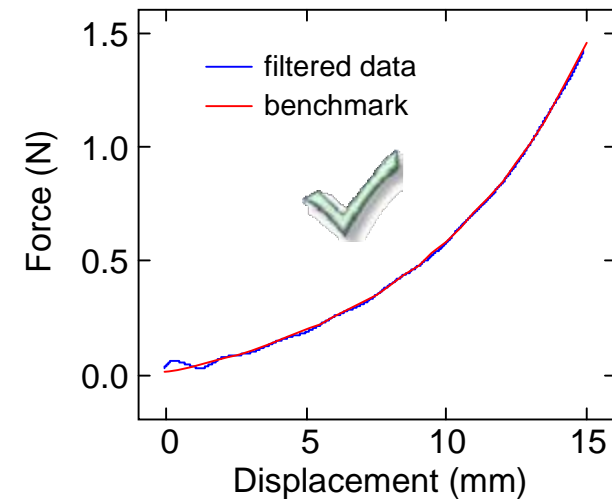
## Kornucopia® DSP Technology is Robust



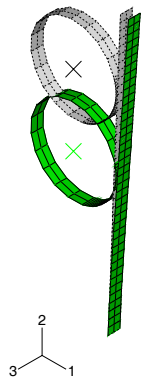
Raw Data



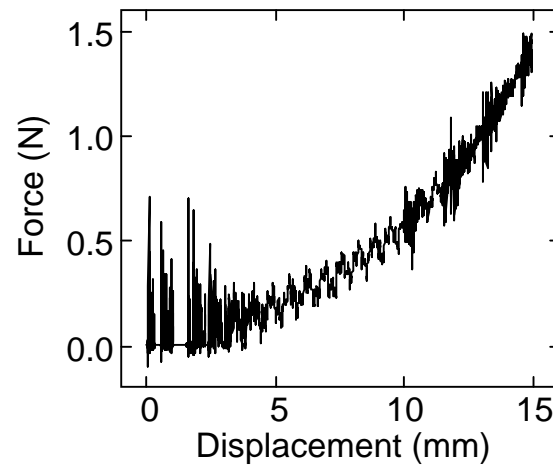
```
smooth := smoothXY_k(data, 99.5%, "" )
```



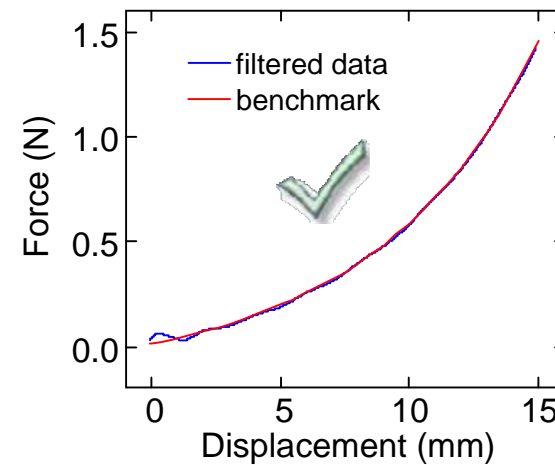
# Kornucopia® DSP Technology is Robust



Raw Data

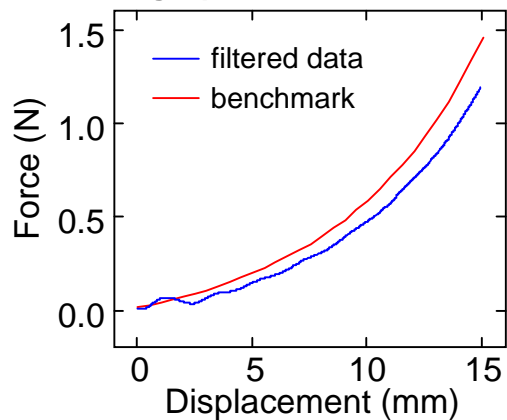


```
smooth := smoothXY_k(data, 99.5%, "" )
```

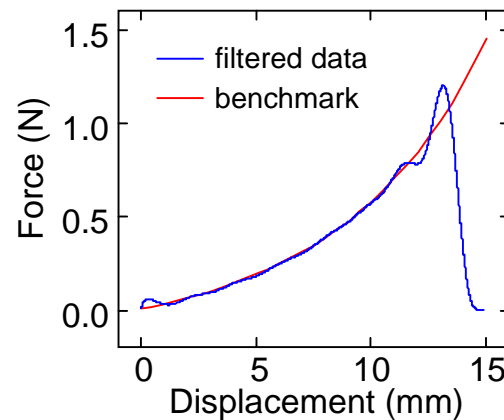


## Other DSP Software & Approaches

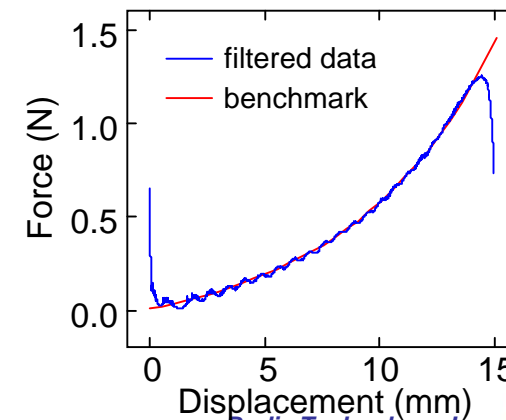
Single pass Butterworth filter



Bi-directional Butterworth filter



FFT filter



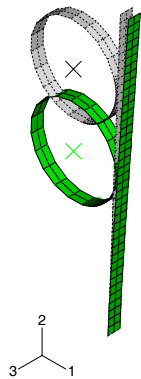
Copyright © 2004 - 2010 Bodie Technology, Inc.



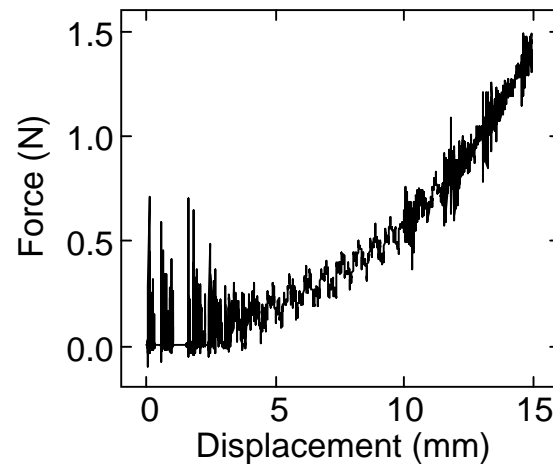
Bodie Technology, Inc  
Smart-Tools for Analysis™



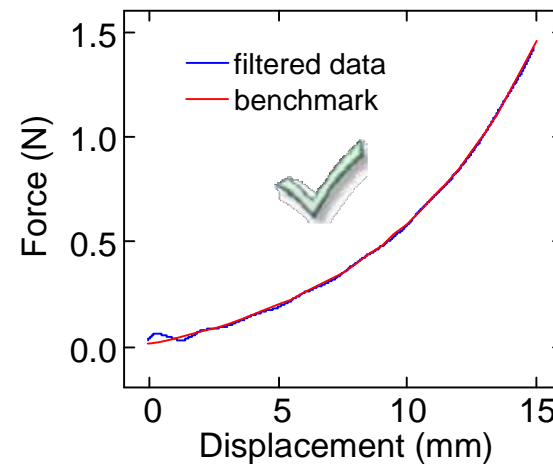
## Kornucopia® DSP Technology is Robust



Raw Data

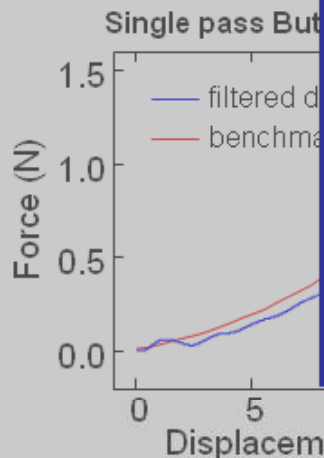


```
smooth := smoothXY_k(data, 99.5%, "")
```

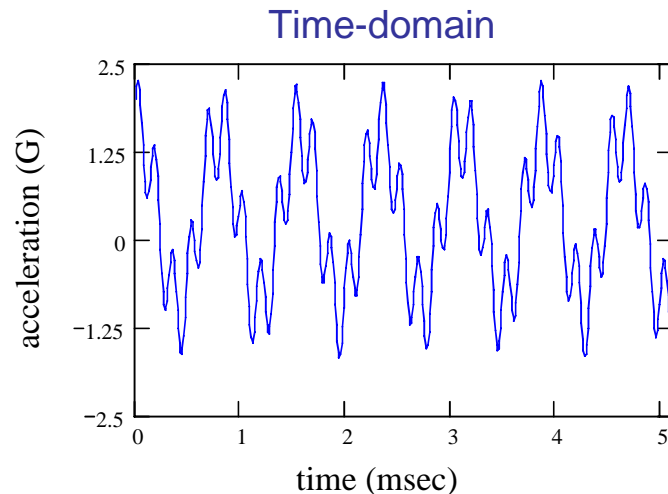


### smoothXY\_k

- Works well over a broad range of data
- Uses Kornucopia® Smart-Function™ DSP technology
  - ✓ Bi-directional Butterworth filter
  - ✓ Automatic end-effect minimization algorithm
  - ✓ User-friendly input parameters



## Time-Domain and Frequency-Domain – “FFT” Example



$$A(t) = a_{\text{DC}} + a_1 \sin(2\pi f_1 t + \phi_1) + a_2 \sin(2\pi f_2 t + \phi_2)$$

Analytical frequency content	
Freq (kHz)	Amplitude (G)
0.0	0.3
1.3	1.27
6.0	0.7

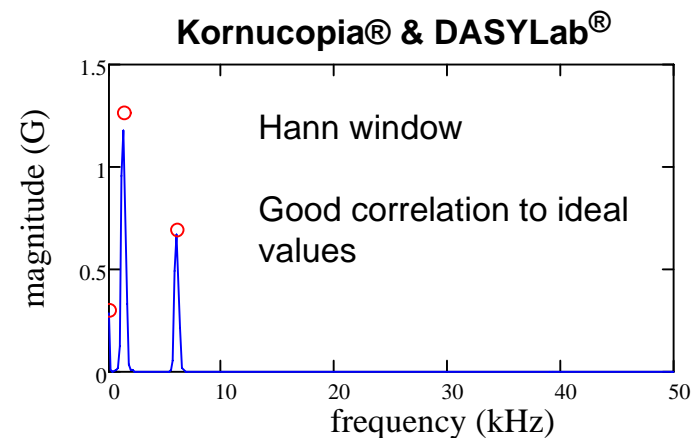
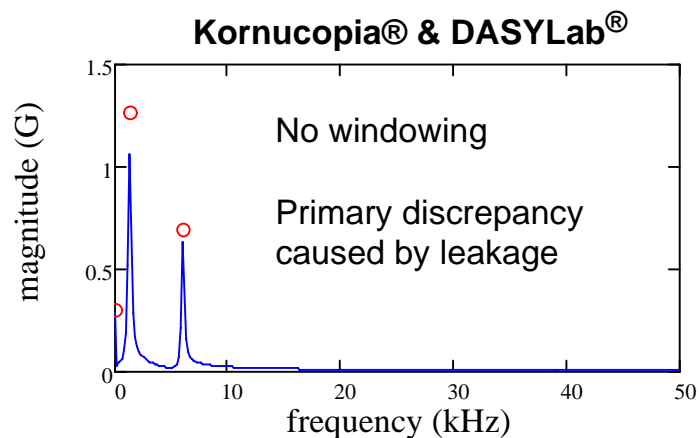
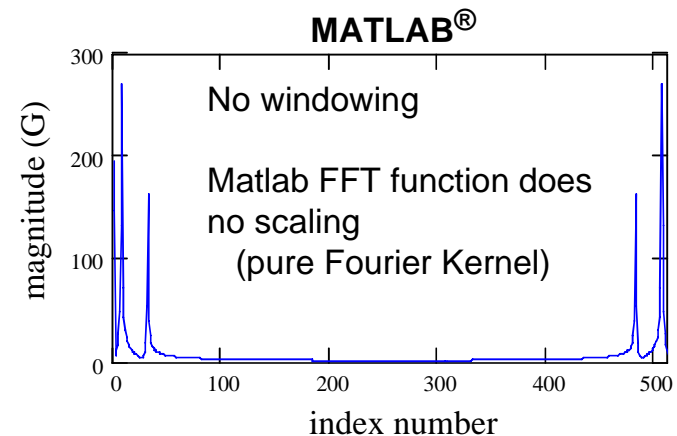
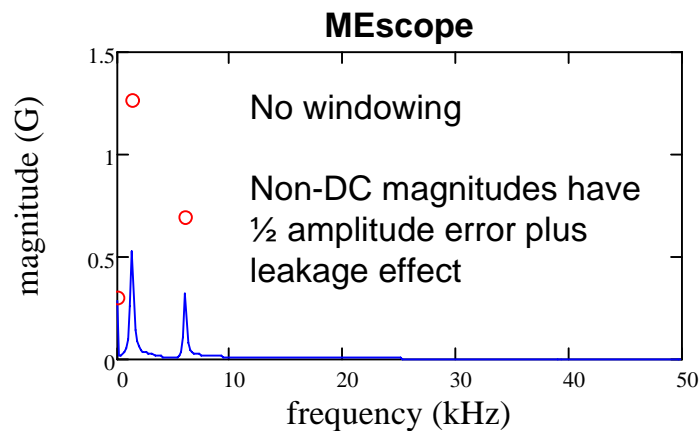
- **MEscope**, Version 4.0.0.69, released 10/17/2005.
  - “FFT” calculated using a rectangular window and the menu commands of Transform, FFT.
- **MATLAB® R2006a**, Version 7.2.0.232.
  - “FFT” calculated via `plot(abs(fft(A)))` where A is the time-domain amplitude vector.
- **DASYLab®**, V7.00.03, released 1/28/2003.
  - “FFT” calculated using a rectangular & hanning window and requesting a real FFT of real data via Signal Analysis, FFT, Amplitude Spectrum.
- **Kornucopia®**, V1.4, released June, 2009.
  - “FFT” calculated using a rectangular & hann window via the following commands

`mnoWin:= fourierMag_k(A,boxcar_k,"")`      `mhann:= fourierMag_k(A,hann_k,"")`



# Time-Domain and Frequency-Domain - "FFT" Example

Analytical frequency content	
Freq (kHz)	Amplitude (G)
0.0	0.3
1.3	1.27
6.0	0.7





## Working with Highly Over-Sampled Data

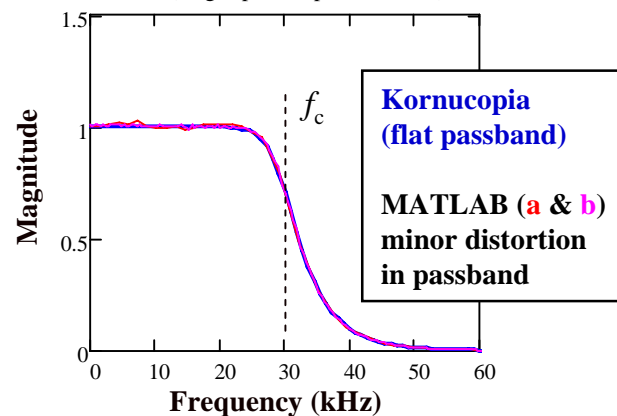
- **MATLAB®'s Signal Processing toolbox versus Kornucopia®**
  - The analysis is based on results initially published by:  
Diehl, T., et. al., "Applications of DSP to Explicit Dynamic FEA Simulations of Elastically-Dominated Impact Problems," *Journal of Shock and Vibration*, Vol 7, 2000, pp. 167-177.
    - Note: The MATLAB® results have been updated in 2007 and the Kornucopia® results were added in 2007.
- The evaluation examines performance of the two DSP software packages when data is highly over-sampled and a relatively aggressive filter is applied.
  - $f_s = 6$  MHz Sampling Rate.
  - 8th-order Butterworth Lowpass Filter
  - Values for typical for explicit-dynamics models and filters potentially applied by a "non-DSP" FEA user.



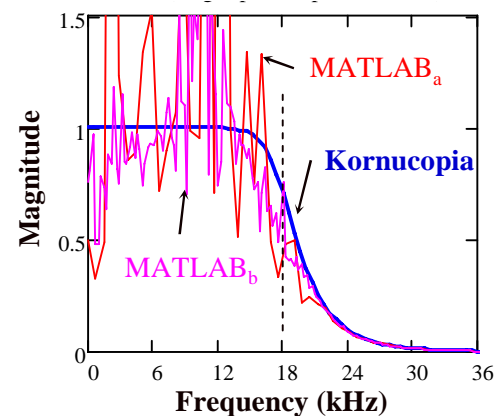
## Working with Highly Over-Sampled Data

- FRF Evaluations
  - FRF shows how filter will attenuate frequency content of signal

$f_c = 30 \text{ kHz}, \Omega_c = 0.005$



$f_c = 18 \text{ kHz}, \Omega_c = 0.003$



MATLAB®' has  
difficulty as  
normalized cutoff  
frequency is  
lowered.

$\Omega_c$  is the normalized cutoff frequency ( $f_c/f_s$ ).  $f_s = 6 \text{ MHz}$  (all cases)

**Kornucopia®** - Used function `FRFmag_k(C,  $\Omega_{\text{plot}}$ , "delay compensation : 0")`

**MATLAB<sub>a</sub>** - Used FFT-based algorithm via the MATLAB® command `[h,f] = freqz(b,a,n,Fs)`

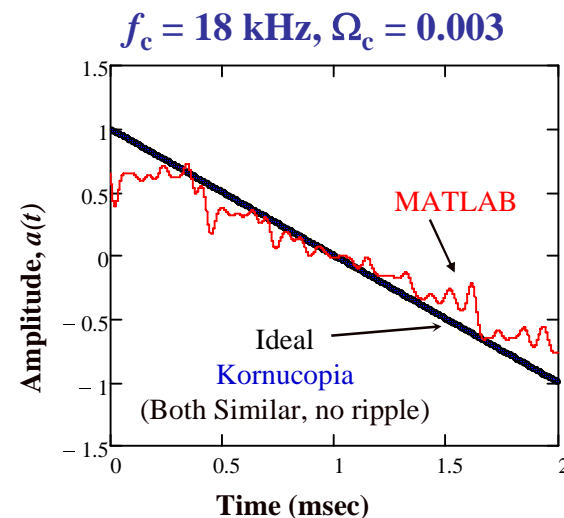
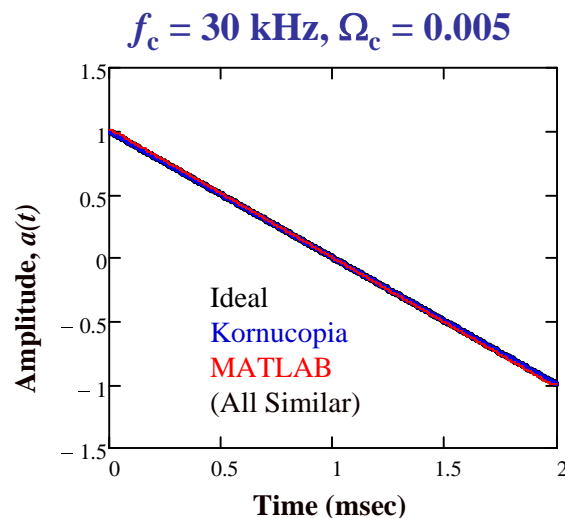
**MATLAB<sub>b</sub>** - Used algorithm based on Horner's polynomial eval. via the MATLAB® command `[h,f] = freqz(b,a,f,Fs)`



## Working with Highly Over-Sampled Data

Time-domain results of filtering a **sloped line**.

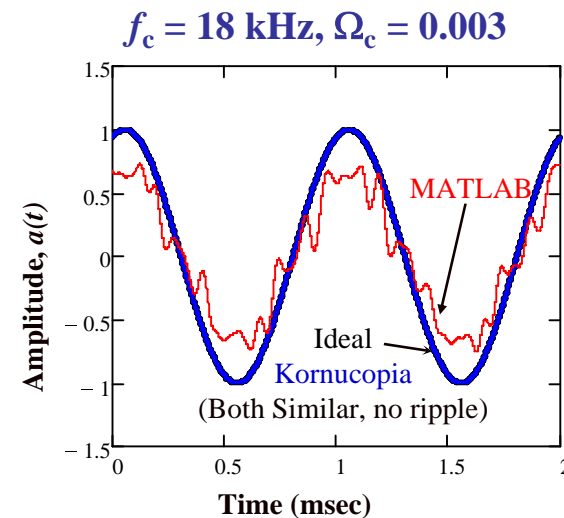
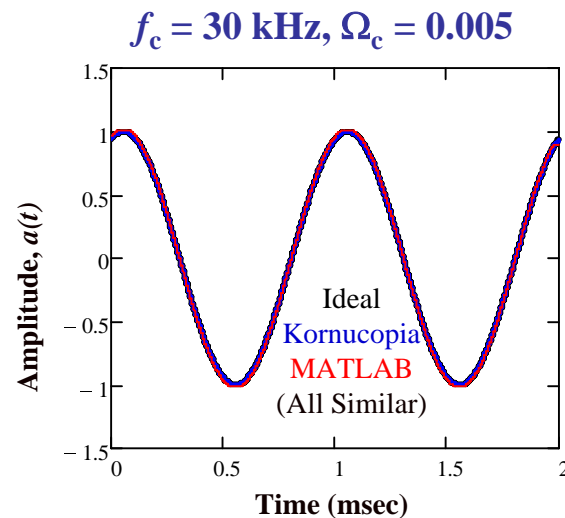
- The MATLAB® filter function utilized was `filtfilt`, a bi-directional time-domain filter. This function does NOT use a cascaded filter implementation.
- The lowpass filter utilized by Kornucopia® was `filterY_k`, a bi-directional time-domain filter, implemented in a cascade form.
- **MATLAB® becomes unstable with small change in cutoff frequency.**



## Working with Highly Over-Sampled Data

Time-domain results of filtering a simple **1.0-kHz sinusoidal signal**.

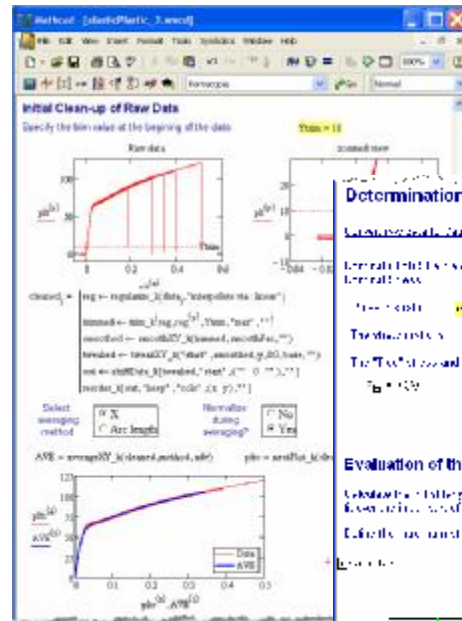
- Since the cutoff frequencies are well above the signal's frequency content, the filtered result should yield back the original 1.0-kHz sine wave.
- The MATLAB® and Kornucopia® filter functions are same as before.
- Similarly poor results occur again with MATLAB®.



# Enhancing Material Characterization from Raw Data

## Basic Steps for Elastic/Plastic Data

- Clean and average raw data
- Convert nominal stress/strain to true stress/strain
- Determine modulus
- Obtain yield stress vs plastic strain curve
- Output to ASCII file for FEA or other use



## Determination of Material Law Constants

Use the following equations to determine the material law constants:

For the elastic region, the material law is:

$$\sigma = E \epsilon$$

For the plastic region, the material law is:

$$\sigma = K \epsilon^n$$

where  $\sigma$  is the true stress,  $\epsilon$  is the true strain,  $E$  is the elastic modulus,  $K$  is the strength coefficient, and  $n$  is the strain hardening exponent.

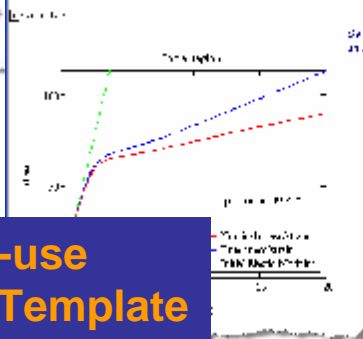
## Evaluation of the Initial Elastic Modulus

Calculate the initial elastic modulus from the initial linear portion of the stress-strain curve.

Use the following equation to calculate the initial elastic modulus:

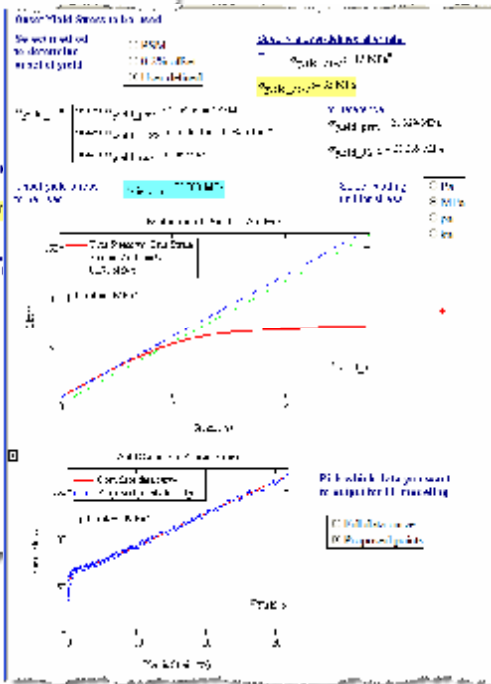
$$E = \frac{\Delta \sigma}{\Delta \epsilon}$$

where  $\Delta \sigma$  is the change in true stress and  $\Delta \epsilon$  is the change in true strain.



**Ready-to-use  
Kornucopia® Template**

**Reusable, well  
documented Mathcad  
analysis worksheet**



# Improving the Fit of Test Data to Hyperfoam Model

**Beginning of User Input**

Ogden-Hill Material Constants to be used in this document ("HYPERFOAM")

Number of terms in material fit:  $n_{\text{terms}} = 2$   $n = 1..n_{\text{terms}}$  (initial tangent shear modulus)

Shear terms:  $\mu_1 = 4.726 \text{ psi}$   $\mu_2 = -0.4805 \text{ psi}$   $\mu_0 = \sum \mu_n$   $\mu_0 = 4.245 \text{ psi}$

Power terms:  $\alpha_1 = 10.35$   $\alpha_2 = 3.293$

Generalized Poisson terms:  $\nu_1 = 0.09718$   $\nu_2 = 0.1117$   $\beta_n = \frac{\nu_n}{1 - 2\nu_n}$   $\beta = \begin{pmatrix} 0.049 \\ -12.748 \end{pmatrix}$

Initial check of material constants validity:  $\frac{1}{\mu_0} \left[ \sum_n \mu_n \left( \frac{1}{3} + \beta_n \right) \right] = 2.257$   $\Rightarrow$  This should yield a positive number if material parameters are valid

**General Ogden-Hill "HYPERFOAM" strain-energy density function**

$W_1(I_1, I_2, I_3) = \sum_n \frac{2\mu_n}{(\alpha_n)^2} \left( \lambda_1^{\alpha_n} + \lambda_2^{\alpha_n} + \lambda_3^{\alpha_n} - 3 \right)$  Define index clusters for 3-D elasticity  $i, j = 1..3$

$W_2(J) = \sum_n \frac{2\nu_n}{(\alpha_n)^2} J^{\alpha_n} \left[ \frac{1}{3} \left( \lambda_1^{-\alpha_n} + \lambda_2^{-\alpha_n} + \lambda_3^{-\alpha_n} - 1 \right) \right]$

$W(I_1, I_2, I_3) = W_1(I_1, I_2, I_3) + W_2(I_2, I_3)$

**General equations for principal stresses as a function of principal stretches**

The principal nominal stresses are:  $T_{\text{nom}, \text{principal}} = \frac{dW}{d\lambda_i} \Rightarrow T_{\text{nom}, \text{principal}}(I_1, I_2, I_3) = \frac{1}{\lambda_i} \sum_n \frac{2\mu_n}{\alpha_n} \left[ \lambda_i^{\alpha_n} - \alpha_n \lambda_i^{\alpha_n-1} \right]$

The principal Cauchy stresses are:  $\sigma_{\text{principal}}(I_1, I_2, I_3) = \frac{\lambda_i}{J} T_{\text{nom}, \text{principal}}(I_1, I_2, I_3)$

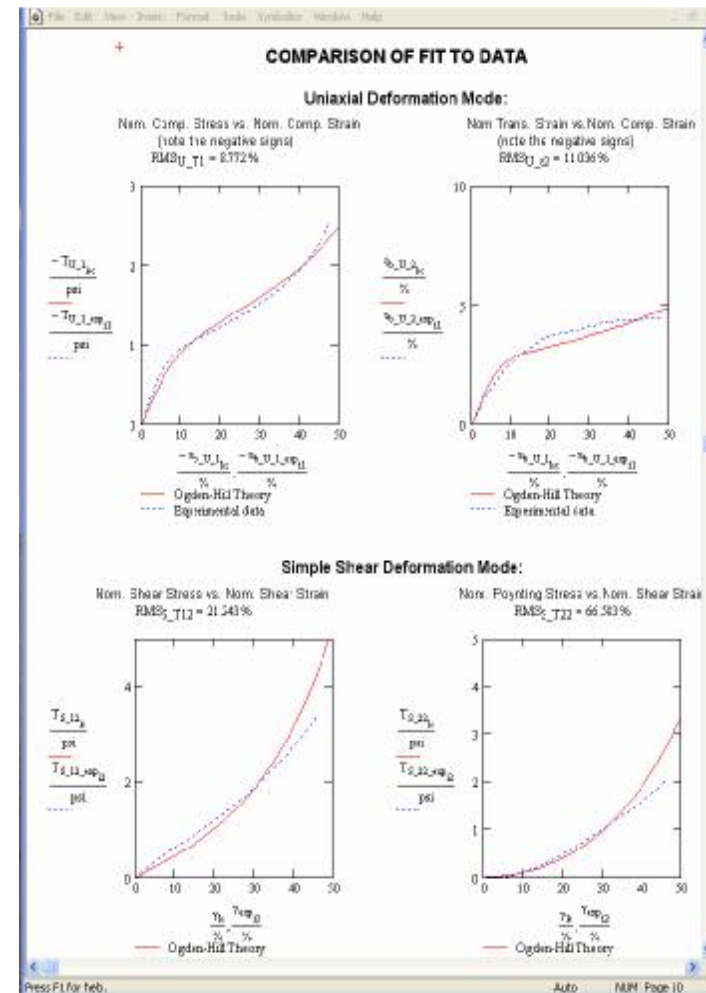
**General Form of Tangent Material Elasticity Matrix.**

$E(I_1, I_2, I_3, J) = 2 \left[ \sum_n \mu_n \begin{pmatrix} \lambda_1^{\alpha_n-1} & \lambda_2^{\alpha_n-1} & \lambda_3^{\alpha_n-1} \\ \lambda_1^{\alpha_n-1} & \lambda_2^{\alpha_n-1} & \lambda_3^{\alpha_n-1} \\ \lambda_1^{\alpha_n-1} & \lambda_2^{\alpha_n-1} & \lambda_3^{\alpha_n-1} \end{pmatrix} + \sum_n \nu_n \begin{pmatrix} \lambda_1^{-\alpha_n-1} & \lambda_2^{-\alpha_n-1} & \lambda_3^{-\alpha_n-1} \\ \lambda_1^{-\alpha_n-1} & \lambda_2^{-\alpha_n-1} & \lambda_3^{-\alpha_n-1} \\ \lambda_1^{-\alpha_n-1} & \lambda_2^{-\alpha_n-1} & \lambda_3^{-\alpha_n-1} \end{pmatrix} \right]$

**General equations for 2nd-order tensor invariants**

Invariants as function of the Tensor components

$I_1(A) = \sum_i A_{i,i}$   $I_2(A) = \frac{1}{2} \left[ I_1(A)^2 - \sum_{i,j} A_{i,j} A_{j,i} \right]$   $I_3(A) = |A|$

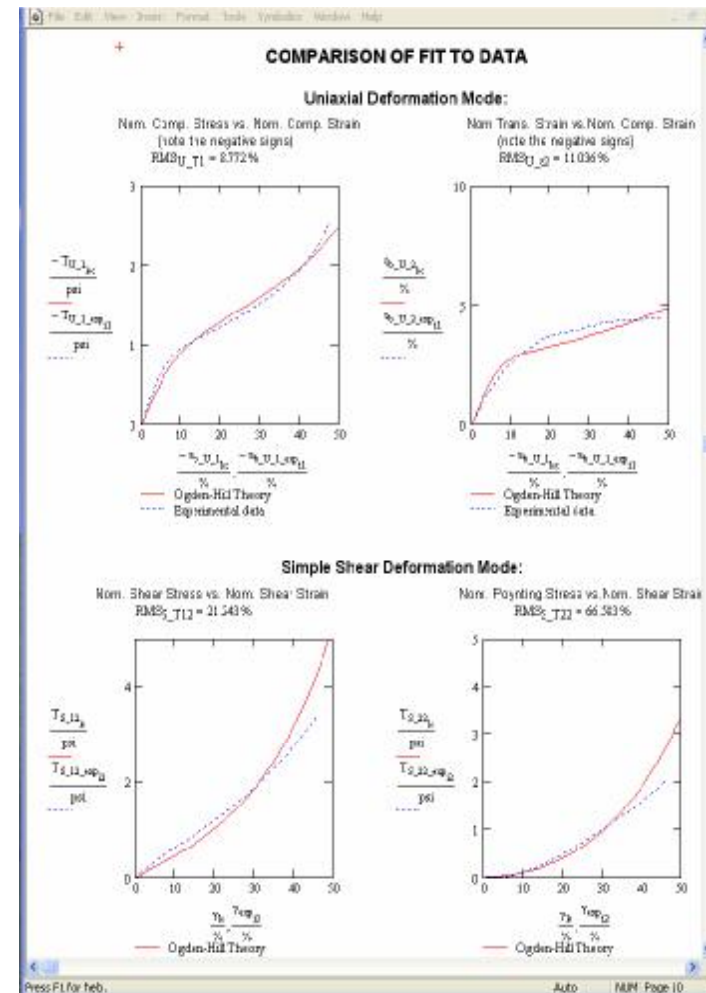
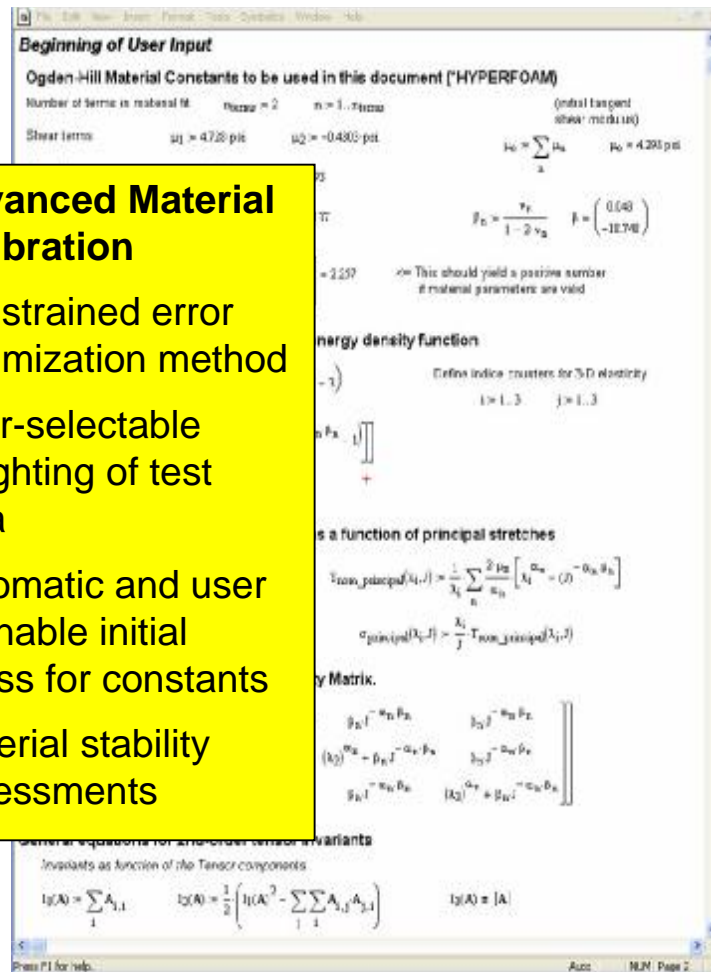




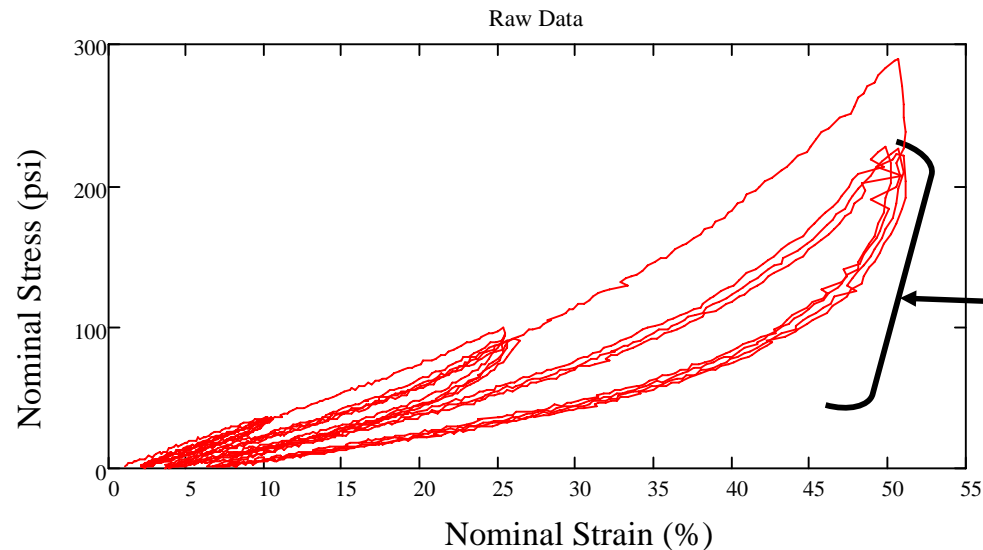
## Improving the Fit of Test Data to Hyperfoam Model

## Advanced Material Calibration

- Constrained error minimization method
- User-selectable weighting of test data
- Automatic and user definable initial guess for constants
- Material stability assessments

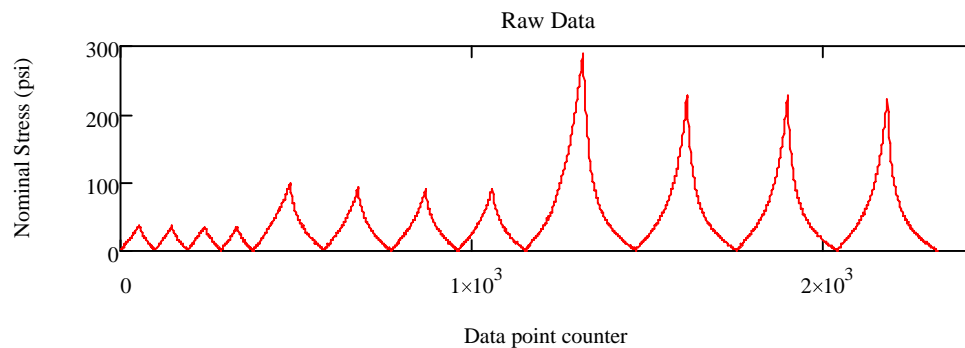


## Hysteresis Test Data - Often a Real Headache



Reciprocating process  
equipment data has  
similar issues

Problem caused by  
noise in optical  
strain measurement  
using a laser sensor

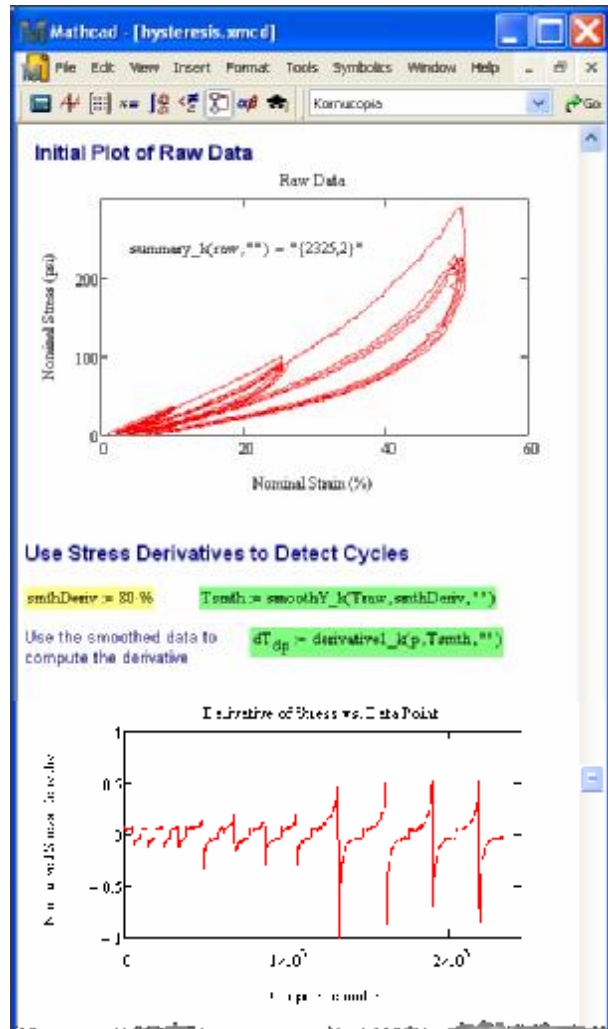


Can we use derivatives of  
stress or strain to  
automatically separate  
each cycle (loop)?



# Another Ready-Made Solution in the Kornucopia® Library

**Kornucopia®  
Meets the  
Challenge!**



## Plotting Cleaned Data

Specify smoothing factor for final result

smoothFac := 90.0%

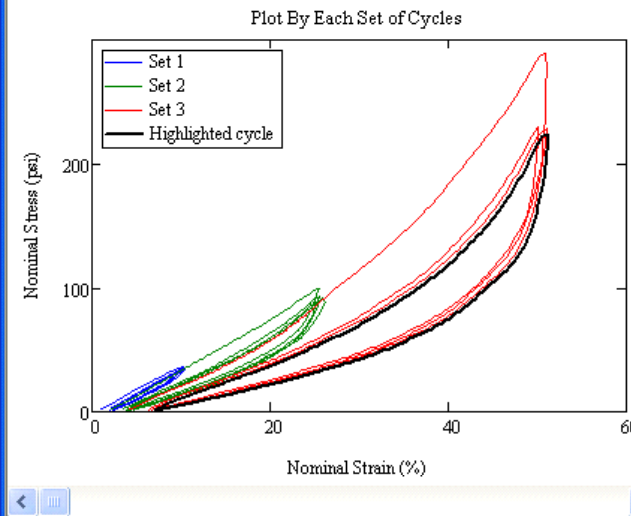
Specify a specific cycle to highlight

Set S := 3

Cycle C := 4

☒ Highlight On  
☐ Highlight Off

Process to find cycles



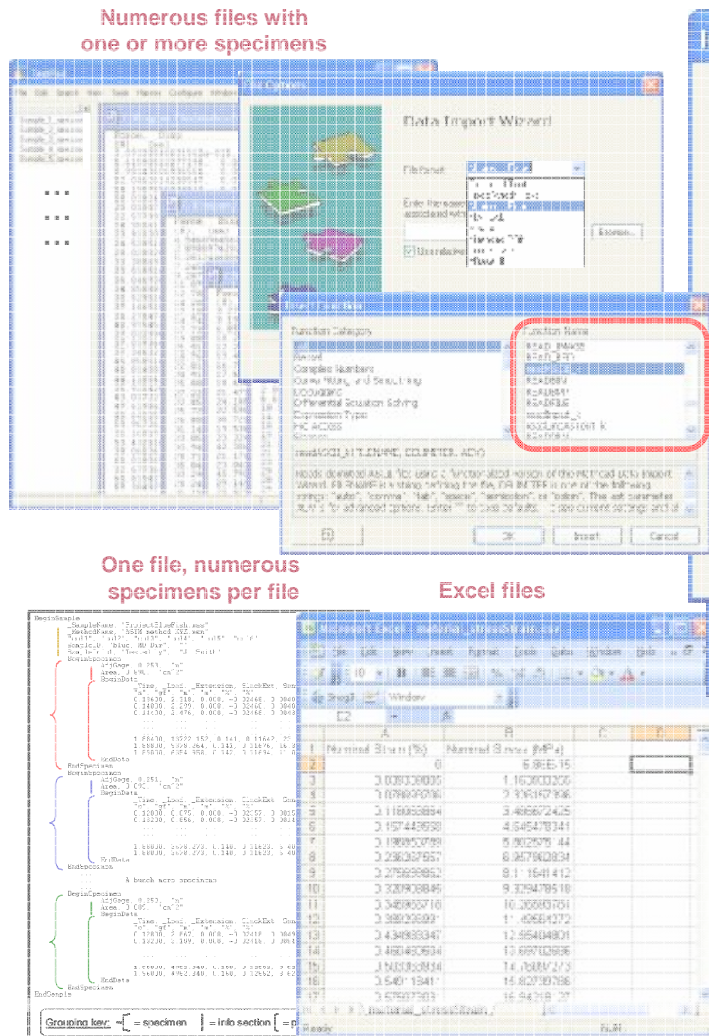
## Solution

Ready-made template that uses:

- DSP smoothing
- Derivatives
- Index searching
- Programming



# Kornucopia Improves Work-Flows That Use Data

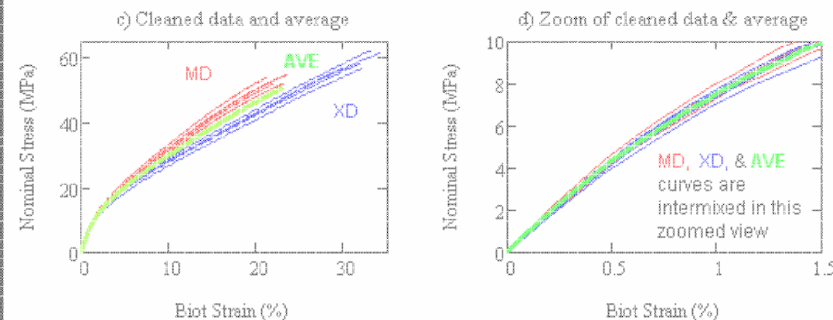


Numerous files with one or more specimens

One file, numerous specimens per file

Excel files

- Powerful, easy-to-use functionality
- Logical work-flows
- Efficiently process data files
  - ASCII, Excel, ...
  - Eliminates wasteful hand-editing of files
  - Keep header text with your data!
    - ✓ Improve data integrity
  - Single file or many files



## Kornucopia® Readily Handles Numerical Data and Text

```
BeginSample
  _SampleName, "ProjectBlueFish.nss"
  _MethodName, "ASTM method XYZ.nsn"
  "col1", "col2", "col3", "col4", "col5", "col6"
  SampleID, "blue, MD-Dir", ""
  SampleInfo1, "Tested by", "J. Smith"
  BeginSpecimen
    AdjGage, 0.253, "m"
    Area, 0.890, "cm^2"
    BeginData
      _Time, _Load, _Extension, SlackExt, Sensor 1, Sensor 2
      "s", "gf", "mm", "mm", "%", "%"
      0.13600, 2.318, 0.000, -0.02468, 0.00404, -2.46793
      0.14000, 2.299, 0.000, -0.02468, 0.00401, -2.46793
      0.14400, 2.476, 0.000, -0.02468, 0.00431, -2.46793
      ...
      1.88400, 13722.152, 0.141, 0.11642, 23.90619, 11.64224
      1.88800, 9378.264, 0.141, 0.11676, 16.33844, 11.67631
      1.89000, 6354.958, 0.142, 0.11694, 11.07135, 11.69353
    EndData
  EndSpecimen
EndSample
```

1.96000, 4952.340, 0.150, 0.12552, 8.62777, 12.55221  
1.96000, 4952.340, 0.150, 0.12552, 8.62777, 12.55221

EndData  
EndSpecimen  
EndSample

**Grouping key:**  $\{$  = specimen | = info section  $[$  = primary data





# Kornucopia Readily Handles Numerical Data and Text

```

BeginSample
  SampleName, "ProjectBlueFish.ms"
  MethodName, "ASTM method XYZ.ms"
  col1, "col2", "col3", "col4",
  SampleID, "blue_MD-Dir",
  SampleInfo, "Tested by", "J S"
BeginSpecimen
  AdjGage, 0.253, "m"
  Area, 0.890, "cm^2"
  BeginData
    Time, Load, E
    "s", "gf", "m"
    0.13600, 2.318,
    0.14000, 2.299,
    0.14400, 2.476,
    ...
    1.88400, 13722.1
    1.88800, 9378.26
    1.89000, 6354.95
  EndData
EndSpecimen
BeginSpecimen
  AdjGage, 0.251, "m"
  Area, 0.893, "cm^2"
  BeginData
    Time, Load, E
    "s", "gf", "m"
    0.12800, 0.875,
    0.13200, 0.856,
    ...
    1.88000, 3678.27
    1.88000, 3678.27
  EndData
EndSpecimen
...
A bunch more speci
...
BeginSpecimen
  AdjGage, 0.250, "m"
  Area, 0.809, "cm^2"
  BeginData
    Time, Load, E
    "s", "gf", "m"
    0.12800, 2.867,
    0.13200, 3.109,
    ...
    1.96000, 4952.34
    1.96000, 4952.34
  EndData
EndSpecimen
EndSample
    
```

**Grouping key:** { = specimen

**Mathcad - [ProcessingPackedFile\_MTS\_webinar.xmcd]**

File Edit View Insert Format Tools Symbolics Window Help

**Read Data File**

file := readASCII\_k("multiSpecimens\_MTS.txt", "comma", "")

**Unpack Numerical Data**

data := unpack\_k(file, (1), ("BeginData"), (3), (-1), "")

summary\_k(data, "") =

{ {440,6}  
 {440,6}  
 {397,6}  
 {360,6}  
 {422,6}  
 {460,6}

**Unpack Column Headers**

fullHead := unpack\_k(file, (1), ("BeginData"), (1), (2), "")

fullHead =

"_Time"	"_Load"	"_Extension"	"SlackExt"	"Sensor 1"	"Sensor 2"
"s"	"gf"	"m"	"m"	"%"	"%"
"_Time"	"_Load"	"_Extension"	"SlackExt"	"Sensor 1"	"Sensor 2"
"s"	"gf"	"m"	"m"	"%"	"%"
"_Time"	"_Load"	"_Extension"	"SlackExt"	"Sensor 1"	"Sensor 2"
"s"	"gf"	"m"	"m"	"%"	"%"
"_Time"	"_Load"	"_Extension"	"SlackExt"	"Sensor 1"	"Sensor 2"
"s"	"gf"	"m"	"m"	"%"	"%"
"_Time"	"_Load"	"_Extension"	"SlackExt"	"Sensor 1"	"Sensor 2"
"s"	"gf"	"m"	"m"	"%"	"%"

**Cleaning Header Text**

fullHead<sub>1</sub> := stringCleanup\_k(fullHead<sub>1</sub>, "remove", "\_", "")

fullHead<sub>1</sub> =

"Time"	"Load"	"Extension"	"SlackExt"	"Sensor 1"	"Sensor 2"
"s"	"gf"	"m"	"m"	"%"	"%"

**Quick plot of raw data**

plt := nestPlot\_k(data, "")





# Kornucopia Readily Handles Numerical Data and Text

```

BeginSample
  SampleName, "ProjectBlueFish.msc"
  MethodName, "ASTM method XYZ.msc"
  "col1", "col2", "col3", "col4",
  SampleID, "blue_MD-Dir", ""
  SampleInfo, "Tested by", "J. Smith"
  BeginSpecimen
    AdjGage, 0.253, "m"
    Area, 0.890, "cm^2"
    BeginData
      Time, Load, Ext, "s", "gf", "m", "m", "%", "%"
      0 13600, 2.318, 0
      0 14000, 2.299, 0
      0 14400, 2.476, 0
      ...
      1 88400, 13722.15
      1 88800, 9378.264
      1 89000, 6354.958
    EndData
  EndSpecimen
  BeginSpecimen
    AdjGage, 0.251, "m"
    Area, 0.893, "cm^2"
    BeginData
      Time, Load, Ext, "s", "gf", "m", "m", "%", "%"
      0 12800, 0.875, 0
      0 13200, 0.856, 0
      ...
      1 88000, 3678.273
      1 88000, 3678.273
    EndData
  EndSpecimen
  ...
  A bunch more specimens
EndSample
    
```

### Extract and Assign Units

**Force data**

$F_1 := \text{forceUnit}(\text{fullHead}_1, 2, 2)$

$F_1 = (\text{data}_1)^{(2)} \cdot F_{\text{unit}_1}$

**Displacement data**

$\delta_{\text{unit}_1} := \text{lengthUnit}(\text{fullHead}_1, 2, 3)$

$$F = \begin{Bmatrix} \{440,1\} \\ \{440,1\} \\ \{397,1\} \\ \{360,1\} \\ \{422,1\} \\ \{460,1\} \end{Bmatrix} \frac{\text{m} \cdot \text{kg}}{\text{s}^2}$$

$$\delta = \begin{Bmatrix} \{440,1\} \\ \{440,1\} \\ \{397,1\} \\ \{360,1\} \\ \{422,1\} \\ \{460,1\} \end{Bmatrix}$$

$$W = \begin{Bmatrix} \{440,1\} \\ \{440,1\} \\ \{397,1\} \\ \{360,1\} \\ \{422,1\} \\ \{460,1\} \end{Bmatrix} \text{J}$$

**fullHead<sub>1</sub>** = ( "Time" "Load" "Extension" "SlackExt" "Sensor 1" "Sensor 2" )  
 ( "s" "gf" "m" "m" "%" "%" )

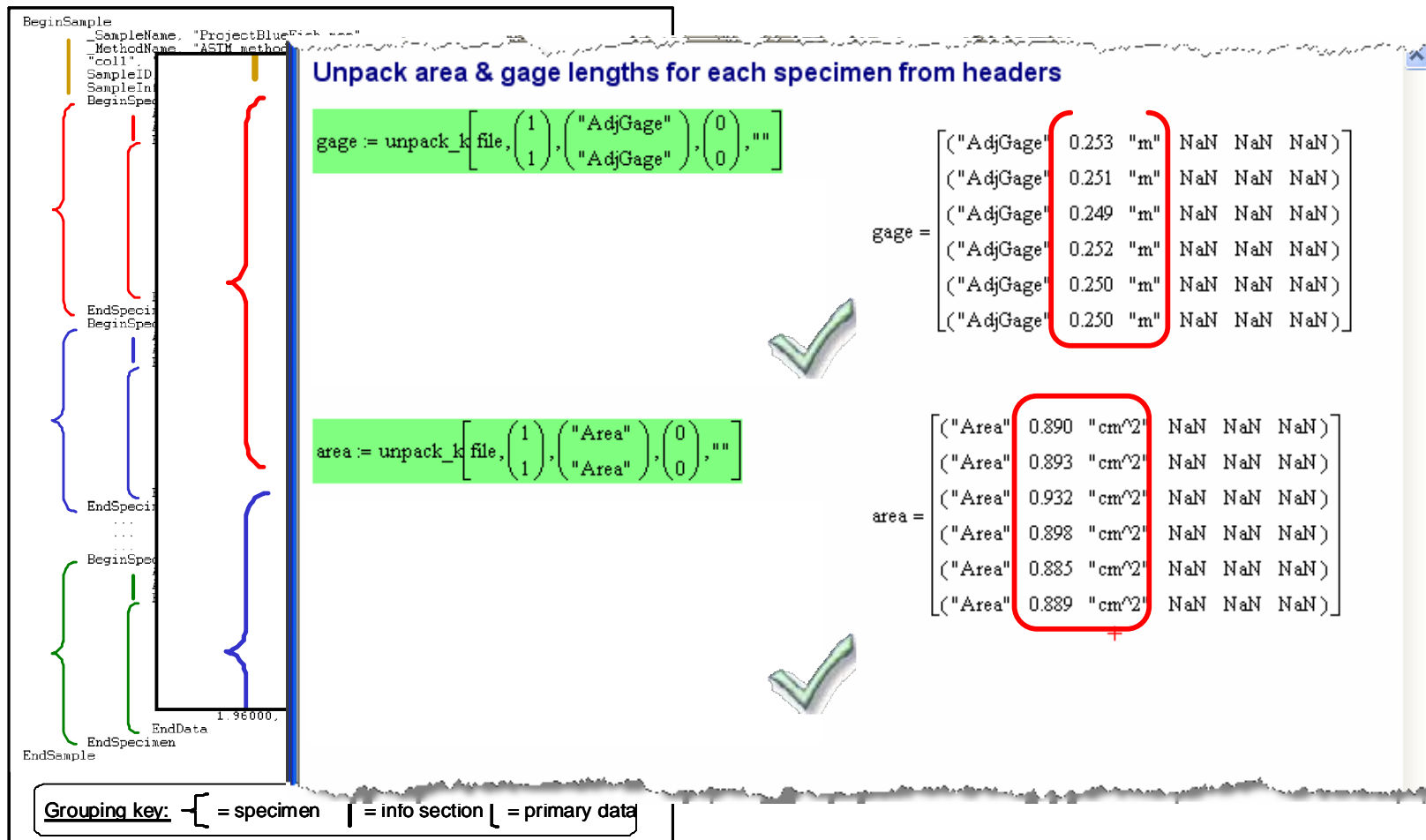
**Text to Units Functions**

Function	Logic
<code>forceUnit(forceUnitString) :=</code>	return N if forceUnitString = "N" return lbf if forceUnitString = "lbf" return gf if forceUnitString = "gf" error("Invalid forceUnitString")
<code>lengthUnit(lengthUnitString) :=</code>	return m if lengthUnitString = "m" return mm if lengthUnitString = "mm" return in if lengthUnitString = "in" error("Invalid lengthUnitString")
<code>areaUnit(areaUnitString) :=</code>	return m <sup>2</sup> if areaUnitString = "m^2" return cm <sup>2</sup> if areaUnitString = "cm^2" return mm <sup>2</sup> if areaUnitString = "mm^2"

**Grouping key:** { = specimen | = into section | = primary data



## Kornucopia Readily Handles Numerical Data and Text

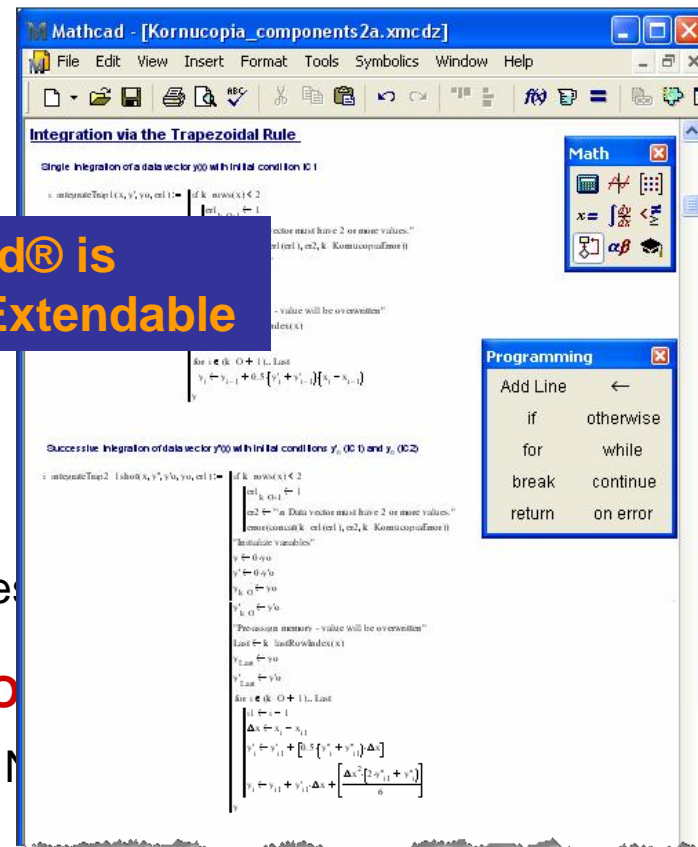
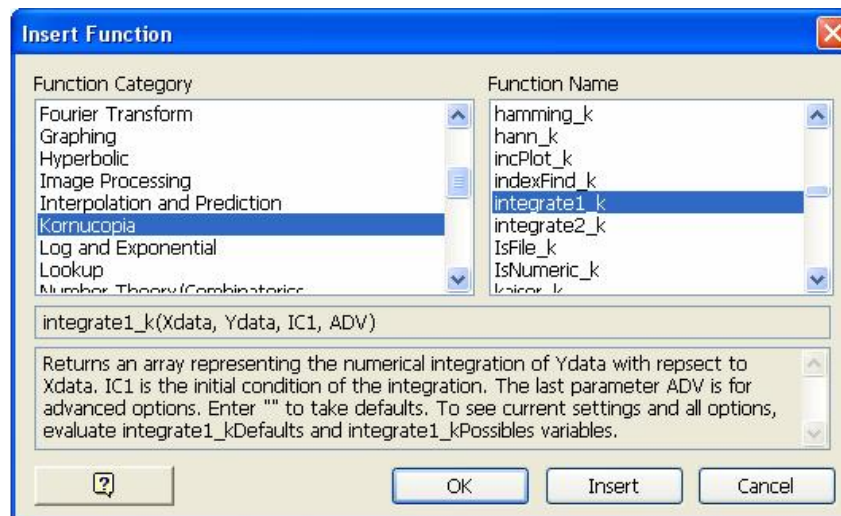


## Power of Mathcad® + Kornucopia®

### Kornucopia® is Built With Mathcad® For Engineers & Researchers

- Written by an Engineer who has used Mathcad for 20+ years
- Mathcad features used:
  - “Smart” referenced worksheets
    - Collapsed, lockable areas
  - Programming (~98%)
  - “C” user DLL’s (~2%)

**Mathcad® is  
Powerful & Extendable**



# Learning About & Accessing Kornucopia® Functions is Easy

Mathcad - [elasticPlastic\_1.xmcd]

File Edit View Insert Format Tools Symbolics Window Help

For a given strain offset, the following function finds the appropriate initial yield stress.

```


$$\sigma_{\text{yield\_find}}(\epsilon_{\text{offset}}) := \begin{cases} \text{on error } k \leftarrow \text{indexFind\_k}(\epsilon_{\text{ln\_pl\_raw}}, "cut after", \epsilon_{\text{offset}}, "return hit : last") \\ \quad \text{"Cannot find any crossings, return zero"} \\ \quad \text{return } 0 \cdot \sigma_{\text{ORIGIN}} \\ \text{if } k = \text{last}(\sigma) \\ \quad \text{"No interpolation possible, return last value"} \\ \quad \text{return } \sigma_{\text{last}}(\sigma) \\ \text{"use simple linear extrapolation to estimate yield stress"} \\ \text{on error } \sigma_{\text{yield}} \leftarrow \sigma_k + (\epsilon_{\text{offset}} - \epsilon_{\text{ln\_pl\_raw}_k}) \\ \quad \text{"linear interp failed, return closes point"} \\ \quad \sigma_{\text{yield}} \leftarrow \sigma_k \\ \sigma_{\text{yield}} \end{cases}$$


```

This function is useful to plot the offset in  
against a complete stress/strain curve

$\sigma_{\text{offset}}(\epsilon_{\text{ln}}, \epsilon_{\text{offset}}) :=$

[Onset Yield Stress using the Plastic Strain Method \(PSM\)](#)

For this method, the offset is set to zero, or some other "near zero" value

$\epsilon_{\text{offset\_psm}} := 0.0\%$     *<= The analyst may chose to modify this from a value of 0.0% for numerical purposes*

**Insert Function**

Function Category	Function Name
Fourier Transform	hamming_k
Graphing	hann_k
Hyperbolic	incPlot_k
Image Processing	indexFind_k
Interpolation and Prediction	integrate1_k
Kornucopia	integrate2_k
Log and Exponential	IsFile_k
Lookup	IsNumeric_k
Number Theory/Combinatorics	kricker_k

indexFind\_k(DATA, CONDITION, VALUE, ADV)

Finds the index in array DATA for which VALUE satisfies a specified search CONDITION. VALUE is either a scalar or the special strings of "min" or "max" for which the function will use the min or max of DATA as the VALUE. Search conditions are specified by one of the following strings: "cut before", "cut after", "closest", "eq",

OK Insert Cancel



## A Rich Library of Example Documents and Templates

Over 30 examples showing how to process a variety of challenging, realistic, datasets

The screenshot shows the Kornucopia Help application window. On the left is a 'Contents' pane with a tree view. The main area displays a preview of a worksheet titled 'Using Highpass Filtering to Improve the Correlation of a Plate Shock Problem (Compact Version)'. The worksheet includes a graph of 'Relative Displacement' vs 'Time (msec)' showing two oscillating curves, one labeled 'after HP filter'. A blue box with orange text is overlaid on the worksheet preview, stating 'Helpful Work-Flows & Best Practices'. Below the graph, there is a link: 'Click here to work interactively in Mathcad® with this worksheet.' A red arrow points from this link to another blue box with orange text that says 'ALL Template Example Files can be opened LIVE in Mathcad® and modified as desired by user'. The bottom of the window shows a 'Notes' section.

**Contents:**

- TOC
- Release Notes
- Introduction and Overview
- Mathcad Tips
- Functions
- Extra Units
- Examples
  - Tips on Using Examples Effectively
  - Tutorials
  - Simple Usage
    - Quick Start
    - The ADV Parameter
    - Read/Write Files
    - Creating an Average Curve
    - Tweaking Data
    - Fourier Analysis and Filtering E
    - Typical Fourier and Filter Appli
    - Computing Arc Lengths of Data
  - Elaborate Examples
    - Cantilever Beam Analysis
    - Catenary Analysis
    - Cleaning, Averaging, and Twe
    - Creating Elastic/Plastic Materia
    - DCB Failure
    - Decimating Data
    - Derivatives and Integrals of Di
    - derivativesAndIntegrals\_S
    - derivativesAndIntegrals\_D
    - General Interpolation via Param
    - Highpass Filter of Plate Shock
      - Plate Shock - Compact
      - Plate Shock - Detailed
    - Hysteretic and Cyclic Data Pro
    - Improving User-Friendliness of
    - Learning DSP
    - Lens-Ball Impact
    - Moon Penetrator
    - Processing Multiple Files Effic

**Using Highpass Filtering to Improve the Correlation of a Plate Shock Problem (Compact Version)**

Relative Displacement

Time (msec)

after HP filter

**Helpful Work-Flows & Best Practices**

This is an HTML version of the worksheet. It is intended to be used for fast browsing.  
[Click here to work interactively in Mathcad® with this worksheet.](#)

**ALL Template Example Files can be opened LIVE in Mathcad® and modified as desired by user**

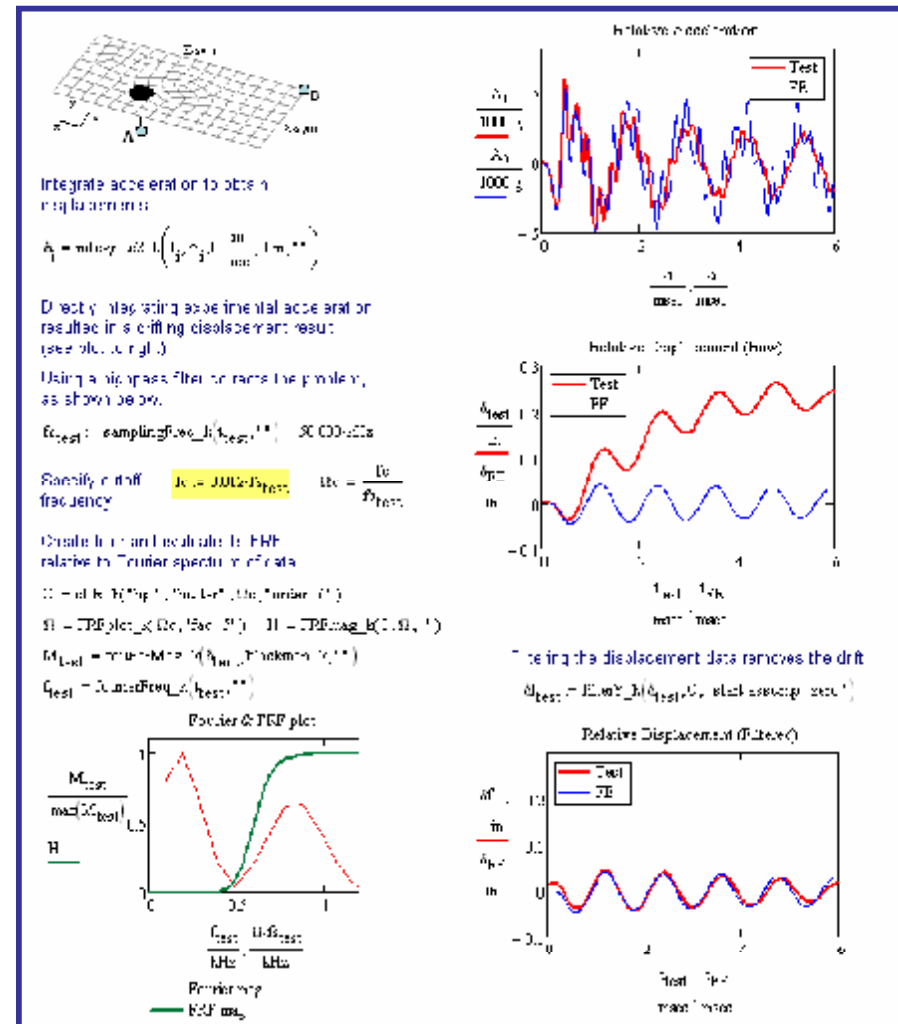
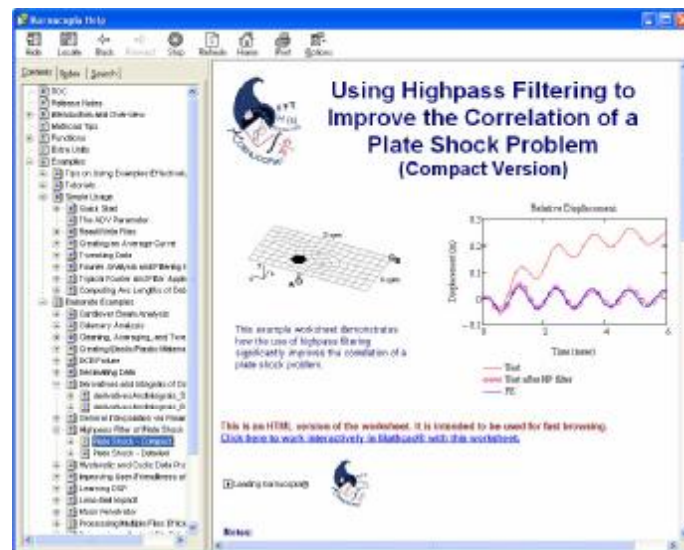




## A Rich Library of Example Documents and Templates

## Examples and Templates:

- Walk user through the analysis process
- Reusable by user for their own data
- Fully customizable



Learn how to  
effectively work  
with your data!

# Bodie Technology Inc

## Training Seminars

# Introduction to Kornucopia® and Mathcad®

“Without Kornucopia® I really doubt the quality  
and quantity of work would have been what it  
was. The 1 on 1 instruction was invaluable.”

**Lieutenant Colonel Kelly Laughlin, PhD**  
**US Army, Picatinny Arsenal**

# Analyzing Noisy Data via Filtering and DSP

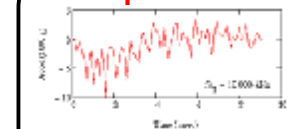
“This DSP seminar should be mandatory for every  
explicit dynamics user. Ted is a great lecturer.”

**Pedro Bastias, NACCO – Matl’s Handling Group**

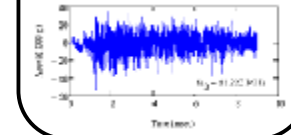
Learn how to  
get great results  
with confidence!

## Raw Data

### Experiment

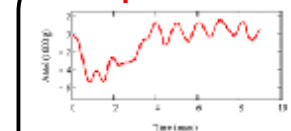


### FEA

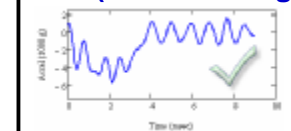


## Decimation & Filtering

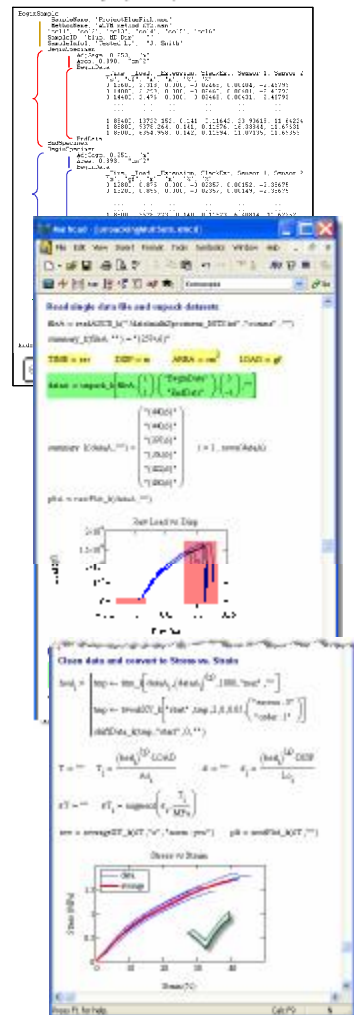
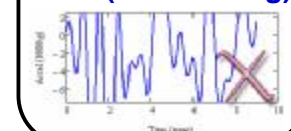
### Experiment



### FEA (With Training)



### FEA (NO Training)





# Introduction to Kornucopia® and Mathcad®

## Day 1 - Basics of Mathcad®

- What's possible with Mathcad® & Kornucopia®
  - Symbolics, numerical methods, data analysis, ...
  - Analyzing challenging data
- Mathcad® basics
  - Worksheet layout and calculation order
  - Creating/editing math, graph, & text regions
  - Referenced worksheets and collapsed areas
- Working with units
  - In equations, plots, arrays, and data files
- Creating your first worksheets
  - Some simple calculations
  - Working with ASCII data files

## Day 2 - Kornucopia® (Part 1)

- Arrays, range variables, and looping
  - Matrices, 2-D arrays, and nested arrays
  - Various ways to loop equations and functions
- Reading and writing data files
- Tips on using solve-blocks
- Easy-to-use programming within Mathcad®
  - *NO need to be a C or Scripting wizard!*

## Day 2 Continued

- Kornucopia® features for analyzing challenging data
  - Functions & example worksheets
  - The ADV parameter
  - Accessing help and documentation
  - Connecting to the Kornucopia® library
- Enhanced file reading & writing
  - Working with "real-world" ASCII files with header text, stacked datasets, etc.
  - Unpacking data files

## Day 3 - Kornucopia® (Part 2)

- Array and string manipulation
  - Reorder rows & cols, nested array tools, find locations in data that meet criteria, string manipulation & parsing
- Techniques for easily plotting multiple curves

**Customizable to fit YOUR NEEDS  
with YOUR DATA**

**1-Day to 3-Day Formats**

**More details on our website  
[www.BodieTech.com](http://www.BodieTech.com)**

- Working with Excel and PowerPoint



# Analyzing Noisy Data via Filtering and DSP

## Day 1 Concepts of DSP, Filtering, and More

- Motivation for using DSP with experimental and/or simulation data
  - Workshop – experiencing common DSP errors
- DSP fundamentals
  - Data collection and sampling: avoiding aliasing
  - FFT's, Fourier Analysis, windows ...
    - it is not a black box!
  - Lowpass, highpass, bandstop, bandpass filters
  - IIR and FIR filters, Butterworth & Chebyshev filters
  - Filter parameters: cutoff freq., filter order, single/double pass
  - Filter induced distortions, end effects & time delays
  - FRF (Filter Response Functions)
  - Decimation and upsampling
- DSP features in Kornucopia®
- DSP features within Abaqus
- Workshops
  - Learning to use DSP functions with simple signals
  - Computing derivatives & integrals from noisy data

## Day 2 Applications of DSP (Part 1)

- Review of DSP fundamentals, solidifying key concepts
- Developing a DSP strategy for a given problem
- Working with experimental data and validation of simulation and/or experimental results
- DSP using various software
- Working with transient-dynamic events
  - Workshop – Transient impact analysis
  - Workshop – Salvaging shock data via hp filtering
  - Workshop – Penetration problem (comparing multiple models to test data)

## Day 3 Applications of DSP (Part 2)

- Working with quasi-static models created using transient simulation techniques.

**Customizable to fit YOUR NEEDS  
with YOUR DATA**

**1-Day to 3-Day Formats**

**More details on our website  
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