ME-3901. Engineering Experimentation

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Initial parameters:

$t := 0.003$ (in) $\delta t := 5 \cdot 10^{-4}$

$r := 1.28$ (in) $\delta r := 5 \cdot 10^{-3}$

$E := 10.0 \cdot 10^{6}$ (lf/in^2) $\delta E := 0.1 \cdot E$ $\delta E = 1 \times 10^{6}$

$\nu := 0.3$ $\delta \nu := 0.05$

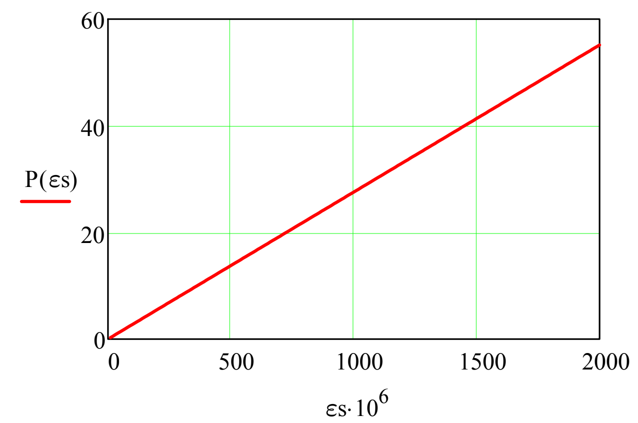
$\delta \varepsilon s := 25 \cdot 10^{-6}$ (microstrain)

Define range for strain:

$\varepsilon s := 10 \cdot 10^{-6}, 20 \cdot 10^{-6} .. 2000 \cdot 10^{-6}$ $P(\varepsilon s) := E \cdot t \cdot \dfrac{\varepsilon s}{\left(1 - \dfrac{\nu}{2}\right) \cdot r}$

(Example: pressure at 1370 microstrains)

$P\left(1370 \cdot 10^{-6}\right) = 37.776$ (psi)



Define partial derivatives functions:

$fE(\varepsilon s) := t \cdot \dfrac{\varepsilon s}{r \cdot \left(1 - \dfrac{1}{2} \cdot \nu\right)}$ $fthi(\varepsilon s) := E \cdot \dfrac{\varepsilon s}{r \cdot \left(1 - \dfrac{1}{2} \cdot \nu\right)}$

$f\varepsilon s(\varepsilon s) := E \cdot \dfrac{t}{r \cdot \left(1 - \dfrac{1}{2} \cdot \nu\right)}$ $fra(\varepsilon s) := -E \cdot t \cdot \dfrac{\varepsilon s}{r^2 \cdot \left(1 - \dfrac{1}{2} \cdot \nu\right)}$

$f\nu(\varepsilon s) := \dfrac{1}{2} \cdot E \cdot t \cdot \dfrac{\varepsilon s}{r \cdot \left(1 - \dfrac{1}{2} \cdot \nu\right)^2}$

Uncertainty in pressure as a function of strain:

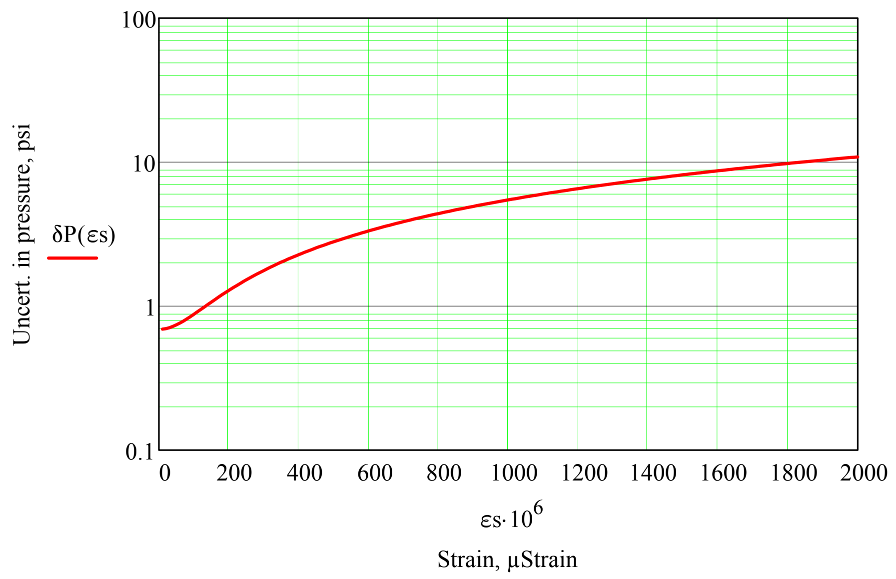
$\delta P1(\varepsilon s) := (fE(\varepsilon s) \cdot \delta E)^2 + (fthi(\varepsilon s) \cdot \delta t)^2 + (f\varepsilon s(\varepsilon s) \cdot \delta \varepsilon s)^2 + (fra(\varepsilon s) \cdot \delta r)^2 + (f\nu(\varepsilon s) \cdot \delta \nu)^2$

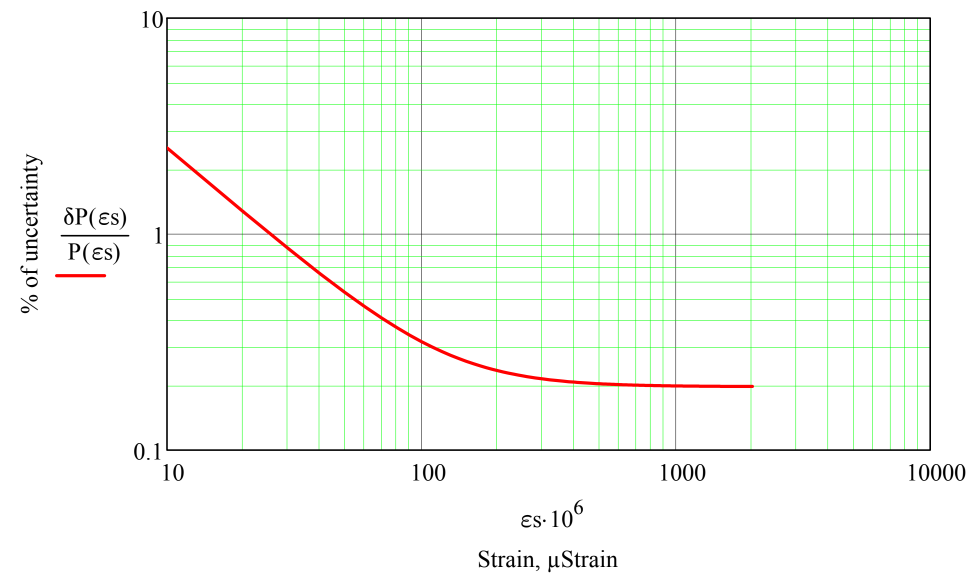
$\delta P(\varepsilon s) := \delta P1(\varepsilon s)^{0.5}$ Uncertainty as a function of strain

$\delta P\left(1370 \cdot 10^{-6}\right) = 7.459$ (Example: strain at 1370 microstrains)

$P\left(1370 \cdot 10^{-6}\right) = 37.776$ $fra\left(1370 \cdot 10^{-6}\right) \cdot \delta r = -0.148$ $f\nu\left(1370 \cdot 10^{-6}\right) \cdot \delta \nu = 1.111$

$fE\left(1370 \cdot 10^{-6}\right) \cdot \delta E = 3.778$ $fthi\left(1370 \cdot 10^{-6}\right) \cdot \delta t = 6.296$ $f\varepsilon s\left(1370 \cdot 10^{-6}\right) \cdot \delta \varepsilon s = 0.689$





Percentage constributions:

$$PIE(\varepsilon s) := \left(\frac{fE(\varepsilon s)\cdot \delta E}{\delta P(\varepsilon s)}\right)^2 \qquad PIthi(\varepsilon s) := \left(\frac{fthi(\varepsilon s)\cdot \delta t}{\delta P(\varepsilon s)}\right)^2 \qquad PI\varepsilon s(\varepsilon s) := \left(\frac{f\varepsilon s(\varepsilon s)\cdot \delta \varepsilon s}{\delta P(\varepsilon s)}\right)^2$$

$$PIra(\varepsilon s) := \left(\frac{fra(\varepsilon s)\cdot \delta r}{\delta P(\varepsilon s)}\right)^2 \qquad PI\nu(\varepsilon s) := \left(\frac{f\nu(\varepsilon s)\cdot \delta \nu}{\delta P(\varepsilon s)}\right)^2$$

$$TU(\varepsilon s) := PIE(\varepsilon s) + PIthi(\varepsilon s) + PI\varepsilon s(\varepsilon s) + PIra(\varepsilon s) + PI\nu(\varepsilon s)$$

$$PcPIE(\varepsilon s) := 100\cdot\frac{PIE(\varepsilon s)}{TU(\varepsilon s)} \qquad PcPIthi(\varepsilon s) := 100\cdot\frac{PIthi(\varepsilon s)}{TU(\varepsilon s)} \qquad PcPI\varepsilon s(\varepsilon s) := 100\cdot\frac{PI\varepsilon s(\varepsilon s)}{TU(\varepsilon s)}$$

$$PcPIra(\varepsilon s) := 100\cdot\frac{PIra(\varepsilon s)}{TU(\varepsilon s)} \qquad PcPI\nu(\varepsilon s) := 100\cdot\frac{PI\nu(\varepsilon s)}{TU(\varepsilon s)}$$

$$Check(\varepsilon s) := PcPIE(\varepsilon s) + PcPIthi(\varepsilon s) + PcPI\varepsilon s(\varepsilon s) + PcPIra(\varepsilon s) + PcPI\nu(\varepsilon s)$$

(to make sure it adds 100 %)

Order of importance for the numerical data used:

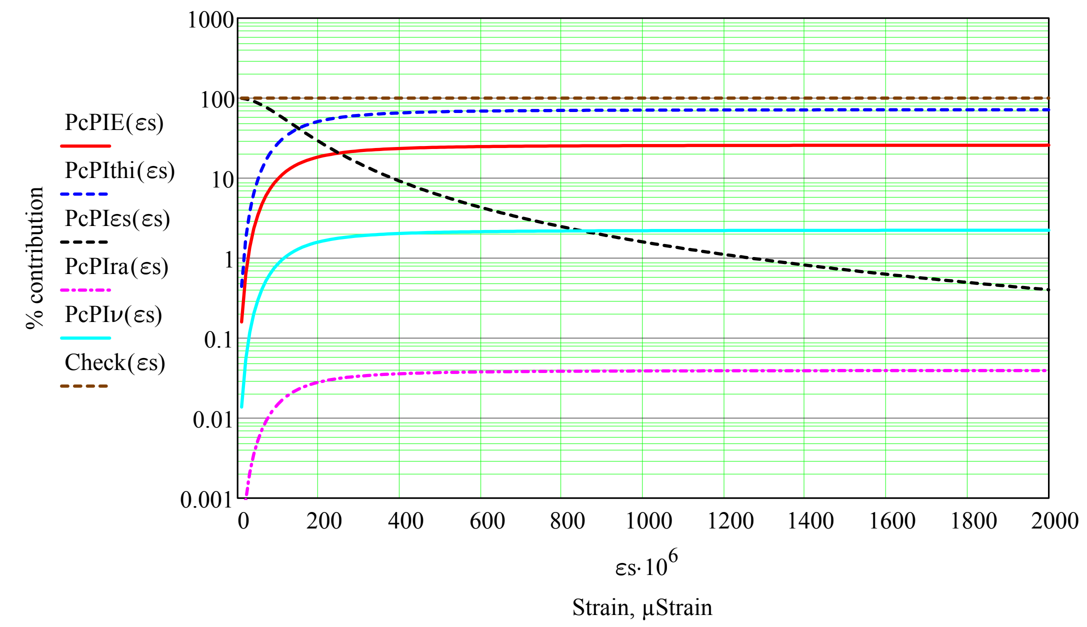
$PcPIthi\left(600\cdot 10^{-6}\right) = 68.767$

$PcPIE\left(600\cdot 10^{-6}\right) = 24.756$

$PcPI\varepsilon s\left(600\cdot 10^{-6}\right) = 4.298$ (Example: evaluated at 600 microstrains)

$PcPI\nu\left(600\cdot 10^{-6}\right) = 2.142$

$PcPIra\left(600\cdot 10^{-6}\right) = 0.038$



Order of importance for the numerical data used:

$PcPI\varepsilon s\left(100\cdot 10^{-6}\right) = 61.784$

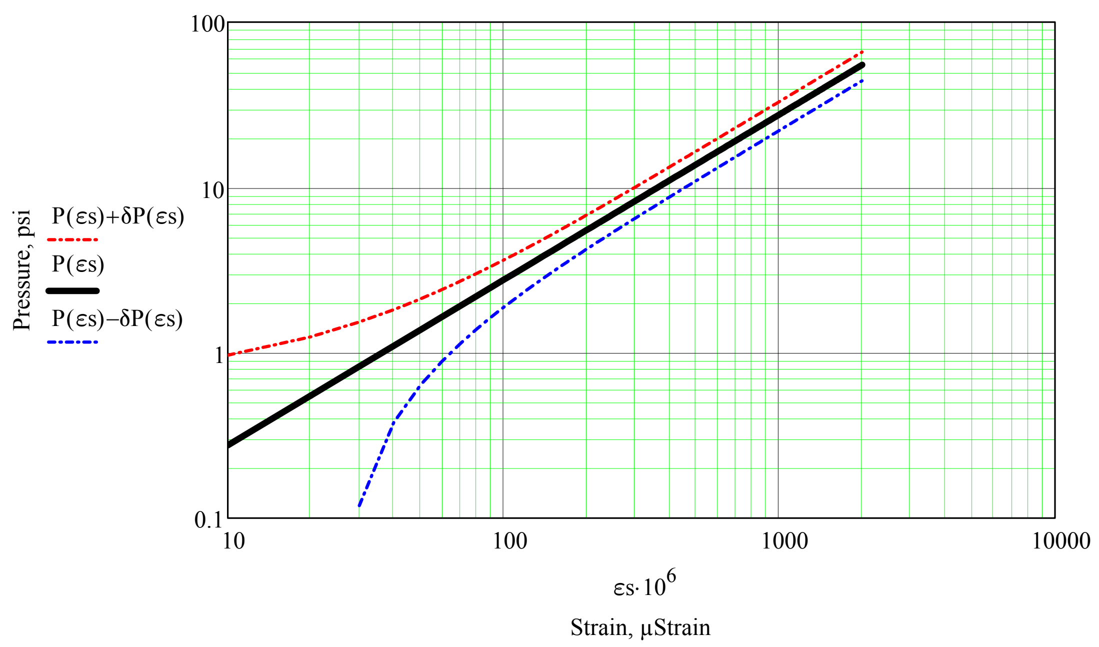
$PcPIthi\left(100\cdot 10^{-6}\right) = 27.46$

$PcPIE\left(100\cdot 10^{-6}\right) = 9.886$ (Example: evaluated at 100 microstrains)

$PcPI\nu\left(100\cdot 10^{-6}\right) = 0.855$

$PcPIra\left(100\cdot 10^{-6}\right) = 0.015$

(Note that uncertainity range is greater at low values of strain.
This can be clearly seen when using a log-log scale)



At low levels of strain:

$P\left(200\cdot 10^{-6}\right) = 5.515$

$\delta P\left(200\cdot 10^{-6}\right) = 1.285$

$$\frac{\delta P\left(200\cdot 10^{-6}\right)}{P\left(200\cdot 10^{-6}\right)} = 0.233$$

At higher levels of strain:

$\delta P\left(1600\cdot 10^{-6}\right) = 8.702$

$P\left(1600\cdot 10^{-6}\right) = 44.118$

$$\frac{\delta P\left(1500\cdot 10^{-6}\right)}{P\left(1500\cdot 10^{-6}\right)} = 0.197$$